Nanometrics

Trillium Compact
User Guide

STRATEGIC INTELLIGENCE
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Trillium Compact Seismometer User Guide

Applies to the following products:

Product Name	**Model Number**	**Part Number**
Trillium Compact, 120 second	TC120-SV1	16838
Trillium Compact, 20 second	TC20-SV1	16838-20
Trillium Compact Posthole, 120 second, 300 m	TC120-PH2	17327
Trillium Compact Posthole, 20 second, 300 m	TC20-PH2	17327-20

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About This Document

Document Conventions

Essential and Supplementary Information		
	Warning	Explains a risk of irreversible damage to data, software, or equipment and provides recommendations for preventive action.
	Caution	Explains a risk of damage to data, software, or equipment where recovery is likely to be troublesome and provides recommendations for preventive action.
	Note	Provides additional information related to the current text.
	Tip	Explains a best practice or provides helpful information related to the current text.
	Example	Provides an example related to the current text.
Text Conventions		
	bold text	Identifies referenced elements in the graphical user interface (GUI) (for example, "click **Cancel** to discard the changes").
	italic text	Identifies variables such as parameter names and value placeholders (for example, "select Configuration > *Sensor Name*").
	`courier text`	Identifies commands that must be entered exactly as shown (for example, "type `mkdir $APOLLO_LOCATION/config`").

Changes Included in This Revision

Revision number 16889R7 includes the following changes:

- Corrected errors around frequency response and calibration input sensitivity. See Chapter 9, "Transfer Function and Noise Floor".
- Changed power consumption levels to approximately 180 mW for 120 s models and approximately 195 mW for 20 s models. (See Section 4.6 "Power Consumption" on page 28.)
- Updated cable part number 18005. (See Table 1-1 "List of cables and accessories" on page 4.)
- Removed information relating to obsolete models.
- Formatting and typographical changes.

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Chapter 1
Getting Started

1.1 About Trillium Compact Seismometers

Trillium Compact is extremely simple to deploy with no mass lock and no mass centering required. The exceptionally small size significantly reduces the time and effort required for site preparation and installation. Continuous quality data are available within minutes of deployment with no requirement for further intervention.

All Trillium Compact seismometers are observatory-class three-component, very broadband, low-noise seismometers with extended low frequency range useful out to beyond 1000 s, low noise, and a high clip level that is ideal for teleseismic, regional, and local studies.

- Low-noise broadband seismometer performance
- Broadband performance, 20 or 120 second to 100 Hz, with improved noise floor at high frequency
- Exceptionally high clip level of 26 mm/s permits on scale recording of larger events closer to the source
- Ultra low power consumption of just 180 mW for low operating costs and higher station reliability
- Ease of deployment through no mass lock, no mass centering and wide tilt range
- Integrated web server for efficient instrument management

Trillium Compact seismometers are available with 20 s or 120 s low corner period. The 20 s variants have a wide operational tilt range of ±10° and are suitable for downhole installations where the seismometer cannot be levelled, or for rapid deployments where a quick settling time is needed. The 120 s variants have lower long-period noise and a narrower tilt range of ±2.5° and are suitable for installations where the seismometer can be manually levelled or placed on a level surface (in a vault or at the bottom of a suitably prepared borehole).

Featuring low sensitivity to both tilt and temperature, Trillium Compact seismometers do not require mass centring under normal operation. With the wide tilt range, levelling is simple and If additional levelling is required, the seismometer can be levelled in seconds by seating it in its optional levelling cradle, which corrects an uneven installation surface by up to ±9°. See Appendix B "Levelling Cradle and Spike Kit" for more information.

The Trillium Compact has an integrated Web server that is accessible using a standard Web browser and the RS-232 serial interface available on the connector. A desktop computer with a serial port configured with serial-over-Internet-Protocol (SLIP) can be used to browse into the Trillium Compact and configure optional features, check factory information or state-of-health, and update firmware. Current generation Nanometrics digitizers support this interface so users can access the Web-based features of the Trillium Compact remotely, even with the unit in service.

The symmetric triaxial arrangement of the sensing elements ensures uniformity between vertical and horizontal outputs. The ability to remotely select either the raw (UVW) or resulting horizontal-vertical (XYZ) outputs allows for the calibration of each axis separately. For some studies, it may be preferable to use UVW mode instead of XYZ mode for recording seismic data.

Trillium Compact is available in several variants to facilitate vault, surface, or buried downhole deployments:

Model TC120-SV1 A surface vault seismometer in an aluminum enclosure with a

- 14-pin MIL-C-26482 Series I connector
- bandwidth of -3 dB points at 120 s and 108 Hz

Model TC20-SV1 A surface vault seismometer in an aluminum enclosure with a

- 14-pin MIL-C-26482 Series I connector
- bandwidth of -3 dB points at 20 s and 108 Hz

Model TC120-PH2 A posthole seismometer in a submersible stainless steel enclosure that

- has a 16-pin marine-class connector
- is suitable to a depth of 300 m
- has a bandwidth of -3 dB points at 120 s and 108 Hz

Model TC20-PH2 A posthole seismometer in a submersible stainless steel enclosure that

- has a 16-pin marine-class connector
- is suitable to a depth of 300 m
- has a bandwidth of -3 dB points at 20 s and 108 Hz

1.2 Unpacking and Handling a Trillium Compact

The shipping box and packing for Trillium Compact seismometers have been designed and tested to protect these seismometers against the impact of accidental drops during hand-carrying and from vibration and shock during shipping. To maintain warranty protection, Trillium Compact seismometers must always be transported in packaging approved by Nanometrics. Save the original packaging and reuse it any time you are transporting a Trillium Compact. If custom packaging is required for a particular application, please consult Nanometrics (see Contacting Nanometrics on page 67).

After delivering a Trillium Compact to its installation site, you can safely remove it from the packaging or carrying case and handle it without any special precautions other than taking care not to drop it or bang it against hard surfaces. Trillium Compact seismometers do not require any mass lock mechanisms or mass centring. The seismometer is ready to operate right out of the box and can tolerate normal handling with no degradation in performance or service life.

1.3 Selecting a Site

There is no substitute for a geological survey when it comes to site selection. A survey provides knowledge of the structures over which the seismometer will be installed. Where possible, seismometers should be installed on bedrock and as far away as possible from sources of cultural noise such as roads, dwellings, and tall structures.

Use the worksheet in Section 1.6 "Site Record" on page 7 to record information about the structure, cultural environs, and climatic conditions of the site, as well as information about the type and length of the installation.

1.4 Cables and Accessories

Table 1-1 lists cables and accessories for the Trillium Compact that can be purchased separately.

Table 1-1 List of cables and accessories

Name	Part Number	Description
Models TC120-SV1, TC20-SV1 (surface vault)		
Trillium Compact Carrying Case / Insulating Cover	16862	Dual-purpose enclosure that serves as both a carrying case when transporting the Trillium Compact and as an insulating cover. As a carrying case, this enclosure provides cushioning protection during transport. When installed as an insulating cover, this enclosure thermally insulates the seismometer and protects it from external air currents. See Appendix A, "Carrying Case" for information and instructions on using this product to transport your Trillium Compact. See Chapter 3, "Performing a Surface Vault Installation" for instructions on using this product as an insulating cover in an installation.
Foam Plug for Trillium Compact Carrying Case / Insulating Cover	MEC16852R1	A foam plug specially designed for the carrying case. This plug prevents movement of the Trillium Compact and levelling cradle when a cable is not packed in the case.
Cable – Trillium seismometer to Nanometrics digitizer	16777–3M 16777–5M 16777–10M 16777–15M 16777–25M	Double-shielded, ultra-flexible cable with Trillium Compact right-angled connector on one end and Nanometrics digitizer connector on the other end. In addition to connecting the analog inputs, power, and control line signals to the digitizing and data logging features of the digitizer, this cable also provides access to the Web interface of the seismometer through the Web interface of the digitizer. Standard cable lengths are 3 m, 5 m, 10 m, 15 m, and 25 m. Custom cable lengths are available upon request.

Table 1-1 List of cables and accessories

Name	Part Number	Description
Cable – Trillium seismometer to open end	16865–3M 16865–5M 16865–10M 16865–15M 16865–25M	Double-shielded, ultra-flexible cable with Trillium Compact right-angled connector on one end and open-ended at the other end for attaching the connector of a third-party digitizer. In addition to connecting the analog inputs, power, and control line signals to the digitizing and data logging features of the digitizer, this cable also provides access to the Web interface of the seismometer through the Web interface of the digitizer. Standard cable lengths are 3 m, 5 m, 10 m, 15 m, and 25 m. Custom cable lengths are available upon request.
Cable – Trillium seismometer to third party digitizer	Contact Nanometrics	Double-shielded, ultra-flexible cable with Trillium Compact right-angled connector on one end and a connector for a common third party digitizer, such as a Q330 or REFTEK D130 on the other end. Contact Nanometrics (see Contacting Nanometrics on page 67) for a full listing of cables with connectors to third party digitizers.
Cable – Serial communications and power cable, molded	16978–2M	A cable that provides serial communications and power to the Trillium Compact. The cable has a Trillium Compact connector on one end and splits into two 2 m lengths. One end of the cable split has a DB-9 serial connector that connects to the serial port of a computer, and the other end has a two-prong banana plug for power. Standard cable length is 2 m. Custom cable lengths are available upon request.
Models TC120-PH2 and TC20-PH2 (posthole)		
Cable – Trillium Compact Posthole to Nanometrics Digitizer, Molded	17768-10M 17768-30M	A cable with a molded neoprene connector on one end that connects to the Trillium Compact Posthole connector and a connector on the other end for connecting to a Nanometrics digitizer. The cable features a robust neoprene cable jacket that is suitable for buried deployments. In addition to connecting the analog inputs, power, and control line signals to the digitizing and data logging features of the digitizer, this cable also provides access to the Web interface of the seismometer through the Web interface of the digitizer.
Cable – Trillium Compact Posthole to Open End, Molded	18005-5M 18005-10M 18005-30M 18005-70M	A cable with a molded neoprene connector on one end that connects to the Trillium Compact Posthole connector and is open-ended on the other end. In addition to connecting the analog inputs, power, and control line signals to the digitizing and data logging features of the digitizer, this cable also provides access to the Web interface of the seismometer through the Web interface of the digitizer.
Bubble Level	MSC0225	For applications where precise levelling is required, the bubble level is placed on top of the seismometer during installation.

Table 1-1 List of cables and accessories

Name	Part Number	Description
Adjustable Feet Kit	17245	A kit including three adjustable locking feet that should be used on model numbers TC120-PH2 and TC20-PH2 instead of the default fixed studs in a surface vault installation.
All models		
70 mm Spike Kit	17247	Spikes that attach to the base of the seismometer for installations in soft soil.
Levelling Cradle	16863	Tripod deployment cradle for rapid levelling. See Appendix B, "Levelling Cradle and Spike Kit" for information and instructions for using this product.
Levelling Cradle Spike Kit	16874	Kit containing three types of spikes that attach to the levelling cradle. Use the spikes to stabilize the cradle in soil, gravel, or sand. See Appendix B, "Levelling Cradle and Spike Kit" for information and instructions for using this product.

1.5 Technical Support and Maintenance

If you need technical support, please submit your request by email or fax. Include a full explanation of the problem and any supporting information (such as the maximum mass position reading, photographs of the site, operating input voltage and current) to help us direct your request to the most knowledgeable person for reply. Before returning a unit for repair, contact Nanometrics Technical Support (see Contacting Technical Support on page 67) to obtain an RMA number.

The mechanical and electronic elements of Trillium Compact have been designed to be robust and reliable. The internal reverse-voltage protection and over-current protection automatically resets when the fault is removed, so there are no fuses to replace.

1.5.1 Recording Your Serial Number and IP Address

Before installing your Trillium Compact, it is important to record both the serial number and the IP address of the unit. Both numbers are provided on the unit label.

Keep this information readily available. You will need to reference the serial number when contacting Technical Support. You will need the IP address of the unit to access the Web interface. See Chapter 6 "Configuring Serial Communications" for more information.

If the IP address of the unit is not recorded, it can be calculated later using the serial number. See Section 6.3 "Calculating the IP Address" on page 33 for instruction.

1.6 Site Record

Use the following table to record information about the site, including its structure, cultural environs, and climatic conditions. This information will be helpful in identifying changes to the site over time and for determining when mass recentring may be necessary due to temperature change.

Table 1-2 Record of installation site details

<table>
<tr><td rowspan="4">Site name (full name / station code / network code, for example, Yellowknife / YKN / CN):</td><td>Latitude:</td></tr>
<tr><td>Longitude:</td></tr>
<tr><td>Elevation:</td></tr>
<tr><td>Date of installation (mm/dd/yyyy):</td></tr>
<tr><td>Type of installation (for example, vault, surface, buried, other):
Vault installation:
__________ Depth below surface (m)
__________ Height above sea level (m)
Posthole installation:
__________ Depth of hole (m)
__________ Depth to bedrock (m)
__________ Height above sea level (m)
__________ Orientation in hole (±°)</td><td>Length of installation:
Permanent or temporary:

If temporary, expected time frame (mm/dd/yyyy to mm/dd/yyyy):</td></tr>
<tr><td>Ground surface type (for example, rock, soil, sand, clay, other):</td><td rowspan="2">Distance to potential noise sources (km):
__________ Airport or air traffic
__________ Railway
__________ Roads
__________ Tall structures ________ Height (m)
__________ Trees ________Height (m)
__________ Dwellings
__________ Industrial site
__________ Others (describe):</td></tr>
<tr><td>Seasonal temperature ranges (°C):
_______________ January 1 to March 31
_______________ April 1 to June 30
_______________ July 1 to September 30
_______________ October 1 to December 31</td></tr>
<tr><td colspan="2">Notes:</td></tr>
</table>

Chapter 2

Performing a Posthole Installation

The contents of this chapter are applicable to Trillium Compact, model numbers TC120-PH2 and TC20-PH2.

2.1 Installing a Trillium Compact Posthole

A Trillium Compact Posthole seismometer may be installed in an uncased or cased hole. Units will self-level as long as the Trillium Compact Posthole is within ±2.5° for the 120 s model or ±10° for the 20 s model of vertical, making site preparation simple.

Use the following steps to install a Trillium Compact Posthole in an uncased or cased hole:

1. Prepare the hole for the installation.
    - Uncased hole

      For an uncased hole, the hole should be a minimum of 1 m deep, and have a diameter large enough to accommodate the seismometer, which has a diameter of 97 mm. The minimum hole depth will allow the seismometer to be covered by approximately 0.9 m (3 ft.) of fill once the installation is complete. This backfill creates a buffer between the installation and the surface, shielding it from surface activity and weather. In general, greater depth produces better results with all other conditions being equal.
    - Cased hole

      For a cased hole, the hole diameter must be large enough to accommodate the seismometer, which has a diameter of 97 mm.

      A cased hole must be covered at the top to protect the seismometer from the elements such as wind and rain. This cover must secure and stabilize the electrical and lifting cables, allowing some slack to avoid strain on the seismometer.
2. Connect the cable to the seismometer and digitizer.

   Nanometrics cable 17768-nM (where *n* is the length of the cable in metres) can be used to connect a Trillium Compact Posthole to a Nanometrics digitizer. Alternatively, if you are connecting your Trillium Compact Posthole to a third-party digitizer, you can connect the digitizer's connector to Nanometrics cable 18005-nM (where *n* is the length of the cable in metres), or contact Nanometrics to inquire about the availability of a cable for a specific digitizer (see Contacting Nanometrics on page 67).

   See Chapter 5, "Configuring Your System" for information on configuring your Nanometrics digitizer for a Trillium Compact Posthole and also refer to the digitizer manual.

3. Lower the seismometer into the hole and align it.

   The recommended practices for aligning a Trillium Compact Posthole vary based on the depth of the hole where the unit is installed.

   (1) For recommendations on aligning a Trillium Compact Posthole in a shallow hole of 2 m or less, see 2.2.1 "Using a Surface Line" on page 9.

   (2) For recommendations on aligning a Trillium Compact Posthole in a deeper hole, see 2.2.2 "Using a Surface Seismometer" on page 10.

4. Level and stabilize the seismometer using an appropriate technique to ensure that the seismometer is solidly coupled to the surrounding substrate and will not shift or move.
5. Power the seismometer.
6. Verify a level installation by checking that the mass positions are within an acceptable range (at or very close to zero).
7. Close the hole using the appropriate method for the type of hole ensuring that the cable is not under any strain.
8. Check the mass positions to verify that the unit is undisturbed.

2.2 Aligning a Trillium Compact Posthole to North

There are two typical methods for aligning a Trillium Compact Posthole to north. The method used is usually determined by the depth of the hole where the unit is installed.

For shallow holes,

- Align the north-south guide on the top of the pressure vessel to a surface line. See Section 2.2.1 for details.

For deeper holes,

- Correlate the output of the seismometer with that of a temporarily installed surface-based seismometer that is aligned to true north in order to calculate their relative orientation. See Section 2.2.2 for details.

2.2.1 Using a Surface Line

The surface line method of aligning a Trillium Compact Posthole to north can only be used in shallow holes (usually 2 m or less) where the top of the seismometer pressure vessel is visible and the unit can be turned by hand after being lowered into the hole.

To align a Trillium Compact Posthole to north with a surface line

1. Place a ruler or stake a line across the hole, aligning it to true north.

   If you are using a magnetic compass, account for the local magnetic declination when making the line across the hole.

2. Turn the seismometer until the north-south guide on the top of the pressure vessel is parallel to the line at the top of the hole.

2.2.2 Using a Surface Seismometer

You can use a seismometer installed at the surface to determine the orientation of the horizontal (X and Y) components of the Trillium Compact Posthole once installed in the hole. This method involves comparing the recorded output of both seismometers and computing the relative direction of seismic wave motion to determine the relative azimuth of the down-hole Trillium Compact Posthole compared to the surface seismometer.

When you install the reference seismometer on the surface, ensure that you align it carefully in a known orientation. After both seismometers have been installed, leave the installations undisturbed for at least one hour while collecting data from both. When you are ready to perform your data analysis, ensure that your post-processing software is equipped to apply a rotation transformation, allowing it to measure and correct the relative azimuth.

One advantage of this method of alignment is that it allows you to verify the performance of the down-hole instrument: it should be quieter than the surface instrument.

Contact Nanometrics (see Contacting Nanometrics on page 67) for more information on using this method of alignment.

2.3 Troubleshooting Your Installation

It is normal to see spikes in the horizontal channels of a Trillium Compact as the seismometer settles after installation. However, if these spikes do not diminish after a few days, there may be a problem with the installation and the site should be visited to determine the cause of the spikes.

Table 2-1 lists common types of noise, including horizontal spikes, that may occur and reasons why the noise may be present.

Table 2-1 Types of noise and possible causes for posthole deployments

Noise Type	Possible Cause
Spikes on the horizontal channels	◆ There is unstable soil around the seismometer. ◆ There is a force pulling on the cable.
Continuous low frequency wander (random noise, larger on horizontal channels)	◆ The hole is not sealed and air drafts are causing temperature fluctuations.
Spikes on the vertical channel	◆ Usually due to electrical system noise. For example, power supply noise from a battery charging circuit, or interference from a strong magnetic or radio source that is nearby.
The mass positions are large, but slowly trending towards zero, and one or more of the main velocity outputs has an offset on the order of several volts.	◆ The Trillium Compact is powered and not level or was powered during levelling When a Trillium Compact is left powered while not level, it can take as long as a few hours for the unit to recover after levelling. More importantly, when in this state, the unit is unresponsive to ground motion. For short-term deployments or when immediate confirmation that the sensor is working properly is required, briefly setting the seismometer in short-period mode allows the unit to recover immediately and produce ground-motion recordings. For fast recovery after levelling do one of the following • Leave the sensor un-powered until after it is level • Power cycle the unit, which momentarily puts the unit in short-period mode during start up • Access the user interface, put the unit into short-period mode, and then immediately return it to long-period mode (see Section 7.3 “Seismometer Control” on page 35) • Use the control lines on the digitizer to briefly put the unit into short-period mode, and then return it to long-period mode

Chapter 3

Performing a Surface Vault Installation

The contents of this chapter are applicable to Trillium Compact, model numbers TC120-SV1 and TC20-SV1.

3.1 Planning Your Installation

Before deploying your seismometer, you should have an understanding of how you will install and insulate it. The installation must be designed to provide a stable base for the seismometer without any forces or disturbances acting on it.

Three common types of installations are described in Section 3.3 "Common Types of Installations" on page 13. These are vault installations (which usually involve the construction of a vault and pier, see Section 3.2 on page 12 for recommendation on pier construction), temporary installations on rock, and temporary installations where the seismometer is buried in sediment.

The installations described in Section 3.3 incorporate installation design guidelines that aim to reduce the possibility of installation-related noise. Horizontal spikes in the signal are indicative of installation-related issues, and it is normal to see horizontal spikes following installation. However, if the spikes do not diminish after a few days, there may be a problem with the installation. See Section 3.9 "Troubleshooting Your Installation" on page 24 for more information.

3.2 Recommendations for Pier Construction

If your installation involves the construction of a pier, use Table 3-1 as a guide to constructing it:

Table 3-1 Recommended pier design specifications

Material	Concrete. Homogeneous, 50% Portland cement and 50% sieved sand (see Section 3.2.1 "Choosing the Right Concrete" on page 13).
Size	Large enough to fit all required seismometers, cables, and insulation.
Thickness	Within the range of 2 in. to 4 in. on top of bedrock.
Surface	Smooth, level, and clear of debris.
Decoupling	Decouple the pier from the vault walls (see Section 3.2.2 "Decoupling the Pier and Vault Walls" on page 13).

3.2.1 Choosing the Right Concrete

The concrete used in a seismic pier should be as homogeneous as possible to avoid inducing tilts from differing thermal coefficients of expansion. To create a homogeneous concrete mixture do not use any aggregates and ensure the concrete is free of air bubbles. Steel reinforcement is not necessary as strength is not a concern in seismic piers.

The recommended concrete mixture is 50 percent Portland cement and 50 percent sieved sand.[1] After pouring the concrete, shake it to allow trapped bubbles to escape. Allow 24-hours for the concrete to harden before positioning the seismometer on the pier.

The pier may generate spurious signals as the concrete cures, which can take two to four weeks.

3.2.2 Decoupling the Pier and Vault Walls

When setting up the concrete forms for the pier, include a gap between the edge of the concrete and the walls of the vault. Decoupling the pier and the vault walls prevents the transfer of non-seismic forces, such as wind, from the vault walls to the pier. Such forces can cause the pier to tilt or twist and obscure the desired seismic signal. These signals are mostly long period, so vault wall decoupling is critical for quiet site long period studies.

3.3 Common Types of Installations

Two common types of installations for the standard Trillium Compact are long-term vault installations and temporary installations on rock. The following sections describe each of these installation options.

3.3.1 Vault Installations

Vault installations can be at or below the surface and usually include a pier that provides a level platform for the seismometer to sit on and good coupling to the ground (see Section 3.2 "Recommendations for Pier Construction" on page 12). Insulation of the pier, vault roof, and most importantly the seismometer, is required.

The pier must be insulated from air currents to prevent tilt noise caused by the thermal expansion or contraction of its surface. For a pier solidly connected to the ground (such as a poured cement pad on top of bedrock), a useful technique is to place a thick quilt over the surface of the pier. Cutting a hole out of the quilt allows it to drop over the insulating cover of the seismometer and cover the pier.

Thoroughly insulate the roof of the vault and any exposed sides. Seal the door and any other openings. Do not use a thermostat-controlled heating or cooling system in the vault because the temperature cycling will show up as periodic noise in the seismic signal.

Insulate the seismometer to protect it from drafts and temperature change. To achieve optimal insulation of the seismometer, the following optional equipment is recommended: a Carrying Case / Insulating Cover (Nanometrics part number 16862). In addition, if you are

1. Bob Uhrhammer and Bill Karavas, *Guidelines for Installing Broadband Seismic Instrumentation* (Berkeley: The Regents of the University of California, 1997), http://seismo.berkeley.edu/bdsn/instrumentation/guidelines.html.

installing model number TC120-PH2 or TC20-PH2 as a surface vault seismometer, you will also need the optional levelling bubble (Nanometrics part number MSC0225) and the adjustable levelling feet kit (Nanometrics part number 17245). See Table 1-1 "List of cables and accessories" on page 4 for a description of these items. See also Section 3.7.2 "Insulating with a Rigid Foam Box" on page 21 for another method of insulating the seismometer.

To perform this type of deployment,

1. Plug the cable into the seismometer.
2. Follow Section 3.5 "Best Practices for Alignment and Levelling" on page 17 to properly align and level the seismometer.
3. Place the insulating cover over the seismometer, fitting the cable exit slot over the cable. For more detailed instructions, see Section 3.8 "Installing a Trillium Compact in the Insulating Cover" on page 21.
4. Power the seismometer, and using a digitizer (see Chapter 5, "Configuring Your System") or the Trillium Compact Web interface (see Chapter 6, "Configuring Serial Communications" and Chapter 7, "Using the Web Interface"), verify a level installation by checking that the mass positions are within an acceptable range (at or very close to zero).

3.3.2 Temporary Installations on Rock

Installations on rock are at the surface level and the seismometer must be in a sealed, insulated enclosure to protect it from the elements or other environmental disturbances. To achieve optimal levelness and insulation, the following optional equipment is recommended: a levelling cradle (Nanometrics part number 16863) and a Carrying Case / Insulating Cover (Nanometrics part number 16862). In addition, if you are installing model number TC120-PH2 or TC20-PH2 as a surface vault seismometer, you will also need the optional levelling bubble (Nanometrics part number MSC0225). See Table 1-1 "List of cables and accessories" on page 4 for descriptions of these items. See also Section 3.5 "Best Practices for Alignment and Levelling" on page 17 and Section 3.7.2 "Insulating with a Rigid Foam Box" on page 21 for other methods of levelling and insulating the seismometer.

To perform this type of deployment,

1. Locate the flattest available surface for your installation.
2. Plug the cable into the seismometer and secure it to the side of the unit with a tie wrap.
3. Remove the feet from the seismometer and retain for future deployments.
4. Follow Section 3.5 "Best Practices for Alignment and Levelling" on page 17 and Section B.1 "Using the Levelling Cradle" on page 60 to properly align and level the seismometer in the levelling cradle.
5. Lay sand in a ring around the levelling cradle to create a flat and level sealing surface for the insulating cover.

6. Place the insulating cover over the seismometer, fitting the cable exit slot over the cable. See Section 3.8 “Installing a Trillium Compact in the Insulating Cover” on page 21.

> (1) If the fit around the seismometer is too tight, remove the inner layer of foam from the insulating cover. Retain the pieces of foam for future deployments and transport.
>
> (2) It may be necessary to place a weight on the insulating cover or to bury it to protect it from weather or other disturbances.

7. Power the seismometer, and using a digitizer (see Chapter 5, “Configuring Your System”) or the Trillium Compact Web interface (see Chapter 6, “Configuring Serial Communications” and Chapter 7, “Using the Web Interface”), verify a level installation by checking that the mass positions are within an acceptable range (at or very close to zero).

3.4 Alignment, Levelling, and Placement Features

To aid in the proper alignment of your seismometer, each Trillium Compact has:

- Vertically-scribed marks on the north-south axis.
- A north-south guide on the top of the case.

Chapter 11 “Physical Features and Dimensions” provides illustrations that show the relative orientation of the alignment features in top, bottom, and side views.

For levelling purposes, each Trillium Compact is equipped with:

- Three adjustable-height feet with lock nuts. A 2.5 mm hex screwdriver works well to tighten the lock nuts in place.

> For models TC120-PH2 and TC20-PH2, the adjustable locking feet kit (Nanometrics part number 17245) is optional.

- A levelling bubble on the cover.

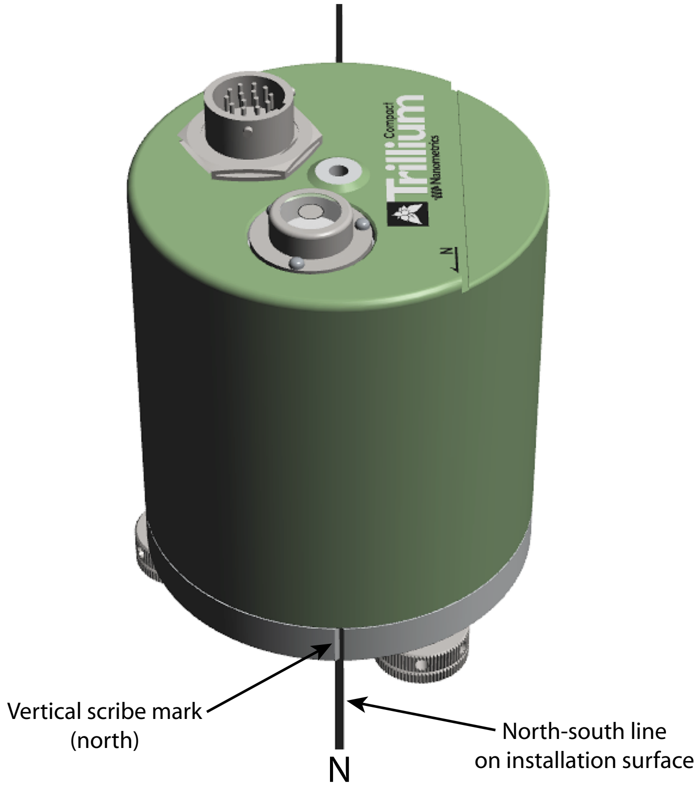
> For models TC120-PH2 and TC20-PH2, the bubble level (Nanometrics part number MSC0225) is optional.

Optional levelling tools for a Trillium Compact are:

- A levelling cradle for rapid levelling on prepared piers or for installation on hard uneven or unlevel surfaces.
- A spike kit for the levelling cradle that facilitates installations in sediment, soil, gravel, or sand.

Figure 3-1 shows the north scribe line on a Trillium Compact aligned with a line drawn on the installation surface that is parallel to north-south.

Figure 3-1 Example of seismometer alignment using vertically scribed marks



The seismometer in Figure 3-1 illustrates model numbers TC120-SV1 and TC20-SV1, but it is also applicable to model numbers TC120-PH2 and TC20-PH2 (stainless steel enclosure).

Figure 3-2 shows the case-top north-south guide with a dashed line indicating where a straight-edge, staked line, or laser level line would fall.

Figure 3-2 Example of seismometer alignment using the case-top guide

The seismometer in Figure 3-2 illustrates model numbers TC120-SV1 and TC20-SV1, but it is also applicable to model numbers TC120-PH2 and TC20-PH2 (stainless steel enclosure).

3.5 Best Practices for Alignment and Levelling

Following are best practices for aligning and levelling a Trillium Compact using the vertically scribed marks on the north-south axis or the north-south guide on the top of the case:

- Prepare the north-south guideline using one of the following methods:

  a) Using the north-south vertically scribed marks: Draw a line on the installation surface parallel to north-south.

  b) Using the case-top north-south guide: Stake a line (for example, using fishing line) parallel to north-south, directly over the location where you want to install the Trillium Compact.

  The north-south line must be aligned to true north. If you are using a magnetic compass, account for the local magnetic declination when drawing the line. For underground installations, you can transfer north measured at the surface to below ground by traversing with survey equipment.

- When you are ready to remove the Trillium Compact seismometer from the box, gently place it on the installation surface in an approximate north-south alignment.

If you are using the optional levelling cradle, you will not be levelling the seismometer using the levelling feet as described in the next bullet. Instead, see Section B.1 "Using the Levelling Cradle" on page 60, or if you are using the levelling cradle with its optional spike kit, see Section B.2 "Using the Levelling Cradle and Spike Kit" on page 61.

- Use the adjustable feet, as required, and the levelling bubble on the cover to level the seismometer. Centre the bubble as precisely as possible inside the black ring to ensure that the Z output is measuring true vertical motion. To level the Trillium Compact using the levelling feet:

  a) Extend the levelling feet as little as possible to achieve a level seismometer. Try to keep one of the feet fully retracted into the seismometer base for greatest stability.

  b) When the Trillium Compact is level, lock the feet by rotating each locking nut tightly against the seismometer base, while preventing the foot from turning. Insert an Allen key into one of the holes in the locking nut to act as a lever and help tighten the locking nut. A foot that is properly locked will not turn easily when touched.

- Precisely align the Trillium Compact to north-south by:

  a) Using the north-south vertically scribed marks: Align the vertical north-south scribe lines on the base of the seismometer (see Figure 3-1 "Example of seismometer alignment using vertically scribed marks" on page 16) with the line drawn on the installation surface.

  b) Using the north-south guide: Align the case-top north-south guide to the staked line, laser level line, or straight edge (see Figure 3-2 "Example of seismometer alignment using the case-top guide" on page 17).

  Care is required when aligning the seismometer to avoid sighting at an angle and introducing a parallax error.

- After aligning the seismometer, verify that it is still level. It may need to be adjusted due to unevenness of the installation surface.

- If you relevelled the Trillium Compact and you are levelling it with the adjustable feet, ensure the feet are locked when finished.

3.6 Theory and Practice of Insulation

Seismometer installations must be thermally insulated to achieve optimal performance, particularly at long periods. There are two broad categories of thermal effects that can cause unwanted noise:

a) Direct thermal sensitivity.

  The Trillium Compact is designed to minimize temperature sensitivity; however, like all seismometers, it has some residual thermal response. There are several components in a seismometer that are temperature sensitive, such as the springs that suspend the inertial masses. The effect of direct thermal sensitivity typically shows up as very long period noise on the vertical channel, in particular, a periodic diurnal variation in response to the day-to-night temperature cycle.

b) Thermally induced tilt.

All seismometers are susceptible to thermally induced tilt. Tilt converts the strong vertical acceleration of gravity into an apparent horizontal acceleration. There are many mechanisms for the conversion of temperature into tilt. For example:

- Movement of air surrounding the seismometer can cause non-uniform thermal expansion or contraction of the pier and the seismometer. Such effects typically have an apparent ground-motion spectrum that is peaked at long periods.
- Movement of anything touching the seismometer, including the digitizer cable and insulation materials, can cause forces to develop that change with temperature. Stick-slip effects typically transform these forces into sudden step changes in tilt. The apparent ground-motion power spectral density is, therefore, inversely proportional to the square of frequency.

For seismometers that are well temperature-compensated, such as the Trillium Compact, but are improperly installed, thermally induced tilt on the horizontal channels will be more significant than direct thermal sensitivity on the vertical channel. Furthermore, due to the natural convection of air, thermally induced tilt is even observable in sealed underground vaults where the temperature is very stable.

Therefore, the objectives of a good installation are to:

- Insulate the seismometer from temperature changes.
- Prevent the movement of air on the surface of the seismometer.
- Insulate the installation surface from temperature changes.
- Prevent the movement of air on the surface of the installation surface, including the sides and underside of surfaces (for instance, piers that consist of a slab raised above the vault floor).
- Prevent anything from touching and thereby applying a mechanical force to the seismometer.

To meet these objectives and achieve the best possible performance, observe the following practices:

- The vault (the space or room where the seismometer is installed) must provide a stable thermal environment. This environment is typically achieved through careful site selection and by installing the seismometer below ground.
- The digitizer cable must be flexible enough to bend without applying significant forces to the seismometer. Nanometrics provides ultra-flexible cables designed for this purpose (see Section 1.4 “Cables and Accessories” on page 4).
- The insulation surrounding the seismometer must:
  - Have low thermal conductivity to insulate the seismometer from temperature changes.
  - Form a nearly airtight seal against the pier to block drafts.
  - Fit closely around the seismometer, eliminating space that may cause convection inside the cover.
  - Not touch the seismometer or the cable. The insulation is subject to temperature expansion and can exert measurable forces on the seismometer.

3.7 Insulation Options

There are two options for insulating a Trillium Compact:

a) Use the Trillium Compact Carrying Case / Insulating Cover (Nanometrics part number 16862). See also Section 3.7.1 "Insulating with the Insulating Cover" on page 20. This is the recommended method.

b) Make a freestanding cover out of rigid foam insulation that is sealed against air drafts, does not touch the seismometer, and minimizes the volume of air trapped between the insulating box and the seismometer. See also Section 3.7.2 "Insulating with a Rigid Foam Box" on page 21.

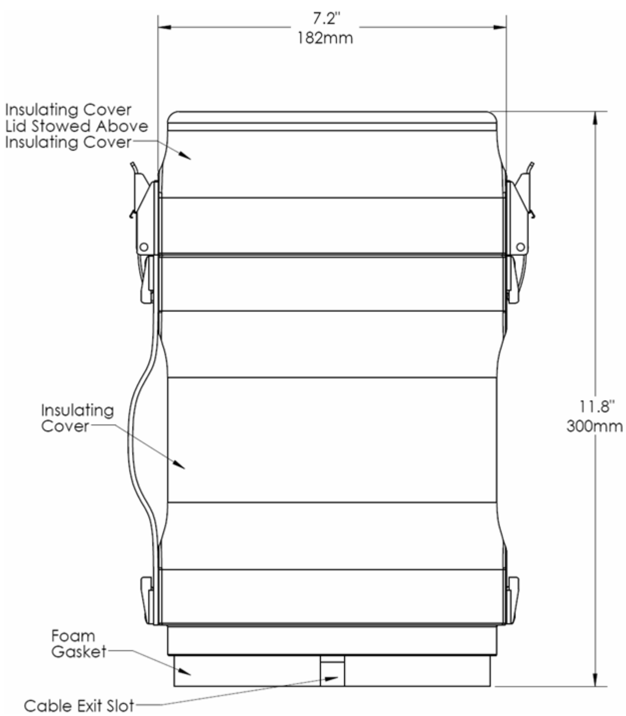
Before proceeding with the implementation of thermal insulation, there are many aspects you must consider in the context of the particular site and type of installation. Section 3.1 "Planning Your Installation" on page 12.

3.7.1 Insulating with the Insulating Cover

Nanometrics recommends insulating your Trillium Compact seismometer with its specially designed Carrying Case / Insulating Cover, which, when properly installed, will attenuate temperature-induced long-period noise.

Made of rigid plastic and lined with insulating foam, the insulating cover is a rugged, form-fitting cover that creates a close fit around a Trillium Compact without touching any part of the seismometer or the cable. When fitted over a Trillium Compact, the cover creates a small air gap between itself and the seismometer. This gap reduces the potential for noise by preventing the cover or other objects from exerting force on the seismometer; by minimizing the amount of air trapped under the cover, thereby eliminating convection; and by providing a cable channel that reduces heat conduction through the cable.

Figure 3-3 Trillium Compact insulating cover features and dimensions



3.7.2 Insulating with a Rigid Foam Box

If you are not using the recommended Trillium Compact Insulating Cover, insulate the seismometer with a rigid foam box. Use the following recommendations as a guide when constructing the box:

When installing a Trillium Compact in a rigid foam insulating box, follow the best practices for aligning and levelling the seismometer that are outlined in Section 3.5 "Best Practices for Alignment and Levelling" on page 17.

- Construct a five-sided box that is large enough to house the seismometer without touching the sides of the seismometer or the cable.

  Preferably, use rigid foam insulation with foil on one or both sides. There are two advantages to the foil-coated foam: it has a higher insulation resistance, and you can make the joints with aluminium tape, which is quicker and cleaner than glue.
- Use insulation that is at least 5 cm (2 in.) thick. Depending on the temperature stability of the site, additional or thicker boxes can be used.
- Cut a groove at the appropriate point in the bottom of the box to allow the seismometer cable to exit.
- Seal the box joints properly:
  - For rigid foam without a foil coating, glue the joints using polystyrene adhesive or polyurethane resin, taking care not to leave any gaps.
  - For rigid foam with a foil coating, tape the joints with aluminium tape, taking care not to leave any gaps.
- Ensure there is a good seal between the bottom edge of the box and the pier. Adhesive weatherstripping that is 1.25cm (0.5 in.) thick creates a good seal.
- Ensure the thermal insulation box is held firmly in place by setting a weight on top of it. A brick works well for this purpose.
- Strain relieve the cable to the installation surface, close to the seismometer. Tie-wraps with tie-wrap anchors or a heavy object are effective tools for achieving strain relief.

3.8 Installing a Trillium Compact in the Insulating Cover

The contents of this section are applicable to Trillium Compact, model numbers TC120-SV1, TC20-SV1.

Use the following steps to install a Trillium Compact in the Carrying Case / Insulating Cover for insulating purposes at the installation site:

1. Prepare a flat installation surface.
2. Secure the cable to the side of the seismometer with a tie wrap (see Figure 3-4 "Cut-away illustration of a Trillium Compact in the insulating cover" on page 23).
3. Use tape or a heavy object to strain relieve the cable on the installation surface.

4. Use your preferred method of aligning and levelling the seismometer (see Section 3.5 "Best Practices for Alignment and Levelling" on page 17).

> If you are burying the Trillium Compact and its insulating cover, pull all of the foam out of the cover. Retain these pieces of foam for future installations and transport. See Section 3.4 "Alignment, Levelling, and Placement Features" on page 15 for more information on buried installations.

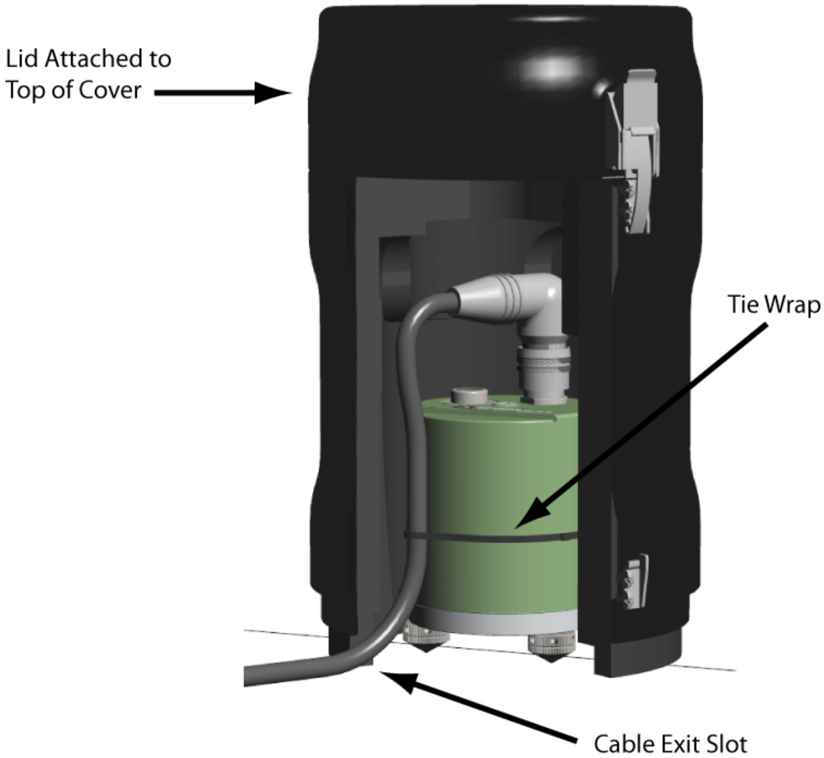
5. Optionally, place the lid on top of the insulating cover and secure it with the latches (see Figure 3-4 "Cut-away illustration of a Trillium Compact in the insulating cover" on page 23). If you choose not to attach the lid to the top of the cover, retain the lid for future deployments and transport.
6. Hold the insulating cover above the sensor, aligning the cable slot with the cable (see Figure 3-4 "Cut-away illustration of a Trillium Compact in the insulating cover" on page 23). Ensure that the insulating cover is centred on the centreline of the Trillium Compact
7. Gradually lower the insulating cover over the Trillium Compact, ensuring that the insulating cover does not touch the seismometer.

> Ensuring the cover does not touch the seismometer is important for keeping the seismometer level and aligned.

   If you are using the optional levelling cradle (see Section B.1 "Using the Levelling Cradle" on page 60), the inside of the foam will fit snugly with the legs of the levelling cradle.

8. Place a brick or other heavy object on top of the insulating cover to compress the foam gasket on the bottom of the insulating cover.

Figure 3-4 Cut-away illustration of a Trillium Compact in the insulating cover



The seismometer in Figure 3-4 illustrates model numbers TC120-SV1 and TC20-SV1.

3.9 Troubleshooting Your Installation

It is normal to see spikes in the horizontal channels of a Trillium Compact as the seismometer settles after installation. However, if these spikes do not diminish after a few days, there may be a problem with the installation and the site should be visited to determine the cause of the spikes.

Table 3-2 lists common types of noise, including horizontal spikes, that may occur and reasons why the noise may be present.

Table 3-2 Types of noise and possible causes for surface vault deployments

Noise Type	Possible Cause
Spikes on the horizontal channels	◆ The feet of the seismometer are not locked. ◆ There is a force pulling on the cable. ◆ There is something touching the sides of the seismometer.
Continuous low frequency wander (random noise, larger on horizontal channels)	◆ Insulation is missing or not well sealed, allowing drafts to blow over the seismometer. ◆ There are forces, such as wind, acting on the installation.
Spikes on the vertical channel	◆ Usually due to electrical system noise. For example, power supply noise from a battery charging circuit, or interference from a strong magnetic or radio source that is nearby.
The mass positions are large, but slowly trending towards zero, and one or more of the main velocity outputs has an offset on the order of several volts.	◆ The Trillium Compact is powered and not level When a Trillium Compact is left powered while not level, it can take as long as a few hours for the unit to recover after levelling. More importantly, when in this state, the unit is unresponsive to ground motion. For short-term deployments or when immediate confirmation that the sensor is working properly is required, briefly setting the seismometer in short-period mode allows the unit to recover immediately and produce ground-motion recordings. For fast recovery after levelling do one of the following • Leave the sensor un-powered until after it is level • Power cycle the unit, which momentarily puts the unit in short-period mode during start up • Access the user interface, put the unit into short-period mode, and then immediately return it to long-period mode (see Section 7.3 “Seismometer Control” on page 35) • Use the control lines on the digitizer to briefly put the unit into short-period mode, and then return it to long-period mode

Part 2

Operation

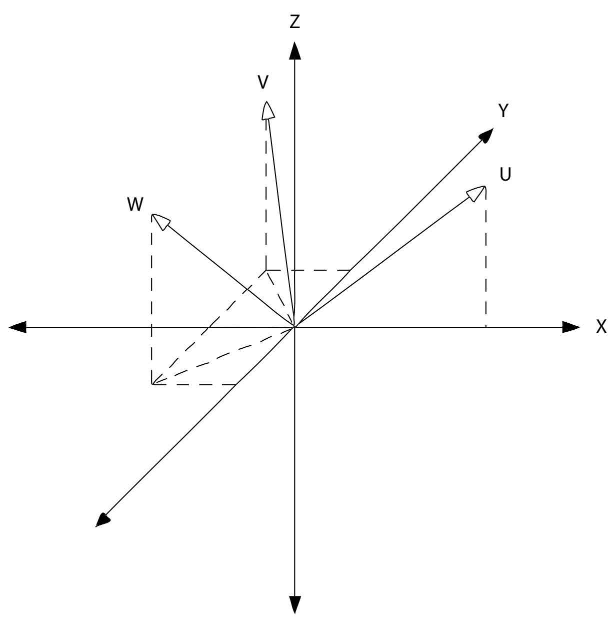
Chapter 4
Input and Output Signals

4.1 UVW and XYZ Output Signals

The Trillium Compact can be configured to output either XYZ or UVW signals. The "natural" output is UVW where the outputs represent the actual motion of the three sensor component masses. The "conventional" seismometer output is XYZ where the outputs represent horizontal and vertical motion.

To understand the difference between the UVW and XYZ outputs, see Figure 4-1. By design, the Trillium Compact axes are identical and sense motion in orthogonal directions. The U axis is aligned with the X axis when projected into the horizontal plane.

Figure 4-1 Trillium Compact axis orientation



This arrangement results in the following transformation equations:

$$\begin{bmatrix} u \\ v \\ w \end{bmatrix} = \frac{1}{\sqrt{6}} \cdot \begin{bmatrix} 2 & 0 & \sqrt{2} \\ -1 & \sqrt{3} & \sqrt{2} \\ -1 & -\sqrt{3} & \sqrt{2} \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad \text{(EQ 1)}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{\sqrt{6}} \cdot \begin{bmatrix} 2 & -1 & -1 \\ 0 & \sqrt{3} & -\sqrt{3} \\ \sqrt{2} & \sqrt{2} & \sqrt{2} \end{bmatrix} \cdot \begin{bmatrix} u \\ v \\ w \end{bmatrix} \quad \text{(EQ 2)}$$

The first equation is implemented mechanically in the Trillium Compact through the orientation of the individual axes. The second equation is implemented electronically when the Trillium Compact is in XYZ mode.

Alternatively, seismic data can be digitized with the Trillium Compact seismometer in UVW mode and the transformation to horizontal and vertical signals being implemented when the data are processed. For example, UVW mode is particularly useful for the calibration of the transfer function of individual axes.

To account for the source impedance, see Table 9-1 "Ground motion response nominal parameters for 120 s models" on page 44 and Table 9-2 "Ground motion response nominal parameters for 20 s models" on page 44.

4.2 Serial RS-232 Communications

The 9600 baud serial communications interface is provided on the Rx and Tx signals of the connector, where the DGND serves as the ground reference for the serial link.

A Trillium Compact automatically senses when valid serial communication on the Rx line is being received, and turns on the Tx line to transmit. The Rx and Tx signals share pins with the CTRL and UVW control inputs. Care must be taken to ensure that the UVW/TX line is not being simultaneously driven by the digitizer/data logger. When serial communications are occurring on the Rx and Tx lines, the control line signals CTRL (or SP/LP) and UVW that share these pins are not effective. For more details, see Section 4.3 "Digital Control Input Signals" on page 27, Section 10.1 "Pinout for 14-Pin Trillium Compact Connector" on page 48, and Section 10.2 "Pinout for 16-Pin Trillium Compact Connector" on page 49.

4.3 Digital Control Input Signals

A Trillium Compact has two digital control input signals: UVW and CTRL. UVW changes the output mode (which is XYZ by default) to UVW mode. By default, CTRL enables the calibration function. You can reconfigure the CTRL control line to activate short period mode (the default is long period mode) instead. The seismometer will respond to changes in the state of the control signal within 5 s.

(1) Long period mode is the normal mode for collecting seismic data. However, you may want to use short period mode when bench-testing the Trillium Compact, such as by tilting the seismometer to see the response of the mass position outputs. When in long period mode, the mass positions ramp very slowly and changes due to tilt may take several minutes. In short period mode the mass positions respond within a second, allowing you to watch the effects of tilting the seismometer.

(2) The UVW/TX input control signal is disabled when the seismometer is transmitting serial communications because this pin is used as the RS-232 serial Tx output signal. For more information on serial communication with a Trillium Compact, see Section 4.2 "Serial RS-232 Communications" on page 27 and Chapter 6 "Configuring Serial Communications."

Each input is optically isolated from the input voltage, the output signals, and the calibration input signals. Therefore, signals applied to these pins must be referenced to DGND rather than ±PWR or AGND.

All of the control input signals are active-high signals. See Table 10-1 "Pinout for 14-pin Trillium Compact connector" on page 48 and Table 10-2 "Pinout for 16-pin Trillium Compact connector" on page 49 for details. All inputs can tolerate at least ±15V except for UVW/TX which can tolerate voltages from –7 V to +15 V. The CTRL and UVW control lines are shared with the serial RS-232 port (see Section 4.4). It is recommended that you use +12 V to activate these control lines and high impedance for deactivation.

4.4 Calibration Input Signal

The Calibration Input Signal is provided to allow for relative calibration of the seismometer across frequency and over time.

Since the Trillium Compact is a symmetric triaxial seismometer, calibration is best performed on the individual axes (UVW) rather than the horizontal and vertical outputs (XYZ). Individual axis outputs can be digitized by placing the seismometer in UVW mode. For instruction on how to set a Trillium Compact to UVW mode, see Section 4.1 “UVW and XYZ Output Signals” on page 26.

4.5 State-of-Health Output Signal

The mass position output signal (MAXIMUM MASS POSITION) is provided to monitor the effect of tilt and temperature on the spring that sets the rest position of the boom. As with the calibration signal, this signal represents the state of the individual axes (UVW) rather than the horizontal and vertical outputs (XYZ).

This signal represents the axis with the highest absolute mass position and its operational range is ±4 V, with an optimal output of 0 V. A maximum mass position output signal greater than ±3.5 V indicates that the Trillium Compact is no longer sufficiently level and may not be providing useful seismic signals. Should this occur, visit the installation site as soon as possible to level the unit.

4.6 Power Consumption

Following are power consumption scenarios typical of Trillium Compact seismometers:

- Under normal operation (the unit is level, there is a low seismic signal, the unit has settled for at least 30 minutes, and the RS-232 serial port is not transmitting), power consumption for 120 s models is approximately 180mW and approximately 195 mW for 20 s models.
- On start-up, power consumption may briefly surge to 1 W.
- Once level and operating normally, any additional power consumption above normal quiescent is roughly proportional to the output signal and is largely independent of mass position, providing the seismometer does not shift and is no longer sufficiently level.
- For a settled and level unit, a seismic signal that approaches the maximum clip level of the seismometer may draw as much as a 0.8 W peak (the average power consumption would be much lower).

For long cables, account for the resistive voltage drop due to the cable length and, if necessary, increase the voltage at the source.

For example, 50 m of 24 AWG wire has a resistance of 4.2 Ω in each direction. Therefore the voltage drop due to the possible 100 mA startup inrush at 10 V would be 0.84 V. The supply should also be able to sustain a 1 W peak output at a voltage that guarantees the seismometer receives at least 9 V.

Chapter 5

Configuring Your System

5.1 Selecting the Trillium Compact Configuration for a Nanometrics Instrument

The method for selecting the default Trillium Compact configuration on a Nanometrics instrument varies by instrument. For instance, current generation Nanometrics instruments feature an on-board sensor library that contains the default configurations for all Nanometrics sensors; whereas, an instrument such as a version 2.x Taurus uses a configuration file that is uploaded to the instrument.

Table 5-1 provides a guide to the method for sensor selection on several Nanometrics instruments as well as basic instructions for sensor selection. Refer to the user guide for your instrument for full instructions on using it with a seismometer. Complete the sensor selection through the Web interface of the instrument, or if you are using a Taurus portable seismograph, you can also use the display screen on the unit.

Table 5-1 Configuring a Nanometrics instrument for a Trillium Compact

Instrument type	Sensor selection method	Instructions for selection
Centaur Taurus version 3.x and greater Cygnus 205	Sensor library	1. Log into the instrument. 2. Select **Default Trillium Compact** from the Sensor Library list. 3. **Apply** and **Commit**.
Taurus version 2.x	Configuration file	1. Contact Nanometrics to get the configuration file for the Trillium Compact. 2. Log into the Taurus. 3. Select **Advanced Configuration** from the **Status** menu. 4. Select **Browse** and navigate to the **Trillium Compact.cfg** file. 5. Select **Upload**. 6. When the upload is complete, **Apply** and **Commit**.

5.2 Using a Trident Digitizer with a Trillium Compact

Refer to the user guide for your Trident digitizer for complete instructions on using it with a seismometer. Nanometrics cable 17334-nM (where *n* is the length of the cable in metres) can be used to connect a Trillium Compact to a Trident digitizer. See Table 1-1 “List of cables and accessories” on page 4 for descriptions of these cables.

This section does not refer to Trident 305 digitizers. A Trident 305 is configured though the NMXbus-enabled device to which it is attached, such as a Taurus or Cygnus. Refer to the Trident 305 user guide and the user guide for the NMXbus device for configuration details.

Following are instructions for configuring your Trident and NaqsServer to work with a Trillium Compact seismometer.

1. Match the settings on the **Configuration** tab of Nanometrics UI to those in the following table.

Nanometrics UI Configuration Tab		Value	Notes
Section	**Setting**		
Front End	Input Range	40 Vpp	
Sensor Control	High Voltage Level	+5 V	
	Calibration Mode	Voltage (active high)	
	Line 1 Level	Low	Low is equivalent to XYZ mode and High is equivalent to UVW mode.
	Line 2 Level	Low	Set to High to enable calibration. The unit can also be configured to use this line to enable short-period mode. See Section 4.3 “Digital Control Input Signals” on page 27
	Line 3 Level	Not used	

2. Ensure the NaqsServer Naqs.stn file contains the following information:

```
[ Sensor ]                   // predefined sensor - all fields mandatory
TypeName = TrilliumCompact   // name of this prototype - may be same as model
Model = TrilliumCompact      // sensor model name
SensitivityUnits = M/S       // units of ground motion:  M, M/S or M/S**2
Sensitivity = 0.3e9          // counts per unit of ground motion
SensitivityFreq = 1.0        // frequency at which sensitivity is correct
CalibrationUnits = VOLTS     // calibration input units:  VOLTS or AMPS
CalCoilResistance = 133000   // calibration coil resistance in ohms
CalCoilConstant = 100        // calibration units per m/s/s
CalEnable = 2                // digital enable signal for calibration
CalRelay  = 0                // analog relay for calibration (0 = use channel number)
MassCenterEnable = -1        // digital enable signal for mass centering
MassCenterDuration = -1      // duration of mass centering signal (optional)
CalSource = Trident          // gives the source of the Cal signal
```

Note that the *CalCoilResistance* and *CalCoilConstant* parameters need to be adjusted according to the selected model of Trillium Compact. The computation of the nominal system sensitivity of your model is described in Section 5.3 “Increasing System Sensitivity” on page 31. The correct values for your model can be found in Section 9.1 “Frequency Response for 120 s and 20 s Models” on page 43. The *CalCoilConstant* in V/(m/s²) is simply the inverse of the calibration input sensitivity in (m/s²)/V.

5.3 Increasing System Sensitivity

If increased system sensitivity is required for either the Taurus or Trident, decrease the digitizer input range and increase the sensitivity. Use Table 5-2 as a guide.

Increasing the sensitivity of a digitizer by decreasing the input range below the 40 Vpp output range of the Trillium Compact can cause the digitizer to clip during the strong events.

Table 5-2 Increasing system sensitivity

Digitizer Input Range (Vpp)	Digitizer Software Gain	Digitizer Sensitivity (count /μV)	Sensor Sensitivity (V/(m/s))	System Sensitivity (Counts/(m/s))
40	1	0.4	750	0.3e9
16	1	1	750	0.75e9
8	1	2	750	1.5e9
4	1	4	750	3e9
2	1	8	750	6e9

Note that the exact nominal system sensitivity will vary depending on the normalization frequency (typically 1 Hz) and the lower corner period. The exact nominal sensor sensitivity for a particular model of Trillium Compact can be taken from the appropriate table in Section 9.1 “Frequency Response for 120 s and 20 s Models” on page 43.

Chapter 6

Configuring Serial Communications

6.1 About Serial Communications

The Trillium Compact has an integrated Web server that is accessible using a standard Web browser and the RS-232 serial interface. The sensor web page can be used to retrieve sensor information, access state-of-health information and control features, and configure the sensor.

The simplest way to connect to the sensor's web page is to use a Nanometrics digitizer, such as Centaur or Taurus (see Section 6.2 "Connecting through a Nanometrics Digitizer" on page 32). The web page is accessed through the Web interface of the digitizer (See Chapter 7, "Using the Web Interface"). The Web Interface is a series of Web pages that retrieve information about the seismometer, access state-of-health (SOH) information and control features, and configure the seismometer.

If you are not using a Nanometrics digitizer, connecting to a Trillium Compact requires an IP connection over a Serial port. Most modern PCs, laptops, and handheld devices do not include a physical serial port. In addition, currently supported Microsoft Windows operating systems do not support Serial Line Internet Protocol (SLIP) connections.

Nanometrics has developed a simple, low-cost appliance that converts ethernet to SLIP to allow IP communication with sensors from PCs or laptops. Alternatively, advanced Linux users can build their own SLIP appliance. For more information about the Nanometrics SLIP appliance, instructions on building your own SLIP appliance, and other methods of accessing your Nanometrics smart sensor web interface, refer to the Nanometrics technical note *Accessing Your Nanometrics Smart Sensor Web Interface*, or go to support.nanometrics.ca.

6.2 Connecting through a Nanometrics Digitizer

Current generation Nanometrics digitizers support the Web interface of the Trillium Compact, allowing you to access the Web-based features of the seismometer through the Web interfaces of those instruments. This integration will allow you to access the unit remotely, without requiring a serial cable and a SLIP connection on a co-located computer.

See the documentation for your Nanometrics digitizer for details on how to access the Trillium Compact Web interface through these instruments. See Section 7.1 "About the Web Interface" on page 34 for descriptions of each page.

6.3 Calculating the IP Address

You will need the IP address if you are not using a Nanometrics digitizer to access thesensor's Web interface (see Chapter 7, "Using the Web Interface"). The IP address was provided with the unit. If you cannot locate the IP address, you can calculate it using the method described below.

The IP address of the Trillium Compact is 2.23.x.y, where x and y are calculated from the serial number of the unit. To calculate the values for x and y in the serial number

$x = \text{SerialNumber} / 256$

Use the resulting whole number for the value of x and discard any decimal amounts.

$y = \text{SerialNumber}\ \textit{modulo}\ 256$

The reference to *modulo* 256 in the equation for y means that it is the remainder after 256 is divided into the serial number.

Given that the IP address of a Trillium Compact is 2.23.x.y, and assuming a serial number of 800, you can use the above equations to determine that:

- x = 800 / 256, which results in a value of 3.125. Only the whole number is required, leaving x equal to 3.
- y = 800 *modulo* 256, which results in a value of 32.

Therefore, having solved for x and y, the IP address of a Trillium Compact with a serial number of 800 is 2.23.3.32.

Chapter 7

Using the Web Interface

7.1 About the Web Interface

The Trillium Compact has an integrated Web server that is available using a standard Web browser and the RS-232 serial interface (see Chapter 6 “Configuring Serial Communications”). This interface is provided through either the serial connector or the main connector. Use the Web interface to retrieve information about the unit, access state-of-health information and control features, and to configure the unit.

Ensure that the proxy server is disabled when using a Web browser with a Trillium Compact.

The home page of the Trillium Compact presents links to other pages. The following sections describe these pages:

- Section 7.2 “State-of-Health”
- Section 7.3 “Seismometer Control”
- Section 7.4 “Control Lines”
- Section 7.5 “Sensor Response”
- Section 7.6 “Hardware Information”
- Section 7.7 “Firmware”

The simplest way to access the sensor’s Web Interface is to use a Nanometrics digital recorder. See Section 6.2 “Connecting through a Nanometrics Digitizer” on page 32.

If you’re not using a Nanometrics digital recorder, you will need to acquire a Nanometrics appliance that converts ethernet to Serial Line Internet Protocol (SLIP) or build your own SLIP device. For more information, see Section 6.1 “About Serial Communications” on page 32.

Use this interface to retrieve information about the seismometer, access state-of-health information and control features, and configure the seismometer. Access the Trillium Compact Web interface through the Web interface of the Taurus or Centaur digital recorder, or by connecting the optional cable 16978-2M, where 2M is the length of the cable in metres, to an RS-232 port on a computer.

The serial port should not be accessed when the highest quality seismic signal is desired as serial port traffic may cause low levels of noise on the analog output signals of the Trillium Compact.

7.2 State-of-Health

The SOH page provides information that indicates the health and status of the unit. Click the **Refresh** button to update the page with the current information.

The sections on the page are as follows:

- Mass Positions (Range ±4.000)

  The mass position values for the U, V, and W axes. These values range from 0 V (perfectly centred) to approximately ±4 V (when decentred and not able to respond to ground motion). The mass position output on pin R of the connector is an analog voltage that corresponds to the axis that is decentred the most. For example, if the U, V, and W mass positions are +0.230 V, -2.200 V, and +1.024 V respectively, then the analog mass position output would be approximately -2.200 V.

  For mass position readings under ±2.5 V, the table cell is green, for readings from ±2.5 V to ±3.5 V, the cell is yellow, and for readings above ±3.5 V, the cell is red.

- Temperature

  The approximate unit temperature in degrees Celsius and Fahrenheit.

- Case tilt

  Displays the tilt of the case from vertical in degrees.

The case tilt feature applies to all Trillium Compact models with serial numbers 2500 and above.

7.3 Seismometer Control

The Seismometer Control page allows you to enable or disable calibration, change the XYZ/UVW output mode, and change the long/short period mode. Click **Apply** to save your settings. These settings will reset to the factory default settings when the firmware is rebooted or the unit is power cycled.

(1) Once a control is set on this page, the corresponding digital control line is subsequently ignored. Selecting the **Use control line** option tells the Trillium Compact to again obey the control line for that function.

(2) Settings on this page are always reset to factory defaults on powered up or reboot.

The sections on the page are as follows:

- Calibration Enable

  Calibration can be enabled for the three U, V, and W axes simultaneously, for a specific axis, or disabled for all axes. Select **Use control line** to permit the control line input to enable or disable calibration. The default setting is **Use control line**.

- Output Mode

  Choose the output mode of XYZ or UVW (see Section 4.1 "UVW and XYZ Output Signals" on page 26 for a definition of these modes). Select **Use control line** to permit the control line input to select between XYZ and UVW modes. The default setting is **Use control line**.

- Long or Short Period Mode

  The lower corner of the seismometer response can be changed from the normal operating mode of 120 s period to a "short period" response of approximately 1 s period. This may be useful when levelling the seismometer, allowing you to see the mass positions quickly respond to changes in tilt, or once the seismometer is levelled, to allow the mass positions to quickly settle. Be sure to leave the seismometer in "120 second" (long period) mode when recording seismic signals. The default setting is **Use control line**.

7.4 Control Lines

Use the **Control Lines** page to reconfigure the function of the CTRL/RX pin on the Trillium Compact connector (referred to as Connector PIN D on the Web page). When set to a positive voltage level (default), the CTRL/RX pin enables calibration. Alternatively, set this pin to activate the short period response of the seismometer.

Click **Apply** to save your settings. This setting is retained when the Trillium Compact is powered off or rebooted.

7.5 Sensor Response

The **Sensor Response** link displays a page for viewing (or exporting to a text file) the factory stored nominal frequency response data for this model and version of the Trillium Compact. Users can also import, view, and export a text file of user-created information, such as seismometer response data created by calibrating the seismometer. The maximum file size that can be imported is 2559 bytes.

7.6 Hardware Information

The **Hardware Information** link displays a page that lists detailed factory information, such as the unit model, serial number, and subcomponent versions and serial numbers. This information can be exported to a text file (.txt) for record keeping or for transmitting to Nanometrics for technical support purposes.

7.7 Firmware

Firmware Version 2.x.x is not compatible with older version hardware. Do not attempt to upgrade to Version 2.x.x if the serial number of your unit is 2499 or less.

To upgrade your firmware from Version 2.x.x, use the following procedure.

1. Copy the firmware file *nmx_trillium_compact_land-2.x.x.nbf* provided by Nanometrics to a location on your PC.
2. From a browser on this PC, access the Trillium Compact web interface.
3. Click the **Firmware** link on the **Home** page.

4. Verify the current firmware Version is shown as 2.x.x.

If the Version is 1.x.x, you cannot upgrade the firmware using this instruction. Please contact Nanometrics.

5. Browse to the firmware file that you copied to your PC in step 1.
6. Click **Upload** to begin the firmware upgrade. Once the firmware upgrade is complete a message indicates that the unit must be rebooted or power cycled for the new firmware to become active.
7. Restart the unit using one of the following methods:
   - Click the **Back** button and click **Reboot** on the previous page to reboot the seismometer.
   - Manually power-cycle the unit.
8. Confirm that the version has been updated by verifying the version at the bottom of the **Home** page after rebooting.

Part 3

Reference

Chapter 8
Specifications

8.1 Technology

Table 8-1 Technology specifications

Topology	Symmetric triaxial
Feedback	Force balance with capacitive transducer
Mass Centring	Not required

8.2 Performance

Table 8-2 Performance specifications

Self-noise	
120 s models	See Figure 9-2 "Self-noise for 120 s models" on page 46
20 s models	See Figure 9-3 "Self-noise for 20 s models" on page 47
Sensitivity	
120 s models	754.3 $V \cdot s/m$ nominal ± 0.5% precision
20 s models	753.1 $V \cdot s/m$ nominal ± 0.5% precision
Off-axis sensitivity	±0.5%
Bandwidth	
120 s models	–3 dB points at 120.2 s and 108 Hz
20 s models	–3 dB points at 20.04 s and 108 Hz
Transfer function	Lower corner poles within ±0.5% of nominal provided High frequency response within 1 dB of nominal up to 45 Hz No peak in response at high frequency See Figure 9-1 "Bode plot for 120 s and 20 s models" on page 43
Clip level	26 mm/s from 0.1 Hz to 10 Hz
Tilt	
120 s models	Dynamic and operational tilt range of ±2.5°
20 s models	Dynamic and operational tilt range of ±10°
Parasitic resonances	None below 200 Hz

8.3 Hardware Interface

Table 8-3 Hardware interface specifications

Connector	
14-pin connector Model numbers TC120-SV1,TC20-SV1 (surface vault)	14-pin Shell size 12 MIL-C-26482 Series I Mounted in top of case
16-pin connector Model numbers TC120-PH2 and TC20-PH2 (posthole)	16-pin Submersible SubConn MCBH16MSS Mounted in top of case
Velocity output	40 Vpp differential Selectable XYZ (east, north, vertical) or UVW mode
Mass position output	Single voltage output representing maximum mass position Three channel mass positions available through serial port
Calibration input	Single voltage input and one active-high control signal to enable all three channels Remote calibration in XYZ or UVW mode Independent channel selection by serial port

8.4 Digital Command and Control Interface

Table 8-4 Digital command and control Interface specifications

Digital interface	RS-232 compatible serial-over-IP (SLIP) Onboard web server standard HTTP
Commands	XYZ/UVW mode switching Calibration channel selection (off, enable all, U, V, or W) Short period/long period mode switching Firmware updates State-of-health request Upload user calibration data
Data outputs	Independent mass position values Instrument temperature Factory sensitivity and sensor response data User calibration data (poles and zeros) Instrument serial number and firmware revision

8.5 Power

Table 8-5 Power specifications

Supply voltage	9 V to 36 V DC isolated inputs
Power consumption	See Section 4.6 "Power Consumption" on page 28 for typical power consumption scenarios
Protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection

8.6 Physical

Table 8-6 Physical specifications for models TC120-SV1 and TC20-SV1

Diameter	90 mm
Height	113 mm – body and connector 128 mm – with levelling feet fully retracted 135 mm – with levelling feet fully extended
Weight	1.2 kg
Housing	Powder coated aluminum surface resistant to corrosion, scratches, and chips
Levelling	Integrated bubble level Adjustable locking feet Optional tripod deployment cradle for rapid levelling
Alignment	Vertical scribe marks for north-south Case-top north-south guide for straight-edge, line, or laser level
Weather resistance	Rated to IP67 for outdoor use, dust, and immersion resistance

Table 8-7 Physical specifications for models TC120-PH2 and TC20-PH2

Diameter	97 mm
Height	160 mm – body and connector 167 mm – on fixed studs 230 mm – on optional 70 mm spikes
Weight	3.3 kg
Housing	Stainless steel surface resistant to corrosion, scratches, and chips
Levelling	Optional bubble level Optional tripod deployment cradle for rapid levelling
Alignment	Vertical scribe marks for north-south Case-top north-south guide for straight-edge, line, or laser level
Weather resistance	Rated to IP68 for full submersion

8.7 Environmental

Table 8-8 Environmental specifications

Operating temperature	–40°C to 60°C
Storage temperature	–65°C to 75°C
Shock	100 *g* half sine, 5 ms without damage, 6 axes No mass lock required for transport
Magnetic	Insensitive to natural variations of the earth's magnetic field

Chapter 9

Transfer Function and Noise Floor

9.1 Frequency Response for 120 s and 20 s Models

Figure 9-1 is a bode plot that shows the nominal frequency response for Trillium Compact, 120 s and 20 s models. This applies for ground motion and also for calibration response, since in Trillium Compact the calibration circuit does not significantly change the frequency response. As illustrated in Figure 9-1, the amplitude response to calibration input signals is nearly identical to that for ground motion. The phase response is slightly different at higher frequencies.

Figure 9-1 Bode plot for 120 s and 20 s models

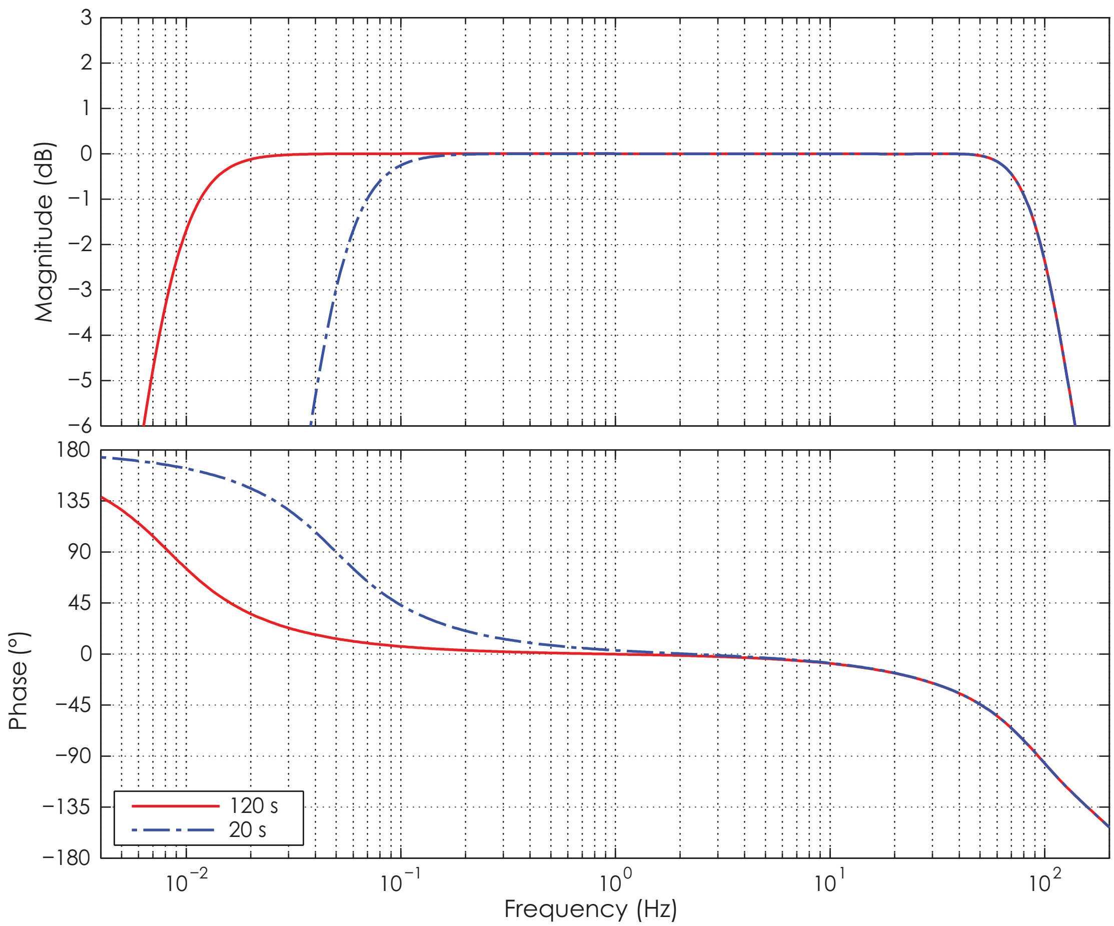


Table 9-1 provides the ground motion response nominal parameters for 120 s models. Table 9-2 provides the ground motion response nominal parameters for 20 s models.

The ground motion sensitivity at f_0 assumes an infinite input impedance at the digitizer. For digitizers with low input impedance, it will become necessary to account for the fact that source impedance of the differential outputs is 300 Ω, ±1 percent (150 Ω for each output).

Table 9-1 Ground motion response nominal parameters for 120 s models

Symbol	Parameter	Nominal Values	Units
z_n	Zeros	0 0 -392 -1960 -1490 ±1740i	rad/s
p_n	Poles	–0.03691 ±0.03702i –343 -370 ±467i -836 ±1522i -4900 ±4700i -6900 -15000	rad/s
k	Normalization factor	4.34493 x 10^{17}	$(\text{rad/s})^5$
f_0	Normalization frequency	1	Hz
S	Ground motion sensitivity at f_0	754.3	V·s/m

Table 9-2 Ground motion response nominal parameters for 20 s models

Symbol	Parameter	Nominal Values	Units
z_n	Zeros	0 0 –392 -1960 -1490 ±1740i	rad/s
p_n	Poles	–0.2214 ±0.2221i -343 -370 ±467i -836 ±1522i -4900 ±4700i -6900 -15000	rad/s
k	Normalization factor	4.34491 x 10^{17}	$(\text{rad/s})^5$
f_0	Normalization frequency	1	Hz
S	Ground motion sensitivity at f_0	753.1	V·s/m

The seismometer sensitivity (S), poles (p_n), and zeros (z_n) define the transfer function according to this equation:

$$F(s) = S \cdot k \cdot \frac{\prod_n (s - z_n)}{\prod_n (s - p_n)} \qquad \text{(EQ 1)}$$

Where the normalization factor (k) is defined by

$$k = \left| \frac{\prod_n (i2\pi f_0 - p_n)}{\prod_n (i2\pi f_0 - z_n)} \right| \qquad \text{(EQ 2)}$$

and is given for informational purposes only.

The calibration sensitivity is not trimmed with the same accuracy as the ground motion sensitivity. The calibration input can be used to verify the frequency response but not the absolute sensitivity. The calibration input sensitivity, combined calibration sensitivity, and input resistance of the available models of Trillium Compact are listed in Table 9-3.

Table 9-3 Calibration circuit parameters for 120 s and 20 s models

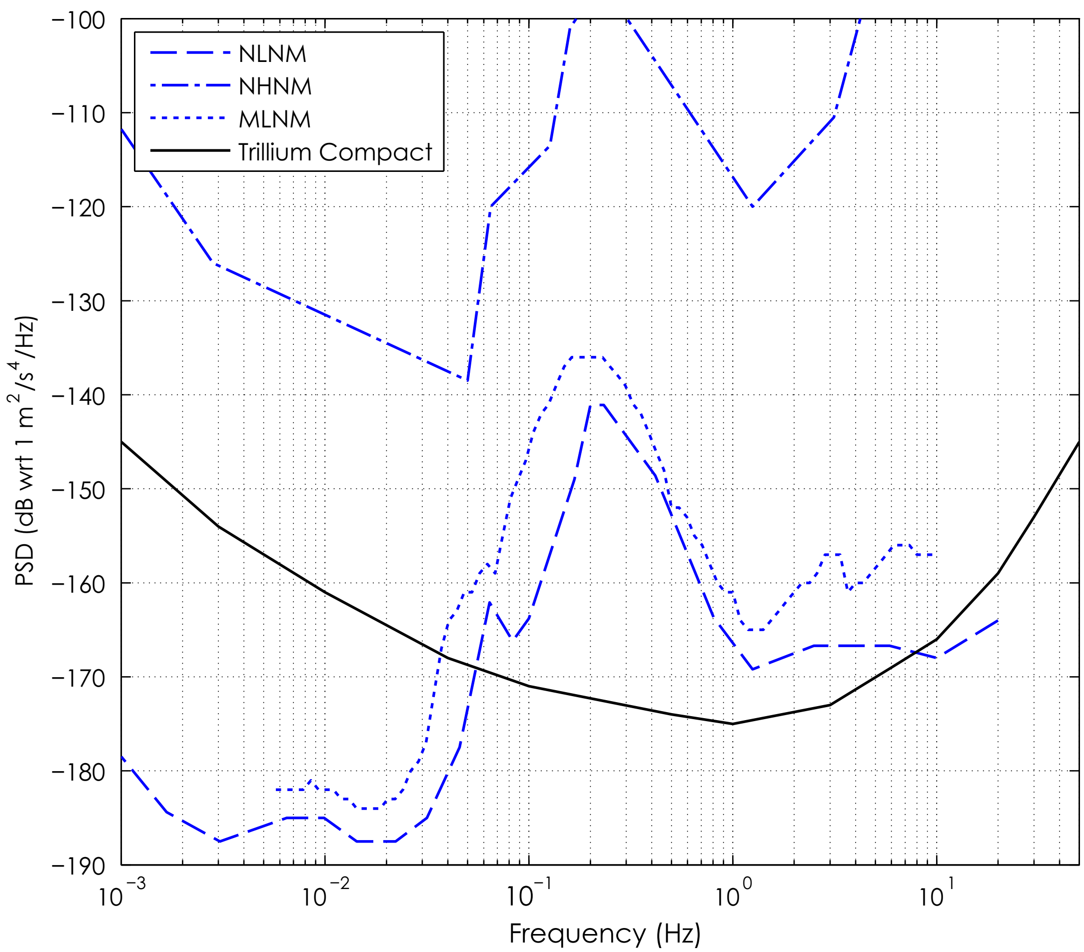
Model	Calibration input sensitivity at 1 Hz	Combined calibration sensitivity at 1 Hz	Calibration input resistance
120 s	-0.011 m/(s^2·V) ±7%	-8.3 rad/s ±7%	120 kΩ
20 s	-0.010 m/(s^2·V) ±7%	-7.5 rad/s ±7%	133 kΩ

The units of the combined calibration response are rad/s because the calibration input produces an equivalent acceleration, while the sensor passband is flat to velocity. Therefore for a sinusoidal calibration you must divide the sensitivity listed by 2 π f, where *f* is the frequency of the sinusoid, to determine the expected gain at that frequency.

9.2 Self-Noise for 120 s Models

Figure 9-2 plots typical self-noise for Trillium Compact seismometers. Three curves are included for reference: Peterson's new low-noise model (NLNM) and new high-noise model (NHNM), and McNamara and Buland's probability density function (PDF) mode low noise model (MLNM).[1] The noise floor shown is the typical level of instrument self-noise assuming proper installation. To achieve best performance for any seismometer, meticulous attention to detail must be paid to choice of site; vault design, if applicable; and seismometer installation. See Section 1.3 "Selecting a Site" on page 4.

Figure 9-2 Self-noise for 120 s models

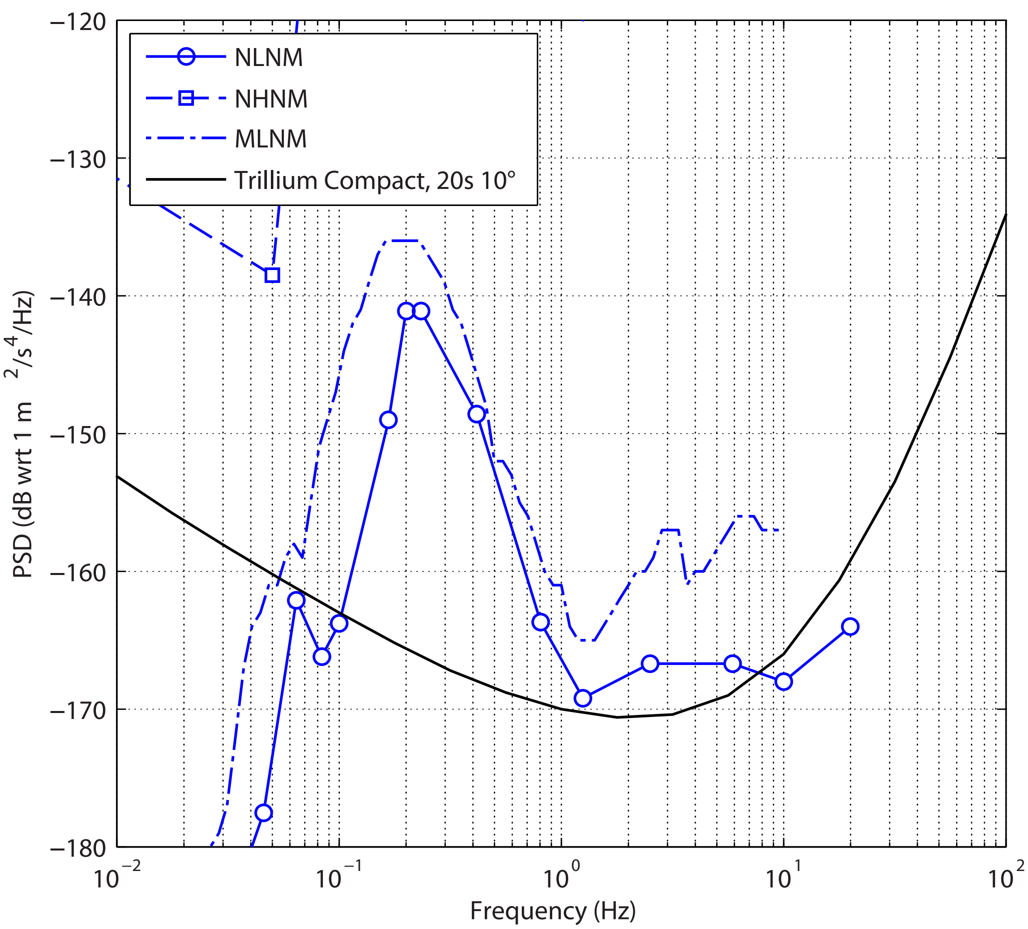


1. See also:
Jon Peterson, *Observations and Modeling of Seismic Background Noise, Open-File Report* 93-922 (Albuquerque, New Mexico: U.S. Department of Interior Geological Survey, 1993).
Daniel E. McNamara and Raymond P. Buland, "Ambient Noise Levels in the Continental United States," *Bulletin of the Seismological Society of America* 94, 4 (August 2004): 1517–1527.
John F. Clinton and Thomas H. Heaton, "Potential Advantages of a Strong-motion Velocity Meter over a Strong-motion Accelerometer," Seismological Research Letters 73, 3 (May/June 2002): 332–342.

9.3 Self-Noise for 20 s Models

Figure 9-3 plots typical self-noise for Trillium Compact seismometers. Three curves are included for reference: Peterson's new low-noise model (NLNM) and new high-noise model (NHNM), and McNamara and Buland's probability density function (PDF) mode low noise model (MLNM). The noise floor shown is the typical level of instrument self-noise assuming proper installation. To achieve best performance for any seismometer, meticulous attention to detail must be paid to choice of site; vault design, if applicable; and seismometer installation. See Section 1.3 "Selecting a Site" on page 4.

Figure 9-3 Self-noise for 20 s models



Chapter 10
Connector and Cables

10.1 Pinout for 14-Pin Trillium Compact Connector

Trillium Compact model numbers TC120-SV1, TC20-SV1 (surface vault) are equipped with a 14-pin male military circular type hermetic connector. Table 10-1 provides the connector pinout.

Table 10-1 Pinout for 14-pin Trillium Compact connector

Pin	Name	Function	Type
B	X+/U+	X axis output (east)	40 Vpp differential
C	X-/U-		
F	Y+/V+	Y axis output (north)	
H	Y-/V-		
L	Z+/W+	Z axis output (vertical)	
M	Z-/W-		
K	CAL_SIG	Calibration signal input	See Table 9-3 “Calibration circuit parameters for 120 s and 20 s models” on page 45
R	MAXIMUM MASS POSITION	Mass position of the axis with the highest absolute mass position	-4 V to +4 V analog
D	CTRL/RX	◆ Calibration enable, Short Period/Long Period mode* -OR- ◆ Serial RS-232 receive input * See Section 4.3 “Digital Control Input Signals” on page 27 and Section 7.3 “Seismometer Control” on page 35 for pin configuration and functionality.	◆ Digital: Active-high 12 V to 15 V (low is equal to open or 0 V) ◆ Serial receive: +5 V/0 V to +15 V/-15 V
J	UVW/TX	◆ Input: Enable UVW outputs instead of XYZ factory default ◆ Output: Serial RS-232 transmit	◆ Digital: Active-high 5 V to 15 V (low is equal to open or 0 V) ◆ Serial transmit: ±3.7 V
E	AGND	Analog ground	N/A
P	+PWR	Power input	9 V to 36 V DC isolated
N	-PWR	Power return	
A	DGND	Digital ground	N/A
shell	CHASSIS	For shielding and safety	N/A

10.2 Pinout for 16-Pin Trillium Compact Connector

Trillium Compact model numbers TC120-PH2 and TC20-PH2 (posthole seismometers) are equipped with a 16-pin male neoprene molded waterproof connector. Table 10-2 provides the connector pinout.

Table 10-2 Pinout for 16-pin Trillium Compact connector

Pin	Name	Function	Type
5	X+/U+	X axis output (east)	40 Vpp differential
6	X-/U-		
7	Y+/V+	Y axis output (north)	
12	Y-/V-		
9	Z+/W+	Z axis output (vertical)	
10	Z-/W-		
8	CAL_SIG	Calibration signal input	◆ See Table 9-3 “Calibration circuit parameters for 120 s and 20 s models” on page 45
14	MAXIMUM MASS POSITION	Mass position of the axis with the highest absolute mass position	-4 V to +4 V analog
3	CTRL/RX	◆ Calibration enable, Short Period/Long Period mode* -OR- ◆ Serial RS-232 receive input * See Section 4.3 “Digital Control Input Signals” on page 27 and Section 7.3 “Seismometer Control” on page 35 for pin configuration and functionality.	◆ Digital: Active-high 12 V to 15 V (low is equal to open or 0 V) ◆ Serial receive: +5 V/0 V to +15 V/-15 V
4	UVW/TX	◆ Input: Enable UVW outputs instead of XYZ factory default ◆ Output: Serial RS-232 transmit	◆ Digital: Active-high 5 V to 15 V (low is equal to open or 0 V) ◆ Serial transmit: ±3.7 V
11	AGND	Analog ground	N/A
1	+PWR	Power input	9 V to 36 V DC isolated
2	-PWR	Power return	
15	DGND	Digital ground	N/A
13	CHASSIS	For shielding and safety	N/A

10.3 Cable Design Guidelines

If you are designing your own cable, use the following cable design guidelines:

- Include effective EMI shielding in the cable design.

Double-shielded twisted-pair cable is a good choice for EMI shielding as the twisted pairs provide magnetic shielding, an inner shield grounded at the digitizer provides good electric field shielding, and a continuous outer shield provides good high RF shielding.

- Use the DGND for the return currents of the control signals. These are CTRL/RX and UVW/TX.
- Use the AGND for the return currents of the analog signals. These are CAL_SIG and MAXIMUM MASS POSITION.
- Ensure that the cable capacitance does not exceed 10 nF. For Nanometrics cables, this corresponds to 25 m.
- Ensure the cable length is sufficient to allow for strain relief.
- Ensure that the peak current requirement of the Trillium Compact does not result in a voltage drop along the cable which takes the power supply voltage below the minimum required at the Trillium Compact. See Table 8-5 "Power specifications" on page 41.
- Ensure the cable is watertight.
- Check the cable electrically after assembly. In particular, ensure that the individual and overall shields are not shorted together unless so specified.
- Make sure cables are labelled with correct drawing numbers and revisions.
- Make sure the digitizer is configured so that the default states of the control lines put the Trillium Compact in the desired state.

Chapter 11
Physical Features and Dimensions

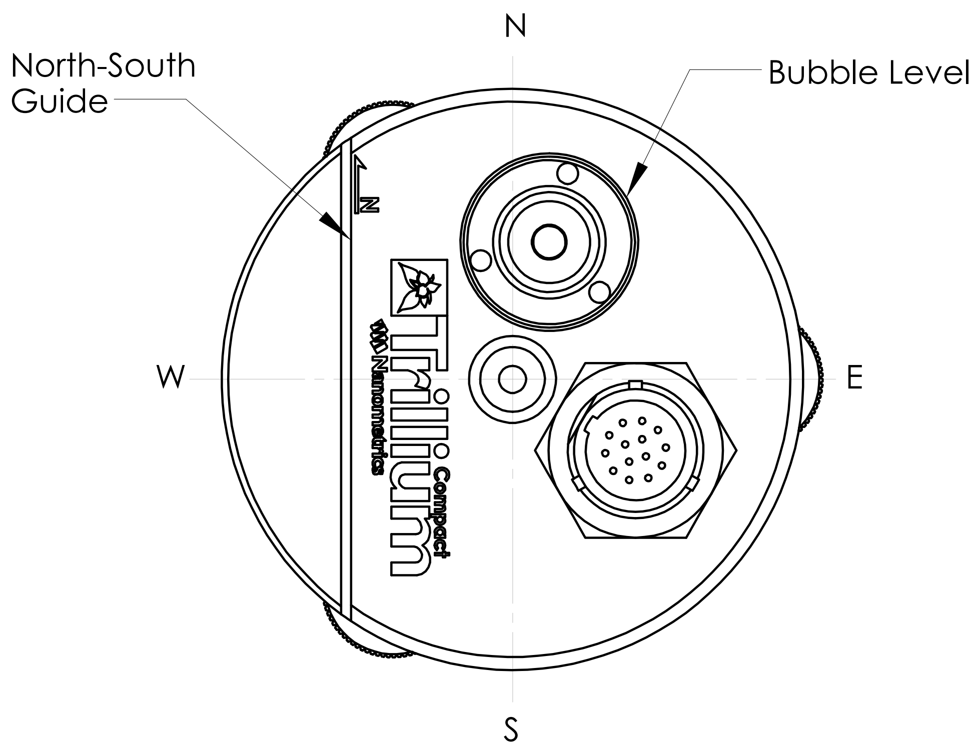
11.1 Top Views

The figures in the following sections are illustrations that show the relative orientation of the north-south alignment features on the various Trillium Compact models.

All dimensions are in millimetres unless otherwise stated.

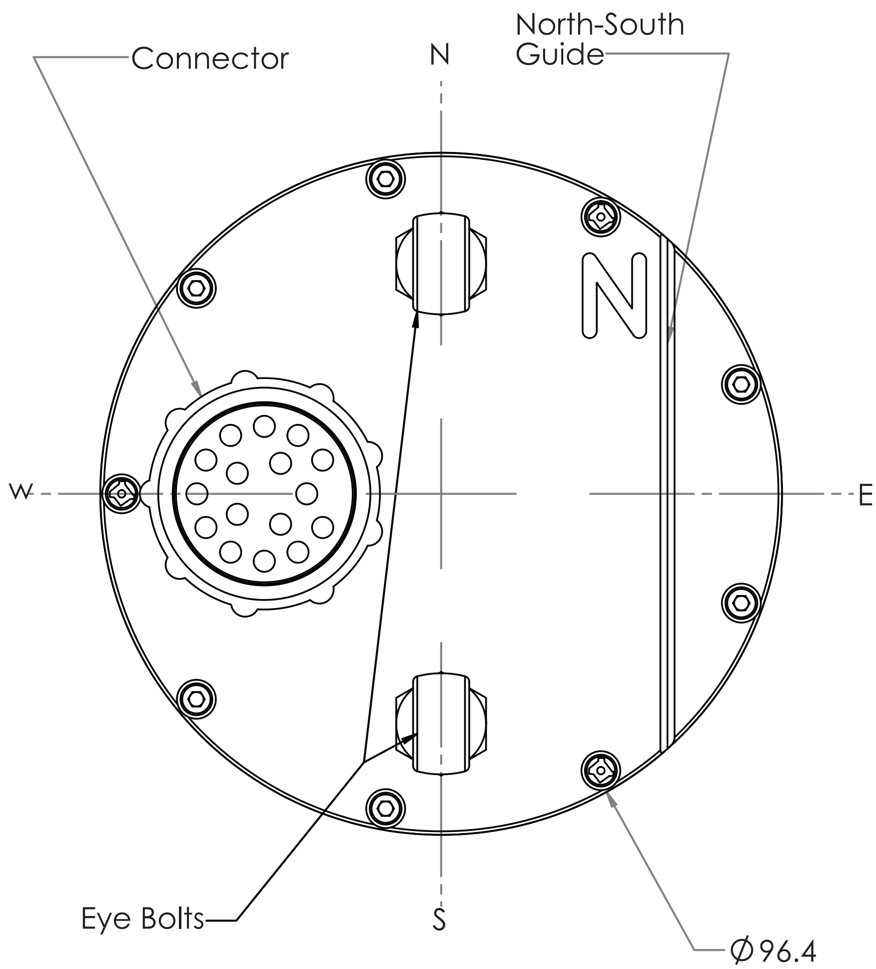
11.1.1 Top View of Models TC120-SV1 and TC20-SV1

Figure 11-1 Top view of models TC120-SV1 and TC20-SV1



11.1.2 Top View of Models TC120-PH2 and TC20-PH2

Figure 11-2 Top view of models TC120-PH2 and TC20-PH2



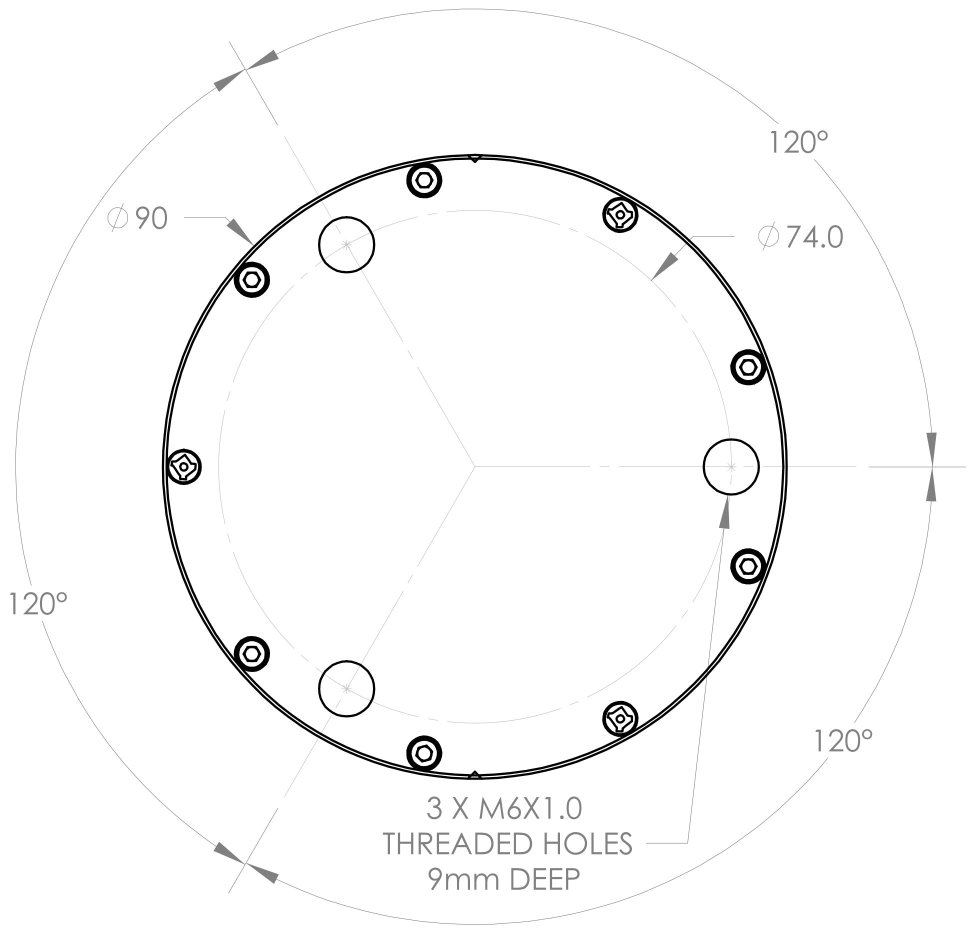
11.2 Bottom Views

The figures in the following sections are illustrations that show the features located on the bottom of the various models of the Trillium Compact.

(1) All dimensions are in millimetres unless otherwise stated.
(2) The feet are removed from the seismometer in all bottom views.

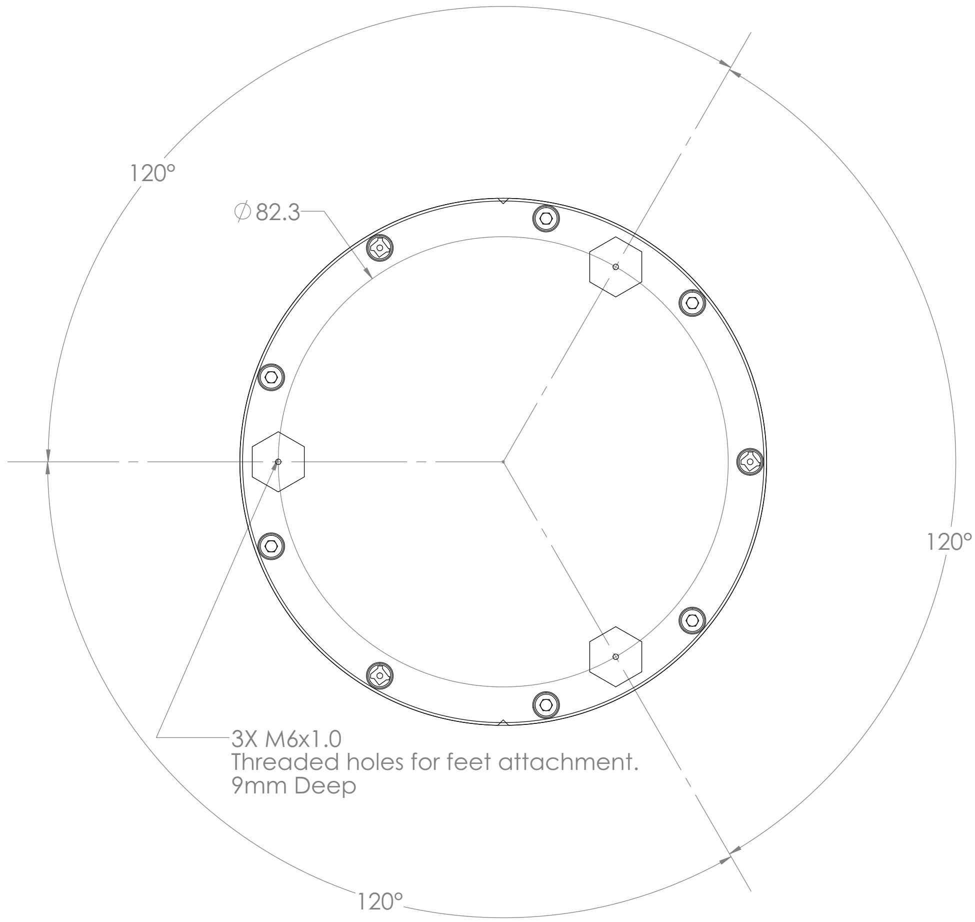
11.2.1 Bottom View of Models TC120-SV1 and TC20-SV1

Figure 11-3 Bottom view of models TC120-SV1 and TC20-SV1



11.2.2 Bottom View of Models TC120-PH2, TC20-PH2

Figure 11-4 Bottom view of models TC120-PH2, TC20-PH2



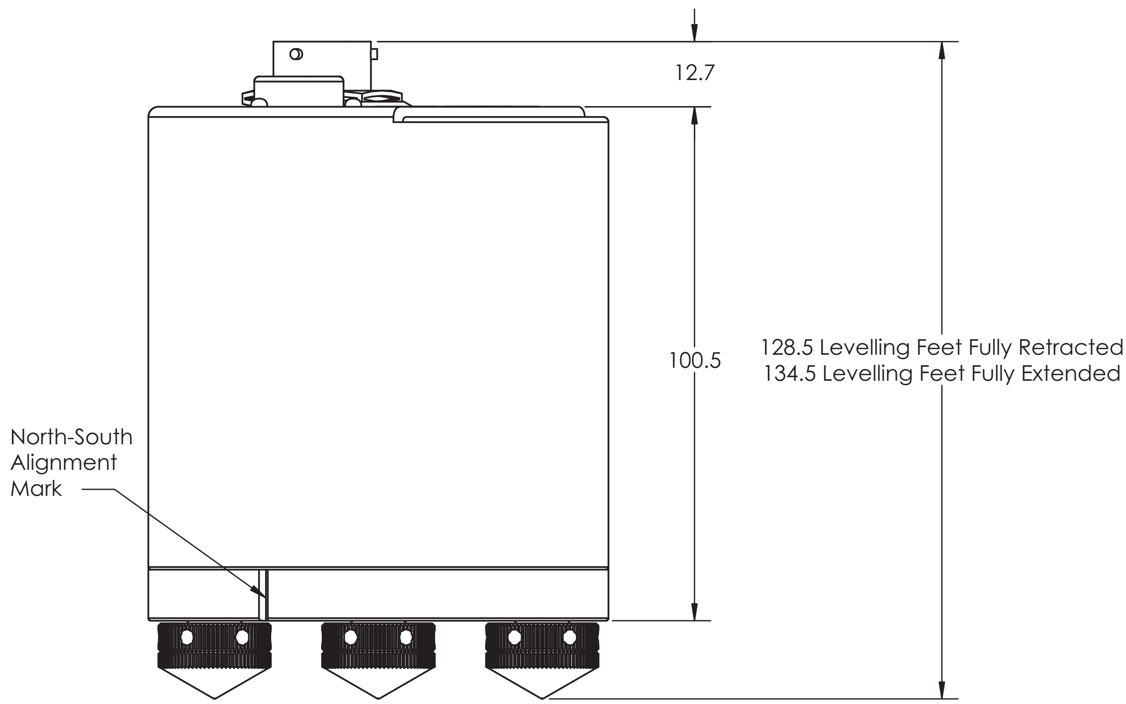
11.3 Side Views

The figures in the following sections are illustrations that show the alignment features and dimensions of the various models of the Trillium Compact.

All dimensions are in millimetres unless otherwise stated.

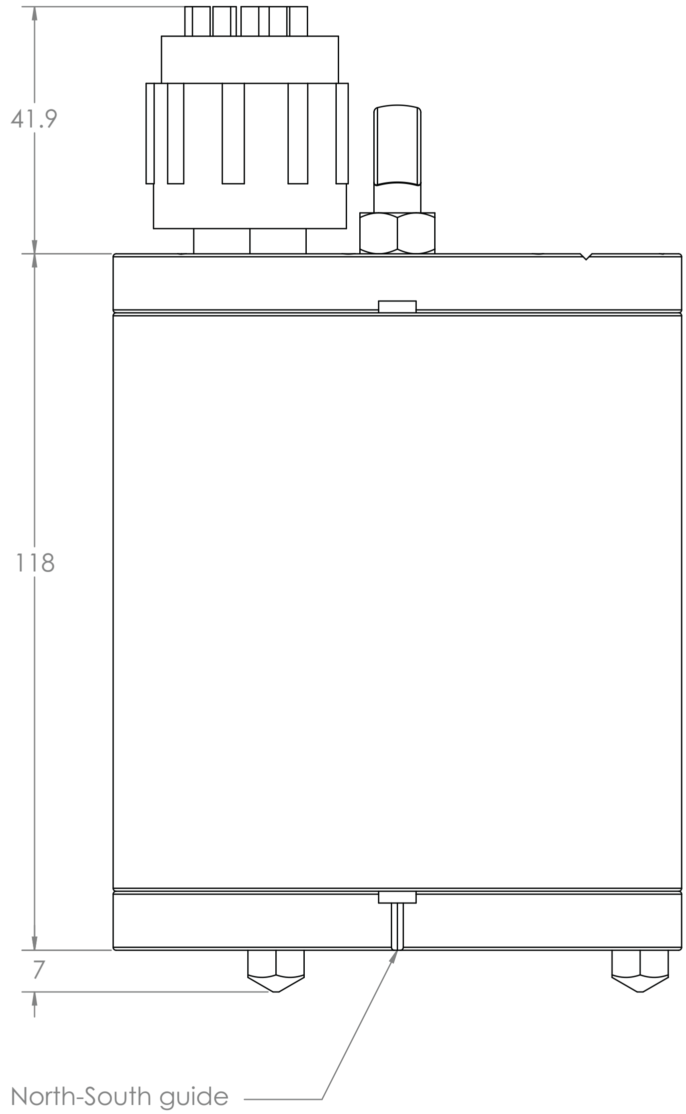
11.3.1 Side View of Models TC120-SV1 and TC20-SV1

Figure 11-5 Side view of models TC120-SV1 and TC20-SV1



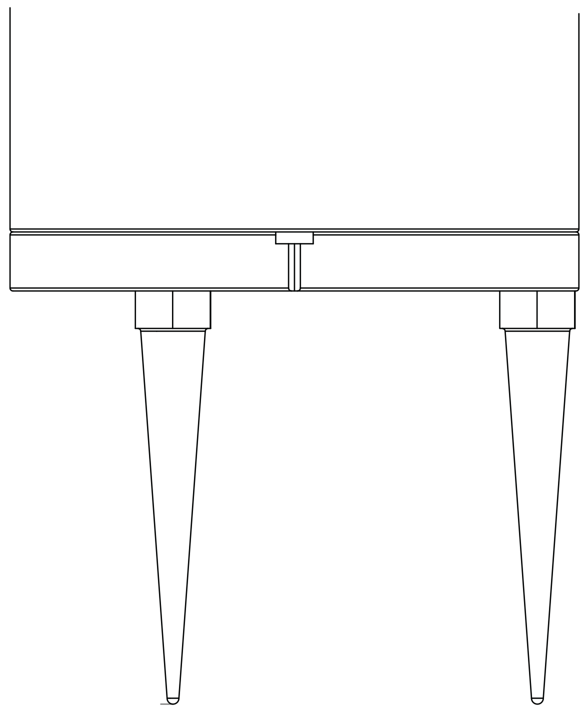
11.3.2 Side View of Models TC120-PH2 and TC20-PH2

Figure 11-6 Side view of models TC120-PH2 and TC20-PH2



11.4 Side View of Optional 70 mm Spikes

Figure 11-7 Side view of optional 70 mm spikes (posthole models only)



Appendix A
Carrying Case

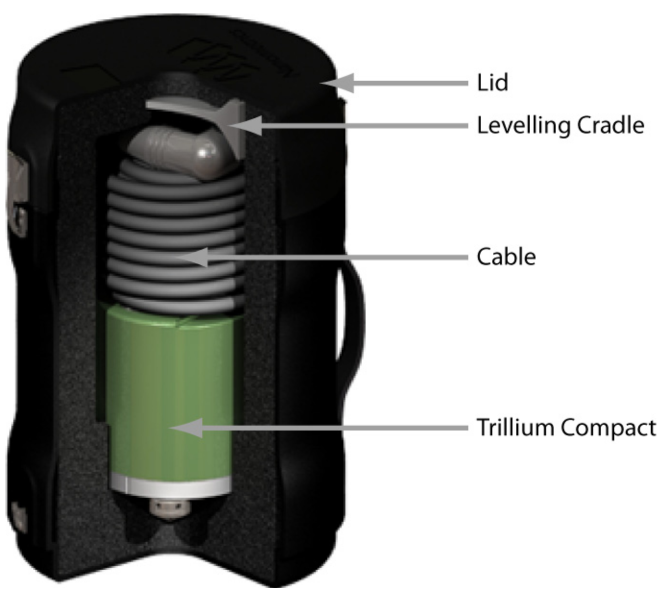
The contents of this appendix are applicable to Trillium Compact, model numbers TC120-SV1, TC20-SV1 (surface vault).

A.1 Transporting a Trillium Compact in the Carrying Case

The recommended method for transporting your Trillium Compact is in its specially designed Carrying Case / Insulating Cover (Nanometrics part number 16862). This enclosure functions as both a carrying case for transporting your Trillium Compact and as an insulating cover at the installation site.

When used as a carrying case (see Figure A-1 "Cut-away illustration of a packed carrying case" on page 58), this enclosure can house the seismometer, a 5 m ultra-flexible cable (Nanometrics part numbers 16777-5M or 16865-5M) or a foam plug (Nanometrics part number MEC16852R1), and a levelling cradle (Nanometrics part number 16863). The case provides cushioning protection and makes transport of the Trillium Compact and its accessories easy with its compact design and handle.

Figure A-1 Cut-away illustration of a packed carrying case



The seismometer in Figure A-1 illustrates model numbers TC120-SV1 and TC20-SV1.

To properly pack your carrying case:

1. Lower the Trillium Compact feet first into the case.
2. Tightly coil the cable (the case will fit up to a 5 m cable) and lower it into the case so that it is resting on top of the Trillium Compact.

   -OR-

   If you are not packing a cable in the case, insert the foam plug or other cushioning material that will prevent movement of the Trillium Compact and levelling cradle during transport.
3. Firmly fit the feet of the levelling cradle into the corresponding slits in the foam of the lid.
4. Place the lid on the case and secure it with the latches.

Appendix B
Levelling Cradle and Spike Kit

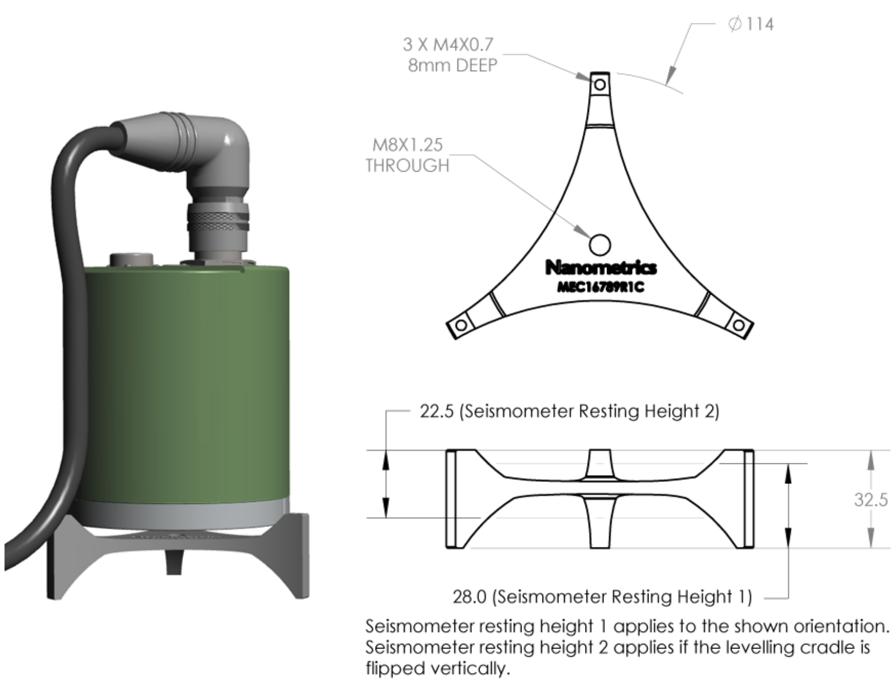
Although images in this chapter show the surface vault Trillium Compact, the contents of this chapter are applicable to all models of the Trillium Compact featured in this user guide.

B.1 Using the Levelling Cradle

The optional Trillium Compact levelling cradle (Nanometrics part number 16863) allows you to accurately level your seismometer in seconds on installation surfaces that are as much as ±9° outside of level. The two-sided cradle provides bowls of two depths. The shallow bowl corrects an uneven surface by up to ±5° and the deep bowl corrects by up to ±9°.

The Trillium Compact rests on three slanted supports that create a bowl shape. Using the levelling bubble on the top of the case, simply adjust the seismometer on the supports until the bubble is in the centre of the black ring. When using the cradle on its own (without the spike kit described in Section B.2 on page 61) use the shallow bowl of the cradle to hold the Trillium Compact. The supports on the deep side of the cradle are designed to act as feet when the spike kit is not in use.

Figure B-1 Levelling cradle features and dimensions



(1) All dimensions in Figure B-1 are in millimetres unless otherwise stated.

(2) Remove the three feet from the seismometer before placing it in the levelling cradle. Retain the feet for future installations.

B.2 Using the Levelling Cradle and Spike Kit

The shallow side of the cradle (see Figure B-1) provides threaded holes for connecting the spikes included with the optional levelling cradle spike kit (Nanometrics part number 16874). The combined levelling cradle and spike kit allows you to achieve a secure, stable, and level installation on unprepared surfaces such as sediment, soil, sand, or gravel.

The levelling cradle spike kit includes three types of spikes, each of which is meant for a different type of installation surface:

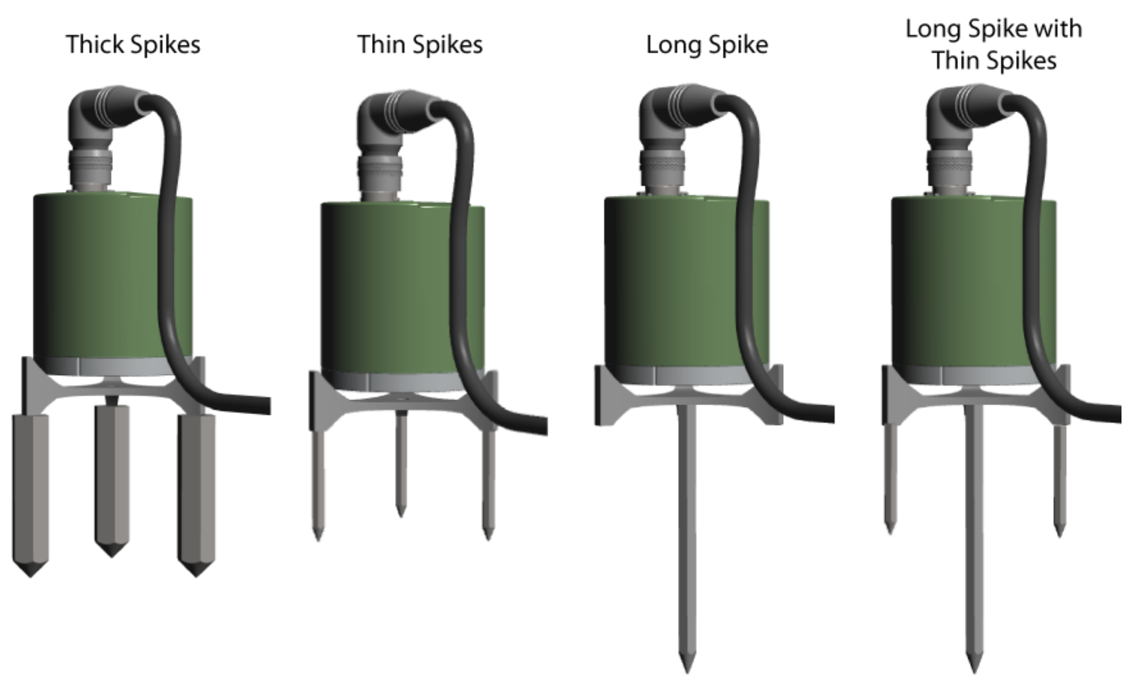
a) Thick spikes: Three spikes for use in sand; dry, loose soil; or snow.

b) Thin spikes: Three spikes for use in dense, wet soil or clay.

c) Long spike: One spike for use in rocky or frozen soil or ice. If more support is required, you can use the three thin spikes with the long spike.

Figure B-2 shows four views of a Trillium Compact mounted on a levelling cradle with the various spike configurations.

Figure B-2 Levelling cradle and spike kit assembly configurations



To use the spike kit:

1. Select the appropriate spikes or spike for the installation surface and thread these tightly into the appropriate threaded holes on the shallow side of the levelling cradle:
   - For sand; dry, loose soil; or snow, thread the three thick spikes into the threaded holes in the feet of the cradle.
   - For dense wet soil or clay, thread the three thin spikes into the threaded holes in the feet of the cradle.
   - For rocky or frozen soil or ice, thread the single long spike into the threaded hole in the centre of the cradle. If more support is needed, also thread the three thin spikes into the feet of the cradle.

2. Push the spikes into the earth, firmly securing the assembly and making it as level as possible.
3. Place the Trillium Compact on the cradle, aligning it to your alignment line (see Section 3.5 “Best Practices for Alignment and Levelling” on page 17).
4. Level the Trillium Compact by adjusting it on the cradle until the levelling bubble is centred in the black ring.
5. Test the stability of the cradle by gently pressing down on a corner of the levelling cradle. It should remain stable and the levelling bubble should not move.

Appendix C
Free Software Information

Trillium Compact software is distributed with free software that is protected by other licenses. A list of this free software and their respective licensing information is available on the Nanometrics Web site: http://www.nanometrics.ca/products/licences

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Appendix D
Glossary

D.1 Glossary of Abbreviations and Terms

A

AGND

Analog Ground

AWG

American Wire Gauge

C

CHGND

Chassis Ground

D

DGND

Digital Ground

E

EMI

Electromagnetic Interference

G

GPS

Global Positioning System

M

MLNM

Mode Low Noise Model

N

NHNM

New High-Noise Model

NLNM

New Low-Noise Model

P

PDF

Probability Density Function

PWR

Power

R

RF

Radio Frequency

RMA

Return Merchandise Authorization

S

SLIP

Serial-Over-IP

T

TCP/IP

Transmission Control Protocol/Internet Protocol

D.2 List of Unit Abbreviations and Symbols

Table D-1 provides a list of unit abbreviations and symbols commonly used in Nanometrics documentation.

Table D-1 Unit Abbreviations and Symbols

Abbreviation or Symbol	Definition
°	degree
Ø	diameter
µ	micro
Ω	ohm
A	ampere
AC	alternating current
b	bit
B	byte
bps	bits per second
C	Celsius
cm	centimetre
dB	decibel
DC	direct current
F	farad
ft.	foot
g	gram
g	gravity
GB	gigabyte
GHz	gigahertz
Hz	hertz
in.	inch
KB	kilobyte
kg	kilogram
kHz	kilohertz
kΩ	kiloohm
kW	kilowatt
L	litre

Abbreviation or Symbol	Definition
lb	pound
m	metre
m/s	metre per second
m/s^2	metre per second, squared
mA	milliampere
MB	megabyte
MΩ	megaohm
MHz	megahertz
mi.	mile
mL	millilitre
mm	millimetre
ms	millisecond
MTU	maximum transmission unit
mV	millivolt
mW	milliwatt
N	Newton
nF	nanofarad
ns	nanosecond
rad	radian
rad/s	radian per second
s	second
sps	samples per second
U	rack unit
V	volt
Vpp	Volts peak-to-peak
W	watt

About Nanometrics

Nanometrics is an award winning company providing monitoring solutions and equipment for studying man-made and natural seismicity. Headquartered in Ottawa, Ontario, with offices and representatives world-wide, Nanometrics has over 30 years' experience, delivering solutions to customers across the globe. Nanometrics real-time and portable systems are utilized by the world's leading scientific institutions, universities and major corporations. Our pedigree is founded on precision instrumentation, network technology and software applications for seismological and environmental research. We specialize in collecting and analyzing critical real time data for global, regional and local seismic networks. We deliver world-class network design, installation and training services throughout the globe in a safety conscious environment.

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Contacting Technical Support

If you need technical support please submit a request on the Nanometrics technical support site or by email or fax. Include a full explanation of the problem and related information such as log files.

Support site: http://support.nanometrics.ca
Email: techsupport@nanometrics.ca