



## VOLT Series

VOLT 108 and VOLT 116  
GRANITE Measurement Modules



# Please read first

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## About this manual

Please note that this manual was produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this. In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users. Differences include the U.S. standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. Please note, however, *that when a power supply adapter is ordered from Campbell Scientific it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials (antennas) may also not be applicable according to your locality. Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered.

## Recycling information for countries subject to WEEE regulations 2012/19/EU



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility, per [The Waste Electrical and Electronic Equipment \(WEEE\) Regulations 2012/19/EU](#). Campbell Scientific can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories. For further support, please contact Campbell Scientific, or your local agent.

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# 1. Introduction

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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](http://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


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- 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



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- 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. 23).
- For more information on accessing the calibration certificate watch a video at [www.campbellsci.com/videos/calibration-certs](http://www.campbellsci.com/videos/calibration-certs) .

## 4. Measurement quickstart using *SURVEYOR*

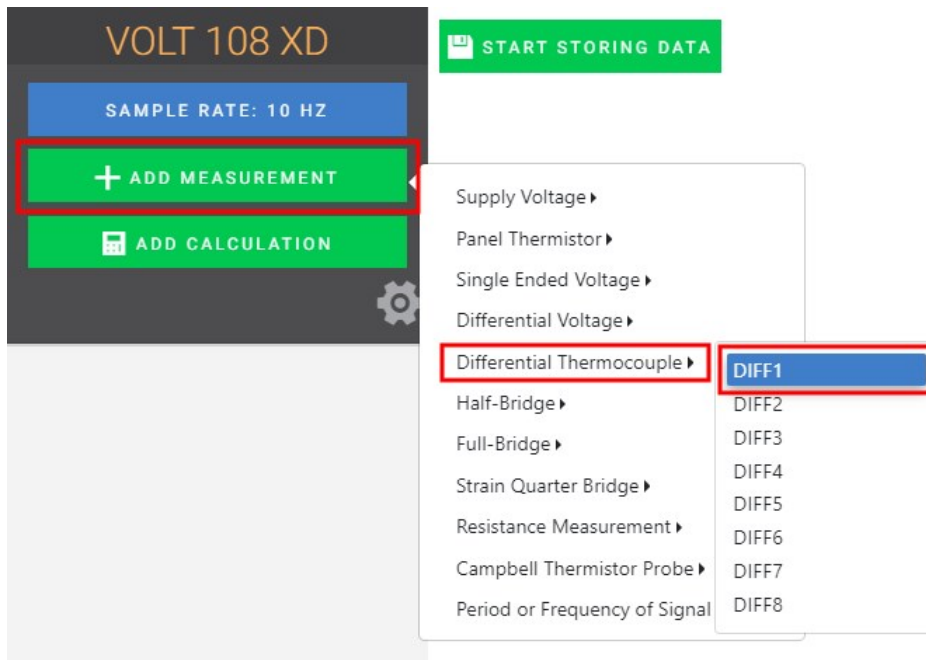
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Campbell Scientific *SURVEYOR* software is an easy way to quickly see measurement results and store data from the VOLT 100 series. The module configuration can be saved on the computer or exported as a CRBasic data logger program. *SURVEYOR* is available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

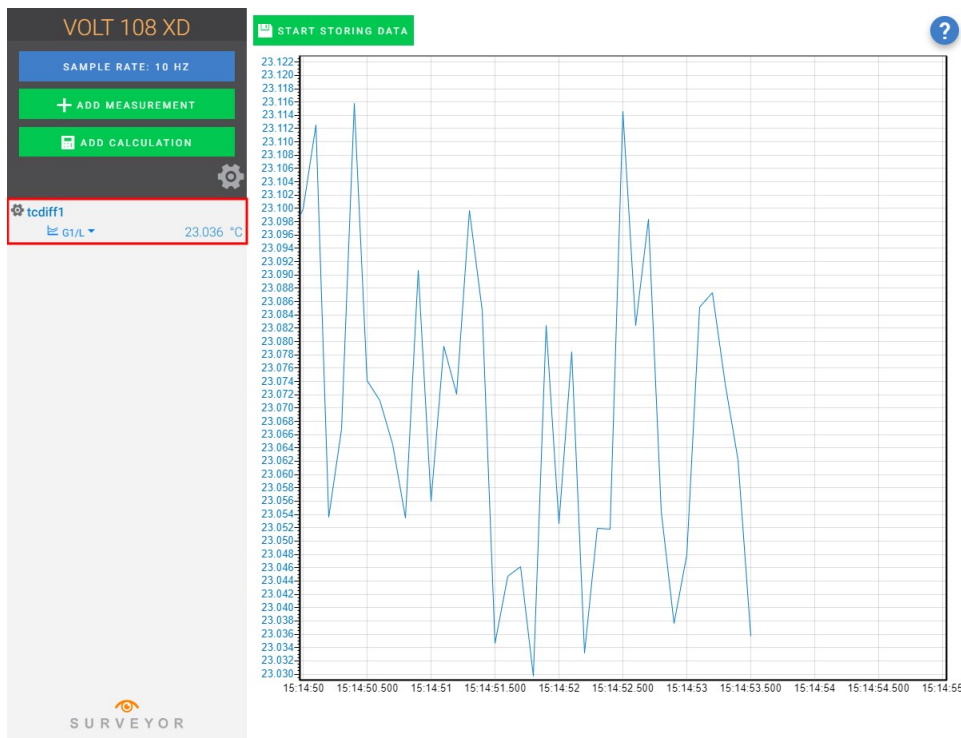
**Variable Name** ⓘ

**Thermocouple Type** ⓘ

**Units** ⓘ

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

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



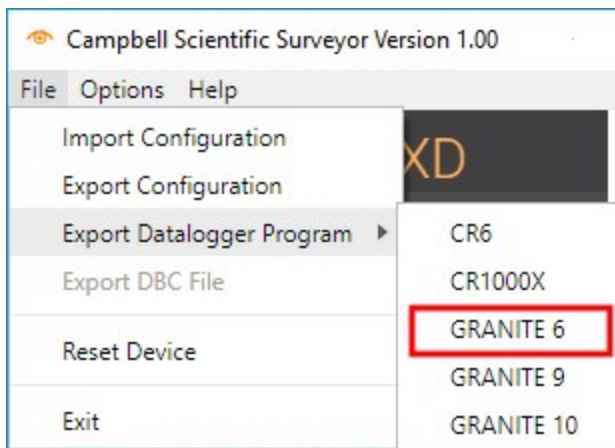
13. Click **START STORING DATA** . While data is being stored, the options to stop and pause data storage become available.

## 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.

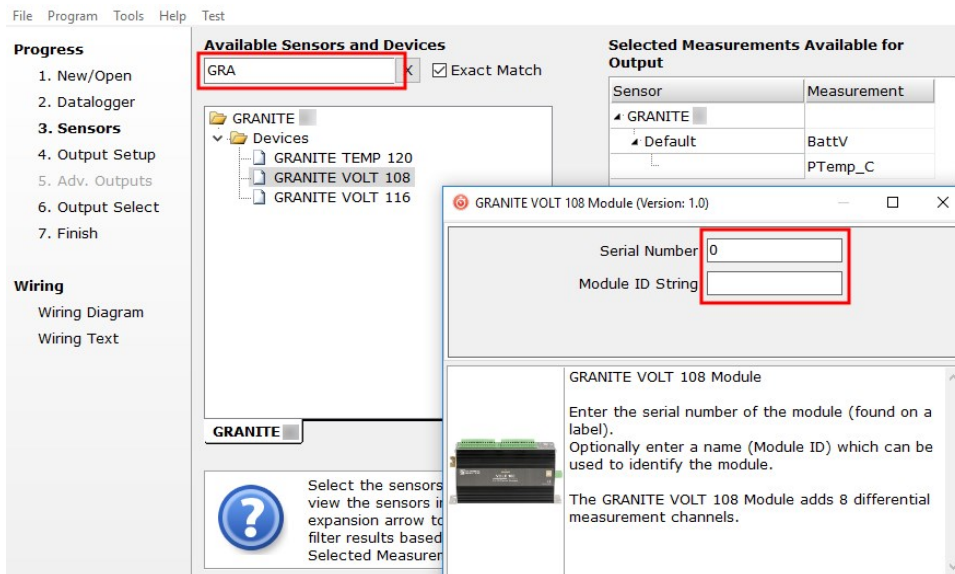
## 6. Programming quickstart using *Short Cut*

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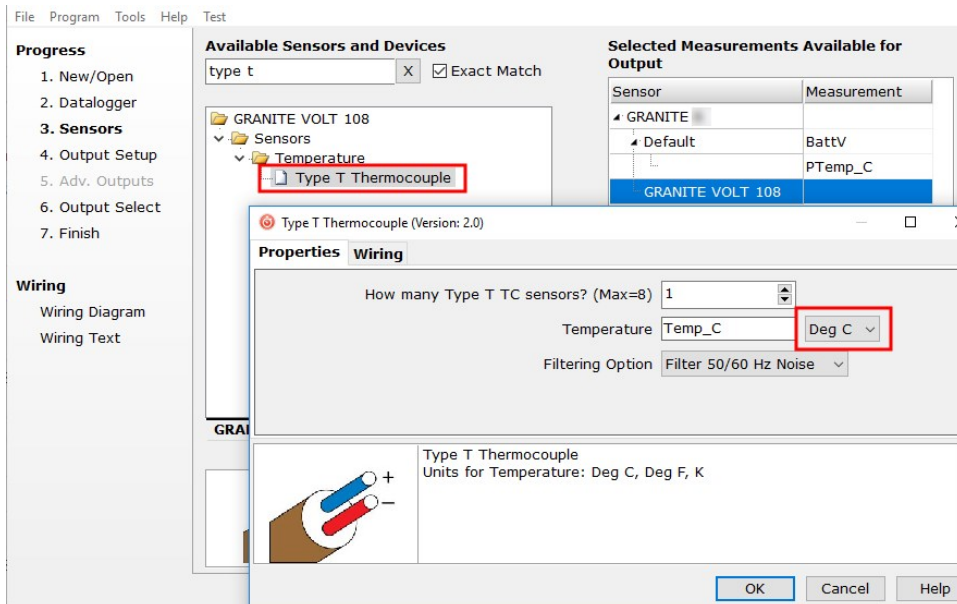
*Short Cut* is another easy way to program a Campbell Scientific data acquisition system to measure a sensor and assign wiring terminals. *Short Cut* is available as a download from [www.campbellsci.com/shortcut](http://www.campbellsci.com/shortcut). It is also included in installations of *LoggerNet*,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

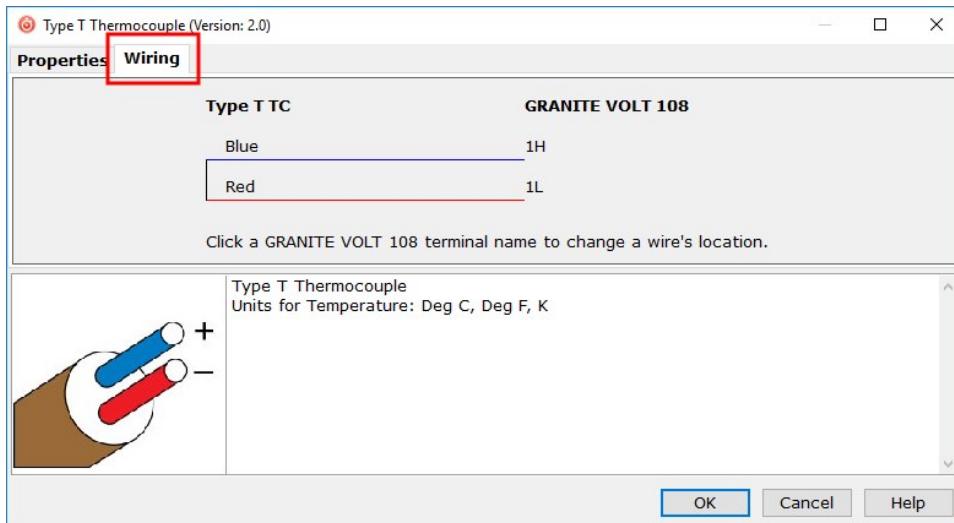


4. In the **Available Sensors and Devices** box, type Type T. You can also locate the thermocouple in the **Sensors > Temperature** folder. Double click **Type T Thermocouple**. Type the number of type T thermocouples connected to the VOLT 100 series. The temperature defaults to degree C. This can be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

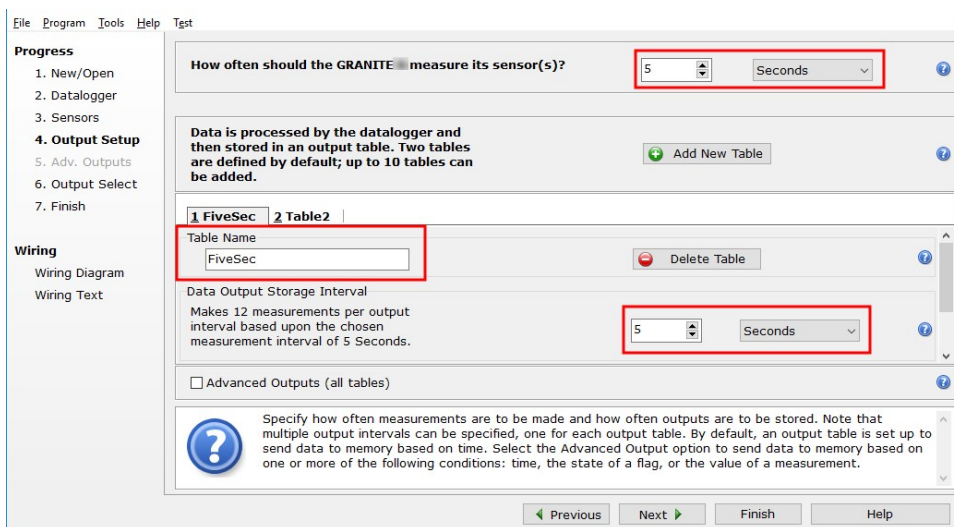




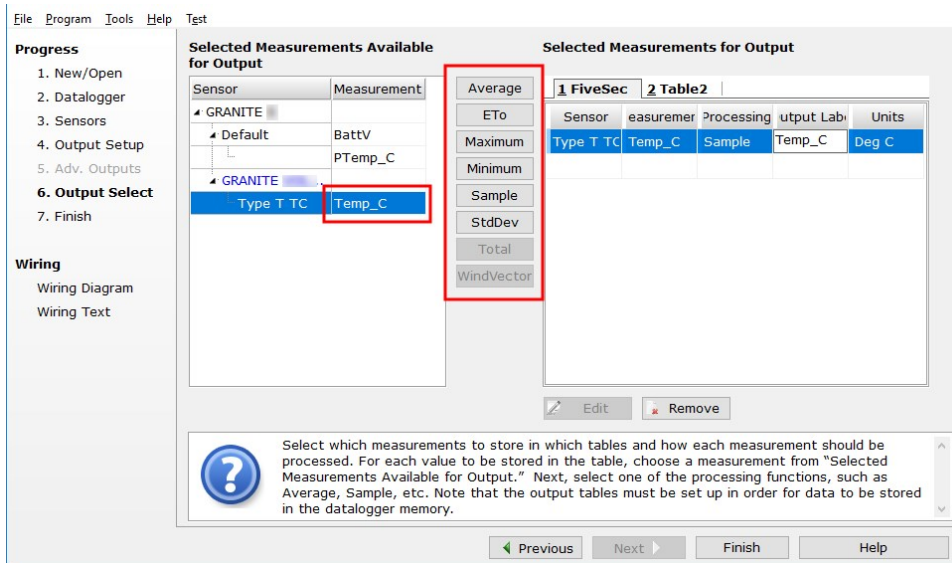
- Click on the **Wiring** tab to see how the sensor is to be wired to the VOLT 100 series. Click **OK** after wiring the thermocouple.



- 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](http://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.

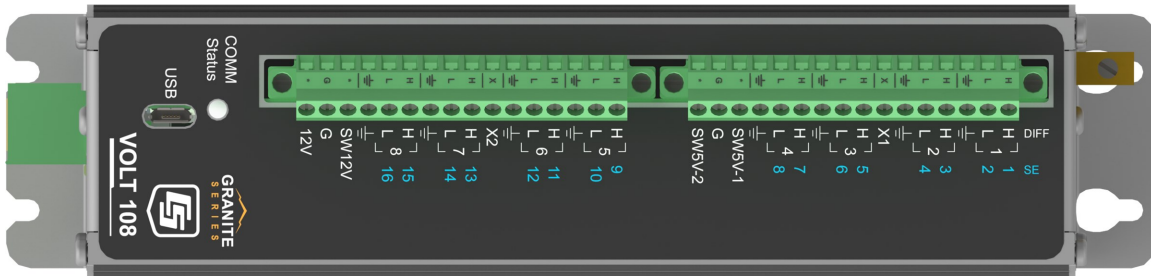


Figure 7-1. VOLT 108 Wiring panel

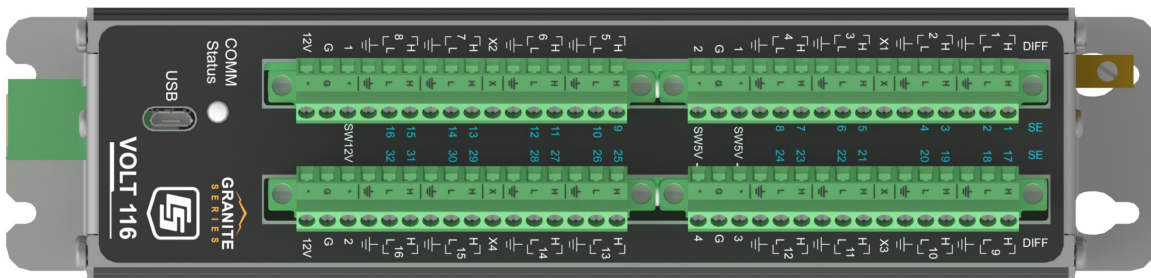


Figure 7-2. VOLT 116 Wiring panel

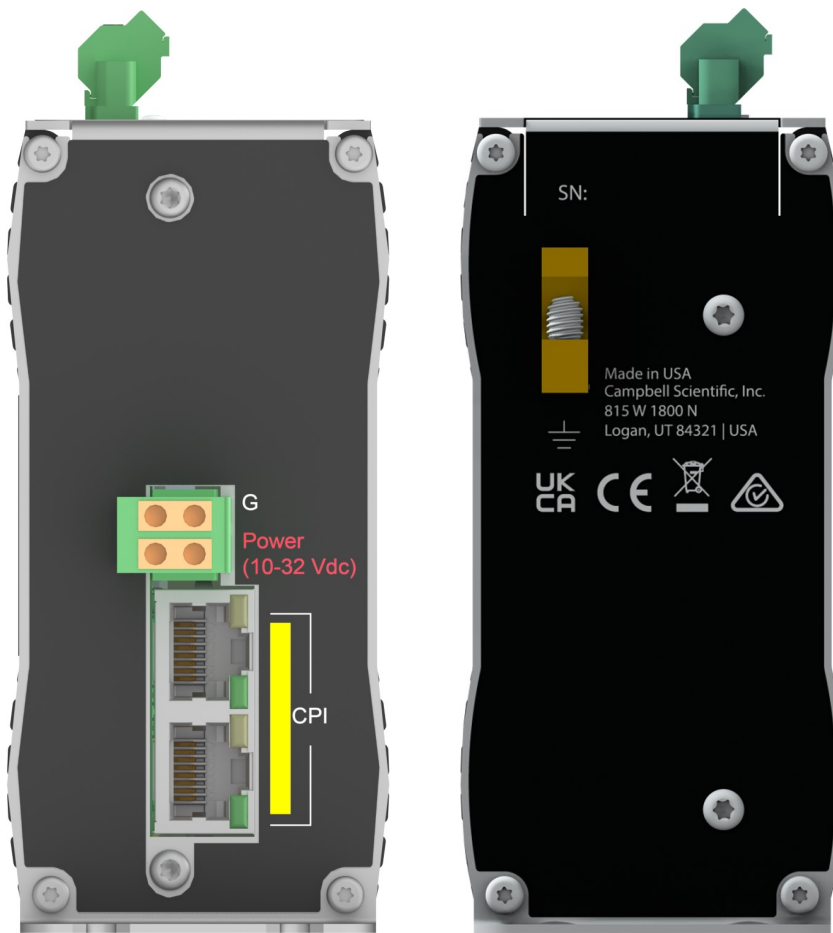


Figure 7-3. Power and CPI ports view (left) and ground lug view (right)

## 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  $\perp$ .

### 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  $\pm 5000$  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  $\pm 2.5$  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. 20) 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. 45).

### 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. 45).

# 8. Specifications

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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:  $\pm 5000$ ,  $\pm 1000$ ,  $\pm 250$  mV. See [Table B-1](#) (p. 47)

## Accuracy<sup>1</sup>

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. 47)

Speed: See [Table 8-2](#) (p. 16)

See also [Designing fast measurement networks](#) (p. 36)

Input resistance: >20 GΩ

Input limits:  $\pm 5 \text{ VDC}$

Maximum input voltage:  $\pm 20 \text{ VDC}$

DC common-mode rejection: >120 dB with input reversal  
 $\geq 86 \text{ dB}$  without input reversal

Normal-mode rejection: >70 dB at 60 Hz

Input current:  $\pm 3 \text{ nA}$  typical at 25 °C  
 $\pm 12 \text{ nA}$  maximum at 50 °C  
 $\pm 100 \text{ nA}$  maximum at 85 °C

<sup>1</sup> Accuracy specification does not include sensor error or measurement noise.

<sup>2</sup> See [Table 8-1](#) (p. 15)

Table 8-1: Analog voltage measurement accuracy offsets		
Range (mV)	Differential with input reversal (μV)	Differential or single-ended without input reversal (μV)
$\pm 5000$	$\pm 4$	$\pm 40$
$\pm 1000$	$\pm 2$	$\pm 10$
$\pm 200$	$\pm 1$	$\pm 3$



Table 8-2: Analog voltage measurement speed<sup>1</sup>

$f_{N1}$ (Hz)	Multiplexed <sup>2</sup> measurement			
	With input reversal		Without input reversal	
	Time (ms)	Rate (Hz)	Time (ms)	Rate (Hz)
30000	1.46	698.49	0.75	1394.05
15000	1.53	667.41	0.78	1332.15
7500	1.66	612.87	0.85	1223.49
3750	1.93	526.78	0.98	1051.89
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

<sup>1</sup> Default settling time of 500  $\mu$ s.

<sup>2</sup> 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<sup>1,2</sup>

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

<sup>1</sup> 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.

<sup>2</sup> 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  $\Omega$ ,  $\pm 0.005\%$  @ 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:	$\pm 5000$ mV
Accuracy <sup>1</sup>	
0 to 40 °C:	$\pm(0.05\%$ of setting + 2.5 mV)
–40 to 70 °C:	$\pm(0.08\%$ of setting + 2.5 mV)
–55 to 85 °C:	$\pm(0.1\%$ of setting + 2.5 mV)
Resolution:	1.25 mV

Maximum source or sink

current:  $\pm 50$  mA

Current excitation

Range:  $\pm 2.5$  mA

Accuracy<sup>1</sup>

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

–40 to 70 °C:  $\pm(0.08\%$  of setting + 2.5  $\mu$ A)

–55 to 85 °C:  $\pm(0.1\%$  of setting + 2.5  $\mu$ A)

Resolution: 638 nA

Compliance voltage<sup>2</sup>:  $\pm 5000$  mV

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

<sup>2</sup> 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:  $\pm(0.01\%$  of reading + resolution)

Resolution: 130 ns  $\div$  number of cycles

Table 8-3: Period average ranges			
Voltage gain	Minimum peak-to-peak Signal <sup>1,2</sup> (mV)	Minimum pulse width ( $\mu$ s)	Maximum frequency (kHz)
1	500	2.4	200
3.8	50	8	50

Table 8-3: Period average ranges			
Voltage gain	Minimum peak-to-peak Signal <sup>1,2</sup> (mV)	Minimum pulse width (μs)	Maximum frequency (kHz)
19	10	50	8
67	2	80	5
<sup>1</sup> With signal centered around VOLT 108/116 ground.			
<sup>2</sup> 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 output<sup>1</sup>: 12.5 ± 0.5 VDC

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

<sup>1</sup> Unregulated below 14.5 V.

### 8.5.2 Switched 12 VDC

#### Terminals

VOLT 108: SW12V-1

VOLT 116: SW12V-1-2

Voltage output<sup>1</sup>: 12.5 ± 0.5 VDC

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

<sup>1</sup> 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:  $4.75 \pm 0.25$  VDC

Off:  $<0.1$  VDC

Output resistance:  $30\ \Omega$

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

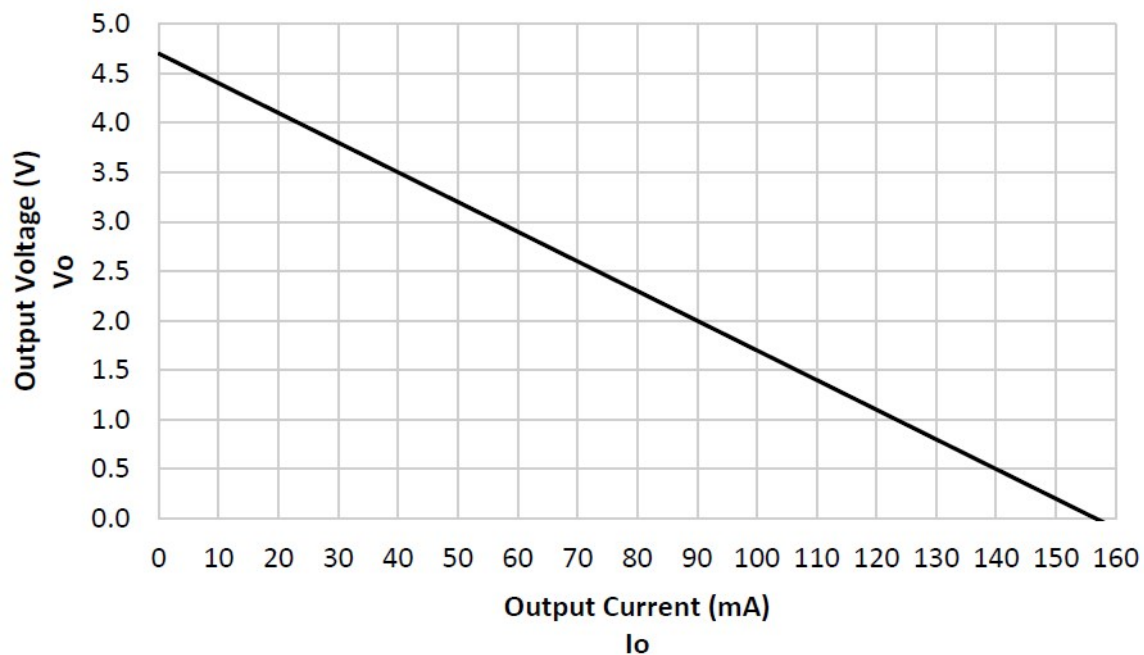


Figure 8-1. Current sourcing on SW5V terminals

## 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 <sup>1</sup> :	2 mA, estimated
Active 20 Hz Scan <sup>1</sup> :	20 mA
Active 1 kHz Scan <sup>2</sup> :	67 mA

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

<sup>2</sup> 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](http://www.campbellsci.com/volt108)  and [www.campbellsci.com/volt116](http://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 good measurements are being made, data is collected by the data logger, and data from the data logger can be copied to a computer.

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## 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 *Device Configuration Utility*, select **Granite > VOLT 100 series**. Click **Install USB Driver** 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](http://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 with a default CPI address of 1. 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\(\)](#) 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. 50).

**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 **Connecting with USB Instructions** text provided on the right.
4. Apply 9.6 to 32 VDC to the power terminals on the device.
5. 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.
6. Select **Direct** under **Connection Type**.
7. Under **Communication Port**, 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. 43) 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. 46). Complete program examples can be found in: [Example programs](#) (p. 50).

## 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. 39) and listed in [Table 10-6](#) (p. 39).

Use the CPI calculator at [www.campbellsci.com/downloads/cpi-calculator](http://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. 28).

**NOTE:**

Do not use a CPI terminator with this configuration.

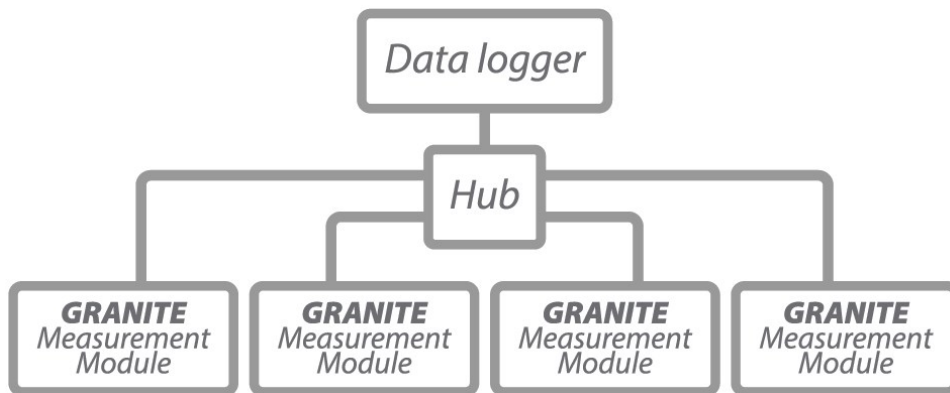


Figure 9-2. Multiple GRANITE Measurement Modules connected in a star topology

## 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  $12.5 \pm 0.5$  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. 29). 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 and then the data logger. This procedure will reduce the time required to synchronize the CPI bus.

See [COMM status LED](#) (p. 44) 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 [Wiring panel overview](#) (p. 10). At a minimum, 14 AWG ground wire is recommended. The earth side of the connection should be connected to a grounding rod or other grounded device.

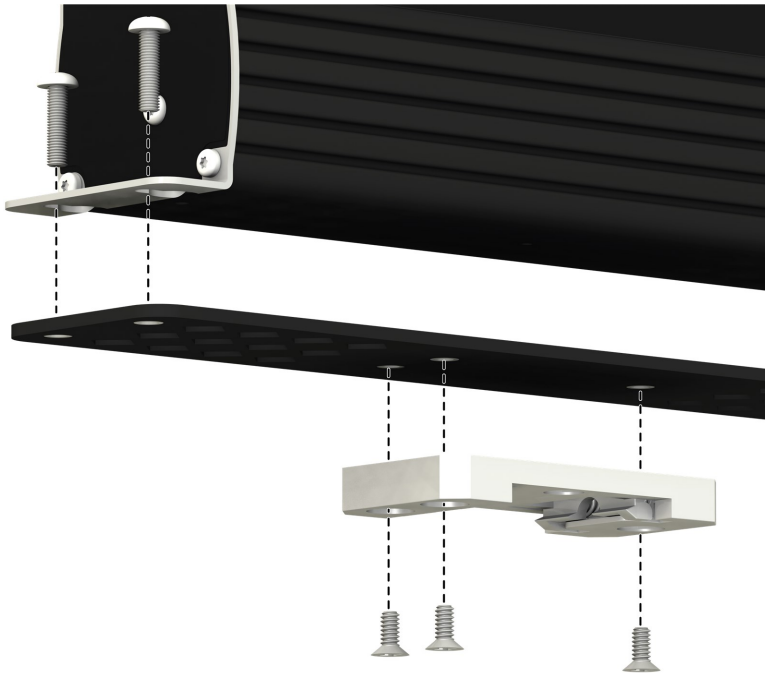
## 9.9 Mounting in an enclosure

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. 16).

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 Measurement speed tables

The tables in this section show possible measurement speeds based on the configuration of parameters in *CRBasic* instructions. These instructions include [CDM\\_BRFull\(\)](#), [CDM\\_BRHalf\(\)](#), and [CDM\\_VoltDiff\(\)](#). See the [CRBasic Help](#) for details on these instructions. For simplicity, the "CDM\_" prefix has been omitted in the tables. The specific instruction parameters that affect measurement speed include:

1. **RevEx** - Determines whether the excitation should be reversed and applied to the sensor after the first measurement is made. Using RevEx cancels out voltage offsets caused by the sensor, wiring, and excitation circuitry but does not compensate for operational input voltage errors.
2. **RevDiff** - Determines whether the inputs are reversed and a second measurement is taken. RevDiff eliminates voltage offset errors caused by the data logger measurement circuitry, including operational input voltage errors. Enabling this parameter doubles the measurement time, and the measurement time will increase fourfold if RevEx is also enabled.
3. **SettlingTime** - The amount of time to delay, in microseconds, after setting up a measurement and before making the measurement.
4.  $f_{N1}$  - First notch filter. Determines the lowest frequency that will be eliminated or notched out by the sinc filter.

To compare performance, three modes of operation are described based on the configuration of the above measurement parameters:

1. **Best:** 60Hz noise filtering, reverse excitation, and reverse differential measurement
2. **Compromise:** Reverse excitation and reverse differential, but no noise filtering
3. **Fast:** No noise filtering, reverse excitation, or reverse differential measurement

### NOTE:

The values in these tables have not been empirically tested. They represent what CRBasic allows you to code. It is recommended to conduct lab testing before deploying in the field.

Table 10-1: Operation modes based on measurement parameter configuration			
	Best	Compromise	Fast
RevEx <sup>1</sup>	True	True	False
RevDiff <sup>2</sup>	True	True	False
Settling Time	500 (default)	500 (default)	100
$f_{N1}$	60	30000	30000
<sup>1</sup> No RevEx possible for CDM_VoltDiff()			
<sup>2</sup> No RevDiff possible for CDM_BRHalf()			

Table 10-2: Measurement speed based on measurement mode and number of channels measured												
# of Channels	BrFull						VoltDiff/BrHalf					
	Best		Compromise		Fast		Best		Compromise		Fast	
	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)
1	14.3	70	250	4	1000	1	28.6	35	500	2	1000	1
2	7.1	140	143	7	1000	1	14.3	70	250	4	1000	1
3	4.8	209	100	10	500	2	9.5	105	200	5	500	2
4	3.6	279	77	13	500	2	7.1	140	143	7	500	2
5	2.9	348	63	16	500	2	5.7	174	125	8	500	2
6	2.4	418	53	19	333	3	4.8	209	100	10	333	3
7	2.1	487	45	22	333	3	4.1	244	91	11	333	3
8	1.8	557	40	25	333	3	3.6	279	77	13	333	3
9	1.6	626	36	28	250	4	3.2	313	71	14	250	4
10	1.4	696	33	30	250	4	2.9	348	63	16	250	4
11	1.3	765	30	33	250	4	2.6	383	59	17	250	4
12	1.2	835	28	36	200	5	2.4	418	53	19	200	5
13	1.1	904	26	39	200	5	2.2	452	50	20	200	5

**Table 10-2: Measurement speed based on measurement mode and number of channels measured**

# of Channels	BrFull						VoltDiff/BrHalf					
	Best		Compromise		Fast		Best		Compromise		Fast	
	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)	Hz	Scan rate (msec)
14	1.0	974	24	42	167	6	2.1	487	45	22	200	5
15	1.0	1043	22	45	167	6	1.9	522	43	23	167	6
16	0.9	1113	21	48	167	6	1.8	557	40	25	167	6

**Table 10-3: Hertz only**

# of Channels	BrFull			VoltDiff/BrHalf		
	Best	Compromise	Fast	Best	Compromise	Fast
	Hz	Hz	Hz	Hz	Hz	Hz
1	14.3	250	1000	28.6	500	1000
2	7.1	143	1000	14.3	250	1000
3	4.8	100	500	9.5	200	500
4	3.6	77	500	7.1	143	500
5	2.9	63	500	5.7	125	500
6	2.4	53	333	4.8	100	333
7	2.1	45	333	4.1	91	333
8	1.8	40	333	3.6	77	333
9	1.6	36	250	3.2	71	250
10	1.4	33	250	2.9	63	250
11	1.3	30	250	2.6	59	250
12	1.2	28	200	2.4	53	200
13	1.1	26	200	2.2	50	200
14	1.0	24	167	2.1	45	200

Table 10-3: Hertz only						
# of Channels	BrFull			VoltDiff/BrHalf		
	Best	Compromise	Fast	Best	Compromise	Fast
	Hz	Hz	Hz	Hz	Hz	Hz
15	1.0	22	167	1.9	43	167
16	0.9	21	167	1.8	40	167

Table 10-4: Scan rate only						
# of Channels	BrFull			VoltDiff/BrHalf		
	Best	Compromise	Fast	Best	Compromise	Fast
	Scan rate (msec)	Scan rate (msec)	Scan rate (msec)	Scan rate (msec)	Scan rate (msec)	Scan rate (msec)
1	70	4	1	35	2	1
2	140	7	1	70	4	1
3	209	10	2	105	5	2
4	279	13	2	140	7	2
5	348	16	2	174	8	2
6	418	19	3	209	10	3
7	487	22	3	244	11	3
8	557	25	3	279	13	3
9	626	28	4	313	14	4
10	696	30	4	348	16	4
11	765	33	4	383	17	4
12	835	36	5	418	19	5
13	904	39	5	452	20	5
14	974	42	6	487	22	5
15	1043	45	6	522	23	6
16	1113	48	6	557	25	6

## 10.3.3 Designing fast measurement networks

The [Measurement speed tables](#) (p. 32) display measurement speeds based on the configuration of parameters in **CRBasic** instructions used for measurements. When designing fast-measurement networks, there are additional factors to consider. 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 equations](#) [p. 36]).
2. Calculate the CPI bit rate necessary to keep up with the sum of data generated by all devices ([CPI network bit rate](#) [p. 39]).
3. Determine if the physical layout of your network will allow for the calculated CPI bit rate (See [Table 10-6](#) [p. 39]).

Use the CPI calculator at [www.campbellsci.com/downloads/cpi-calculator](http://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. 55) for complete examples.

### 10.3.3.1 Measurement speed equations

These equations can be used 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 10-5: Multiplexed analog voltage measurement speed <sup>1,2,3</sup>		
Without input or excitation reversal	Measurement time (μs)	$\text{repetitions} \bullet \left( T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 184 \mu\text{s} \right) + 31 \mu\text{s}$
	Sample rate (Hz)	$10^6 \bullet \left( T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 184 \mu\text{s} \right)^{-1}$
With input or excitation reversal	Measurement time (μs)	$\text{repetitions} \bullet \left[ 2 \bullet \left( T_{\text{settle}} + \frac{10^6 \mu\text{s/s}}{f_{N1}} + 180 \mu\text{s} \right) + 5 \mu\text{s} \right] + 31 \mu\text{s}$

Table 10-5: Multiplexed analog voltage measurement speed <sup>1,2,3</sup>		
	Sample rate (Hz)	$10^6 \bullet \left[ 2 \bullet \left( T_{settle} + \frac{10^6 \mu s/s}{f_{N1}} + 180 \mu s \right) + 5 \mu s \right]^{-1}$
With input and excitation reversal	Measurement time (μs)	$repetitions \bullet \left[ 4 \bullet \left( T_{settle} + \frac{10^6 \mu s/s}{f_{N1}} + 180 \mu s \right) + 8 \mu s \right] + 31 \mu s$
	Sample Rate (Hz)	$10^6 \bullet \left[ 4 \bullet \left( T_{settle} + \frac{10^6 \mu s/s}{f_{N1}} + 180 \mu s \right) + 8 \mu s \right]^{-1}$
Burst measurement	Measurement Time (μs)	$repetitions \bullet \frac{10^6 \mu s/s}{f_{N1}} + T_{settle} + 215 \mu s$
	Sample Rate (Hz)	$f_{N1}$
<sup>1</sup> If the instruction uses excitation, calculate the measurement time separately and add 46 μs for each excitation terminal used. Refer to Example 3 in <a href="#">Calculating network restrictions</a> . <sup>2</sup> Refers to multiplexing circuitry internal to the VOLT 100 series series. <sup>3</sup> Default settling time, T <sub>settle</sub> , is 500 μs, minimum 100 μs.		

#### 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.

### 10.3.3.2 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. 16) 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
```

### 10.3.3.3 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. 16) 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
```

#### 10.3.3.4 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. 27]). 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:

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

The network topology and cable length affect the maximum allowable CPI network bit rate. Refer to [Table 10-6](#) (p. 39) 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 10-6: Network topology, bit rate, and cable length**

Bit Rate <sup>1</sup> (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



Table 10-6: Network topology, bit rate, and cable length			
Bit Rate <sup>1</sup> (kbps)	Maximum total cable length (ft)		
	Daisy-chain topology		Star topology
	Full termination	Half termination	No termination
250	500	400	400
125	1200	1000	1000
50	2800	2400	2400
<sup>1</sup> Default Bit Rate is 250 kbps. Change with <code>CPISpeed()</code> instruction.			

## 10.4 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. 27]). 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.

## 10.5 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  $12.5 \pm 0.5$  VDC when the supply voltage is 14.5 to 32 VDC.

## 10.6 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  $0.1^\circ\text{C}$  for temperatures between 0 and  $70^\circ\text{C}$ . 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  $\pm 0.1^\circ\text{C}$  over 0 to  $40^\circ\text{C}$ ,  $\pm 0.3^\circ\text{C}$  from  $-25$  to  $50^\circ\text{C}$ , and  $\pm 0.8^\circ\text{C}$  from  $-55$  to  $85^\circ\text{C}$ .

The panel temperature can be measured with the `CDM_PanelTemp()` 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.

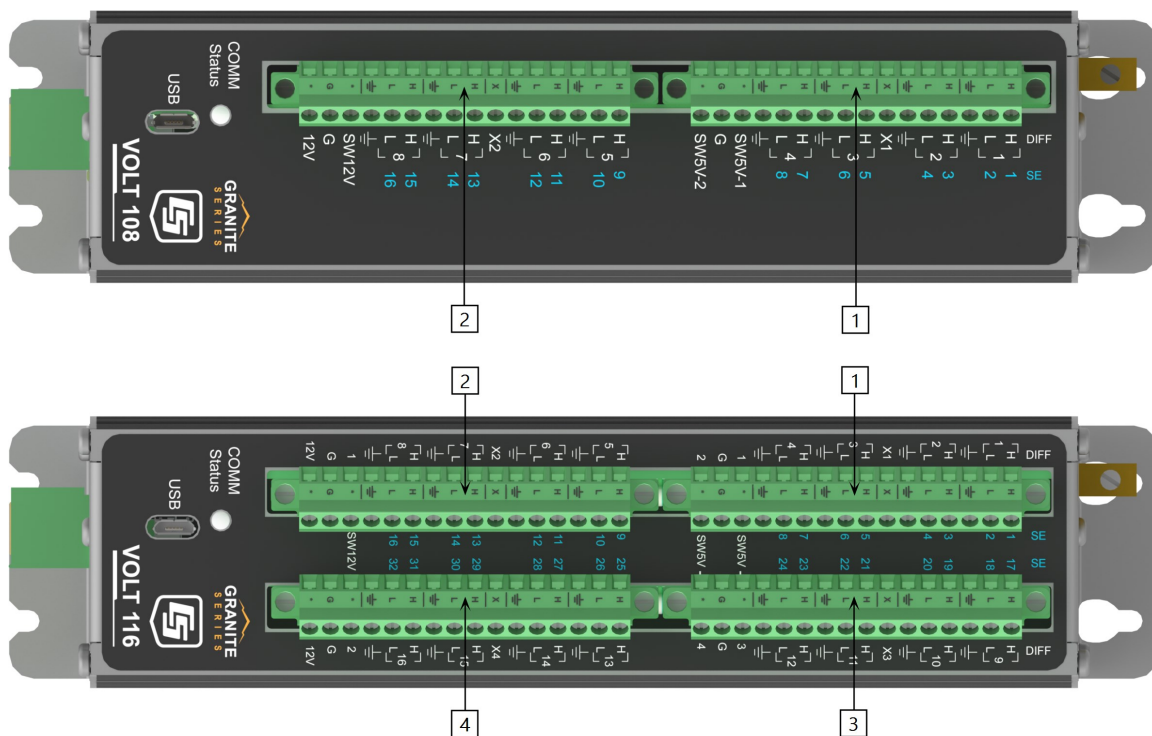


Figure 10-1. Wiring panel thermistor locations on VOLT 108 (top) and VOLT 116 (bottom)

# 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. Verify that enough data logger memory has been allocated for real-time data buffering. Typically, a [Scan\(\)](#) BufferOption of 300 to 500 should suffice. 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 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 the scan rate is long enough for the measurement time. (See [Measurement speed equations](#) (p. 36).) The data logger compiler often catches scan rates that are too fast.
7. Ensure 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. 39].)

## **12.1 CPIStatus table**

Information in the **CPIStatus** table, located in the data logger, helps in troubleshooting.

Record No	21
Time Stamp	9/9/2020 1:15:56 PM
BusLoad	0.192
ModuleReportCount	2
ActiveModules	2
BuffErr	0
RxErrMax	0
TxErrMax	0
FrameErr	0
ModuleInfo(1)	CDM-VW300,1050,4,4,Unused,CDM-VW300.06
ModuleInfo(2)	VWIRE305,2005,VWIRE305,3,Unused,VWIRE305.06
ModuleInfo(3)	VOLT108,1605,CDM A108,1,Active
ModuleInfo(4)	VOLT116,1701,A116,2,Active
ModuleInfo(5)	TEMP120,5,MyThermometer,5,Unused,TEMP120.Beta.01.00.2020.09.08.1457

Figure 12-1. CPIStatus table

The **ModuleInfo()** array shows the following information:

Module Type, Serial Number, Device Name, CPI Address, Activity, Operating System Version

The activity entry in the **ModuleInfo()** index shows the current state of the module. Possible activity entries and their meanings are shown in the following table. The device serial number is displayed after the activity entry.

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 the attempts of a data logger 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 *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, then save it. Click the **Advanced** tab then the **CRBasic Editor** button. Your program file will open in CRBasic with a generic name. 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.

2. To add the *Short Cut* wiring information into the new CRBasic program, open the .DEF file located in the C:\campbellsci\SCWin folder. Copy the wiring information found at the beginning of the .DEF file.
3. Go into the CRBasic program and paste the wiring information at the beginning of the program.
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 <sup>1</sup> (Hz)	Range <sup>2</sup> (mV)	Typical effective resolution <sup>3</sup>			
		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
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



Table B-1: Analog voltage measurement range and resolution

fN1 <sup>1</sup> (Hz)	Range <sup>2</sup> (mV)	Typical effective resolution <sup>3</sup>			
		Differential measurements with input reversal		Single-ended measurements or differential measurements without input reversal	
		RMS (μV)	bits	RMS (μV)	bits
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
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

**Table B-1: Analog voltage measurement range and resolution**

fN1 <sup>1</sup> (Hz)	Range <sup>2</sup> (mV)	Typical effective resolution <sup>3</sup>			
		Differential measurements with input reversal		Single-ended measurements or differential measurements without input reversal	
		RMS (μV)	bits	RMS (μV)	bits
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

<sup>1</sup> First notch frequency

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

<sup>3</sup> 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 SEVol1t1
Public SEVol1t2
Public SEVol1t3
'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,SEVol1t1,1,mV5000,1,True,500,60,1,0)
  CDM_VoltSe(VOLT108,5,SEVol1t2,1,mV5000,1,True,500,60,1,0)
  CDM_VoltSe(VOLT108,6,SEVol1t3,1,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.

Table C-1: Wiring for example B-3			
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 10-5](#) (p. 36):

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

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

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

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 ( $1 \div 0.02 \text{ s}$ ). Using the equation found in [CPI network bit rate](#) (p. 39), the kilobits of data generated each second is

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



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. 39), 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. 39]).

## 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 10-5](#) (p. 36):

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

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  $\mu\text{s}$ ), 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  $\mu\text{s}$ ), settling time of 100  $\mu\text{s}$ , 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. 47), this would improve the resolution to 9.012  $\mu\text{VRMS}$  for the largest voltage range,  $\pm 5000 \text{ mV}$ .

## D.3 Example 3

How fast can a VOLT 116 measure ten 3 k $\Omega$  full-bridge sensors using the default settling time (500  $\mu\text{s}$ ) and both excitation and input reversal, and achieve a resolution of less than 1  $\mu\text{VRMS}$ ? 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. 47). To achieve a resolution of less than 1  $\mu\text{VRMS}$  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  $\mu$ s) and the first notch frequency figured earlier (100 Hz), the sum of the above equations gives a total measurement time of **427511  $\mu$ s** (427.511 ms). Therefore, a practical scan rate for this setup would be 500 ms.

# Limited warranty


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Covered equipment is warranted/guaranteed against defects in materials and workmanship under normal use and service for the period listed on your sales invoice or the product order information web page. The covered period begins on the date of shipment unless otherwise specified. For a repair to be covered under warranty, the following criteria must be met:

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3. The defect must have occurred within a specified period of time; and
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# Assistance

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When returning equipment, a RMA number must be clearly marked on the outside of the package. Please state the faults as clearly as possible. Quotations for repairs can be given on request.

It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment. In support of this policy, when equipment is returned to Campbell Scientific, Logan, UT, USA, it is mandatory that a “[Declaration of Hazardous Material and Decontamination](#)” form be received before the return can be processed. If the form is not received within 5 working days of product receipt or is incomplete, the product will be returned to the customer at the customer’s expense. For details on decontamination standards specific to your country, please reach out to your [regional Campbell Scientific](#) office.

## NOTE:

All goods that cross trade boundaries may be subject to some form of fee (customs clearance, duties or import tax). Also, some regional offices require a purchase order upfront if a product is out of the warranty period. Please contact your [regional Campbell Scientific](#) office for details.

# Safety

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DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

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](http://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, such as those of the FAA in the USA.
- 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.

## 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.

#### Use and disposal of batteries

- Where batteries need to be transported to the installation site, ensure they are packed to prevent the battery terminals shorting which could cause a fire or explosion. Especially in the case of lithium batteries, ensure they are packed and transported in a way that complies with local shipping regulations and the safety requirements of the carriers involved.
- When installing the batteries follow the installation instructions very carefully. This is to avoid risk of damage to the equipment caused by installing the wrong type of battery or reverse connections.
- When disposing of used batteries, it is still important to avoid the risk of shorting. Do not dispose of the batteries in a fire as there is risk of explosion and leakage of harmful chemicals into the environment. Batteries should be disposed of at registered recycling facilities.

#### Avoiding unnecessary exposure to radio transmitter radiation

- Where the equipment includes a radio transmitter, precautions should be taken to avoid unnecessary exposure to radiation from the antenna. The degree of caution required varies with the power of the transmitter, but as a rule it is best to avoid getting closer to the antenna than 20 cm (8 inches) when the antenna is active. In particular keep your head away from the antenna. For higher power radios (in excess of 1 W ERP) turn the radio off when servicing the system, unless the antenna is installed away from the station, e.g. it is mounted above the system on an arm or pole.

#### 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.

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