PRODUCT MANUAL

Measurement and Control Peripheral

Spectrum Series

High-Speed Anti-Aliased Analog Input Modules for Spectral Analysis

Revision: 03/2025

RELIABLE MONITORING SINCE 1974

Campbell SCIENTIFIC®

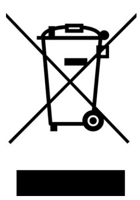
Please read first

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

The Spectrum series is designed for high-speed analog measurements with features tailored for spectral analysis applications. Key features include anti-alias filtering, synchronous sampling across all analog input channels, and real-time fast Fourier transforms (FFT). Each analog input channel has dedicated hardware, including amplifiers, filters, and analog-to-digital controllers (ADCs), rather than the multiplexed-input approach found in traditional data loggers.

The Spectrum 103 and Spectrum 109 are the same hardware design with 3 or 9 input channels, respectively. The multiples of 3 channels make the Spectrum well-suited for 3-axis accelerometers and strain gages. Throughout this manual, Spectrum refers to both models, unless specified.

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 Spectrum 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 Spectrum, and the data logger. Update as needed. See Operating systems (p. 24).
- For more information on accessing the calibration certificate watch a video at www.campbellsci.com/videos/calibration-certs.

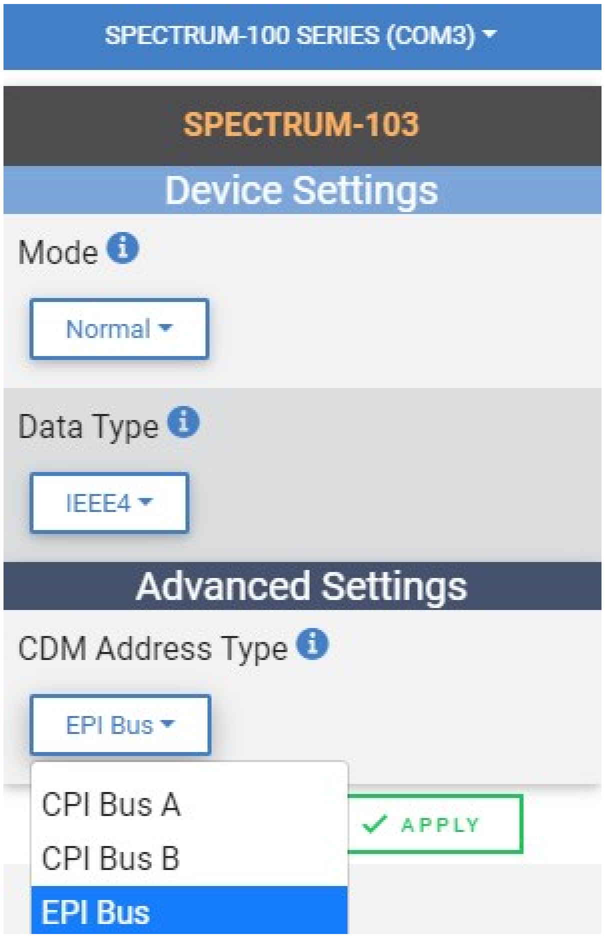
4. Measurement quickstart using *SURVEYOR*

Campbell Scientific ***SURVEYOR*** software is an easy way to quickly see measurement results and store data from the Spectrum. 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.

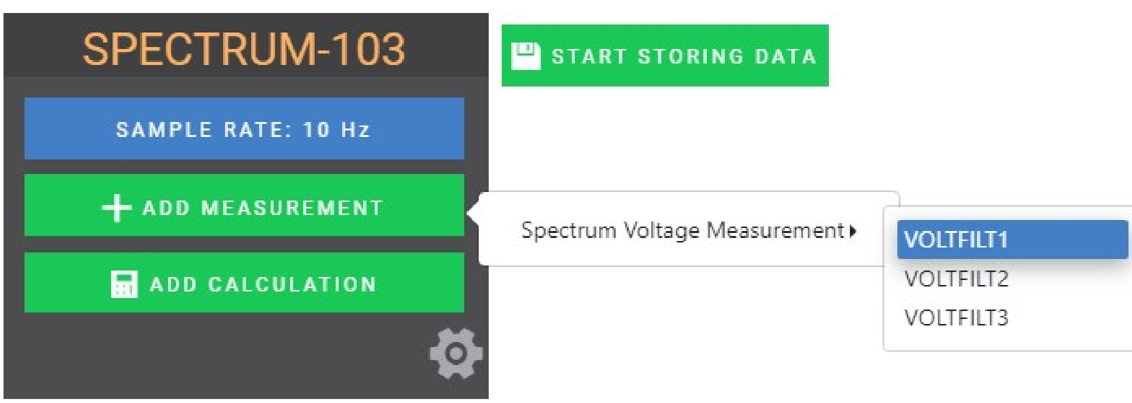
This section will guide you through reading a differential Type-T thermocouple on a Spectrum. With minor changes, these steps can apply to other compatible measurements.

1. Open ***SURVEYOR***.
2. Connect a USB cable between your computer and the Spectrum **USB** port.
3. Apply 10 to 30 VDC external power using the green **Power** connector on the side of the Spectrum.
4. Select **Connect Now**.
5. Select the communications port; it will be labeled similar to **Spectrum (COM3)**.

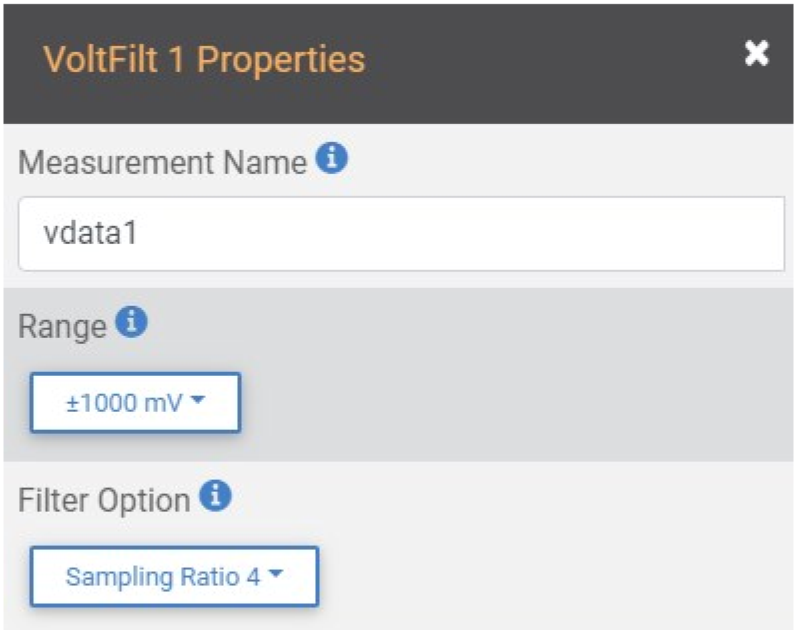
6. Make selections for **Mode**, **Data Type**, and **CDM Address Type**. For this exercise, select normal **Mode**. See the ***SURVEYOR*** help for more information on all settings.



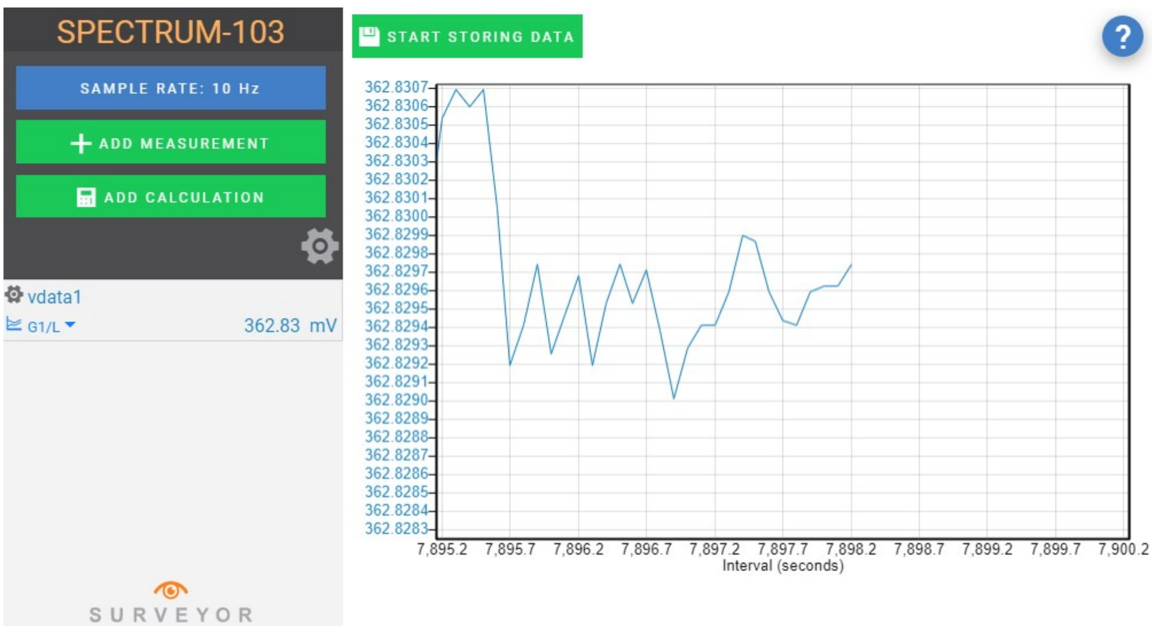
7. Click **APPLY**.
8. Select a **SAMPLE RATE**. For this exercise, select **10 Hz**.
9. **ADD MEASUREMENT**(s). For this exercise, add a Spectrum Voltage Measurement on **VOLTFILT1**. Insert the sensor into Terminal 1 on the Spectrum.

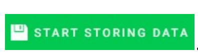


10. Complete the rest of the form and **APPLY** to save the configuration.



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



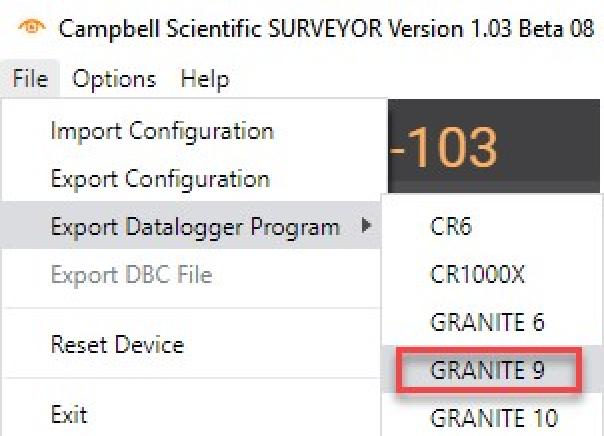
12. Click **START STORING DATA** 

. 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 Spectrum Campbell Scientific data acquisition system.

1. Configure the Spectrum 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 Spectrum to. For this example, we'll select GRANITE 9.



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

6. Specifications

All Spectrum units meet electrical specifications in a temperature range of –40 to 70 °C, non-condensing environment. Specifications given are assumed to be valid over this full temperature range unless otherwise noted. Recommended calibration interval is every three years.

6.1 Measurements

6.1.1 Analog inputs

Terminals	
SPECTRUM103:	3 Differential V in, 3 Excitation
SPECTRUM109:	±9 Differential V in, 9 Excitation
Common-mode input voltage (mV):	±10000, ±5000, ±1000, ±200
Common-mode input voltage:	±15 VDC
Absolute max input voltage:	±16 VDC
A/D converters:	32-bit SAR-ADCs
Measurement accuracy @ 20 °C	±(0.04% of Reading ± 130 µV)[1]
Input resistance:	80 MΩ
Input time constant:	230 ns
Input offset current:	5 nA typical, max @ 50 °C

[1] Accuracy specification does not include sensor error or measurement noise.

6.1.2 Analog range and resolution

Table 6-1: Sample ratio 20: signal to noise ratio (SNR) and effective resolution (ER)

Sample ratio = 20	200 mV		1000 mV		5000 mV		10000 mV	
Sample rate	SNR dB	ER bits	SNR dB	ER bits	SNR dB	ER bits	SNR dB	ER bits
1	132.6	22.0	133.6	22.2	135.1	22.4	141.2	23.4
10	130.7	21.7	134.2	23.3	134.5	22.3	140.3	23.3
100	131.5	21.8	135.3	22.5	135.6	22.5	139.2	23.1
1000	129.1	21.4	132.8	22.1	133.7	22.2	136.9	22.7
10000	121.6	20.2	127.3	21.2	128.4	21.3	130.6	21.7

Table 6-2: Sample ratio 4: signal to noise ratio (SNR) and effective resolution (ER)

Sample ratio = 4	200 mV		1000 mV		5000 mV		10000 mV	
Sample rate	SNR dB	ER bits	SNR dB	ER bits	SNR dB	ER bits	SNR dB	ER bits
1	126.9	21.1	134.1	22.3	136.2	22.6	140.4	23.3
10	127.6	21.2	133.7	22.2	136.0	22.6	139.9	23.2
100	129.0	21.4	133.7	22.2	135.4	22.5	138.3	23.0
1000	126.0	20.9	131.6	21.9	132.5	22.0	135.0	22.4
10000	118.1	19.6	124.8	20.7	125.8	20.9	127.6	21.2

6.1.3 Anti-aliasing filters

Output sample rate (f samp):	1 to 10,000 sps
Sample ratio (f_samp/f_pass):	4 or 20 (user selected)
End of the pass band (f_pass):	(f_samp/4) or (f_samp/20)
Beginning of the pass band (f_stop):	(f_samp/2) or (f_samp/3.3)
Pass band ripple:	<0.01 dB
Digital filter stop band attenuation:	-90 dB or (1/32000)
Digital filter group delay:	12/f_samp seconds
Analog filter pass band flatness:	<0.005 dB (direct current (0 to 3 kHz)
Analog filter group delay:	66 ±1 µs (0 to 3 kHz)
Linear phase response:	group delay is independent of signal frequency
Ch-Ch sampling simultaneity:	± 10 ns
Module to Module sampling simultaneity over EPI:	± 100 ns

6.1.4 Excitations

10V excitation: *Nominal output:* 10,000±5 mV (1 kΩ load)
Load regulation: (350 Ω): 0.005% typical (@25°C relative to 1 kΩ load)
Load regulation: (120 Ω): 0.02% typical (@25°C relative to 1 kΩ load)
Max output current: > 100 mA

5V excitation: *Nominal output:* 5000±5 mV (1 kΩ load)
Load regulation: 0.005% typical (@25°C relative to 1 kΩ load)
Load regulation: 0.02% typical (@25°C relative to 1 kΩ load)
Max output current: > 100 mA

10 mA excitation: *Nominal output:* 10±0.05 mA (1 kΩ load)
Load regulation: 0.1% typical (@25°C relative to 1 kΩ load)
Load regulation: (120 Ω): 0.02% typical (@25°C relative to 1 kΩ load)
Max output voltage: > 12 V

NOTE:
For bridge measurements, excitation error is canceled out due to the internal ratiometric relationship between the excitation and the input measurement and is corrected with internal calibration. This advantage is realized when the excitation is utilized as part of the integrated CRBasic bridge measurement process. Consequently, excitation accuracy error can be disregarded and should not be included in the calculation of total error alongside input measurement accuracy error. Instead, refer only to the specified input measurement accuracy when performing bridge measurements.

6.2 System

6.2.1 Communications

USB: USB micro-B device only, 2.0 full-speed 12 Mbps, for computer connection.

EPI: Campbell Scientific proprietary interface based on Ethernet and the IEEE 1588 Precision Time Protocol. Provides data communications and device synchronization between Campbell Scientific data loggers, sensors, and GRANITE Modules.

Data logger compatibility: GRANITE 9, 10
EPI max number of Spectrum devices: 10
EPI max measurement sample rate: 10k sample/sec (using subscans)
EPI max sampling synchronization: 50 ns
EPI max data bit rate: 100 Mbps
EPI max cable length: 100 meters (328 feet) between modules

CPI: CPI works well for slower measurements (< 1,000 Hz) with a single Spectrum module.

Campbell Scientific proprietary interface based on the CAN 2.0 and RS-485 standards.

Data logger compatibility: GRANITE 9, GRANITE 10, GRANITE 6, CR6, CR1000X
CPI max number of devices: 1
CPI max measurement sample rate: 1000 samples/sec (no subscan option)
CPI max data bit rate: 1000 kbps

CPI max total cable length: 850 meters (2800 feet)[1]

[1]See Designing Physical Network Layouts for the CPI Bus.

6.2.2 Hardware

Processor:	Digital Signal Processor 32-bit with floating point units
Processor speed:	400 MHz
Memory:	128 MB SRAM
Onboard oscillator accuracy:	± 50 ppm (-10 to 60°C), active when module is not connected to EPI
EPI master clock accuracy:	± 25 ppm (-40 to 85°C), active when module is connected to EPI

6.2.3 Power requirements

Voltage: 10 to 30 VDC

Table 6-3: Typical current drain

Model	Power supply			
	@12V without excitation	@12V with excitation	@24V without excitation	@24V with excitation
103	310 mA typical	310 mA + 3.3 *sensor_ current	190 mA	190 mA + 1.7 *sensor_ current
109	680 mA typical	680 mA + 3.3 *sensor_ current	360 mA	360 mA + 1.7 *sensor_ current

NOTE:
Power consumption is independent of measurement speed.

6.2.4 Compliance

View EU Declarations of Conformity at www.campbellsci.com/spectrum.

6.2.5 Physical attributes

Dimensions:	21.6 x 13.7 x 7.6 cm (8.5 x 5.4 x 3.0 in); additional clearance required for cables and wires
Weight:	1.6 kg (3.53 lb)
Operating temperature:	–40 to 70 °C
Storage temperature:	–55 to 85 °C
Passive heat sink thermal resistance w/o air gap:	Max 0.35 °C/W
Air gap clearance for operation w/o heatsink:	Min 4 inches
IP rating:	IP20
Humidity:	0 to 99% Non-condensing
Sensor terminal wire gage:	16-28 AWG
Power terminal wire gage:	2-24 AWG

7. Overview

The Spectrum is a 3 or 9 channel analog-input module that includes programmable anti-alias filtering and DC excitation. The program scan interval determines the filter module output interval. Data is passed from the filter module to the data loggers CPU over the Ethernet Peripheral Interface (EPI) or CAN Peripheral Interface (CPI) bus for processing and final storage at this scan interval. The filter module collects alias-free, 10-kHz samples from each of its 3 or 9 analog-to-digital converters, applies additional real-time, finite-impulse-response filtering, and down-samples the 10-kHz data to the programmed scan rate.

The Spectrum is compatible with any EPI or CPI-enabled data logger, such as the GRANITE 10, GRANITE 9, GRANITE 6, CR6 and CR1000X.

8. EPI and CPI networks

GRANITE 9 and GRANITE 10 data loggers support EPI networks. EPI is the preferred Spectrum-to-data logger connection due to multi-module support, superior time synchronization between modules (with a precision of 50 ns compared to 100 µs for EPI vs CPI, respectively), and higher data transfer rates than those achievable with a CPI network.

Data loggers such as the GRANITE6, CR6, or CR1000X do not support EPI, but can connect to a Spectrum using their CPI bus. A CPI network works well for slower measurements (less than 1,000 Hz) with a single Spectrum module.

> **NOTE:**
> When a Spectrum is on a CPI network, no other CPI devices can be present.

8.1 EPI basics

- GRANITE 9 and GRANITE 10 data loggers support one EPI network with two EPI ports
- EPI networks offer 100 times greater throughput than CPI networks
- Module-to-module synchronization is on the order of 1000 times better compared to CPI synchronization (100 ns for EPI vs. 100 µs for CPI)
- In a EPI network, devices are daisy-chained with a 100-meter (328 feet) cable limit between devices
- Each Spectrum features two EPI ports for signal reception and renewal, facilitating network expansion by up to 100 meters between modules
- A maximum of 10 EPI modules can be connected in a single EPI network
- When using multiple Spectrums on an EPI network, assign a unique EPI address (1-120) to each module
- Monitor EPI network capacity in the host data loggers CPIStatus and EPIStatus tables (p. 30)

> **CAUTION:**
> A CPI terminator should never be used in an EPI network.

8.2 CPI basics

- Only one Spectrum can be on a CPI network
- A CPI terminator may improve network performance
- The CPI network speed can be optimized for data speed or cable distance

- The ***CPI Calculator*** (a downloadable Excel file from the Spectrum web page on the Campbell Scientific web site) can help determine CPI network capacity
- Monitor the CPI network capacity (percent) in the host data logger Status table

9. Measurement channels

Each differential channel of the Spectrum module is equipped with an identical set of 5 terminals. These are labeled Vin+, Vin–, EX, and 2 grounds. The signal paths within the Spectrum module are carefully managed within these terminal sets. A sensor should be connected in such a way that all the related signals are contained within a single terminal set. Bridging grounds or excitations from neighboring terminal sets may compromise the calibration accuracy of the measurements.

The configuration parameters (input range and excitation) can vary for each differential channel. The only setting that is common to all channels is the sample rate and the sample ratio.

9.1 Wiring panel overview

CAUTION:
To avoid damage to sensors and devices, ensure that each removable wiring-terminal strip is connected to the Spectrum in the proper location before applying power. Each terminal strip is keyed identically, which allows strips to be swapped from one device to another.

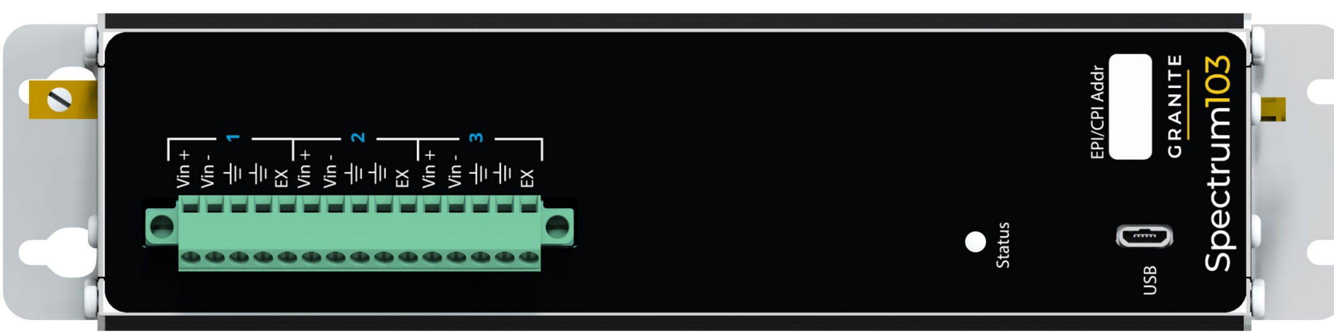


Figure 9-1. Spectrum 103 wiring panel

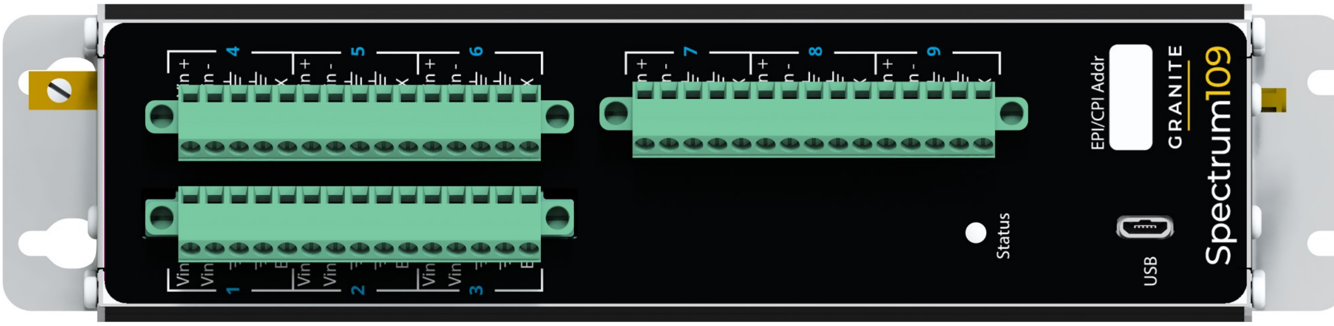


Figure 9-2. Spectrum 109 wiring panel

Figure 9-3. Power, EPI and CPI ports view (left) and ground lug view (right)

9.2 Analog inputs

The Spectrum module is equipped with fully differential analog input terminals. These inputs are labeled as Vin+ and Vin- and appear as a pair for each differential channel (see also Wiring panel overview [p. 13]). In order to maintain a high input impedance, neither terminal is internally connected to the device ground or any other reference voltage. Therefore, it is the responsibility of the user to ensure that the input signal is biased in such a way that the common-mode input voltage range requirement is satisfied. If the input signal is truly isolated and therefore has no common-mode reference voltage, then the Vin- terminal can be connected to a ground terminal with a jumper wire to ensure common-mode range compliance.

The voltage inputs have true bipolar input capability. Firstly, this means the inputs Vin+ and Vin- can vary both positively and negatively relative to one another. Secondly, it also means the absolute voltage of either input can vary above or below the system ground voltage, provided it remains within the common-mode input range.

The inputs are designed to accept differential signals. If a single-ended signal is to be measured, it should be connected to the Vin+ terminal and the Vin- terminal must be externally connected to ground by the user.

The inputs have four selectable input signal ranges. The ranges are ±200 mV, ±1000 mV, ±5000 mV, and ±10,000 mV. Best practice is to select the smallest input range that will capture the expected full-scale range of the measured signal.

9.3 Ground

Two ground terminals are provided for each differential channel. These grounds are tied directly to one another internally and can be used interchangeably within a channel. The grounds should serve as the return points for the excitation signal and for the shield wire of the sensor cable. Additionally, they can be manually jumpered to the Vin- terminal for single-ended or isolated input signals.

9.4 Excitation

Each differential channel has an excitation terminal labeled EX. This terminal can be used as either a calibrated excitation for a resistive bridge measurement or as a general voltage source for powering an amplified sensor. Each excitation terminal has four settings:

1. Off. The terminal stays in a high-impedance state
2. 5 V. This is a constant voltage source set to 5 V. The excitation can source up to 100 mA at this voltage
3. 10 V. This is a constant voltage source set to 10 V. The excitation can source up to 100 mA at this voltage
4. 10 mA. This is a constant current source set to 10 mA. The excitation can rise to as much as 12 V while maintaining this current

The absolute accuracy of an excitation voltage or current should be considered differently depending on whether it is being used in a bridge measurement or as an independent power source. When used as an independent power source, the accuracy given in the specification table applies.

When the excitation is used to power a bridge sensor, the CRBasic instruction `CDM_BridgeFilt()` should be used. When excitation is used with this instruction, excitation error is canceled out due to the internal ratiometric relationship between the excitation and the input measurement. Excitation error is also corrected with internal calibration over the full temperature range. Thus, the excitation accuracy error can be ignored and should not be added to the input measurement accuracy error to compute total error. Instead, refer only to the specified input measurement accuracy when performing bridge measurements.

9.5 Anti-aliasing

Aliasing is a phenomenon that can occur whenever a discrete-time sample is taken of a continuous-time analog signal. A basic tenet of sampling theory is that a continuous analog signal can be sampled at a periodic rate and these samples contain enough information for the original continuous signal to be reconstructed from the samples.

The Nyquist-Shannon Sampling Theorem instructs that for this tenet to hold true, the sample rate must be greater than twice the frequency of the highest frequency contained in the analog signal. If the Nyquist limit is not observed then aliasing will occur. This also suggests that the analog signal must have a finite bandwidth or the sample rate can never be high enough to avoid aliasing. Aliasing manifests in the reconstructed signal as information reconstructed at the wrong frequency.

Anti-aliasing is a sampling technique that controls the bandwidth of the analog signal to ensure aliasing does not occur. The process has three basic steps.

1. Apply a low-pass analog filter to the signal. This analog filter will have a minimum pass-band (non-attenuated frequencies) and fairly long transition to the stop-band (fully-attenuated frequencies).
2. Sample the filtered signal at a much higher rate than the Nyquist requirement of simply twice the bandwidth of the pass-band.
3. Apply a digital filter to the sampled data that creates a much sharper transition from the pass-band to the stop-band. The combination of the rate of over sampling data, combined with the relative bandwidths of the analog and digital filters creates the special condition called anti-aliasing. Put simply, anti-aliasing controls the bandwidth of the original signal to

ensure that the reconstruction of the signal will not have any frequency components represented at an incorrect frequency.

The anti-aliasing filter plays a crucial role in ensuring the fidelity of signal samples by accurately capturing the entire frequency SPECTRUM of the original signal within the specified pass-band. Adhering to the Nyquist theorem, the sample rate must exceed twice the signal bandwidth, emphasizing the necessity for a rate greater than, not equal to, twice the bandwidth.

To ensure accurate signal reconstruction, it is wise to include a margin in the sample rate-to-bandwidth ratio. By widening the gap between these values, we can more easily achieve a faithful reconstruction of the signal. This concept is illustrated in the image provided.

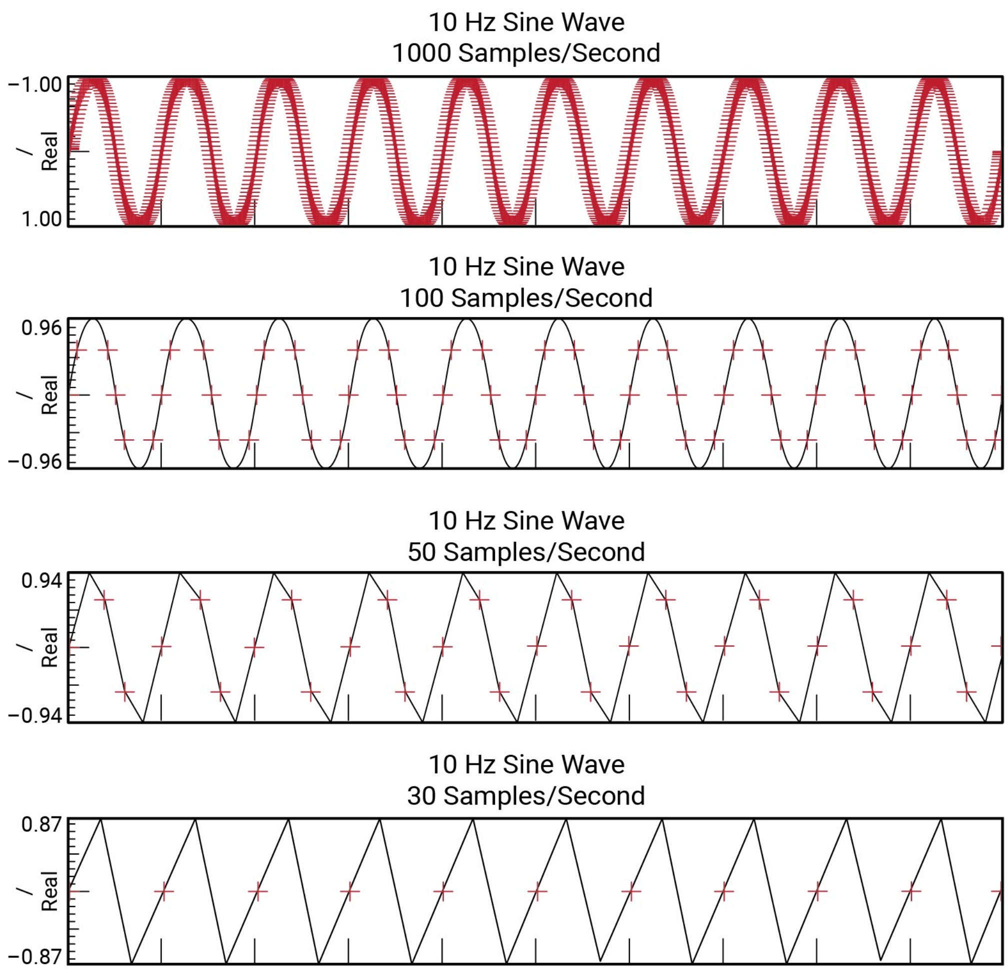


Figure 9-4. Demonstration of 1000, 100, 50, and 30 samples per second of a 10 Hz sine wave

This visual representation illustrates four graphs depicting a sine wave of the same frequency, sampled at progressively higher rates—all satisfying the Nyquist requirement.

Analogous to a reconstruction filter, the human eye exemplifies this concept. Observing the same frequency sine wave at varying sample rates, the eye effortlessly discerns the original waveform in higher sample rate data. It is imperative to recognize, however, that despite these perceptual differences, all examples equally and accurately represent the original signal.

The Spectrum devices offer two ratio options: 4 and 20. The user must select the sample rate and the oversample ratio. From these two numbers, the filtered bandwidth of the signal is determined. For example, a sample rate of 1 kHz with an oversample ratio of 20, will have a signal bandwidth of 1000/20=50 Hz. The same sample rate with a 4 ratio will have a signal bandwidth of 1000/4=250 Hz. The maximum output sample rate of the Spectrum is 10 kHz and the maximum analog bandwidth is 2.5 kHz.

9.6 Synchronization

The channel-to-channel sampling synchronization within a single module is approximately ±10 ns. If the EPI bus is used to synchronize multiple modules then the module-to-module synchronization is approximately ±50 ns.

9.7 Measurement speed and filter options

Follow these steps to select the most appropriate measurement speed and filter options. The measurement speed is the CRBasic program `Scan()` rate and the filter option (`FiltOpt`) is a parameter specified in the measurement instructions. See the CRBasic Help for measurement instruction details:

1. **Determine the fastest signal:** Determine the highest expected frequency in the signal or system. For example, if measuring a bridge with an expected resonant frequency of 1 to 3 Hz, consider 3 Hz as the fastest signal. Specifying a measurement frequency that significantly exceeds the maximum bandwidth will increase noise in the signal.
2. **Determine the filter option:** To prevent aliasing and ensure accurate signal reconstruction, the sample rate should be at least double the highest signal frequency (Nyquist theorem). The filter option, available in 4 and 20, represents oversampling. Filter option 4 captures at least 4 points within a wavelength cycle of the fastest frequency. Filter option 20 captures 20 points for a higher resolution visualization of the signal, but fundamentally does not contain more information about a sinusoidal signal than filter option 4. Benefits of higher resolution (filter option 20) may include a smoother wave reconstruction during post processing or improved edge computing with a data logger program determining the signal highs and lows.

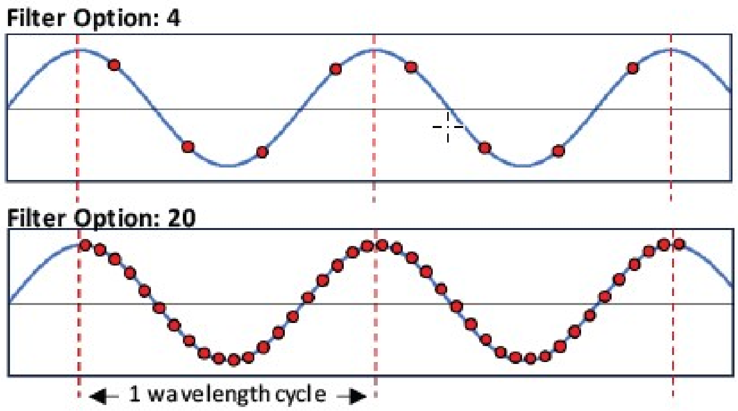


Figure 9-5. Filter options 4 and 20

3. **Calculate the minimum sample rate (scan rate):**To calculate the minimum scan rate for the data logger program, multiply the fastest sensor or system scan rate by the selected filter option.

9.7.1 Example to determine measurement speed based on filter option

1. **Determine the fastest frequency possible (fPass):** A user wants to measure a signal and determines the fastest frequency response possible is 25 Hz.
2. **Determine the filter option:** The user wants the highest fidelity signal possible to enable edge computing in the data logger program to monitor the maximum amplitudes of the signal. The desired Filter Option is 20.
3. **Calculate the Scan rate (a.k.a. sample rate, or fSample):**

   Scan rate = 1/[(fPass) x (Filter Option)] = 1/[(25 Hz) x (20)] = 1/(500 Hz) = 2 mSec

   In a CRBasic program, the scan rate is set using: `Scan`(2, msec, 1500,0).

> **NOTE:**
> In this `Scan()` example, the `BufferOption` is 1500. The scan buffer allocates extra memory for the data logger to process incoming data while handling other tasks. Typically, a `BufferOption` of 400 works well for networks operating slower than 10 Hz. A `BufferOption` of 1500 is recommended for networks that operate faster than 10 Hz.

9.8 Real-time-FFT

The CRBasic instruction, `CDM_FFTFilt()`, passes an entire SPECTRUM for each channel to the data logger CPU at the scan interval.

The FFT operation provides spectra from "seamless" time-series snapshots, if the scan interval is set to the FFT length divided by the time-series sample rate. Slower SPECTRUM rates can be selected by increasing the scan interval above this quotient.

The CRBasic instruction, `FFTSample()` can be used to store the current spectral components of a source signal to a final output table.

10. Data logger programming

10.1 Programming with Surveyor

Campbell Scientific Spectrum includes a CRBasic program file generator. Programs created with Spectrum can be sent to the data-acquisition system using ***LoggerNet***, ***RTDAQ***, or ***Device Configuration Utility*** for any Campbell Scientific data logger.

See Programming quickstart using SURVEYOR (p. 5) for a Spectrum tutorial.

Complete program examples can be found at: www.campbellsci.com/downloads/spectrum-example-programs.

> NOTE:
> *SURVEYOR* is limited to programming a single GRANITE module.

10.2 Programming with CRBasic

The Spectrum is supported by these CRBasic instructions:

- `CPIAddModule()` – can be used to programatically configure the module.
- `CDM_VoltFilt()` – used to pass individual voltage measurements for each channel on a Spectrum to the data logger CPU at the scan interval.

- `CDM_BridgeFilt()` – used to make a strain gauge measurement on the Spectrum Module. The mV/Volt output from CDM_BridgeFilt can be converted into microstrain (με) with the `StrainCalc()` instruction or with the `FieldCalStrain()` instruction and the LoggerNet Calibration Wizard.
- `CDM_FFT_Filt()` – passes an entire SPECTRUM for each channel to the data logger CPU at the scan interval.
- `FFTSample()` – stores the current spectral components of a source signal.

Downloadable CRBasic program examples demonstrating the application of these instructions are available at: www.campbellsci.com/downloads/spectrum-example-programs.

> NOTE:
> When using a CPI or EPI device, improve data logger performance by adjusting the CRBasic `SCAN()` BufferOption to approximately 400 for networks operating slower than 10 Hz and 1500 for networks faster than 10 Hz. This allocates extra memory for the data logger to process incoming data while handling other tasks.

11. High-speed data management

The Spectrum series is designed for high-speed, synchronous sampling of analog inputs over EPI, resulting in large data sets. Given the rapid data collection speed of the Spectrum, a well-thought-out data management plan is crucial. Here are some steps for effective data management:

1. **Streamline data collection:** Only keep necessary data. Adjust measurement or recording speeds to capture only needed data points without excess.
2. **Use event-based triggers:** Event triggers help filter and store only relevant data.
3. **Implement local data processing:** Employ data logger real-time tools like Rainflow histograms, averaging, statistics, or the FFT function with the Spectrum CRBasic instruction `CDM_FFTFilt()` to reduce large data volumes.
4. **Use integrated Ethernet port:** For high-speed applications, use the integrated data logger Ethernet port for fast and cost-effective data transfer. Integrated Ethernet may reduce concerns with cellular costs, Wi-Fi bandwidth, or USB throughput.

5. **Use FTP for Remote Transfers:** Use FTP to send data from the data logger to a remote server. FTP is reliable, automated, and ensures easy access to the data on a server.

11.1 FTP streaming example:

Sending data over FTP is implemented by streaming data records from local final-storage tables with the optional **FTP streaming parameters** of the `FTPClient()` instruction. See the CRBasic Help for details. Also, see the Data Streaming application note. The example code below demonstrates configuring data streaming with the `FTPClient()` instruction:

```
 'FTP streaming information
Const FTP-site = "ftp.box.com"
Const User = "User@domain.com"
Const PW = "UserPassWord"
Const Destination-Directory = "SPECTRUM Data/UserDirectory/"

'Public Variables
Dim TStamp As String *22
Public FTP_result
Public LastSentRecord As String *22
'Data Tables
DataTable (Static_AND_Temp, True, -1) ' Combined static strain and temperature
table for FTPing
DataInterval (0,1,Sec,10)
Sample (8,StaticStrain_1(),IEEE4)
      ...
      ...
      ...
EndTable
'Measurement and processing instructions
    ...
    ...
    ...
SlowSequence
  Scan (1,hr, 0,0)
 TStamp = Mid (Public.Timestamp(5,1),1,16)
'Stream data from local Final storage table to FTP server
 FTP_result = FTPClient (FTP-site,User,PW,"Static_AND_Temp",     Destination-
Directory & "1085_STATIC_AND_TEMP_",2,0,0,hr,8)
If FTP_result = -1 Then LastSentRecord = TStamp
  NextScan
EndProg
```

12. 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.

12.1 Physical deployment

The GRANITE series, including the Spectrum, can be mounted in a standard environmental enclosure, distributed across a site in different enclosures, or in a GRANITE Chassis. The GRANITE Chassis is a rugged housing offering portability or a mounting option in a server cabinet.

Figure 12-1. GRANITE modules installed in a GRANITE Chassis

Modules may be connected in an enclosure or between multiple enclosures using an EPI network.

Figure 12-2. Spectrum modules daisy chained on GRANITE 9 EPI network

12.2 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 Spectrum via USB for the first time.

To install the device driver using ***Device Configuration Utility***, select **Granite** > **Spectrum**. Click **Install USB Driver** and follow the prompts.

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

12.3 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:
> It is strongly advised that all devices (data logger and measurement modules) in an EPI or CPI network use the most recently released operating system for each device.

12.4 Configuring Spectrum

The Spectrum arrives ready to be connected to a system with a default CPI or EPI 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 Spectrum using one of four methods: through ***SURVEYOR***, the `CPIAddModule()` program instruction, ***Device Configuration Utility*** software, or the **CPIStatus** table.

12.4.1 Configuring with *SURVEYOR*

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

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

12.4.2 Configuring with the CPIAddModule() instruction

To configure a Spectrum 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.

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

12.4.3 Configuring with *Device Configuration Utility*

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

1. Open ***Device Configuration Utility***.
2. Under **Device Type**, select **Granite** > **Spectrum**.
3. Carefully review the **Connecting with USB Instructions** text provided on the right.
4. Apply 10 to 30 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 Spectrum.
6. Select **Direct** under **Connection Type**.
7. Under **Communication Port**, select the port labeled **Spectrum**.

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

12.4.4 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
```

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 Spectrum through Campbell Scientific software without editing the CRBasic program or connecting directly to the **USB** port.

See CPIStatus and EPIStatus tables (p. 30) for additional information.

12.5 Data logger connection

Spectrum devices communicate with a data logger through a **CPI** or **EPI** port. Each Spectrum 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** and two **EPI** ports are available on the Spectrum. The **CPI** or **EPI** port on the Spectrum connects directly to the **CPI** or **EPI** port on a GRANITE 9 or GRANITE 10 data logger. The CR1000X, CR6, and GRANITE 6 do not have an EPI port, so the Spectrum connects to their CPI port.

12.6 Power connection

Connect the power supply to the removable **Power** connector on the side of the Spectrum. Power supplies providing voltages from 10 to 30 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.

12.6.1 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 Spectrums and then the data logger. This procedure will reduce the time required to synchronize the CPI bus.

See COMM status LED (p. 32) for more information.

12.7 Earth ground connection

Earth grounding provides protection from static discharge, transients, and power surges. A ground lug is provided on the Spectrum for connection to earth ground, see Wiring panel overview (p. 13). 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.

12.8 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.

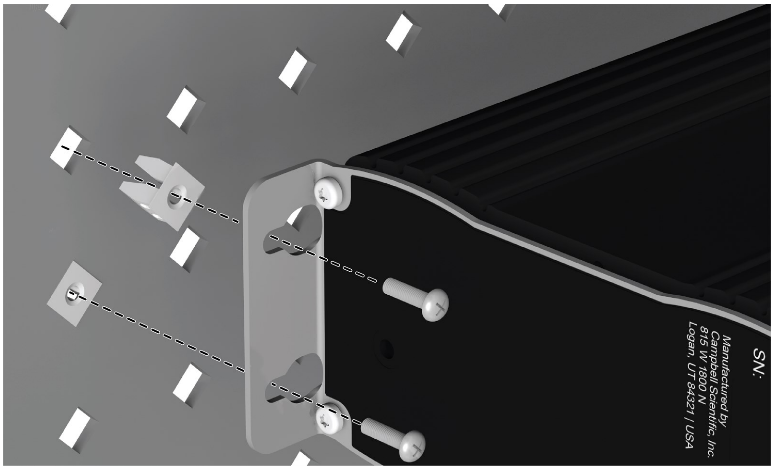


Figure 12-3. Enclosure backplate mounting

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

Figure 12-4. GRANITE DIN-Rail Mounting Kit

Figure 12-5. DIN rail mounting

13. Maintenance and calibration

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

If sending the Spectrum to Campbell Scientific for calibration or repair, consult first with a Campbell Scientific representative. If the Spectrum 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.

14. Troubleshooting

1. Check the voltage of the power source at the **Power** connector. It should be between 10 and 30 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 enough data logger memory has been allocated for real-time data buffering. Typically, a `Scan()` BufferOption of 400 works well for networks operating slower than 10 Hz. A BufferOption of 1500 is recommended for networks that operate faster than 10 Hz. 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 Spectrum in the network has a unique EPI or CPI address.
5. Check the data logger and Spectrum operating system and update them as needed.
6. Check the scan rate is long enough for the measurement time. The data logger compiler often catches scan rates that are too fast.
7. If using CPI, ensure the CPI network bit rate is fast enough for the data generated and that it can accommodate the cable lengths in use.

14.1 CPIStatus and EPIStatus tables

Information in the **CPIStatus** and **EPIStatus** tables, 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 14-1. CPIStatus table

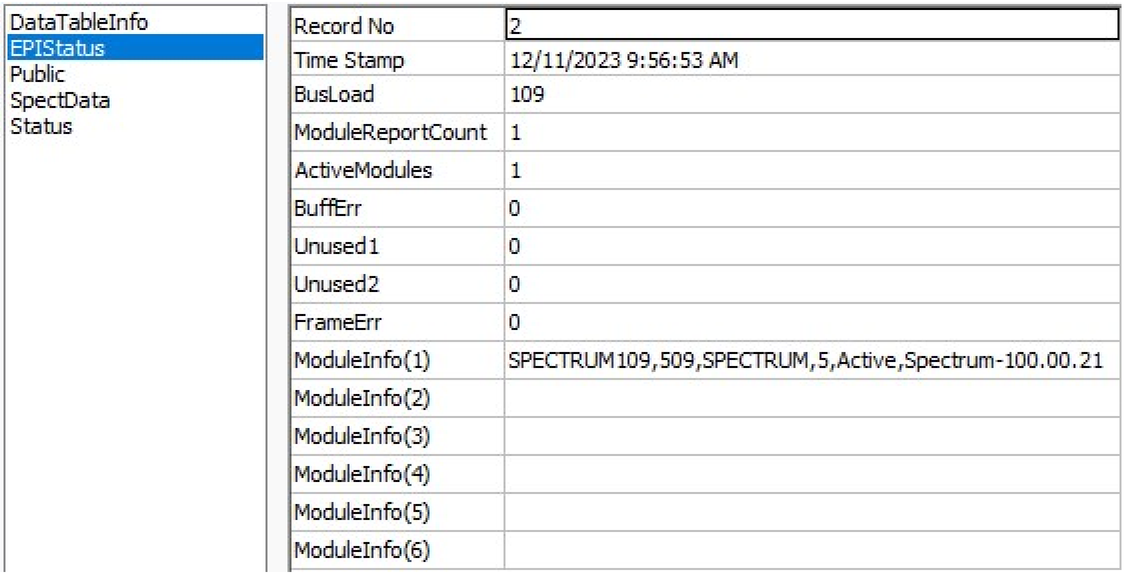


Figure 14-2. EPIStatus table

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 14-1: CPIStatus and EPIStatus 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.

14.2 COMM status LED

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

Table 14-2: 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

14.3 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 14-3: CPI port LED activity		
Green	Flashing	Frame sync
Orange	Flash	CPI activity
	Solid	CPI bus fault

14.4 EPI port LEDs

The EPI LEDs are controlled by the Ethernet chip and indicate activity.

Table 14-4: EPI port LED activity		
Yellow	Solid	Valid Ethernet link
	None	Invalid Ethernet link
	Flashing	Ethernet activity
Green	Solid	100 Mbps link
	None	10 Mbps link

14.5 Replacing a GRANITE Measurement Module

An existing Spectrum can be replaced with a new module using the same CPI or EPI address without requiring a change to the program.

Limited warranty

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:

1. There must be a defect in materials or workmanship that affects form, fit, or function of the device.

2. The defect cannot be the result of misuse.

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

4. The determination must be made by a qualified technician at a Campbell Scientific Service Center/ repair facility.

The following is not covered:

1. Equipment which has been modified or altered in any way without the written permission of Campbell Scientific.

2. Batteries; and

3. Any equipment which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country. For directions on how to return equipment, see Assistance.

Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.

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MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Campbell Scientific hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the products, whether express, implied, or statutory, other than those expressly provided herein.

Campbell Scientific will, as a default, return warranted equipment by surface carrier prepaid. However, the method of return shipment is at Campbell Scientific's sole discretion. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This warranty and the Company’s obligation thereunder is in lieu of all other warranties, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

In the event of any conflict or inconsistency between the provisions of this Warranty and the provisions of Campbell Scientific's Terms, the provisions of Campbell Scientific's Terms shall prevail. Furthermore, Campbell Scientific's Terms are hereby incorporated by reference into this Warranty. To view Terms and conditions that apply to Campbell Scientific, Logan, UT, USA, see Terms and Conditions. To view terms and conditions that apply to Campbell Scientific offices outside of the United States, contact the regional office that serves your country.

Assistance

Products may not be returned without prior authorization. Please inform us before returning equipment and obtain a **return material authorization (RMA) number** whether the repair is under warranty/guarantee or not. See Limited warranty for information on covered equipment.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country.

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

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 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.

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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