



VOLT Series

VOLT 108 and VOLT 116 GRANITE Measurement Modules



Table of contents

| | |
|--|-----------|
| 1. Introduction | 1 |
| 2. Precautions | 1 |
| 3. Initial inspection | 1 |
| 4. Measurement quickstart using SURVEYOR | 2 |
| 5. Programming quickstart using SURVEYOR | 5 |
| 6. Programming quickstart using Short Cut | 6 |
| 7. Overview | 9 |
| 7.1 Wiring panel overview | 10 |
| 7.1.1 Analog input | 11 |
| 7.1.1.1 Single-ended measurements | 11 |
| 7.1.1.2 Differential measurements | 12 |
| 7.1.1.3 Period averaging | 12 |
| 7.1.2 Voltage and current excitation | 12 |
| 7.1.3 Switched voltage output | 12 |
| 7.1.4 Grounding terminals | 12 |
| 7.1.5 Power terminals | 13 |
| 7.1.5.1 Power in | 13 |
| 7.1.5.2 Power out | 13 |
| 7.1.6 Communications ports | 13 |
| 7.1.7 LED indicators | 13 |
| 7.1.7.1 COMM status | 13 |
| 7.1.7.2 CPI port | 14 |
| 8. Specifications | 14 |
| 8.1 Voltage measurements | 14 |
| 8.2 Resistance measurements | 16 |
| 8.3 Voltage and current excitation | 17 |
| 8.4 Period averaging | 18 |
| 8.5 Voltage output | 19 |
| 8.5.1 Continuous 12 VDC | 19 |


| | |
|---|-----------|
| 8.5.2 Switched 12 VDC | 19 |
| 8.5.3 Switched 5 VDC | 19 |
| 8.6 Module | 20 |
| 8.6.1 Communications | 20 |
| 8.6.2 System | 20 |
| 8.6.3 Power requirements | 20 |
| 8.6.4 Compliance | 21 |
| 8.6.5 Physical attributes | 21 |
| 9. Installation | 21 |
| 9.1 Install driver for computer connection | 22 |
| 9.2 Operating systems | 22 |
| 9.3 Configuring VOLT 100 series | 22 |
| 9.3.1 Configuring with SURVEYOR | 23 |
| 9.3.2 Configuring with the CPIAddModule() instruction | 23 |
| 9.3.3 Configuring with Device Configuration Utility | 23 |
| 9.3.4 Configuring with CPIStatus table | 24 |
| 9.4 Data logger programming | 24 |
| 9.4.1 Scan buffers | 25 |
| 9.4.2 GRANITE Measurement Module instructions | 25 |
| 9.5 Data logger connection | 26 |
| 9.6 Connecting multiple GRANITE Measurement Modules | 26 |
| 9.6.1 Daisy-chain topology | 26 |
| 9.6.2 Star topology | 27 |
| 9.7 Power connection | 28 |
| 9.7.1 Power-up sequence | 28 |
| 9.8 Earth ground connection | 29 |
| 9.9 Mounting in an enclosure | 29 |
| 10. Operation | 30 |
| 10.1 SURVEYOR control | 30 |
| 10.2 Data logger control | 31 |
| 10.3 Measurements | 31 |
| 10.3.1 First notch frequency | 31 |
| 10.3.2 Panel temperature | 31 |
| 10.4 Fast measurements | 32 |
| 10.4.1 Measurement speed | 33 |
| 10.4.1.1 Sub-scans | 34 |

| | |
|--|-----------|
| 10.4.1.2 Burst measurements | 34 |
| 10.4.2 CPI network bit rate | 35 |
| 10.5 Multiple devices | 36 |
| 10.6 Switched voltage output | 36 |
| 11. Maintenance and calibration | 37 |
| 12. Troubleshooting | 37 |
| 12.1 CPIStatus table | 38 |
| 12.2 COMM status LED | 39 |
| 12.3 CPI port LEDs | 39 |
| 12.4 Replacing a GRANITE Measurement Module | 40 |
| Appendix A. Importing Short Cut code into CRBasic Editor | 41 |
| Appendix B. Analog voltage measurement range and resolution | 42 |
| Appendix C. Example programs | 45 |
| C.1 Configuring GRANITE Measurement Module with CPIAddModule() | 45 |
| C.2 Measuring TEMP 120 and VOLT 108 at different speeds | 46 |
| C.3 Synchronized TEMP 120 and VOLT 108 measurements | 47 |
| C.4 Controlling an AM16/32B multiplexer | 48 |
| Appendix D. Calculating network restrictions | 50 |
| D.1 Example 1 | 50 |
| D.2 Example 2 | 51 |
| D.3 Example 3 | 52 |

1. Introduction

The VOLT 108 and VOLT 116 are 24-bit analog input modules that significantly increase the number of analog channels in a data logger system. The VOLT 108 has eight differential channels and the VOLT 116 has 16 differential channels.

The VOLT 108 and VOLT 116 feature a 24-bit analog-to-digital converter and a low-noise, analog front-end to provide superior analog measurements. They also support period average measurements and include both current and voltage excitation channels.

Use the CPI calculator at www.campbellsci.com/downloads/cpi-calculator  to estimate the usage and capacity of a CPI network. Select a CDM-A108 for a VOLT 108 and a CDM-A116 when using a VOLT 116.


Throughout this manual, any reference to the VOLT 100 series applies to both the VOLT 108 and VOLT 116, unless specifically noted.

2. Precautions



- READ AND UNDERSTAND the [Safety](#) section at the back of this manual.
- WARNING:
 - Protect from over-voltage
 - Protect from water
 - Protect from ESD (electrostatic discharge)
- IMPORTANT: Maintain a level of calibration appropriate to the application. Campbell Scientific recommends factory recalibration of the VOLT 100 series every three years.

3. Initial inspection




- Inspect the packaging and contents for damage immediately. File damage claims with the shipping company.

- Check packaging materials for all products. Check model numbers, part numbers, product descriptions, and cable lengths against shipping documents. Model or part numbers are found on each product. Cable numbers are normally found at the end of the cable that connects to the measurement device. Check that expected cable lengths were received. Contact Campbell Scientific immediately if you find any discrepancies.
- Check the operating system version in the VOLT 100 series, and the data logger. Update as needed. See [Operating systems](#) (p. 22).
- For more information on accessing the calibration certificate watch a video at www.campbellsci.com/videos/calibration-certs .

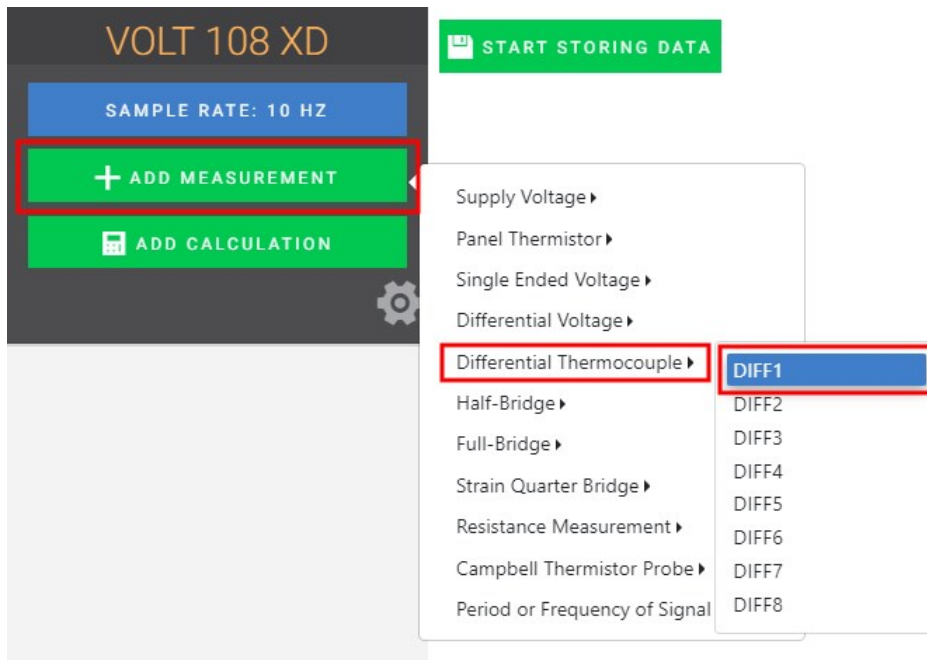
4. Measurement quickstart using *SURVEYOR*

Campbell Scientific *SURVEYOR* software is an easy way to quickly see measurement results and store data from the VOLT 100 series. The module configuration can be saved on the computer or exported as a CRBasic data logger program. *SURVEYOR* is available as a download from www.campbellsci.com/cs-surveyor . A video tutorial is available at www.campbellsci.com/videos/surveyor .

This section will guide you through reading a differential Type-T thermocouple on a VOLT 100 series. With minor changes, these steps can apply to other compatible measurements.

1. Open *SURVEYOR* .
2. Connect a USB cable between your computer and the VOLT 100 series **USB** port.
3. Apply 9.6 to 32 VDC external power using the green **Power** connector on the side of the VOLT 100 series.
4. Select **Connect Now** .
5. Select the communications port, it will be labeled similar to **VOLT 100 series (COM3)**.
6. Make selections for **Speed or Noise Rejection** and **CAN enabled**. See the *SURVEYOR* help  for more information on all settings.
7. Click **Apply**.

8. Select a **Sample Rate**. For this exercise, select **10 Hz**. (1/2 Hz is typical for thermocouple measurements.)
9. **Add Measurement(s)**. For this exercise, add a Type-T differential thermocouple on **DIFF1**.



10. Wire the sensor according to the given wiring diagram.

TCDiff 1 Properties

SHOW WIRING

| Wire | Color | Terminal |
|------|-------|----------|
| Sig+ | Blue | Diff1H |
| Sig- | Red | Diff1L |

Variable Name *i*

tcdiff1

Thermocouple Type *i*

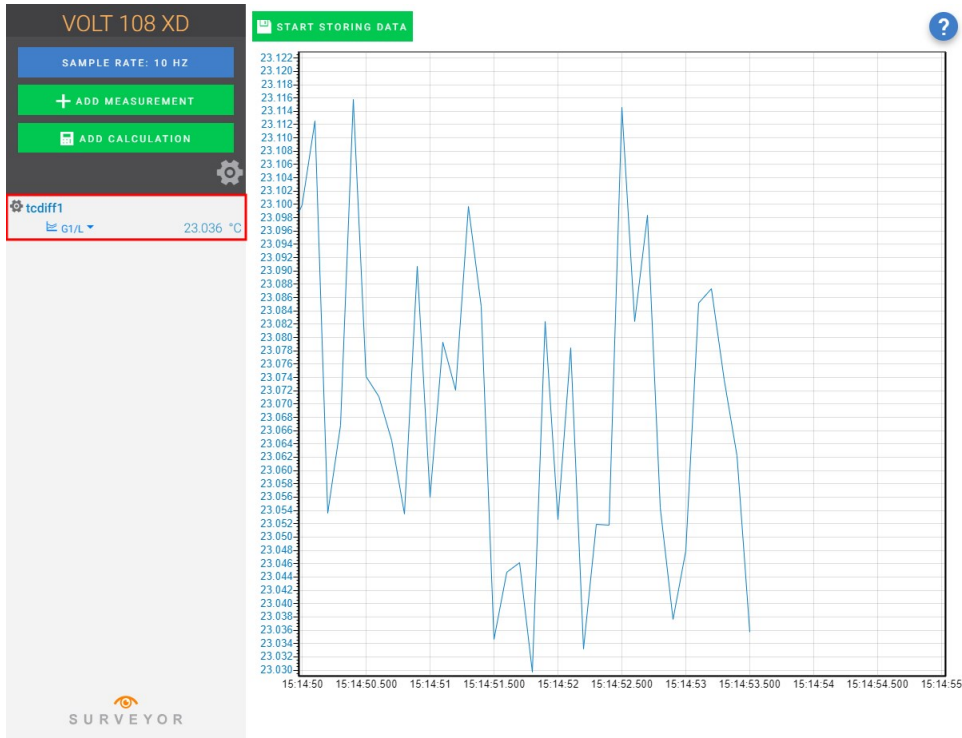
TypeT Copper Constantan ▾


Units *i*

°C ▾

11. Complete the rest of the form and **Apply** to save the configuration.

12. Check the resulting measurements in the numeric and graphic displays.



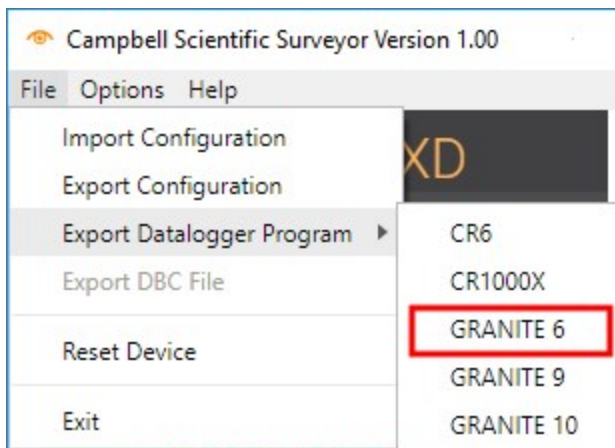
13. Click **Start Storing Data** . While data is being stored the options to stop and pause data storage become available.

5. Programming quickstart using *SURVEYOR*

Campbell Scientific *SURVEYOR* is an easy way to generate a simple CRBasic program for your VOLT 100 series Campbell Scientific data acquisition system.

1. Configure the VOLT 100 series for measurements, see [Measurement quickstart using SURVEYOR](#) (p. 2).

2. Select **File > Export Datalogger Program** then select the data logger you will be connecting the VOLT 100 series to. For this example, we'll select GRANITE 6.



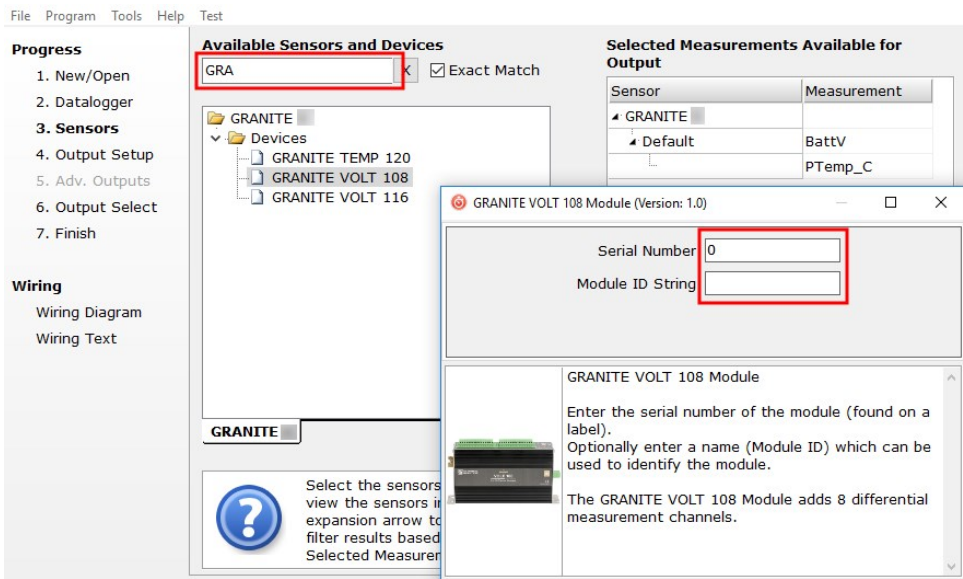
3. By default, the CRBasic program will be saved in C:\Users\username\Documents\SURVEYOR.

6. Programming quickstart using *Short Cut*

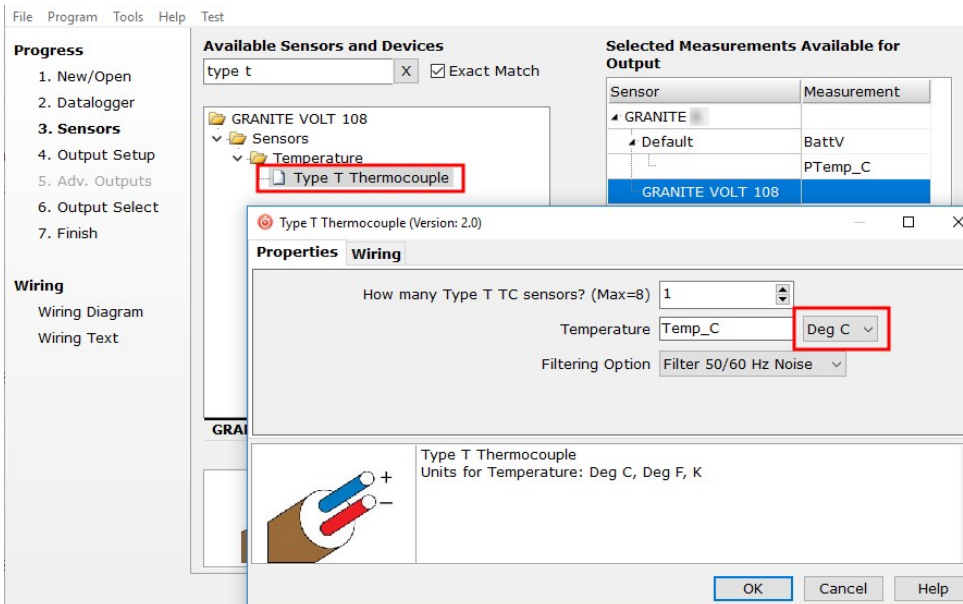
Short Cut is another easy way to program a Campbell Scientific data acquisition system to measure a sensor and assign wiring terminals. *Short Cut* is available as a download from www.campbellsci.com/shortcut. It is also included in installations of *LoggerNet*, *RTDAQ*, and *PC400*.

The following procedure shows using *Short Cut* to program the data logger to measure a type-T thermocouple on a VOLT 100 series.

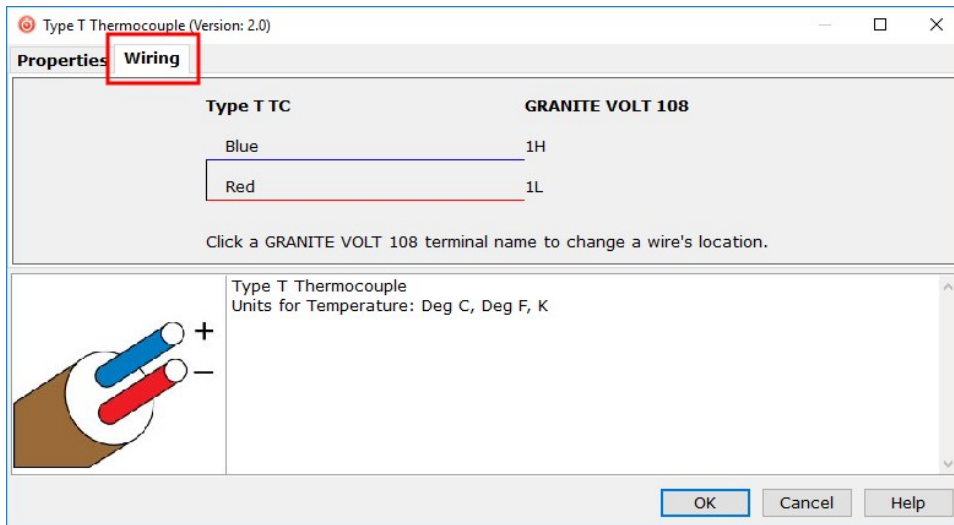
1. Open *Short Cut* and click **Create New Program**.
2. Double-click your data logger.
3. In the **Available Sensors and Devices** box, start typing GRANITE. You can also locate it in the **Devices** folder. Double click the GRANITE Measurement Module you are working with. Type the serial number located on the VOLT 100 series label. Optionally, type a name in the **Module ID String** if you want the module to have an ID. This is useful when multiple VOLT 100 series modules are connected to the data logger.



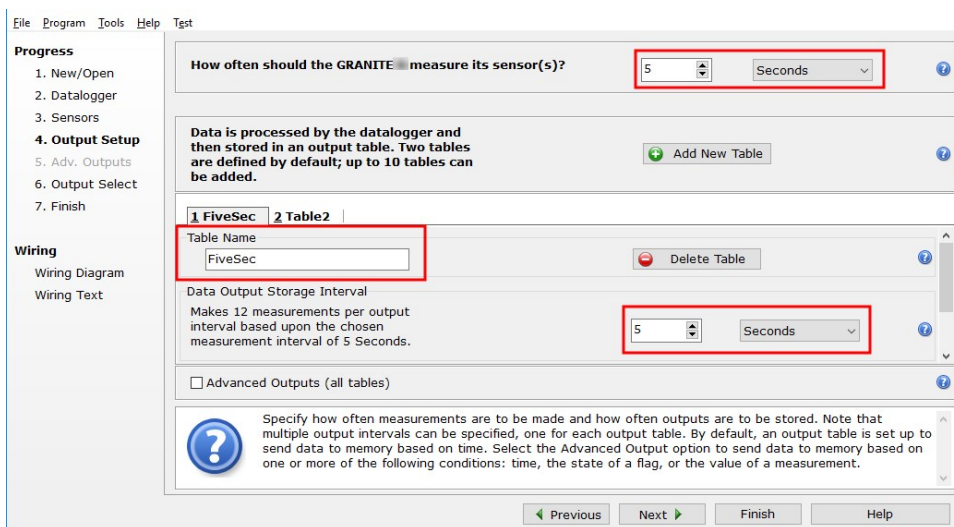
- In the **Available Sensors and Devices** box, type Type T. You can also locate the thermocouple in the **Sensors > Temperature** folder. Double click **Type T Thermocouple**. Type the number of type T thermocouples connected to the VOLT 100 series. The temperature defaults to degree C. This can be changed by clicking the **Temperature** units box and selecting one of the other options.



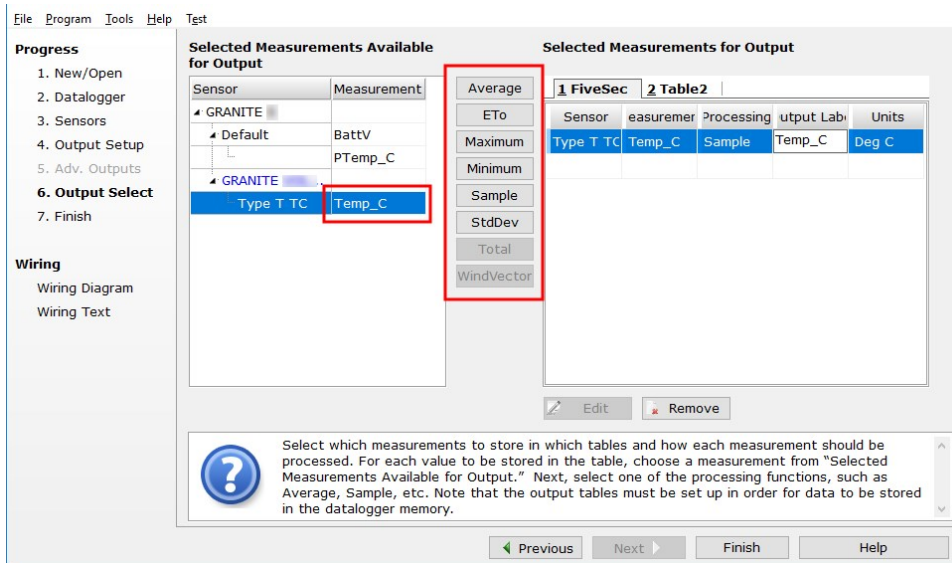
- Click on the **Wiring** tab to see how the sensor is to be wired to the VOLT 100 series. Click **OK** after wiring the thermocouple.



- Repeat steps four and five for other sensors you want to measure. Click **Next**.
- In **Output Setup**, type the scan rate, a meaningful table name, and the **Data Output Storage Interval**.



8. Select the measurement and its associated output option.



9. Click **Finish** and save the program. Send the program just created to the data logger if it is connected to the computer.
10. If the thermocouple is connected to the VOLT 100 series, check the output of the thermocouple in the data display of *LoggerNet*, *RTDAQ*, or *PC400* to make sure it is making reasonable measurements.

7. Overview

The VOLT 100 series expands the number of analog measurement terminals and increases the measurement-speed potential in a data logger system. GRANITE Measurement Modules operate through a data logger program and communicate using the CAN peripheral interface (CPI). A single data logger can operate multiple GRANITE Measurement Modules. Use the CPI calculator at www.campbellsci.com/downloads/cpi-calculator to estimate the usage and capacity of a CPI network. Select a CDM-A108 for a VOLT 108 and a CDM-A116 when using a VOLT 116.

The VOLT 100 series is compatible with the following data loggers:

- GRANITE 10
- GRANITE 9
- GRANITE 6
- CR6
- CR1000X

7.1 Wiring panel overview

CAUTION:

To avoid damage to sensors and devices, ensure that each removable wiring-terminal strip is connected to the VOLT 108 and VOLT 116 in the proper location before applying power. Each strip is keyed identically.

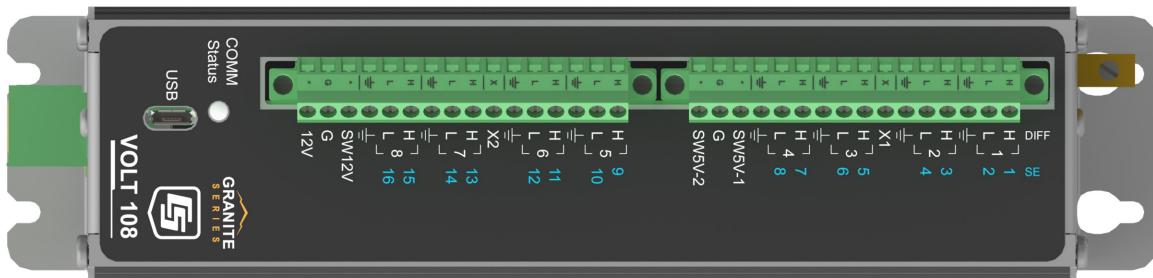


FIGURE 7-1. VOLT 108 Wiring panel

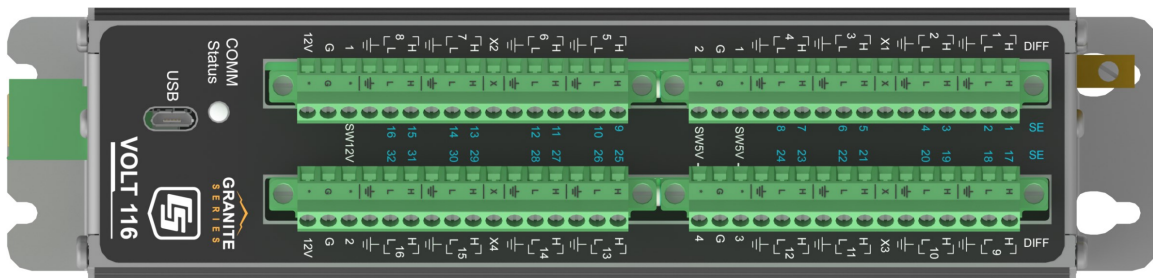


FIGURE 7-2. VOLT 116 Wiring panel

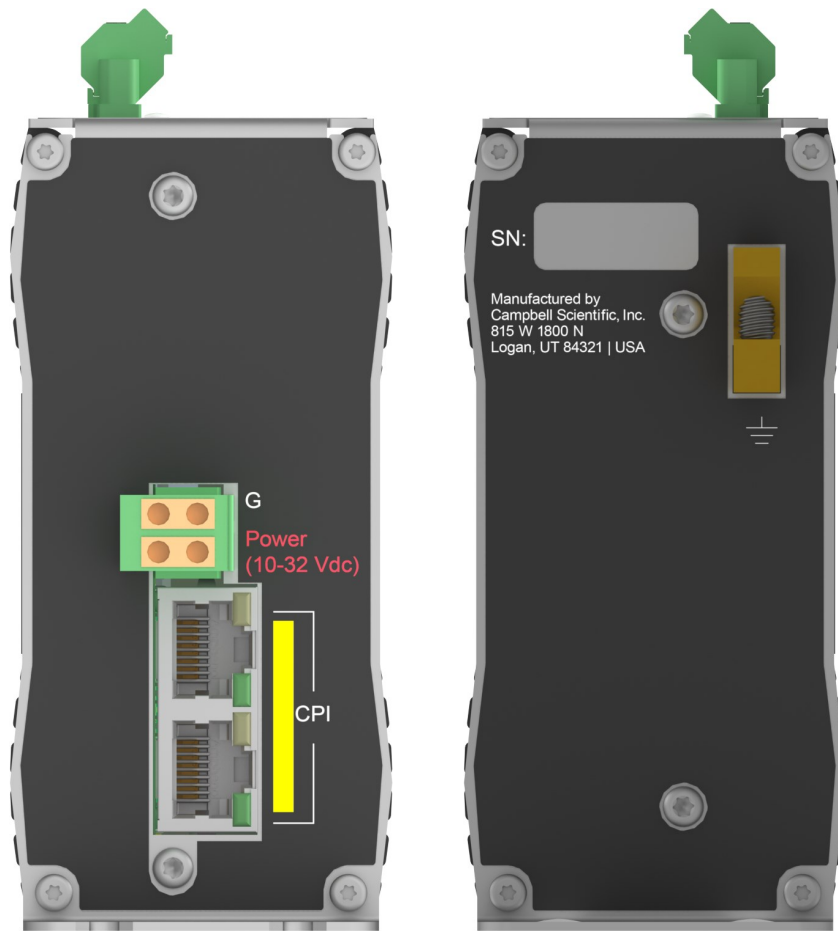


FIGURE 7-3. Power and CPI ports view (left) and ground lug view (right)

7.1.1 Analog input

Analog sensors output a continuous voltage or current signal that varies with the phenomena measured. Sensors compatible with the VOLT 100 series output a voltage. Current output can be made compatible with a resistive shunt. Sensor output is measured with the appropriate CRBasic measurement instruction. Measurement types are described the following sections.

Sensor connection is to **H/L** terminals configurable for differential (**DIFF**), single-ended (**SE**), or period-average inputs. For example, differential channel **1** is comprised of terminals **1H** and **1L**, with **1H** as high and **1L** as low.

7.1.1.1 Single-ended measurements

A single-ended measurement measures the difference in voltage between the terminal configured for single-ended input and the reference ground. Single-ended terminals are labeled in blue. The VOLT 108 has 16 **SE** terminals, and the VOLT 116 has 32. For example, single-ended channel **1** is comprised of terminals **1** and ⏏ .

7.1.1.2 Differential measurements

A differential measurement measures the difference in voltage between two input terminals. Use a differential measurement to measure current by using external resistors to convert current to voltage. The VOLT 108 has 8 H/L differential terminals, and the VOLT 116 has 16.

7.1.1.3 Period averaging

Single-ended terminals on the VOLT 100 series are also configurable for measuring the period of an analog signal.

7.1.2 Voltage and current excitation

X terminals supply switched voltage or current to sensors. The VOLT 108 has two X terminals, and the VOLT 116 has four.

- Voltage Excitation (switched-analog output) – X terminals, configured for voltage excitation output, supply precise voltage in the range of ± 5000 mV. These terminals are regularly used with resistive-bridge measurements.
- Current Excitation (switched-analog output) – X terminals, configured for current excitation output, supply precise current in the range of ± 2.5 mA. These terminals are regularly used with resistive-bridge measurements.

7.1.3 Switched voltage output

SW5V and SW12V terminals supply voltage and control for sensors. The VOLT 108 includes two SW5V and one SW12V terminals. The VOLT 116 includes four SW5V and two SW12V terminals.

7.1.4 Grounding terminals

Proper grounding lends stability and protection to a data acquisition system. It is the easiest and least expensive insurance against data loss. The following terminals are provided for sensor and VOLT 100 series ground connections:

- Signal Ground (\perp) – reference for single-ended analog inputs, excitation returns, and as a ground for sensor shield wires. Current-loop sensors, however, should be grounded to power ground.
- Power Ground (G) – return for 5V, 12V, and current-loop sensors. Use of G grounds for these outputs minimizes potentially large current flow through the analog-voltage-measurement section of the wiring panel, which can cause single-ended voltage measurement errors.

- Earth Ground Lug (⚡) – connection point for a heavy-gage earth-ground wire. A good earth connection is necessary to secure the ground potential of the VOLT 100 series and shunt transients away from electronics. 14 AWG wire, minimum, is recommended.

NOTE:

Several ground wires can be connected to the same ground terminal.

7.1.5 Power terminals

7.1.5.1 Power in

The removable **Power** connector is the connection point for external power supply components. The power supply must be in the range of 9.6 to 32 VDC.

7.1.5.2 Power out

The VOLT 100 series can be used as a power source for sensors. The following voltage terminals are available:

- **12V** and **SW12V** – Regulated 12 VDC when the supply voltage is 14.5 to 32 VDC. Below 14.5 VDC, the voltage tracks the power supply. Current output is limited to 200 mA.
- **SW5V** – See [Switched 5 VDC](#) (p. 19) for information on voltage and current sourcing limits.

7.1.6 Communications ports

One micro-B **USB** port, labeled **USB**, is for communicating with a computer through *SURVEYOR* or *Device Configuration Utility* software.

CPI is a proprietary protocol that supports GRANITE Measurement Modules. Two RJ45 ports labeled **CPI** enable communications with a Campbell Scientific data logger and other GRANITE Measurement Modules.

7.1.7 LED indicators

7.1.7.1 COMM status

When the VOLT 100 series has successfully been configured by a data logger, the **COMM Status** LED will flash green. For scan rates 500 ms or slower, it will flash at the scan rate. For faster scan rates, the LED will flash green every few scans. See [Table 12-2](#) (p. 39).

7.1.7.2 CPI port

When the VOLT 100 series has successfully been configured by a data logger, the green LED on the CPI port will flash. For scan rates 500 ms or slower, it will flash at the scan rate. For faster scan rates, the green LED will flash every few scans. A flashing orange LED indicates bus activity. A solid orange LED indicates a bus error. See [Table 12-3](#) (p. 39).

8. Specifications

All Standard Duty (SD) VOLT 100 series units meet electrical specifications in a temperature range of -40 to 70 °C, non-condensing environment. Extended Duty (XD) units are tested over an extended temperature range of -55 to 85 °C. Recommended calibration interval is every three years.

8.1 Voltage measurements

Voltage measurements use a 24-bit Analog-to-Digital (A-to-D) converter. One channel at a time is measured in numeric succession. Differential and single-ended channels can be mixed.

Terminals

Differential configuration

VOLT 108: DIFF 1H/1L – 8H/8L

VOLT 116: DIFF 1H/1L – 16H/16L

Single-ended configuration

VOLT 108: SE 1 – 16

VOLT 116: SE 1 – 32

Range: ± 5000 , ± 1000 , ± 250 mV. See [Table B-1](#) (p. 42)

Accuracy¹

0 to 40 °C: $\pm(0.04\% \text{ of Reading} + \text{Offset}^2)$

-40 to 70 °C: $\pm(0.06\% \text{ of Reading} + \text{Offset}^2)$

-55 to 85 °C: $\pm(0.08\% \text{ of Reading} + \text{Offset}^2)$

Resolution: See [Table B-1](#) (p. 42)

Speed: See [Table 8-2](#) (p. 15)

See also [Fast measurements](#) (p. 32)

Table 8-2: Analog voltage measurement speed¹

| f _{N1} (Hz) | Multiplexed ² measurement | | | |
|-------------------------|--------------------------------------|--------------|------------------------|--------------|
| | With input reversal | | Without input reversal | |
| | Time (ms) | Rate (Hz) | Time (ms) | Rate (Hz) |
| 2000 | 2.40 | 422.83 | 1.22 | 844.59 |
| 1000 | 3.40 | 297.18 | 1.72 | 593.82 |
| 500 | 5.40 | 186.39 | 2.72 | 372.58 |
| 100 | 21.40 | 46.81 | 10.72 | 93.60 |
| 60 | 34.73 | 28.82 | 17.38 | 57.63 |
| 50 | 41.40 | 24.18 | 20.72 | 48.35 |
| 30 | 68.06 | 14.70 | 34.05 | 29.40 |
| 25 | 81.40 | 12.29 | 40.72 | 24.58 |
| 15 | 134.73 | 7.42 | 67.38 | 14.85 |
| 10 | 201.40 | 4.97 | 100.72 | 9.93 |
| 5 | 401.40 | 2.49 | 200.72 | 4.98 |
| 2.5 | 801.40 | 1.25 | 400.72 | 2.50 |

¹ Default settling time of 500 μs.

² Refers to multiplexing circuitry internal to the VOLT 108/116.

8.2 Resistance measurements

Resistance measurements for four- and six-wire full-bridge and two-, three-, and four-wire half-bridge using voltage excitation or direct resistance measurements using current excitation. Excitation polarity reversal minimizes DC error.

Terminals

VOLT 108:

- SE terminals 1 – 16
- DIFF terminals 1H/1L – 8H/8L
- Excitation terminals X1 – X2

VOLT 116: SE terminals 1 – 32
 DIFF terminals 1H/1L – 16H/16L
 Excitation terminals X1 – X4

Accuracy^{1,2}

0 to 40 °C: ±(0.02% of voltage measurement + offset)
 –40 to 70 °C: ±(0.025% of voltage measurement + offset)
 –55 to 85 °C: ±(0.03% of voltage measurement + offset)

¹ Assumes input reversal for differential measurements and excitation reversal for excitation voltage <1000 mV and excitation current <1 mA, not including bridge resistor errors and sensor and measurement noise.

² See GRANITE 6 Data logger Manual for help estimating measurement accuracy for ratiometric measurements. For [Resistance\(\)](#) instruction, the excitation current is internally measured across an internal resistor (200 Ω, ±0.005% @ 25 °C, 2 ppm/°C TCR) with sensor resistance determined as V_s/I_x , where I_x is the measured excitation current and V_s is the returned sensor signal.

8.3 Voltage and current excitation

Two terminals on the VOLT 108 and four terminals on the VOLT 116 can be configured for voltage or current excitation using a 12-bit D-to-A converter. When used for ratiometric-resistance measurement, excitation is active only during measurement.

Terminals

VOLT 108: X1 – X2
 VOLT 116: X1 – X4

Voltage excitation

Range: ±5000 mV

Accuracy¹

0 to 40 °C: ±(0.05% of setting + 2.5 mV)
 –40 to 70 °C: ±(0.08% of setting + 2.5 mV)
 –55 to 85 °C: ±(0.1% of setting + 2.5 mV)

Resolution: 1.25 mV

Maximum source or sink current: ±50 mA

Current excitation

Range: ±2.5 mA

Accuracy¹

0 to 40 °C: $\pm(0.05\% \text{ of setting} + 2.5 \mu\text{A})$

-40 to 70 °C: $\pm(0.08\% \text{ of setting} + 2.5 \mu\text{A})$

-55 to 85 °C: $\pm(0.1\% \text{ of setting} + 2.5 \mu\text{A})$

Resolution: 638 nA

Compliance voltage²: $\pm 5000 \text{ mV}$

¹ Note that ratiometric accuracy, rather than absolute accuracy, determines overall measurement accuracy of ratiometric-resistance measurements.

² Current excitation meets specified accuracy when voltage at the port remains within the compliance voltage.

8.4 Period averaging

Terminals

VOLT 108: SE 1 – 16

VOLT 116: SE 1 – 32

Range: See [Table 8-3](#) (p. 18)

Accuracy: $\pm(0.01\% \text{ of reading} + \text{resolution})$

Resolution: $130 \text{ ns} \div \text{number of cycles}$

Table 8-3: Period average ranges

| Voltage gain | Minimum peak-to-peak Signal ^{1,2} (mV) | Minimum pulse width (μs) | Maximum frequency (kHz) |
|--------------|---|---------------------------------------|-------------------------|
| 1 | 500 | 2.4 | 200 |
| 3.8 | 50 | 8 | 50 |
| 19 | 10 | 50 | 8 |
| 67 | 2 | 80 | 5 |

¹ With signal centered around VOLT 108/116 ground.

² Maximum period average signal amplitude = 20 V peak-to-peak.

8.5 Voltage output

8.5.1 Continuous 12 VDC

Terminals

VOLT 108: 12V

VOLT 116: 12V

Voltage output¹: 12.5 ± 0.5 VDC

Current sourcing limit (each): 200 mA typical, 180 mA minimum

¹ Unregulated below 14.5 V.

8.5.2 Switched 12 VDC

Terminals

VOLT 108: SW12V-1

VOLT 116: SW12V-1-2

Voltage output¹: 12.5 ± 0.5 VDC

Current sourcing limit (each): 200 mA typical, 180 mA minimum

¹ Unregulated below 14.5 V.

8.5.3 Switched 5 VDC

Terminals

VOLT 108: SW5V-1-2

VOLT 116: SW5V-1-4

Voltage output

On, no load: 4.75 ± 0.25 VDC

Off: <0.1 VDC

Output resistance: 30 Ω

Current sourcing limit: See [FIGURE 8-1](#) (p. 20)

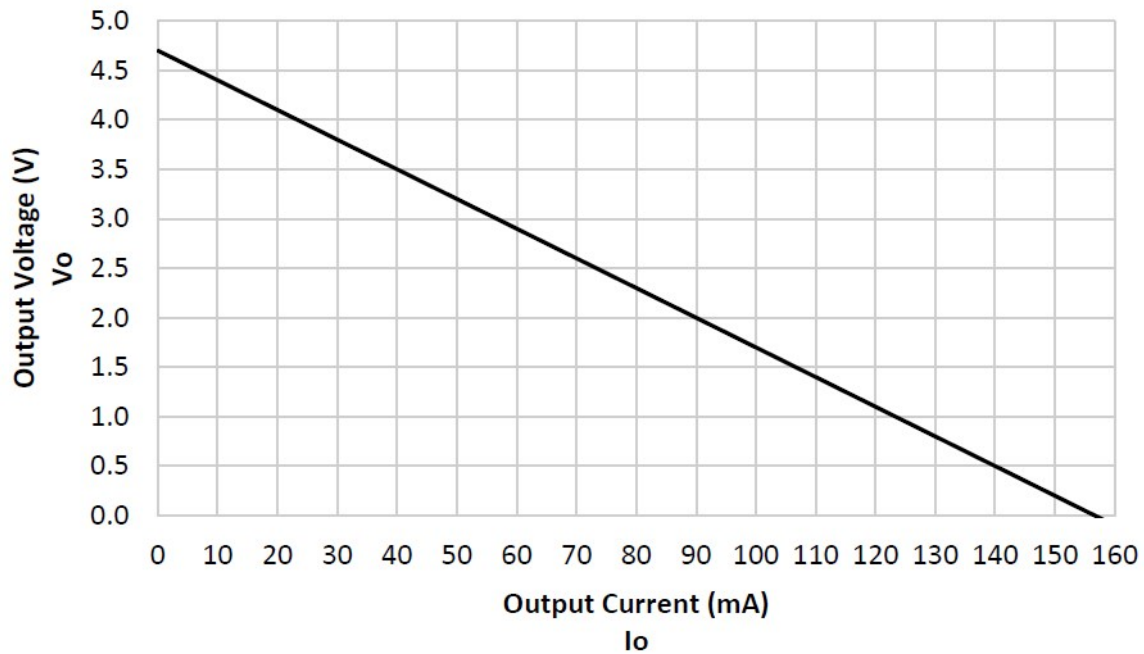


FIGURE 8-1. Current sourcing on SW5V terminals

8.6 Module

8.6.1 Communications

| | |
|-------------|---|
| CPI: | RJ45 interface to Campbell Scientific data loggers, sensors, and GRANITE Measurement Modules. |
| USB: | USB micro-B device only, 2.0 full-speed 12 Mbps, for computer connection. |

8.6.2 System

| | |
|-------------------|---|
| Processor: | Renesas RX63N (32-bit with hardware FPU, running at 96 MHz) |
| Memory: | 2 MB SRAM |

8.6.3 Power requirements

| | |
|------------------------------|--|
| Voltage: | 9.6 to 32 VDC |
| Typical Current Drain | (Sensor excitation or switched power loads are additive to the active values.) |
| Sleep: | <1 mA |

| | |
|----------------------------------|-----------------|
| Active 1 Hz Scan ¹ : | 2 mA, estimated |
| Active 20 Hz Scan ¹ : | 20 mA |
| Active 1 kHz Scan ² : | 67 mA |

¹ Assumes one single-ended measurement with the first notch frequency (f_{N1}) at 30 kHz.

² Assumes one differential measurement with the first notch frequency (f_{N1}) at 30 kHz.

8.6.4 Compliance

View EU Declarations of Conformity at www.campbellsci.com/volt108 and www.campbellsci.com/volt116.

8.6.5 Physical attributes

Dimensions: 20.3 x 12.7 x 5.1 cm (8.0 x 5.0 x 2.0 in); additional clearance required for cables and wires

Weight

VOLT 108: 0.8 kg (1.75 lb)

VOLT 116: 0.9 kg (1.95 lb)

Operating Temperature

Standard Duty (SD): -40 to 70 °C

Extended Duty (XD): -55 to 85 °C

9. Installation

Preconfigure and test stations in an indoor location before doing the field installation.

After installing a field station, wait long enough to confirm that good measurements are being made, that data is collected by the data logger, and that data from the data logger can be copied to a computer.

| | |
|--|----|
| 9.1 Install driver for computer connection | 22 |
| 9.2 Operating systems | 22 |
| 9.3 Configuring VOLT 100 series | 22 |
| 9.4 Data logger programming | 24 |

| | |
|---|----|
| 9.5 Data logger connection | 26 |
| 9.6 Connecting multiple GRANITE Measurement Modules | 26 |
| 9.7 Power connection | 28 |
| 9.8 Earth ground connection | 29 |
| 9.9 Mounting in an enclosure | 29 |

9.1 Install driver for computer connection


SURVEYOR automatically installs the required drivers. See: [Measurement quickstart using SURVEYOR](#) (p. 2). When *SURVEYOR* is not used, the device driver must be installed before connecting to the VOLT 100 series via USB for the first time.

To install the device driver using the *Device Configuration Utility*, select **GRANITE > VOLT 100 series**. Click the **Install the USB** driver link and follow the prompts.

TIP:

Driver installation is optional for computers running Windows 10 and later.

9.2 Operating systems

Campbell Scientific posts operating system (OS) updates at www.campbellsci.com/downloads  when they become available. Before deploying instruments, check OS versions and update as needed to the most recent version. Use the *Device Configuration Utility* and follow the procedures on the **Send OS** tab.

NOTE:

For best performance, use the most recent OS for each device.

9.3 Configuring VOLT 100 series

The VOLT 100 series arrives ready to be connected to a system. Device configuration is only required when multiple GRANITE Measurement Modules are connected to a single data logger. Each module must have a unique CPI address. Set a unique device name for further distinction between GRANITE Measurement Modules.

Configure the VOLT 100 series using one of four methods: through *SURVEYOR*, the [CPIAddModule](#) (C) program instruction, *Device Configuration Utility* software, or the *CPIStatus* table.

9.3.1 Configuring with *SURVEYOR*

Modules are automatically configured when connected to *SURVEYOR*. *SURVEYOR* sets the module CPI address to 1 and uses the device type and serial number to generate and assign a device name such as 'VOLT108-1234'.

For more information see [Measurement quickstart using SURVEYOR](#) (p. 2)

9.3.2 Configuring with the `CPIAddModule()` instruction

To configure a VOLT 100 series within a program, use the `CPIAddModule()` instruction. A separate instruction is used for each device. The `CPIAddModule()` instruction overrides settings entered by other means, such as *Device Configuration Utility* or the `CPIStatus` table.

```
CPIAddModule(CDMType, CDMSerialNo, CDMDeviceName, CPIAddress)
```

The data logger creates an internal list of CPI modules from each `CPIAddModule()` instruction. Modules added to the CPI bus will be checked against this list and reconfigured accordingly. See a programming example: [Configuring GRANITE Measurement Module with CPIAddModule\(\)](#) (p. 45).

NOTE:

The `CPIAddModule()` instruction overrides changes made through *SURVEYOR*, *Device Configuration Utility* or the `CPIStatus` table.

9.3.3 Configuring with *Device Configuration Utility*

Install the device driver before connecting the VOLT 100 series to a computer. This is optional for Windows 10, or later, operating systems.

1. Open *Device Configuration Utility*.
2. Under **Device Type**, select **GRANITE > VOLT 100 series**.
3. Carefully review the Connect Instructions text provided on the right.
4. With the USB device driver installation complete, connect the supplied USB cable between the USB port on your computer and the **USB** port on the VOLT 100 series.
5. Apply 9.6 to 32 VDC to the power terminals on the device.
6. Click the browse button next to **Communication Port**.
7. Select the port labeled **VOLT 100 series**.
8. Click **OK**.

9. Click **Connect** then **OK** to avoid conflicts.
10. Set the **Device Name** (optional) and the **CPI Address**.
 - a. **Device Name** is a user-editable field to set a unique name to the VOLT 100 series. The default name is **VOLT 100**.
 - b. **CPI Address** specifies the address of the VOLT 100 series. Each GRANITE Measurement Module connected to the same data logger must have a unique address. By default, the VOLT 100 series uses a CPI address of 1. Allowable addresses are 1 through 120.
11. Click **Apply** to save your changes.

9.3.4 Configuring with CPIStatus table

When a GRANITE Measurement Module is used in a program, the data logger adds a **CPIStatus** table to display current CPI information. View the **CPIStatus** table in the *LoggerNet* Connect screen, or *Device Configuration Utility Data Monitor* tab. Information about each module included in the data logger program or connected to the CPI bus appears in the **CPIStatus** table within the **ModuleInfo()** array. Information is shown in the following order:

GRANITE Measurement Module Type, Serial Number, Device Name, CPI Address, Activity, CDM OS Version

NOTE:

CDM OS version will be the last element in the **ModuleInfo()** array for VOLT 100 series modules with OS version 7 or newer.

Within the **ModuleInfo()** array index string, the Device Name and CPI Address fields can be edited. This provides a way to rename and readdress a VOLT 100 series through Campbell Scientific software without editing the CRBasic program or connecting directly to the **USB** port.

See [CPIStatus table](#) (p. 38) for additional information.

9.4 Data logger programming

Short Cut is the best source for up-to-date data logger programming code. Programming code is needed when:

- Creating a program for a new data logger installation
- Adding sensors to an existing data logger program

If your data acquisition requirements are simple, you can likely create and maintain a data logger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that

Short Cut creates are a great source for programming code to start a new program or add to an existing custom program.

NOTE:

Short Cut cannot edit programs after they are imported and edited in *CRBasic Editor*.


See [Programming quickstart using Short Cut](#) (p. 6) for a *Short Cut* tutorial. If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in [Importing Short Cut code into CRBasic Editor](#) (p. 41). Complete program examples can be found in: [Example programs](#) (p. 45).

9.4.1 Scan buffers

When VOLT 100 series instructions are included in a program, Campbell Scientific recommends setting the **BufferOption** of the **Scan()** instruction to a value greater than or equal to two seconds' worth of scans. For example, if the scan rate is 50 ms (.05 s), set the **BufferOption** to 40 ($2\text{ s} \div .05\text{ s} = 40$). At a minimum, the **BufferOption** should be set to 3.

The data logger processes the data from the VOLT 100 series in batches according to frame syncs received from the VOLT 100 series. Upon receiving a batch of data, the data logger puts it into a processing queue. Processing the data may take more time than is available in a single scan. The **BufferOption** allows the data logger to balance its task load by processing the data from the VOLT 100 series during subsequent scans while maintaining correct data time stamps. If a **BufferOption** is not set, the data logger will attempt to process all of the data during the scan it is received, which can result in skipped scans. Scan buffers are only used when the data logger is running in pipeline mode.

9.4.2 GRANITE Measurement Module instructions

For the most current information on data logger instructions, refer to the [CRBasic Editor Help](#) .

The first two parameters for each CDM instruction are the **CDMType** and **CPI_Addr**. **CDMType** refers to the GRANITE Measurement Model used. Valid entries are **VOLT108** and **VOLT116**. **CPI_Addr** is the address of the VOLT 100 series. Wire sensors to the terminals specified within the corresponding measurement instructions. The following program example shows the use of the **CDM_VoltSE()** instruction.

CRBasic Example 1: Measuring a single-ended voltage

```
'Program Example: Measuring a single-ended voltage
Public SEVolt
BeginProg
  Scan(5,Sec,3,0)
  'Measure Single-Ended Voltage on VOLT 108, CPI address 1
  CDM_VoltSe(VOLT108,1,SEVolt,1,mV5000,1,True,500,60,1,0)
NextScan
EndProg
```

9.5 Data logger connection

VOLT 100 series devices communicate with a data logger through a **CPI** port. Each VOLT 100 series ships with a 6-inch RJ45 cable for this connection, though any CAT5e, or better, RJ45 cable can be used. To allow daisy-chaining, two **CPI** ports are available on the VOLT 100 series. Either **CPI** port on the VOLT 100 series connects directly to the **CPI** port on a GRANITE 10, GRANITE 9, GRANITE 6, CR6, or CR1000X data logger.

9.6 Connecting multiple GRANITE Measurement Modules

The CPI bus, which handles the communications between the data logger and GRANITE Measurement Modules, can accept addresses **1 to 120**. Multiple GRANITE Measurement Modules may be connected to a single data logger using a daisy-chain or star topology. In both network configurations, as total cable length increases, the maximum possible bit rate decreases. Therefore, in networks with long cable lengths, it may be necessary to use the **CPISpeed()** instruction to decrease the CPI network bit rate from its default 250 kbps. Limitations on cable length and bit rate are discussed further in [CPI network bit rate](#) (p. 35) and listed in [Table 10-2](#) (p. 36).

Use the CPI calculator at www.campbellsci.com/downloads/cpi-calculator  to estimate the usage and capacity of a CPI network. Select a CDM-A108 for a VOLT 108 and a CDM-A116 when using a VOLT 116.

9.6.1 Daisy-chain topology

In a daisy-chain topology, GRANITE Measurement Modules are connected one after another, as shown in [FIGURE 9-1](#) (p. 27).

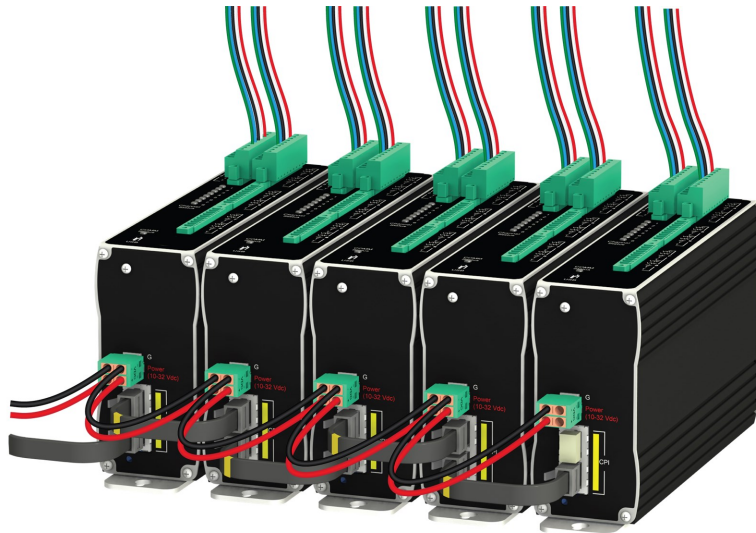


FIGURE 9-1. Multiple GRANITE Measurement Modules connected in a daisy-chain topology

For best performance, a CPI terminator (supplied in a CPI Network Kit) is installed in the open CPI port at the end of a daisy-chain network. For more information see: <https://s.campbellsci.com/documents/us/technical-papers/cpi-bus.pdf>

9.6.2 Star topology

A star topology uses a passive RJ45 hub, such as the HUB-CPI, to connect multiple GRANITE Measurement Modules. An illustration of this is shown in FIGURE 9-2 (p. 27).

NOTE:

Do not use a CPI terminator with this configuration.

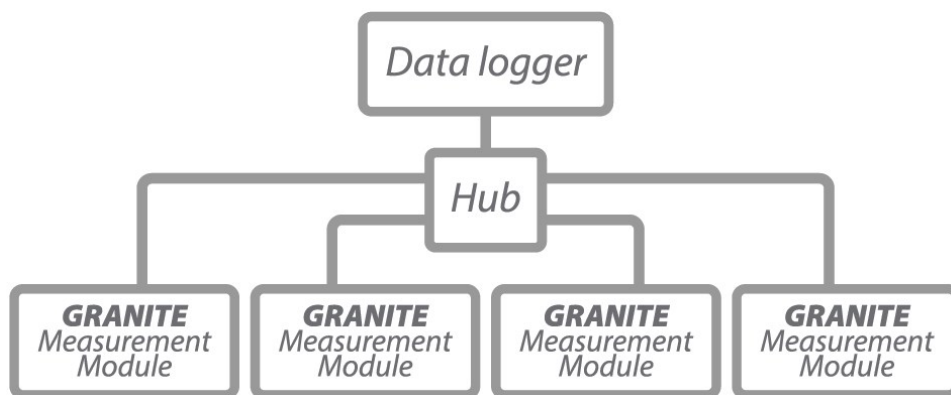


FIGURE 9-2. Multiple GRANITE Measurement Modules connected in a star topology

9.7 Power connection

Connect the power supply to the removable **Power** connector on the side of the VOLT 100 series. Power supplies providing voltages from 9.6 to 32 VDC may be used.

- While the input power requirements of Campbell Scientific instruments vary, there is one constant – they all run on 12 VDC. To keep things simple, we only discuss the use of 12 VDC power supplies in this manual.
- Do not connect energized wires to an instrument. All connections discussed assume de-energized wires. Switch off power supplies before making connections.
- Double check the polarity of connections before switching on power supplies.

NOTE:

When the supply voltage is below 14.5 VDC, the voltage on the **12V** and **SW12V** terminals track the power supply. Voltage on these terminals is regulated to 12.5 ± 0.5 VDC when the supply voltage is 14.5 to 32 VDC.

Open the power connector by inserting a screwdriver into the slots shown in [FIGURE 9-3](#) (p. 28). When the screwdriver is pushed in far enough, the orange terminals will open and remain open until the screwdriver is removed. The power connector includes two positive (+VDC) terminals and two negative (–VDC) terminals to allow for daisy-chaining power supplies. Terminals of the same type open and close together. Insert the positive wire from the power supply into a +VDC terminal, and insert the negative wire into a –VDC terminal.



FIGURE 9-3. Opening the power connector terminals

9.7.1 Power-up sequence

Best practice is to start all instruments in a station simultaneously from a single power supply. If this is not possible, first turn on VOLT 100 series, then the data logger. This procedure will reduce the time required to synchronize the CPI bus.

See [COMM status LED](#) (p. 39) for more information.

9.8 Earth ground connection

Earth grounding provides protection from static discharge, transients, and power surges. A ground lug is provided on the VOLT 100 series for connection to earth ground, see [Power and CPI ports view \(left\) and ground lug view \(right\)](#) (p. 11). Minimum 14 AWG ground wire is recommended. The earth side of the connection should be to a grounding rod or other grounded device.

9.9 Mounting in an enclosure

Campbell Scientific data loggers and GRANITE Measurement Module brackets have mounting holes through which small screws are inserted into nylon anchors in an enclosure backplate.

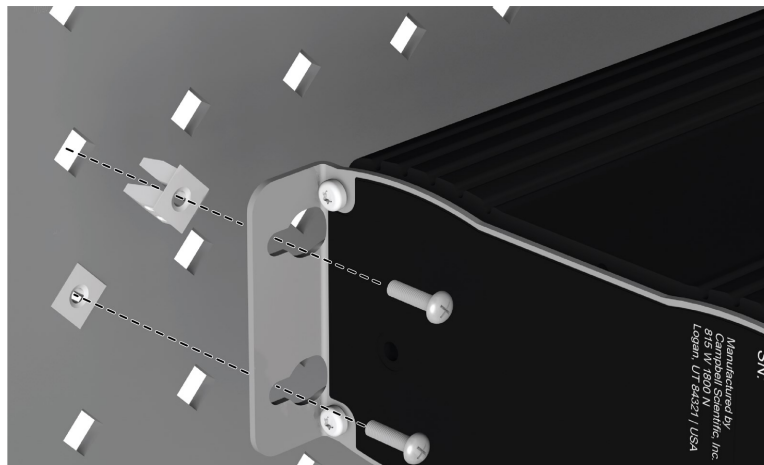


FIGURE 9-4. Enclosure backplate mounting

If mounting to a DIN rail, use the GRANITE-series DIN-Rail Kit as shown in the following images.

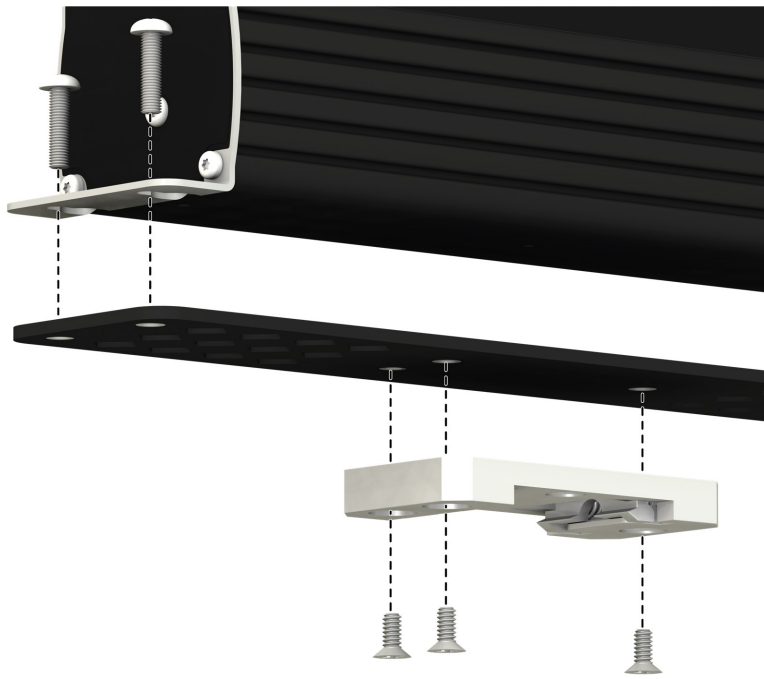


FIGURE 9-5. GRANITE DIN-Rail Mounting Kit



FIGURE 9-6. DIN rail mounting

10. Operation

The VOLT 100 series makes analog measurements either under the direction of *SURVEYOR* or the data logger.

10.1 *SURVEYOR* control

SURVEYOR sets up the VOLT 100 series to start making measurements, display data, and store that data to a computer. For more information, see [Measurement quickstart using SURVEYOR](#) (p. 2).

10.2 Data logger control

Upon compiling the program, the data logger sends information to each VOLT 100 series about every relevant sequence, scan, and measurement. The data logger uses a data sync to initiate measurements on the VOLT 100 series. Because measurements can be made in multiple scans, slow sequences, sub-scans, and subroutines, the data logger firsts sends a message to the modules indicating which measurements are to be made upon the next data sync.

When the VOLT 100 series receives a sync signal, it begins making measurements. The measurement order on the VOLT 100 series follows the sequence of the instructions addressed to it within the current active scan of the data logger program. After the measurements are completed, it sends the data to the data logger for processing.

10.3 Measurements

Because the VOLT 100 series makes measurements similar to the GRANITE 6 series data logger, refer to the [GRANITE 6 Measurement and Control System](#) manual for in-depth measurement details. Information specific to the VOLT 100 series is provided in the subsequent sections.

10.3.1 First notch frequency

The first notch frequency (f_{N1}) determines the lowest frequency that will be eliminated, or notched out, by a sinc filter. This filter notches out frequencies at integer multiples of f_{N1} by averaging for a time equal to $1/f_{N1}$. Thus, lower first notch frequencies result in longer measurement times. Any value between 2.5 Hz and 30 kHz can be entered, but the value will be rounded to the closest of 16 frequency options, with the midway point rounding up. The options for the first notch frequency are shown in [Table 8-2](#) (p. 15).

Common options for filtering noise are:

- 30000 – Performs a 0.0333 millisecond integration (for fast measurements)
- 60 – Performs a 16.67 millisecond integration (filters 60 Hz noise)
- 50 – Performs a 20 millisecond integration (filters 50 Hz noise)

10.3.2 Panel temperature

Each terminal strip has a panel temperature thermistor (Measurement Specialties 10K3A1A) located just under its center-point. The VOLT 108 includes two panel-temperature thermistors, and the VOLT 116 includes four. The thermistor has an interchangeability specification of 0.1 °C for temperatures between 0 and 70 °C. Below freezing and at higher temperatures, this specification is degraded. Combined with possible errors in the completion-resistor measurement and the Steinhart and Hart equation used to calculate the temperature from

resistance, the accuracy of panel temperature is estimated at $\pm 0.1\text{ }^{\circ}\text{C}$ over 0 to 40 $^{\circ}\text{C}$, $\pm 0.3\text{ }^{\circ}\text{C}$ from -25 to 50 $^{\circ}\text{C}$, and $\pm 0.8\text{ }^{\circ}\text{C}$ from -55 to 85 $^{\circ}\text{C}$.

The panel temperature can be measured with the [CDM_Pane1Temp\(\)](#) instruction, where each thermistor is numbered as shown in the following figure. In thermocouple measurements, using the panel temperature for the thermocouple-wiring strip will result in more accurate measurements.

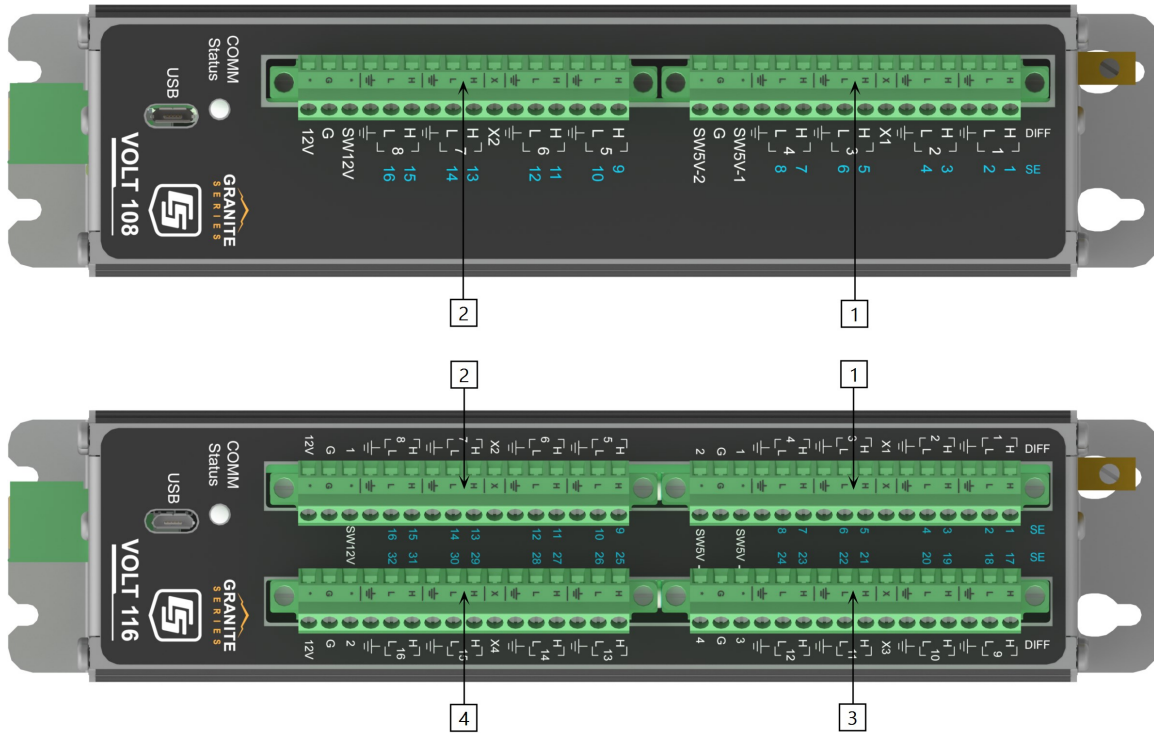


FIGURE 10-1. Wiring panel thermistor locations on VOLT 108 (top) and VOLT 116 (bottom)

10.4 Fast measurements

Use the following steps when designing fast-measurement networks:

1. Calculate the time the VOLT 100 series will take to make all of the measurements (See [Measurement speed](#) (p. 33)).
2. Calculate the CPI bit rate necessary to keep up with the sum of data generated by all devices ([CPI network bit rate](#) (p. 35)).
3. Determine if the physical layout of your network will allow for the calculated CPI bit rate (See [Table 10-2](#) (p. 36)).

Use the CPI calculator at www.campbellsci.com/downloads/cpi-calculator to estimate the usage and capacity of a CPI network. Select a CDM-A108 for a VOLT 108 and a CDM-A116 when using a VOLT 116.

Also, see [Calculating network restrictions](#) (p. 50) for complete examples.

10.4.1 Measurement speed

Use the equations in [Table 10-1](#) (p. 33) to ensure that the VOLT 100 series is able to make measurements at the speed required. Compare that speed with the scan rate options for the data logger to determine if the VOLT 100 series measurements can be done within the main scan or if they need to be performed in a sub-scan or burst. The Sample Rate refers to the rate at which the VOLT 100 series makes measurements when the **Reps** parameter is greater than 1.

These equations show that smaller notch frequencies increase measurement time. At the same time, larger notch frequencies result in lower measurement resolution. Consider this trade-off when designing your system.

| Table 10-1: Multiplexed analog voltage measurement speed ^{1,2,3} | | |
|---|-----------------------|---|
| Without input or excitation reversal | Measurement time (μs) | $\text{repetitions} \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 184 \mu\text{s} \right) + 31 \mu\text{s}$ |
| | Sample rate (Hz) | $10^6 \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 184 \mu\text{s} \right)^{-1}$ |
| With input or excitation reversal | Measurement time (μs) | $\text{repetitions} \cdot \left[2 \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 5 \mu\text{s} \right] + 31 \mu\text{s}$ |
| | Sample rate (Hz) | $10^6 \cdot \left[2 \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 5 \mu\text{s} \right]^{-1}$ |
| With input and excitation reversal | Measurement time (μs) | $\text{repetitions} \cdot \left[4 \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 8 \mu\text{s} \right] + 31 \mu\text{s}$ |
| | Sample Rate (Hz) | $10^6 \cdot \left[4 \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 8 \mu\text{s} \right]^{-1}$ |
| Burst measurement | Measurement Time (μs) | $\text{repetitions} \cdot \frac{10^6 \mu\text{s/s}}{f_{N1}} + T_{\text{settle}} + 215 \mu\text{s}$ |
| | Sample Rate (Hz) | f_{N1} |
| <p>¹ If the instruction uses excitation, calculate the measurement time separately and add 46 μs for each excitation terminal used. Refer to Example 3 in Calculating network restrictions.</p> <p>² Refers to multiplexing circuitry internal to the VOLT 100 series series.</p> <p>³ Default settling time, T_{settle}, is 500 μs, minimum 100 μs.</p> | | |

NOTE:

The VOLT 100 series auto-calibrates to compensate for changes caused by changing temperature and aging. This calibration occurs during downtime for the measurement hardware. A time-consuming program may prevent background calibration if there is insufficient downtime.

10.4.1.1 Sub-scans

To measure at rates faster than the maximum scan rate of the data logger, the **SubScan()**/**NextSubScan** instruction pair is added within the data logger scan. Using this method, the measurement speed is dictated by the **SubInterval** and **Units** parameters.

The following program makes 20 **CDM_VoltSE()** measurements on **SE 1** at 200 Hz. Note that the notch frequency chosen must accommodate the SubScan rate. In this example, f_{N1} must be 500 or greater to allow for a single-ended measurement in a 5 ms SubScan. Refer to [Table 8-2](#) (p. 15) for analog voltage measurement speeds associated with f_{N1} options.

CRBasic Example 2: Measuring VoltSE() in a sub-scan

```
'Program Example: Measuring VoltSE() in a Sub-Scan
Public FastSE(20)
Dim i 'index counter

DataTable(FastSETable, True, -1)
  Sample (20, FastSE(), FP2)
EndTable

BeginProg
  Scan(1, sec, 10, 0)
  i=1 'initialize index counter
  SubScan(5, msec, 20) 'repeat the 200 Hz measurement 20 times
    CDM_VoltSe(VOLT108, 1, FastSE(i), 1, mV5000, 1, False, 150, 500, 1, 0)
    i = i + 1 'increment index counter after each measurement
  NextSubScan
  CallTable FastSETable
NextScan
EndProg
```

10.4.1.2 Burst measurements

To measure at rates greater than the maximum sub-scan rate of the data logger, switch the measurement into burst mode by negating the measurement channel parameter. In burst mode, the measurement dwells on a single channel and measures it at rates up to 30 kHz, as

demonstrated in the following CRBasic example. Burst measurements do not allow offset measurement, input reversal, or excitation reversal.

The measurement rate is determined by the notch frequency (f_{N1}). With f_{N1} set to 15000, the measurement is made at 15 kHz. User-entered notch frequencies will be rounded to the nearest notch-frequency option (see [Table 8-2](#) (p. 15) or the [CRBasic Editor Help](#) for a full list of frequency options). The destination parameter must be an array sized to the total number of measurements to be made. Refer to the CRBasic Help for more information. The following program makes 1,735 `CDM_VoltSE()` measurements on **SE 1** at a rate of 15 kHz.

CRBasic Example 3: Measuring VoltSE() in burst mode

```
Public BurstSE(1735)

DataTable(BurstSETable,True,-1)
  Sample (1735,BurstSE(),FP2)
EndTable

BeginProg
  Scan(1,sec,10,0)
  'Negate the measurement channel to make a burst measurement
  CDM_VoltSe(VOLT108,1,BurstSE(),1735,mV5000,-1,False,150,15000,1,0)
  CallTable BurstSETable
NextScan
EndProg
```

10.4.2 CPI network bit rate

A CPI network is capable of operating at 1000, 500, 250, 125, or 50 kbps, depending on your network configuration (see [Connecting multiple GRANITE Measurement Modules](#) (p. 26)). This is the rate that data are transferred from the GRANITE Measurement Module to the data logger. When multiple GRANITE Measurement Modules are making measurements faster than 1 Hz, it is important to ensure that the CPI network bit rate is higher than the rate that data is generated by the GRANITE Measurement Modules within the network.

To calculate how many kilobits per second (kbps) will be generated, use the following **equation** for each GRANITE Measurement Module in your network:

$$\text{Kilobits per second} = (\text{number of measurements}) \times (\text{measurement frequency}) \times (0.064 \text{ kilobits per measurement})$$


The network topology and cable length affect the maximum allowable CPI network bit rate. Refer to [Table 10-2](#) (p. 36) for the maximum cable length allowed for the topology and bit rate your network requires. The bit rate of the network defaults to 250 kbps and can be changed by using the `CPIspeed()` instruction in the data logger program.

Table 10-2: Network topology, bit rate, and cable length

| Bit Rate ¹ (kbps) | Maximum total cable length (ft) | | |
|------------------------------|---------------------------------|------------------|----------------|
| | Daisy-chain topology | | Star topology |
| | Full termination | Half termination | No termination |
| 1000 | 50 | 1 | not viable |
| 500 | 200 | 200 | 100 |
| 250 | 500 | 400 | 400 |
| 125 | 1200 | 1000 | 1000 |
| 50 | 2800 | 2400 | 2400 |

¹ Default Bit Rate is 250 kbps. Change with `CPISpeed()` instruction.

10.5 Multiple devices

Multiple GRANITE Measurement Modules may be connected to a single data logger using a daisy-chain or star topology (see [Connecting multiple GRANITE Measurement Modules](#) (p. 26)). In both network configurations, as total cable length increases, the maximum possible bit rate decreases. Limitations on cable length and baud rate are examined in the document [Designing Physical Network Layouts for the CPI Bus](#) .

When including two or more VOLT 100 series devices in the program, the processing mode of the data logger affects the measurement timing of each VOLT 100 series. In sequential mode, the VOLT 100 series devices make measurements one after the other, following the order of their instructions within the program. Conversely, in pipeline mode, the devices start their measurements simultaneously. Pipeline mode is recommended.

NOTE:

In either mode, measurements that require excitation **MUST** be made on the same VOLT 100 series that provides the excitation voltage or current.

10.6 Switched voltage output

An **SW5V** terminal is normally used to operate an external relay-driver circuit because the port itself has limited drive capacity. Drive capacity is determined by the 5 VDC supply, a Schottky diode, and a 30 Ω output resistance. It is expressed as:

$$V_0 = 5\text{ V} - 0.3\text{ V} - (30\ \Omega) \times I_0$$

Where V_0 is the drive limit, and I_0 is the current required by the external device. [FIGURE 8-1](#) (p. 20) shows the relationship between supply voltage and current load.

The **SW12V** terminals are used to power devices such as sensors that require 12 VDC during measurement. Current sourcing must be limited to 200 mA or less on each channel. When the supply voltage is below 14.5 VDC, the voltage on the **SW12V** terminals track the power supply. Voltage on these terminals is regulated to 12.5 ± 0.5 VDC when the supply voltage is 14.5 to 32 VDC.

11. Maintenance and calibration

- Protect the VOLT 100 series from humidity and moisture.
- Send to Campbell Scientific for factory calibration every three years.

If sending the VOLT 100 series to Campbell Scientific for calibration or repair, consult first with a Campbell Scientific representative. If the VOLT 100 series is malfunctioning, be prepared to perform some troubleshooting procedures with Campbell Scientific. Many problems can be resolved with a conversation. If calibration or repair is needed, the procedure shown in [Assistance](#) should be followed when sending the product.

12. Troubleshooting

1. Check the voltage of the power source at the **Power** connector. It should be between 9.6 and 32 VDC.
2. Check wires and cables for the following:
 - Loose connection points
 - Faulty connectors
 - Cut wires
 - Damaged insulation, which allows water to migrate into the cable. Water, whether or not it comes in contact with wire, can cause system failure. Water may increase the dielectric constant of the cable sufficiently to impede sensor signals, or it may migrate into the sensor, which will damage sensor electronics.

3. Check the CRBasic program. Create a simplified version of the program, or break it up into multiple smaller units to test individually. For example, if a sensor signal-to-data conversion is faulty, create a program that only measures that sensor and stores the data, absent from all other inputs and data. Write these mini-programs before going to the field, if possible.
4. Verify that each VOLT 100 series in the network has a unique CPI address.
5. Check the data logger and VOLT 100 series operating system and update them as needed.
6. Check that the scan rate is long enough for the measurement time. (See [Measurement speed](#) (p. 33).) The data logger compiler often catches scan rates that are too fast.
7. Ensure that the CPI network bit rate is fast enough for the data generated and that it can accommodate the cable lengths in use. (See [CPI network bit rate](#) (p. 35).)

12.1 CPIStatus table

Information in the **CPIStatus** table, located in the data logger, helps in troubleshooting. The **ModuleInfo()** array shows the following information:

CDM Type, Serial Number, Device Name, CPI Address, Activity

The last entry in the **ModuleInfo()** index shows the activity of the module. Possible entries and their meanings are shown in the following table.

| Table 12-1: CPIStatus activity | |
|--------------------------------|---|
| Response | Meaning |
| Active | The module is connected to the CPI bus and is making measurements according to the data logger program. |
| Offline | The module was present after startup but is no longer responding. |
| Unused | The module is or was connected and powered but is not included in the data logger program. |
| Wait Config | The module has not yet responded to a data logger's attempts to configure it. |
| Config Fail | The module could not be configured. A configuration error message is appended to this response. |

12.2 COMM status LED

The COMM status LED indicates the current operation of the VOLT 100 series, as shown in the following table..

| Table 12-2: COMM Status LED Activity | | |
|--------------------------------------|--------------|---|
| Green | Flashing | Module has been configured by data logger and is receiving sync signals |
| Orange | Flashing | Device has not been configured by data logger |
| Red | Single-Flash | Device has been configured but is not receiving sync signals |
| | Double-Flash | Device has encountered a scan timeout |
| | Solid | Error |

12.3 CPI port LEDs

Green and Orange LEDs on the CPI bus indicate the current operation of the CPI bus as shown in the following table.

| Table 12-3: CPI port LED activity | | |
|-----------------------------------|----------|---------------|
| Green | Flashing | Frame sync |
| Orange | Flash | CPI activity |
| | Solid | CPI bus fault |

12.4 Replacing a GRANITE Measurement Module

An existing VOLT 100 series or CDM-A100 series can be replaced with a new module using the same CPI address without requiring a change to the program.

Appendix A. Importing *Short Cut* code into *CRBasic Editor*


Short Cut creates a .DEF file that contains wiring information and a program file that can be imported into the *CRBasic Editor*. By default, these files reside in the C:\campbellsci\SCWin folder.

Import *Short Cut* program file and wiring information into *CRBasic Editor*:

1. Create the *Short Cut* program. After saving the *Short Cut* program, click the **Advanced** tab then the **CRBasic Editor** button. A program file with a generic name will open in CRBasic. Provide a meaningful name and save the CRBasic program. This program can now be edited for additional refinement.

NOTE:

Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the program it created.

2. To add the *Short Cut* wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder, and copy the wiring information, which is at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information into it.
4. In the CRBasic program, highlight the wiring information, right-click, and select **Comment Block**. This adds an apostrophe (') to the beginning of each of the highlighted lines, which instructs the data logger compiler to ignore those lines when compiling. The **Comment Block** feature is demonstrated at about 5:10 in the [CRBasic | Features](#) video .

Appendix B. Analog voltage measurement range and resolution

Table B-1: Analog voltage measurement range and resolution

| fN1 ¹ (Hz) | Range ² (mV) | Typical effective resolution ³ | | | |
|--------------------------|----------------------------|--|------|---|------|
| | | Differential measurements with input reversal | | Single-ended measurements or differential measurements without input reversal | |
| | | RMS (μV) | bits | RMS (μV) | bits |
| 30000 | ±5000 | 10.350 | 20.0 | 14.756 | 19.5 |
| | ±1000 | 2.239 | 19.9 | 3.148 | 19.4 |
| | ±200 | 0.799 | 19.0 | 1.121 | 18.5 |
| 15000 | ±5000 | 9.012 | 20.2 | 12.819 | 19.7 |
| | ±1000 | 1.948 | 20.1 | 2.809 | 19.5 |
| | ±200 | 0.700 | 19.2 | 1.030 | 18.7 |
| 7500 | ±5000 | 7.158 | 20.5 | 10.050 | 20.0 |
| | ±1000 | 1.544 | 20.4 | 2.266 | 19.8 |
| | ±200 | 0.553 | 19.5 | 0.817 | 19.0 |
| 3750 | ±5000 | 5.410 | 20.9 | 7.851 | 20.4 |
| | ±1000 | 1.166 | 20.8 | 1.689 | 20.3 |
| | ±200 | 0.410 | 20.0 | 0.627 | 19.4 |

Table B-1: Analog voltage measurement range and resolution

| fN1 ¹ (Hz) | Range ² (mV) | Typical effective resolution ³ | | | |
|--------------------------|----------------------------|--|------|---|------|
| | | Differential measurements with input reversal | | Single-ended measurements or differential measurements without input reversal | |
| | | RMS (μV) | bits | RMS (μV) | bits |
| 2000 | ±5000 | 4.047 | 21.3 | 5.806 | 20.8 |
| | ±1000 | 0.894 | 21.2 | 1.290 | 20.7 |
| | ±200 | 0.310 | 20.4 | 0.459 | 19.8 |
| 1000 | ±5000 | 2.838 | 21.9 | 4.359 | 21.2 |
| | ±1000 | 0.613 | 21.7 | 0.931 | 21.1 |
| | ±200 | 0.220 | 20.9 | 0.343 | 20.2 |
| 500 | ±5000 | 2.035 | 22.3 | 2.999 | 21.8 |
| | ±1000 | 0.445 | 22.2 | 0.659 | 21.6 |
| | ±200 | 0.157 | 21.4 | 0.248 | 20.7 |
| 100 | ±5000 | 0.950 | 23.4 | 1.388 | 22.9 |
| | ±1000 | 0.205 | 23.3 | 0.323 | 22.6 |
| | ±200 | 0.071 | 22.5 | 0.131 | 21.6 |
| 60 | ±5000 | 0.769 | 23.7 | 1.140 | 23.2 |
| | ±1000 | 0.162 | 23.6 | 0.261 | 23.0 |
| | ±200 | 0.056 | 22.9 | 0.113 | 21.8 |
| 50 | ±5000 | 0.732 | 23.8 | 1.112 | 23.2 |
| | ±1000 | 0.161 | 23.7 | 0.254 | 23.0 |
| | ±200 | 0.053 | 22.9 | 0.111 | 21.9 |
| 30 | ±5000 | 0.612 | 24.1 | 0.901 | 23.5 |
| | ±1000 | 0.131 | 24.0 | 0.217 | 23.2 |
| | ±200 | 0.042 | 23.3 | 0.099 | 22.0 |

Table B-1: Analog voltage measurement range and resolution

| fN ¹ (Hz) | Range ² (mV) | Typical effective resolution ³ | | | |
|-------------------------|----------------------------|--|------|---|------|
| | | Differential measurements with input reversal | | Single-ended measurements or differential measurements without input reversal | |
| | | RMS (μV) | bits | RMS (μV) | bits |
| 25 | ±5000 | 0.580 | 24.1 | 0.858 | 23.6 |
| | ±1000 | 0.123 | 24.0 | 0.204 | 23.3 |
| | ±200 | 0.038 | 23.4 | 0.095 | 22.1 |
| 15 | ±5000 | 0.502 | 24.4 | 0.734 | 23.8 |
| | ±1000 | 0.107 | 24.2 | 0.177 | 23.5 |
| | ±200 | 0.031 | 23.7 | 0.088 | 22.2 |
| 10 | ±5000 | 0.499 | 24.4 | 0.683 | 23.9 |
| | ±1000 | 0.108 | 24.2 | 0.161 | 23.7 |
| | ±200 | 0.029 | 23.8 | 0.082 | 22.3 |
| 5 | ±5000 | 0.472 | 24.4 | 0.617 | 24.1 |
| | ±1000 | 0.102 | 24.3 | 0.151 | 23.7 |
| | ±200 | 0.024 | 24.1 | 0.082 | 22.3 |
| 2.5 | ±5000 | 0.447 | 24.5 | 0.564 | 24.2 |
| | ±1000 | 0.095 | 24.4 | 0.144 | 23.8 |
| | ±200 | 0.020 | 24.3 | 0.077 | 22.4 |

¹ First notch frequency

² Range overhead of ≈6% on all ranges guarantees that full-scale values will not cause overrange.

³ Effective resolution (ER) in bits is computed from ratio of full-scale range to RMS noise.

Appendix C. Example programs

These programs were written for a GRANITE 6 data logger, except where noted. With slight modifications, they can be used with other Campbell Scientific data loggers.

NOTE:

For the GRANITE 10 and GRANITE 9 data loggers, the `CPIBusAddress` parameter must include the CPI bus when using bus B. Bus A is the default. For example, `CPI_BusB + 2` specifies CPI bus B and CPI address 2.

C.1 Configuring GRANITE Measurement Module with `CPIAddModule()`

The following program sets CPI addresses and device names on VOLT 108s with serial numbers 1234, 1235, and 1236 and makes a single-ended measurement on each module SE 1 channel.

CRBasic Example 4: Using `CPIAddModule()`

```
'GRANITE 6 Datalogger
'This program sets CPI addresses and device names on VOLT108s.
'It makes a single-ended measurement on each unit's SE 1 channel.
'Declare Variables and Units
Public SEVol1
Public SEVol2
Public SEVol3
'Main Program
BeginProg
  'Set CPI Addresses
  CPIAddModule (VOLT108,1234,"A", 4)
  CPIAddModule (VOLT108,1235,"12345", 5)
  CPIAddModule (VOLT108,1236,"VOLT108 in Pump House", 6)
  'Main Scan
  Scan(5,Sec,3,0)
  'Single-ended voltage measurements on VOLT108s w/ CPI addresses 4, 5 and 6
  CDM_VoltSe(VOLT108,4,SEVol1,1,mV5000,1,True,500,60,1,0)
  CDM_VoltSe(VOLT108,5,SEVol2,1,mV5000,1,True,500,60,1,0)
  CDM_VoltSe(VOLT108,6,SEVol3,1,mV5000,1,True,500,60,1,0)
  NextScan
EndProg
```

C.2 Measuring TEMP 120 and VOLT 108 at different speeds

The following program measures a full-bridge sensor on a VOLT 108 at 100 Hz in the main sequence, and 20 type-T thermocouples on a TEMP 120 module in a 5-second slow sequence.

CRBasic Example 5: Measuring TEMP 120 and VOLT 108

```
'GRANITE 6 Datalogger
'This program uses a VOLT 108 module to measure a full-bridge sensor
'at 100 Hz in the main sequence, and a TEMP 120 module to measure 20
'type-T thermocouples in a 5-second slow sequence.
'Declare Variables and Units
Public strain_raw : Units strain_raw = mVpV
Public TC(20)      : Units TC          = DegC
'Define Data Tables
DataTable(OneSec, TRUE, -1)
  DataInterval(0, 1, SEC, 10)
  Maximum(1, strain_raw, FP2, FALSE, TRUE)
EndTable
DataTable(Hourly, TRUE, -1)
  DataInterval(0, 60, MIN, 10)
  Average(20, TC(), FP2, FALSE)
EndTable
'Main Program
BeginProg
  'MainSequence
  Scan(10, MSEC, 20, 0)
  'Measure full-bridge sensor on VOLT 108 at CPI address 1
  CDM_BrFull(VOLT108, 1, strain_raw, 1, mV200, 1, X1, 1, 5000, _
  TRUE, TRUE, 1000, 1000, 1.0, 0.0)
  'Call 1-second data table to process and store data
  CallTable(OneSec)
NextScan
EndSequence
SlowSequence
Scan(5, SEC, 1, 0)
  'Measure 20 Type-T thermocouples on TEMP 120 with CPI address 2
  CDM_TCComp(TEMP120, 2, TC(), 20, 1, TYPET, 1, 0)
  'Call hourly data table to process and store data
  CallTable(Hourly)
NextScan
EndSequence
EndProg
```

C.3 Synchronized TEMP 120 and VOLT 108 measurements

The following program measures a full-bridge sensor on a VOLT 108 at 100 Hz, and 20 type-T thermocouples on a TEMP 120 module at 1 Hz. The measurements are synchronized by putting the faster measurements in a [SubScan](#).

CRBasic Example 6: Synchronized TEMP 120 and VOLT 108 measurements

```
'GRANITE 6 Datalogger
'This program uses a TEMP 120 module to measure 20 type-T thermocouples at
'1 Hz and a VOLT 108 module to measure a full-bridge sensor at 100 Hz. A
'SubScan instruction is used to synchronize the full-bridge
'measurements with the thermocouple measurements.
'Declare Variables and Units
Public TC(20)      : Units TC          = DegC
Public strain_raw : Units strain_raw = mVpV
'Define Data Tables
DataTable(OneSec, TRUE, -1)
  DataInterval(0, 1, SEC, 10)
  Average(20, TC(), FP2, FALSE)
  Maximum(1, strain_raw, FP2, FALSE, TRUE)
EndTable
'Main Program
BeginProg
  Scan(1, SEC, 3, 0)
    'Measure 20 Type-T thermocouples on TEMP 120 with CPI address 1
    CDM_TCComp(TEMP120, 1, TC(), 20, 1, TYPET, 1, 0)
    SubScan(10, MSEC, 100)
      'Measure full-bridge sensor on VOLT 108 with CPI address 2
      CDM_BrFull(VOLT108, 2, strain_raw, 1, mV200, 1, X1, 1, _
        5000, TRUE, TRUE, 1000, 1000, 1.0, 0.0)
    NextSubScan
    'Call data table to process and store data
    CallTable(OneSec)
  NextScan
EndProg
```

C.4 Controlling an AM16/32B multiplexer

The following program makes 32 differential measurements through an AM16/32B multiplexer controlled by a VOLT 108 connected to a CR6 data logger. Programming and wiring for the GRANITE-series data loggers will be similar.

The CPI port on VOLT 100 series connects directly to the CPI port on the CR6. An SC-CPI device is required to connect to CR3000, CR1000X, and CR800-series data loggers. Connect the SC-CPI module to these dataloggers by wiring its 12V, G, C1, C2, and C3 terminals to the corresponding 12V, G, C1, C2, and C3 terminals of the data logger. Connect a CPI port on the VOLT 100 series to the CPI port on the SC-CPI.

| CR6 | AM16/32B (2x32 mode) | VOLT 108 | Sensor |
|-----|-----------------------|----------|-------------|
| | 12V | 12V | |
| | G | G | |
| | RES | SW5-2 | |
| | CLK | SW5-1 | |
| | COM ODD H | 1H | |
| | COM ODD L | 1L | |
| | COM (\perp) | \perp | Ground |
| | High channels 1H-24H | | Signal high |
| | Low channels 1L – 24L | | Signal low |
| CPI | | CPI | |

CRBasic Example 7: Controlling an AM16/32B multiplexer

```
'CR6 Datalogger
'This program sets CPI Address and Device Name on VOLT108 with serial number
'1234, and measures 32 differential voltages through an AM16/32B multiplexer
'controlled by a VOLT108
'***Set AM16/32B to 2x32 mode**
'Declare Variables
Dim LCount
Public MilliVolts(32)
DataTable(TenMin,True,-1)
  DataInterval(0,10,Min,10)
  Average(32,MilliVolts(),FP2,False)
EndTable
'Main Program
BeginProg
  'Set CPI Address to 1
  CPIAddModule (VOLT108,1234,"A",1)
  'Main Scan
  Scan(1,Min,3,0)
    'Turn AM16/32B Multiplexer on, and advance to first channel
    CDM_MuxSelect(VOLT108,1,1,2,20,1,1)
    LCount=0 'reset loop counter
    SubScan(0,uSec,32)
      LCount+=1 'increment loop counter
      'Differential measurement on the AM16/32B Multiplexer
      CDM_VoltDiff(VOLT108,1,MilliVolts(LCount),1,mV5000,1,True,5000,60,1.0,0)
      'Switch to next AM16/32B Multiplexer channel
      CDM_PulsePort(VOLT108,1,1,20000)
    NextSubScan
    'Turn AM16/32B Multiplexer Off
    CDM_SW5(VOLT108,1,2,0,0)
    Delay(0,150,mSec)
    'Call Data Tables and Store Data
    CallTable TenMin
  NextScan
EndProg
```

Appendix D. Calculating network restrictions

This section shows some common questions asked while designing networks with VOLT 100 series and how to calculate their answers. For all examples, the VOLT 108 or VOLT 116 is connected to a GRANITE 6 data logger.

D.1 Example 1

- a. How fast can a VOLT 116 make 32 single-ended measurements?

The equation to calculate the time to make 32 single-ended measurements (which are measurements without input or excitation reversal) is copied from [Table 10-1](#) (p. 33):

$$\text{Measurement Time} = \text{repetitions} \bullet \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 184 \mu\text{s} \right) + 31 \mu\text{s}$$

To make the fastest measurements possible, set f_{N1} to its maximum (30000 Hz) and T_{settle} to its minimum (100 μs). With these inputs and 32 repetitions, the fastest measurement time is calculated as **10186 μs** .

$$\begin{aligned} \text{Measurement Time} &= 32 \bullet \left(100 \mu\text{s} + \frac{10^6 \mu\text{s/s}}{30000 \text{ Hz}} + 184 \mu\text{s} \right) + 31 \mu\text{s} \\ &= 10186 \mu\text{s} \end{aligned}$$

The GRANITE 6 has a scan rate resolution of 1 ms, so the fastest scan rate possible in this example is 11 ms.

- b. Choosing a more practical scan rate of 20 ms, what is the longest cable that could be used between the VOLT 116 and the GRANITE 6 to make these 32 measurements?

A scan rate of 20 ms (0.02 s) equals a measurement frequency of 50 Hz ($1 \div 0.02$ s). Using the equation found in [CPI network bit rate](#) (p. 35), the kilobits of data generated each second is

Kilobits per second = (number of measurements) \times (measurement frequency) \times (0.064 kilobits per measurement)

$$\begin{aligned} &= (32 \text{ measurements}) \times (50 \text{ Hz}) \times (0.064 \text{ kilobits per measurement}) \\ &= 102.4 \text{ kbps} \end{aligned}$$

In this case, the **CPISpeed()** instruction could be used to change the bit rate from the 250 kbps default to 125 kbps, allowing a longer cable. Then, referring to the table: [Network topology, bit rate, and cable length](#) (p. 36), the longest cable length possible is **1200 ft** with the use of a termination plug, or **1000 ft** without.

- c. **What should the scan **BufferOption** be set to for this example?**

The general rule is that the number of scan buffers should be enough to hold 2 seconds' worth of data. With a scan rate of 20 ms, the **BufferOption** should be $2 \text{ s} \div 0.02 \text{ s} = 100$. The **CRBasic Scan()** instruction would be written this way:

```
Scan (20,msec,100,0)
```

- d. **If there were four other VOLT 116s on the network with this same configuration, what restraints would there be on the system?**

Because the system can run in pipeline mode, each VOLT 116 can start its measurements at the same time, not requiring any change in the scan rate. The data generated (102.4 kbps) would be multiplied by a total of five VOLT 116s, giving 512 kbps total. In order to keep up with this data output, the CPI speed would need to be increased to **1000 kbps**. This reduces the total allowable cable length to **50 ft** with the use of a termination plug, or **1 ft** without (see [Network topology, bit rate, and cable length](#) (p. 36)).

D.2 Example 2

- a. **How many differential measurements can a VOLT 116 or VOLT A108 make at 5 ms (200Hz) if input reversal is used?**

This example uses the measurement time equation for measurements with input reversal from [Table 10-1](#) (p. 33):

$$\text{Measurement Time} = \text{repetitions} \cdot \left[2 \cdot \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 5 \mu\text{s} \right] + 31 \mu\text{s}$$

The equation shows that making multiple measurements by using the **Repetitions** parameter within a measurement instruction is more efficient than using multiple measurement instructions. Solving the previous equation for repetitions gives the following:

$$\text{repetitions} = \frac{\text{measurement time} - 31 \mu\text{s}}{2 \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 5 \mu\text{s}}$$

With $f_{N1} = 30000 \text{ Hz}$, $T_{\text{settle}} = 100 \mu\text{s}$, and measurement time = 5 ms (5000 μs), repetitions is calculated to be 7.866, so **7 repetitions**, or measurements, are possible at that scan rate.

$$\text{repetitions} = \frac{5000 \mu\text{s} - 31 \mu\text{s}}{2 \left(100 \mu\text{s} + \frac{10^6 \mu\text{s/s}}{30000 \text{ Hz}} + 180 \mu\text{s} \right) + 5 \mu\text{s}} = 7.866$$

b. At that measurement rate, what is the best attainable resolution for the measurements?

Resolution increases as the f_{N1} decreases, but measurement time increases. Solving the equation for f_{N1} gives the following:

$$f_{N1} = \left(\frac{\frac{\text{measurement time} - 31 \mu\text{s}}{\text{repetitions}} - 5 \mu\text{s}}{2} - T_{\text{settle}} - 180 \mu\text{s} \right)^{-1} \bullet 10^6 \mu\text{s/s}$$

With a measurement time of 5 ms (5000 μs), settling time of 100 μs , and 7 repetitions, f_{N1} must be greater than 13807 Hz.

$$f_{N1} = \left(\frac{\frac{5000 \mu\text{s} - 31 \mu\text{s}}{7} - 5 \mu\text{s}}{2} - 100 \mu\text{s} - 180 \mu\text{s} \right)^{-1} \bullet 10^6 \mu\text{s/s} = 13807 \text{ Hz}$$

Thus, to improve measurement resolution, f_{N1} should be set to 15000. According to [Analog voltage measurement range and resolution](#) (p. 42), this would improve the resolution to 9.012 μVRMS for the largest voltage range, $\pm 5000 \text{ mV}$.

D.3 Example 3

How fast can a VOLT 116 measure ten 3 k Ω full-bridge sensors using the default settling time (500 μs) and both excitation and input reversal, and achieve a resolution of less than 1 μVRMS ? For easier wiring, limit the sensors excited per excitation terminal to four.

The full-bridge measurement, [BrFull\(\)](#), makes a differential measurement. It is given that the measurement will use input reversal, so the resolution is given in the third column of [Analog voltage measurement range and resolution](#) (p. 42). To achieve a resolution of less than 1 μVRMS within the $\pm 5000 \text{ mV}$ range, f_{N1} must be 100 Hz or better.

The measurement time is figured separately for each excitation channel used, where the repetitions are the number of sensors excited on that channel. In this setup, three excitation terminals are used, X1 – X3. The measurement times are given by the following equations:

$$\text{X1 measurement time} = \text{repetitions on X1} \bullet \left[4 \bullet \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 8 \mu\text{s} \right] + 46 \mu\text{s} + 31 \mu\text{s}$$

$$\text{X2 measurement time} = \text{repetitions on X2} \bullet \left[4 \bullet \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 8 \mu\text{s} \right] + 46 \mu\text{s} + 31 \mu\text{s}$$

$$\text{X3 measurement time} = \text{repetitions on X3} \bullet \left[4 \bullet \left(T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 8 \mu\text{s} \right] + 46 \mu\text{s} + 31 \mu\text{s}$$

Because there are 10 measurements total, repetitions on **X1** will be 4, repetitions on **X2** will be 4, and repetitions on **X3** will be 2. Using the default settling time (500 μ s) and the first notch frequency figured earlier (100 Hz), the sum of the above equations gives a total measurement time of **427511 μ s** (427.511 ms). Therefore, a practical scan rate for this setup would be 500 ms.

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Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com. You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.
- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.



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