Trillium Compact Seismometer

User Guide

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SEISMOLOGICAL INSTRUMENTS
Kanata, Ontario • Canada

Trillium Compact Seismometer User Guide

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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 16889R2 includes the following changes:

- Minor changes to references throughout the document
- Formatting changes
- Introduction of the "Changes Included in This Revision" section

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Chapter 1
Getting Started

1.1 About Trillium Compact Seismometers

Trillium Compact is a three-component, very broadband, low-noise seismometer that provides the convenience and ease of installation associated with geophones. Weighing only 1.2 kg, measuring only 9 cm in diameter, and consuming just 160 mW average power, Trillium Compact seismometers are suitable for both portable and fixed applications. With an extended low frequency range useful out to beyond 1000 s, low noise, and high clip level, these observatory-class seismometers are ideal for teleseismic, regional, and local studies.

The symmetric triaxial arrangement of the sensing elements in Trillium Compact seismometers 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.

Featuring low sensitivity to both tilt and temperature, Trillium Compact seismometers do not require mass centring under normal operation. The Trillium Compact can be levelled with its locking adjustable height feet, or it can be levelled in seconds by seating it in its optional levelling cradle, correcting an uneven installation surface by up to ±9°.

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 Trillium Compact 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. Nanometrics digitizers such as Taurus and Trident 305 (release 3.2 or greater) support this interface so users can access the Web-based features of the Trillium Compact remotely even with the unit in service.

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 65).

If you have purchased the optional Carrying Case / Insulating Cover, use this enclosure when transporting your Trillium Compact to the installation site or between sites. You are still encouraged to save the original packaging for long distance shipping.

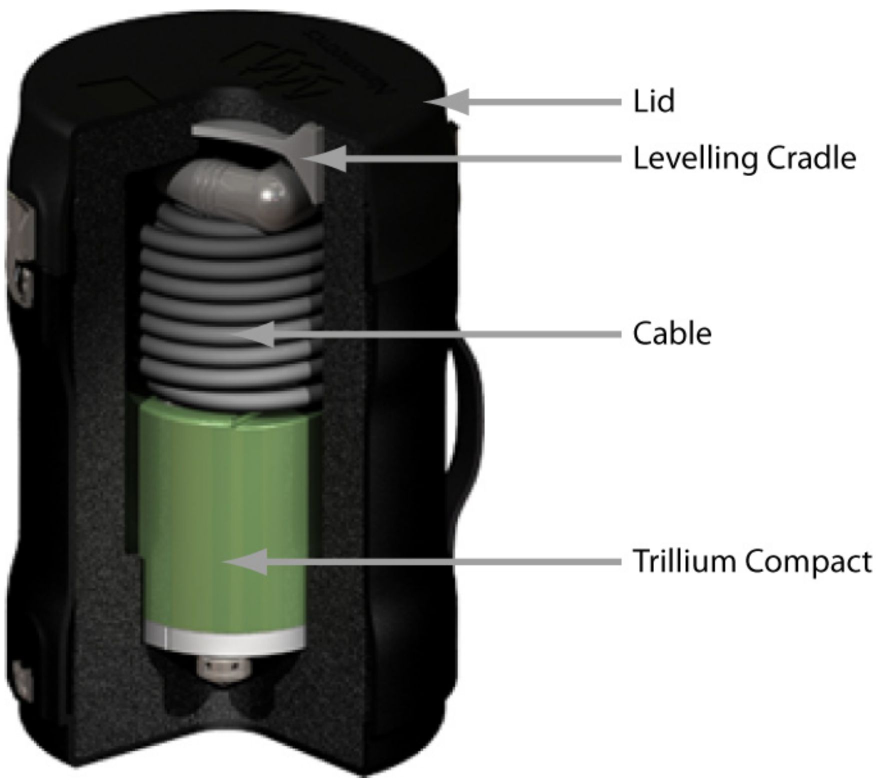
After delivering a Trillium Compact to its installation site, you can safely remove it from the packaging or carrying case and handle it without any special precautions other than taking care not to drop it or bang it against hard surfaces. Trillium Compact seismometers do not require any mass lock mechanisms 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.

1.2.1 Transporting your 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 1.3 “Preparing to Install a Trillium Compact” on page 5), 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 for the Trillium Compact and makes transport of the Trillium Compact and its accessories easy with its compact design and handle.

Figure 1-1 Cut-away illustration of a Trillium Compact, cable, and levelling cradle in the carrying case



To properly pack your carrying case (see 1.3):

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.

1.3 Preparing to Install a Trillium Compact

Advanced planning and preparation for the installation of your Trillium Compact seismometer will ensure that you have a properly prepared site and the tools and materials you need readily available. Follow these recommendations when preparing for your installation:

- Select and prepare your site.

  If the site requires the construction of a pier or other time-consuming labour, factor this time into your installation schedule. See Chapter 2 “Selecting and Preparing a Site” for more information.

- Select your insulation method.

  You can thermally insulate your seismometer with the Trillium Compact Carrying Case / Insulating Cover (recommended) or make a freestanding cover out of rigid plastic foam. Determine which method you will use before your installation so that you have the necessary materials on-site. For more information on insulating your seismometer, see Section 3.3 “Theory and Practice of Insulation” on page 18 and Section 3.4 “Insulation Options” on page 19.

- Gather your installation tools and materials. At a minimum you should have the following on-site when installing your seismometer:
  - Thermal insulation
  - Power source
  - Digitizer and cable (see Table 1-1 “List of Trillium Compact optional equipment” on page 6 for information on Nanometrics digitizers and cables)
  - Compass and drawing utensils for alignment (see See Section 3.2 “Best Practices for Aligning and Levelling a Trillium Compact” on page 15)

- Gather any optional tools and materials you may need. Your installation may also require:
  - A laptop with software and cables required to connect to and communicate with the digitizer if using a digitizer without a display screen.
  - A Carrying Case / Insulating Cover (see Table 1-1 “List of Trillium Compact optional equipment” on page 6) for transporting your seismometer, cable, and levelling cradle and for providing insulating protection to the Trillium Compact at the installation site.

- A levelling cradle (see Table 1-1 “List of Trillium Compact optional equipment” on page 6) for quick and accurate levelling. The cradle can be set on hard surfaces such as rock or a concrete pier, or on softer surfaces such as soil, gravel, or sand when using the optional levelling cradle spike kit.
- A levelling cradle spike kit (see Table 1-1 “List of Trillium Compact optional equipment” on page 6) if deploying your seismometer on an unprepared surface such as soil, gravel, or sand.

1.4 Trillium Compact Optional Equipment

Nanometrics offers optional equipment that add convenience to the installation and use of your Trillium Compact seismometer. The table below describes a number of these options.

Table 1-1 List of Trillium Compact optional equipment

Name	Part Number	Description
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 the Trillium Compact with cushioning protection during transport. When installed with a Trillium Compact as an insulating cover, this enclosure thermally insulates the seismometer and protects it from external air currents.
Foam Plug for Trillium Compact Carrying Case / Insulating Cover	MEC16852R1	A foam plug specially designed to prevent movement of the Trillium Compact and levelling cradle in the carrying case when a cable is not packed in the case.
Levelling Cradle	16863	Tripod deployment cradle for rapid levelling.
Levelling Cradle Spike Kit	16874	Kit containing three types of spikes that attach to the levelling cradle to stabilize the cradle in soil, gravel, or sand.
Cable – Trillium seismometer to Nanometrics digitizer	16777–3M 16777–5M 16777–10M 16777–15M 16777–12M	Double-shielded, ultra-flexible cable with Trillium Compact seismometer right-angled connector on one end and Nanometrics digitizer connector on the other end for connecting a Taurus or Trident. Standard cable lengths are 3 m, 5 m, 10 m, 15 m, and 25m. Custom cable lengths are available upon request.
Cable – Trillium seismometer to open end	16865–3M 16865–5M 16865–10M 16865–15M 16865–25M	Double-shielded, ultra-flexible cable with Trillium Compact seismometer right-angled connector on one end and open-ended at the other end for attaching the connector of a third-party digitizer. Standard cable lengths are 3 m, 5 m, 10 m, 15 m, and 25m. Custom cable lengths are available upon request.
Cable – Trillium seismometer to third party digitizer	Contact Nanometrics	Double-shielded, ultra-flexible cable with Trillium Compact seismometer 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 65) for a full listing of cables with connectors to third party digitizers.

Table 1-1 List of Trillium Compact optional equipment

Name	Part Number	Description
Cable – Serial communications and power cable	16864–3M	Cable to provide power to the Trillium Compact and enable serial communications between the seismometer and a laptop. Standard cable length is 3 m. Custom cable lengths are available upon request.
Taurus Portable Seismograph	14977	Compact, self-contained, 24-bit digitizer and data logger with low power consumption, and 142 dB dynamic range. Use as a stand-alone time-series data logger or as a component in a data acquisition network. Incorporates a three-channel 24-bit digitizer, GPS receiver and system clock, removable data storage, and remote communication options. Can be installed in the seismometer vault, requiring only a short cable. Configurable locally using the colour display screen and integrated browser or remotely using any Web browser over a TCP/IP connection.
Trident 305 Digitizer	14072	A 24-bit digitizer with 142 dB dynamic range and Nanometrics NMX-bus for connecting to Taurus, Cygnus 205 satellite transceiver, or other NMX-bus enabled device. The NMX-bus host device, such as a Taurus, supplies GPS timing and power to the Trident. Can be installed in the seismometer vault, requiring only a short cable. Weather-sealed enclosure also allows outdoor installations. Configurable locally using the host Taurus or remotely using any Web browser over a TCP/IP connection.

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 65) to obtain an RMA number.

The Trillium Compact mechanical and electronic elements have been designed to be robust and reliable, to ensure there is no need to open units for on-site maintenance. 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 located on a label on the side of the unit.

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 when configuring the SLI P interface and to access the Web interface of the Trillium Compact. See Chapter 7 "Using the Trillium Compact Web Interface" for more information.

If the IP address of the unit is not recorded, it can be calculated later using the serial number. See Section 7.1.1 "Finding the IP Address of Your Trillium Compact" on page 35 for instruction.

Chapter 2

Selecting and Preparing a Site

2.1 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. Low porosity is important as water seepage through the rock can cause tilts which overwhelm the seismic signal at long periods. Clay soils and, to a lesser extent, sand are especially bad in this sense.

For installations on unprepared hard surfaces, such uneven rock, use the optional levelling cradle (Nanometrics part number 16863) to create a secure, stable, and level installation (see Section 3.2.1 "Levelling a Trillium Compact with the Levelling Cradle" on page 16). For installations on softer and loose surfaces, such as soil, gravel, or sand, the optional levelling cradle spike kit (Nanometrics part number 16874) may be used to stabilize the levelling cradle (see Section 3.2.2 "Levelling a Trillium Compact with the Levelling Cradle and Spike Kit" on page 17).

Use the worksheet in Section 2.4 "Site Record" on page 12 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. Section 2.2.1 "Common Types of Installations" on page 10 provides recommendations for some common installation types.

2.2 Planning Your Installation

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

The installation methods described in this section 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 4.3 "Troubleshooting Your Installation" on page 24 for more information.

2.2.1 Common Types of Installations

Following are three common methods for installing and insulating a seismometer (see Section 3.3 "Theory and Practice of Insulation" on page 18 and Section 3.4 "Insulation Options" on page 19 for more information on insulation):

a) Vault installation

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.

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 because the temperature cycling will show up as periodic noise in the seismic signal.

b) Temporary deployment on rock

Install the seismometer on the flattest available surface (using a levelling cradle as preferred or if needed), and lay sand in a ring around it to create a flat sealing surface for the rigid insulation that will cover it.

c) Temporary deployment in sediment

Dig a pit to bury the seismometer. A depth of 2 ft. is sufficient to ensure the seismometer and insulation will be completely covered and not disturbed. If possible, place a metal plate or paving stone at the bottom of the pit to create a hard, flat surface and place the optional levelling cradle on this surface. Alternatively, use the levelling cradle with its optional spikes installed, driving the spikes into the sediment or soil so that the cradle is firmly seated. Place the seismometer in the cradle, level it, and cover it with a rigid insulating cover (the Trillium Compact Carrying Case / Insulating Cover with internal foam removed is ideal). The cover will prevent the seismometer from being disturbed by sediment shifting and settling against it. Hold the cover down while piling sediment around it to ensure that it does not shift as it is buried.

A simpler but less optimal method is to place the seismometer directly in the ground and bury it. This method provides good insulation, but horizontal noise spikes may be observed due to instability of the soil.

2.3 Recommendations for Pier Construction

If your installation involves the construction of a pier, use Table 2-1as a guide to constructing your pier:

Table 2-1 Recommended pier design specifications

Material	Concrete. Homogeneous, 50% Portland cement and 50% sieved sand (see Section 2.3.1 "Choosing the Right Concrete" on page 11).
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 2.3.2 "Decoupling the Pier and Vault Walls" on page 11).

2.3.1 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.

2.3.2 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.

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.

2.4 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 2-2 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, other):

__________ Depth below surface (m)
__________ Height above sea level (m)</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 3
Installing a Trillium Compact

3.1 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 “Alignment 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 seismometer is equipped with:

- Three adjustable-height feet with lock nuts. An Allen key is provided to help tighten the lock nuts in place.
- A levelling bubble on the cover.

Optional levelling tools for Trillium Compact seismometers 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

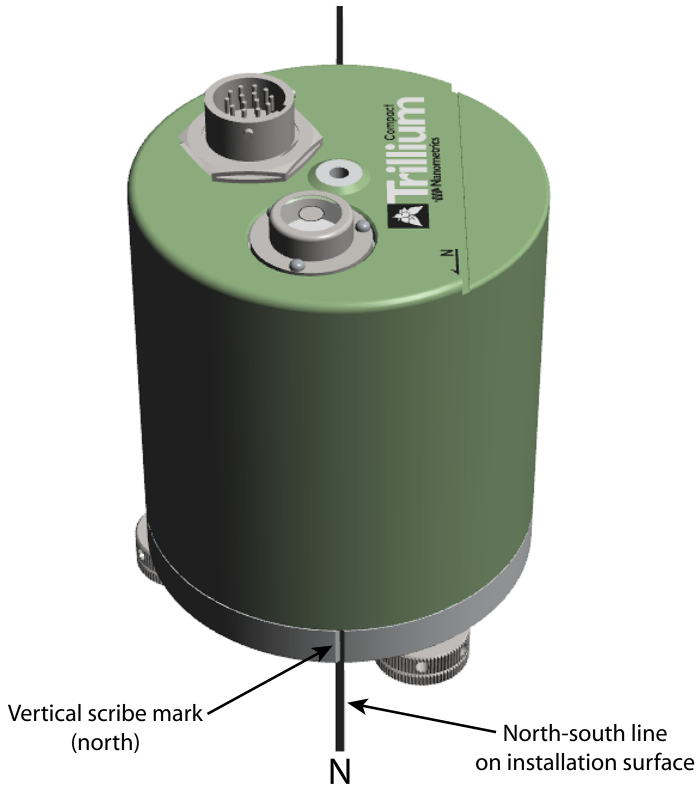


Figure 3-2 shows the case-top north-south guide with a dashed line indicating where a straight-edge, staked line, or laser level line would fall.

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

3.2 Best Practices for Aligning and Levelling a Trillium Compact

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 3.2.1 "Levelling a Trillium Compact with the Levelling Cradle" on page 16, or if you are using the levelling cradle with its optional spike kit, see Section 3.2.2 "Levelling a Trillium Compact with the Levelling Cradle and Spike Kit" on page 17.

- 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 the provided 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 14) 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 14).

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

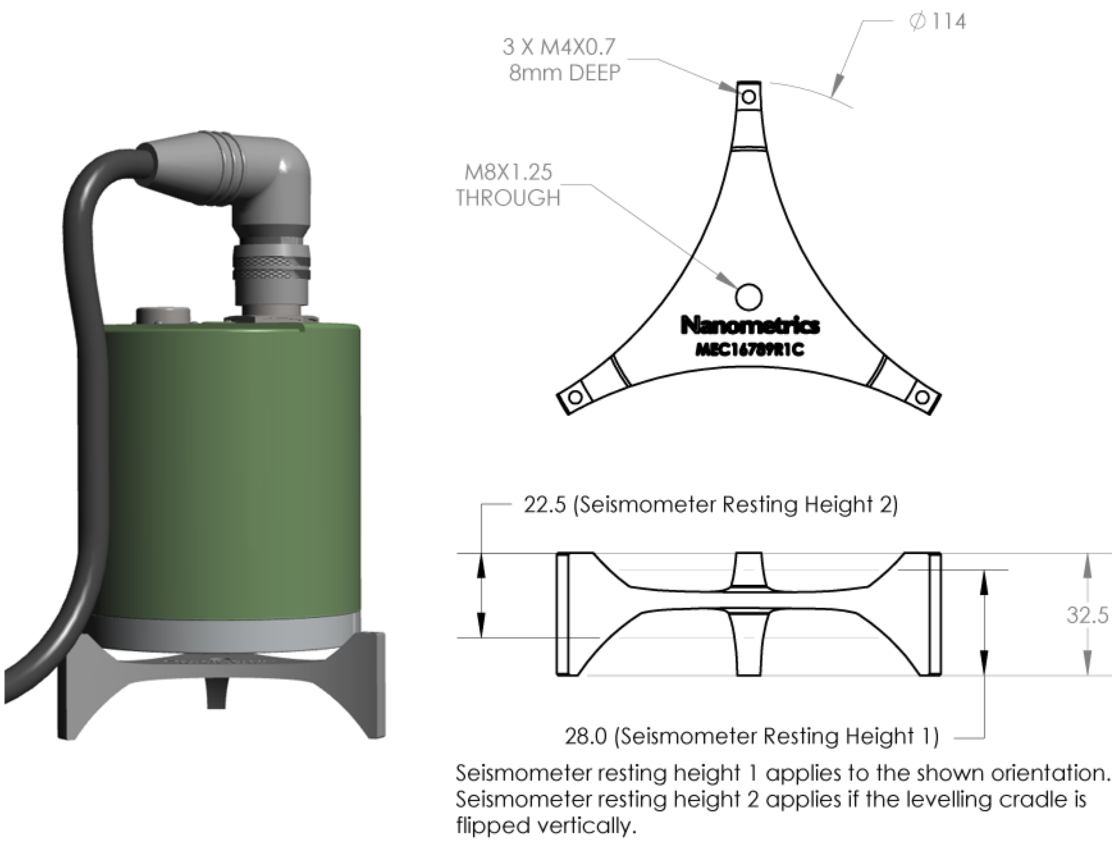
- After aligning the seismometer, verify that it is still level. It may need to be adjusted due to unevenness of the installation surface.
- If you relevelled the Trillium Compact and you are levelling it with the adjustable feet, ensure the feet are locked when finished.

3.2.1 Levelling a Trillium Compact with 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. Shown in Figure 3-3, the two-sided cradle provides bowls of two depths. The shallow bowl will correct an uneven installation surface by up to ±5° and the deep bowl will correct by up to ±9°.

As Figure 3-3 illustrates, 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 3.2.2 "Levelling a Trillium Compact with the Levelling Cradle and Spike Kit" on page 17) 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 3-3 Levelling cradle features and dimensions



All dimensions in Figure 3-3 are in millimetres unless otherwise stated.

3.2.2 Levelling a Trillium Compact with the Levelling Cradle and Spike Kit

The shallow side of the cradle (see Figure 3-3) 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:

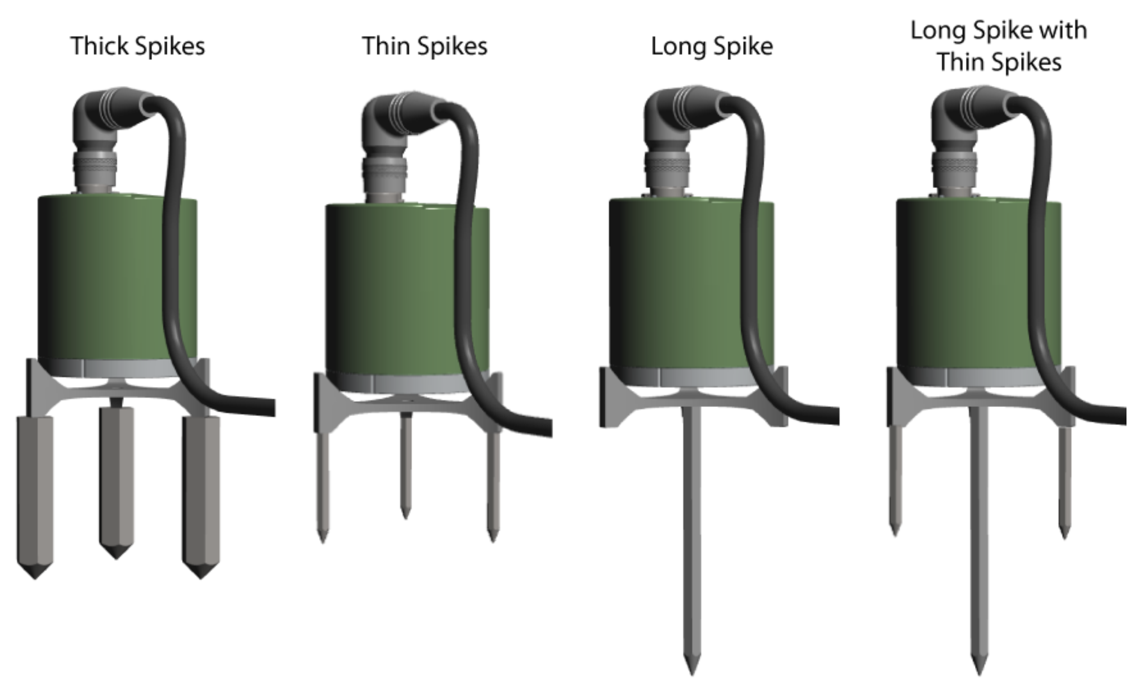
a) Thick spikes: Three spikes for use in sand; dry, loose soil; or snow.

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 3-4 shows three views of a Trillium Compact mounted on a levelling cradle with the spikes used on unprepared surfaces such as soil or rock.

Figure 3-4 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 3.2 "Best Practices for Aligning and Levelling a Trillium Compact" on page 15).
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 pressing gently down on a corner of the levelling cradle. It should remain stable and the levelling bubble should not move.

3.3 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 (see Chapter 2 “Selecting and Preparing a Site”) 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 “Trillium Compact Optional Equipment” on page 6).
- 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. The insulation is subject to temperature expansion and can exert measurable forces on the seismometer.

3.4 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 3.4.1 “Insulating a Trillium Compact with the Insulating Cover” on page 20. This is the recommended method.

b) Make a freestanding cover out of rigid plastic foam 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 3.4.2 “Insulating a Trillium Compact with a Rigid Foam Box” on page 21.

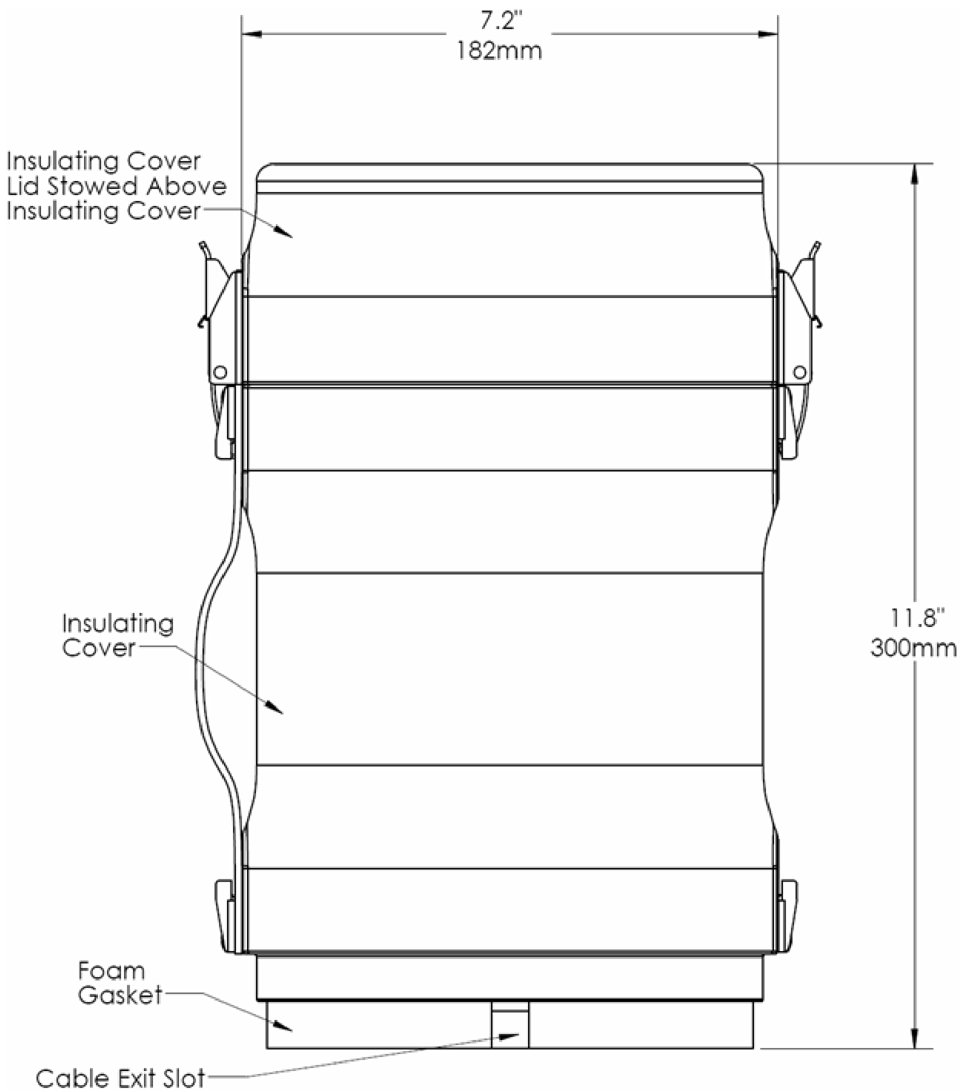
Before proceeding with the implementation of thermal insulation, there are many aspects you must consider in the context of the particular site and type of installation. Section 2.2 “Planning Your Installation” on page 9 outlines common types of installations.

3.4.1 Insulating a Trillium Compact 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 3-5 Trillium Compact insulating cover features and dimensions



3.4.2 Insulating a Trillium Compact 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 3.2 "Best Practices for Aligning and Levelling a Trillium Compact" on page 15.

- 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.

3.5 Installing a Trillium Compact in the Insulating Cover

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 3-6 "Cut-away illustration of a Trillium Compact in the insulating cover" on page 22).
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 3.2 "Best Practices for Aligning and Levelling a Trillium Compact" on page 15).

If you are burying the Trillium Compact and its insulating cover in sand or soil, pull the four innermost pieces of foam out of the insulating cover. This will leave one layer of insulating foam inside the cover.

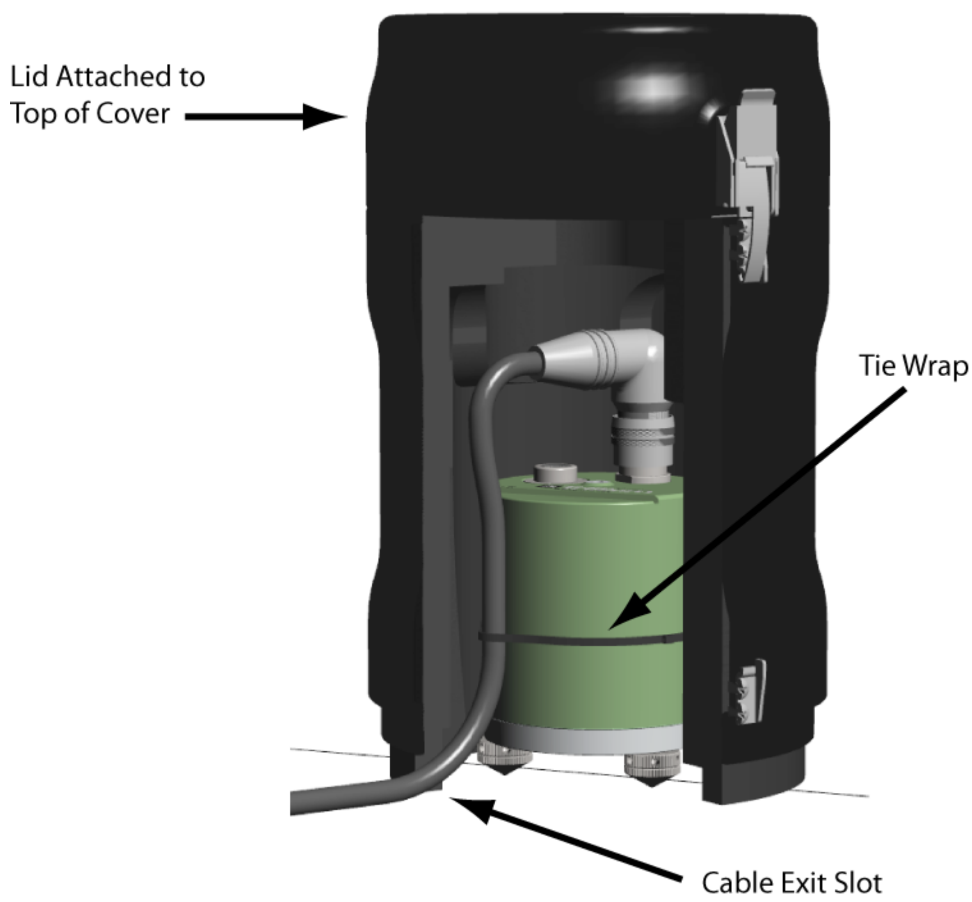
5. Place the lid on top of the insulating cover and secure it with the latches (see Figure 3-6 "Cut-away illustration of a Trillium Compact in the insulating cover" on page 22).
6. Hold the insulating cover above the sensor, aligning the cable slot with the cable (see Figure 3-6 "Cut-away illustration of a Trillium Compact in the insulating cover" on page 22). 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 3.2.1 "Levelling a Trillium Compact with the Levelling Cradle" on page 16), 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 3-6 Cut-away illustration of a Trillium Compact in the insulating cover



Chapter 4
Post-Installation Activities

4.1 Grounding the Digitizer and Trillium Compact

The digitizer and seismometer cases must have a low-resistance path to ground for safety. However, directly earthing both instruments will result in a ground loop. When the digitizer and seismometer are far apart, differences in ground potential may cause spurious signals to appear unless the loop is broken. The solution is to earth the digitizer case and isolate the seismometer case.

Trillium Compact seismometers have stainless steel adjustable feet which, when mounted directly onto dry rock or concrete, provide a relatively high resistance to ground. In wet environments it may be necessary to mount the seismometer on a plate of glass embedded in sand. For more details on earthing the digitizer and seismometer, refer to the user guide for your digitizer.

4.2 Installation Checklist

Use the following checklist to help you verify that you have completed all of the necessary steps in the installation of your Trillium Compact.

- ❑ Installation surface is clear of debris.
- ❑ Trillium Compact is level.
- ❑ Trillium Compact is aligned to north-south.
- ❑ The feet of the Trillium Compact are locked.
- ❑ Trillium Compact serial number is noted.
- ❑ Trillium Compact IP address is noted.
- ❑ Cable is connected to the Trillium Compact and the digitizer.
- ❑ Cable is strain-relieved to the installation surface.
- ❑ Cable is not touching the Trillium Compact case.
- ❑ Thermal insulation is in place.
- ❑ Thermal insulation is not touching the Trillium Compact or cables.
- ❑ If using a rigid-foam insulating box, it is weighted down.

4.3 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 4-1 lists common types of noise, including horizontal spikes, that may occur with a Trillium Compact seismometer and reasons why the noise may be present.

Table 4-1 Types of noise and possible causes

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.

Part 2

Operation

Chapter 5

Input and Output Signals

5.1 UVW and XYZ Output Signals

To account for the source impedance, see Table 9-1 “Ground motion response nominal parameters” on page 48. A control signal switches the Trillium Compact output signal to either UVW output mode or XYZ output mode. 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.

See Table 5-1 for the polarities of the XYZ outputs and the correspondence of each to the directions of the compass.

Table 5-1 Axis orientation and polarity of XYZ outputs

Axis	Orientation	Positive Voltage
X	east-west	represents case motion to the east
Y	north-south	represents case motion to the north
Z	vertical	represents upward case motion

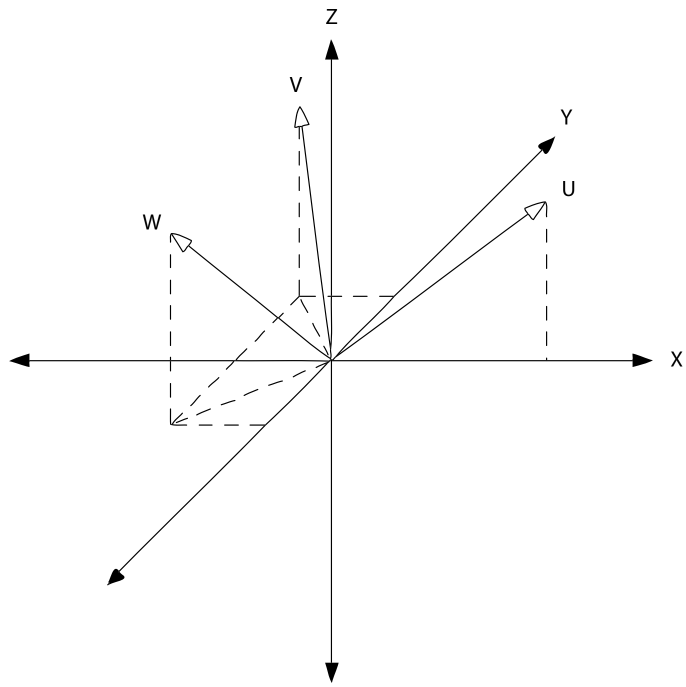
The seismometer will respond to changes in the type of output signal within 4 s. To select the

- UVW outputs, pull the UVW/TX pin high.
- XYZ outputs, leave the UVW/TX pin floating or set it to 0 V.

The UVW/TX input control signal is disabled when the seismometer is transmitting through a serial port because this pin is used as the RS-232 serial TX output signal. For more information on serial port communication with a Trillium Compact, see Chapter 7 “Using the Trillium Compact Web Interface.”

To understand the difference between the UVW and XYZ outputs, see Figure 5-1. By design, the Trillium Compact axes are identical and sense motion in orthogonal directions. The U axis is aligned with the east-west axis when projected into the horizontal plane.

Figure 5-1 Trillium Compact axis orientation



This arrangement results in the following transformation equations:

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

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

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. This method allows for studies and calibrations where both UVW and XYZ data are required.

5.2 Digital Control Input Signals

Trillium Compact seismometers have two digital control input signals: CALEN and UVW. CALEN enables the calibration function of the Trillium Compact. UVW changes the output mode (which is XYZ by default) to UVW mode. You can reconfigure the CALEN control line to be SP instead. SP activates the short period mode (the default is long period mode) of the Trillium Compact.

Long period mode is the normal mode for collecting seismic data. However, you may want to use short period mode when levelling the seismometer to see the response of the mass position outputs. When in long period mode, these outputs ramp very slowly and changes during levelling may take several minutes. In short period mode the outputs respond within a second, allowing you to watch the effects of levelling.

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 12 V signals. Specifically, any voltage greater than 3.5 V at a current greater than 0.5 mA enables the relevant functionality, while any voltage less than 0.8 V or a high impedance disables it. All inputs can tolerate at least ±15V except for UVW/TX which can tolerate voltages from –7 V to +15 V. The CALEN and UVW control lines are shared with the serial RS-232 port (see Section 5.3). It is recommended that you use +12 V to activate these control lines and high impedance for deactivation.

5.3 Serial RS-232 Communications

The Rx, Tx, and DGND signals implement a 9600 baud RS-232 communications interface. The 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 CALEN and UVW control inputs. Care must be taken to ensure that the UVW/TX line is not being simultaneously driven by the digitizer. When serial communications are occurring on the Rx and Tx lines, the control line signals CALEN (or SP/LP) and UVW that share these pins are not effective. For more details, see Section 5.2 “Digital Control Input Signals” on page 29 and Section 10.1 “Connector Pinout” on page 51.

5.4 Calibration Input Signals

Calibration input signals are provided to allow for relative calibration of the Trillium Compact 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 5.1 “UVW and XYZ Output Signals” on page 27.

All of the axes use a common calibration input signal, CAL_SIG. See Section 9.1 “Frequency Response” on page 47 for sensitivity and frequency response information.

5.5 State-of-Health Output Signals

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 signals, 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.

5.6 Power Consumption

Following are power consumption scenarios typical of Trillium Compact seismometers:

- Under normal operation (the Trillium Compact is level, there is a low seismic signal, the Trillium Compact has settled for at least 30 minutes, and the RS-232 serial port is not transmitting), power consumption is approximately 160mW.
- On start-up, power consumption may briefly surge to 1W.

  Power consumption above normal quiescent, after the initial power-on inrush, is roughly proportional to the output signal.
- For a settled and level Trillium Compact, 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 6

Using a Nanometrics Digitizer with a Trillium Compact

6.1 Using a Taurus Portable Seismograph with a Trillium Compact

Refer to the user guide for your Taurus portable seismograph for complete instructions on using it with a seismometer. The instructions that follow are a guide to selecting the default configuration for a Trillium Compact on your Taurus, using the Taurus graphical user interface on either the Taurus display screen or through a web browser.

Nanometrics cable 16777-nM (where n is the length of the cable in metres) can be used to connect a Trillium Compact to a Taurus. See Table 1-1 “List of Trillium Compact optional equipment” on page 6 for a description of this cable.

If you are using a version 3.x Taurus (with firmware version 3.1.14 or higher) with a Trillium Compact

1. Log into the Taurus with either the tech or central user account.
2. Select **Configuration** > **Sensor Library**.
3. Select **Default Trillium Compact** from the list of seismometers.
4. Select **Apply**.
5. Select **Commit**.

If you are using a version 2.x Taurus with a Trillium Compact

1. Log into the Taurus with either the tech or central user account.
2. Select **Advanced Configuration** from the **Status** menu.
3. Select **Browse** and navigate to the **Taurus_Trident** folder of the Trillium software CD.
4. Select the **TrilliumCompact.cfg** file.
5. Select **Upload**.
6. When the upload is complete, select **Apply**.
7. Select **Commit**.

6.2 Using a Trident Digitizer and NaqsServer with a Trillium Compact

Refer to the user guide for your Trident digitizer for complete instructions on using it with a seismometer. Nanometrics cable 16777-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 Trillium Compact optional equipment” on page 6 for a description of this cable.

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 or as desired	
Sensor Control	High Voltage Level	+12 V	
	Calibration Mode	Voltage (active-high)	
	Line 1 Level (UVW/TX, Pin J)	Low	Low is equivalent to XYZ mode and High is equivalent to UVW mode.
	Line 2 Level (CALEN/SP/RX, Pin D)	Low	Low is equivalent to disabling calibration, and High is equivalent to enabling calibration on all three axes. If pin D is configured to be SP/LP, then Low is equivalent to long period mode and High to short period mode.
	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 = 2.996e+8        // counts per unit of ground motion
SensitivityFreq = 1.0         // frequency at which sensitivity is correct
CalibrationUnits = VOLTS      // calibration input units:  VOLTS or AMPS
CalCoilResistance = 102000    // calibration coil resistance in ohms
CalCoilConstant = 99.8        // 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
```

6.3 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 6-1 as a guide.

Increasing the sensitivity of a digitizer by decreasing the input range can cause the digitizer to clip. For example, there is a high potential for clipping if the digitizer input is reduced to 2 Vpp and the Trillium Compact has a 40 Vpp output.

Table 6-1 Increasing system sensitivity

Digitizer Input Range	Digitizer Software Gain	Digitizer Sensitivity	Trillium Compact Sensitivity	System Sensitivity (Counts/(m/s))
40 Vpp	1	0.4 count /µV	749.1 $V \cdot s/m$	2.996e+8
16 Vpp	1	1 count /µV	749.1 $V \cdot s/m$	7.491e+8
8 Vpp	1	2 count /µV	749.1 $V \cdot s/m$	1.498e+9
4 Vpp	1	4 count /µV	749.1 $V \cdot s/m$	2.996e+9
2 Vpp	1	8 count /µV	749.1 $V \cdot s/m$	5.993e+9

Chapter 7

Using the Trillium Compact Web Interface

7.1 Configuring a SLIP Connection to a Trillium Compact on Windows XP

The Trillium Compact has an integrated Web server that is available using a standard Web browser and the SLIP (serial-over-Internet-Protocol) RS-232 serial interface provided on the Trillium Compact connector. Communications to the Trillium Compact is set up by configuring a SLIP port on a Microsoft® Windows® XP computer (see Section 7.1.1 "Finding the IP Address of Your Trillium Compact") and connecting the Trillium Compact to a serial port on the computer. If the computer is not equipped with a serial port, a commercially available USB-to-serial adapter can be used.

With the internal Web server of the Trillium Compact, use a standard Web browser to retrieve information about the seismometer, access state-of-health information and control features, and configure the seismometer. The Trillium Compact must be connected to a Taurus or Trident 305 running firmware version 3.2 or higher, or to the serial port of a personal computer (see Section 7.1.2 "Configuring the SLIP Connection on Your Computer" on page 36).

When used with a Nanometrics Taurus or Trident 305 Digitizer, the digitizer uses the Trillium Compact serial interface to make the Trillium Compact Web page accessible through the Taurus remote Web browser interface without additional hardware required.

Serial port traffic may cause low levels of noise on the analog output signals of the seismometer, and so, the serial port should not be accessed when the highest quality seismic signal is desired.

7.1.1 Finding the IP Address of Your Trillium Compact

The IP address of your Trillium Compact seismometers is 2.23.x.y, where x and y are calculated from the serial number of the unit. You will need the IP address when configuring your SLIP connection (see Section 7.1.2 "Configuring the SLIP Connection on Your Computer" on page 36) and to access the Trillium Compact Web interface (see Section 7.3 "Using the Trillium Compact Web Interface" on page 38). There are two ways you can find the IP address of your Trillium Compact:

- Look on the label on the side of the unit
- Calculate the IP address using the serial number of the unit

To calculate the values for x and y in the serial number:

- x = SerialNumber / 256

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

- y = SerialNumber *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.

7.1.2 Configuring the SLIP Connection on Your Computer

Use the following steps to configure a SLIP port on a Windows XP computer:

1. In Control Panel, select Network Connections.
2. Click **File** > **New Connection** to open the New Connection Wizard.
3. Click **Next**.
4. Click **Set up an advanced connection** and click **Next**.
5. Click **Connect directly to another computer** and click **Next**.
6. Click **Guest** and click **Next**.
7. Enter a name for the connection and click **Next**.
8. Select the communications port where the Trillium Compact is attached and click **Next**.
9. Click **Anyone's use** and click **Next**.
10. Click **Finish**.
11. Open the properties for the new connection.
12. Click the **General** tab and click **Configure**.
13. Set the **Maximum speed (bps)** to 9600, clear all check boxes, and click **OK**.
14. Click the **Options** tab and clear the **Prompt for name and password, certificate, etc.** check box.
15. Click the **Networking** tab and select **SLIP: Unix Connection** from the **Type of dial-up server I am calling** list.

16. Clear all check boxes except for the **Internet Protocol (TCP/IP)** check box in the **This connection uses the following items** list.

17. Click **Properties** for **Internet Protocol (TCP/IP)**.

18. Type an IP address in the range of 2.23.0.2 to 2.23.0.254 in the **IP address** box. This is an arbitrary IP address that represents the computer. It must be on the same subnet as the Trillium Compact, which is 2.23.0.0/16. The IP address of the Trillium Compact is 2.23.x.y (see Section 7.1.1 "Finding the IP Address of Your Trillium Compact" on page 35 for information on determining the full IP address).

19. Click **Advanced**.

20. On the **General** tab, clear the **Use default gateway on remote network** check box and the **Use IP header compression** check box.

21. Click **OK** in the Advanced TCP/IP Settings, Internet Protocol (TCP/IP) Properties, and connection properties dialog boxes.

7.1.3 Establishing a Connection with the Trillium Compact

Use the following steps to establish a connection between the Windows XP computer and Trillium Compact using the SLIP port (see Section 7.1.2 "Configuring the SLIP Connection on Your Computer" on page 36) and visit its home page:

1. Ensure the Trillium Compact is connected and powered on.

2. In Control Panel, select Network Connections.

3. Right-click on the SLIP connection for the Trillium Compact and select **Connect**. A brief handshake will take place before establishing the connection. The Windows operating system will not establish the connection unless the handshake is successful.

4. Open a Web browser on the same computer the Trillium Compact is connected to and go to `http://2.23.x.y` (the IP address of the Trillium Compact) to access the home page of the seismometer. See Section 7.1.1 "Finding the IP Address of Your Trillium Compact" on page 35 for information on determining the full IP address of the Trillium Compact.

For example, if the IP address label on the Trillium Compact is 2.23.1.200, then the URL to access the home page of the seismometer is http://2.23.1.200.

7.2 Connecting to a Trillium Compact through a Taurus or Trident 305

If the Trillium Compact is connected to a Taurus

- The IP address of the Taurus appended by port number 8082 is used to access the Trillium Compact home page.

For example, if the you access the Taurus using the URL http://10.12.2.38, then the Trillium Compact home page is found at http://10.12.2.38:8082.

If the Trillium Compact is connected to a Trident 305 (one or two of which may be attached to a Taurus)

- The IP address of the Taurus appended by port number 8083 for the first Trident 305 or 8084 for the second is used to access the Trillium Compact home page.

Using the same Taurus IP address as in the example above, and with the Trillium Compact connected to the first Trident 305 on the Taurus, the Trillium Compact home page is found at http://10.12.2.38:8083. If the Trillium Compact is connected to the second Trident 305 on the Taurus, the Trillium Compact home page is found at http://10.12.2.38:8084.

See Taurus and Trident 305 user documentation for more detail.

7.3 Using the Trillium Compact Web Interface

The home page of the Trillium Compact presents links to other pages that are organized into three categories:

- State-of-Health
- Seismometer Control
- Configuration

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

Click the **State-of-Health** link to view a page that shows the separate mass positions of 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 least well-centred of these three axes. 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. The State-of-Health page also displays the approximate unit temperature. This page does not automatically refresh; use the **Refresh** button on this page to display new readings.

Click the **Seismometer Control** link to display a page that provides the means to enable calibration, change the output mode, and put the seismometer into short period mode. Calibration can be enabled for the three U, V, and W axes simultaneously, for a specific axis, or disabled for all axes. Choose the output mode of XYZ or UVW (see Section 5.1 “UVW and XYZ Output Signals” on page 27 for a definition of these modes). 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.

Once a control is set on this web 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. Settings in this section are always reset to factory defaults when the Trillium Compact is powered up or the firmware rebooted.

The Configuration section of the home page has links for accessing factory information about the seismometer hardware, firmware, and response; to configure control line functionality; to import and retrieve user-created seismometer response data; and to update firmware.

Use the **Control Lines** link to reconfigure the function of pin D on the Trillium Compact connector. When set to a positive voltage level, pin D, by default, enables calibration. Alternatively, set this pin to activate the short period response of the seismometer. This setting is retained when the Trillium Compact is powered off or rebooted.

The **Firmware** page shows the current version of the firmware and provides a button to reboot (restart) the firmware. As the firmware exits a message stating “Goodbye” appears. To access the home page of the rebooted Trillium Compact, wait 20 s and return to the home page using the IP address.

A restarted Trillium Compact does not automatically display the home page. The user must access it using its IP address via the Web browser.

To update to a new version of the Trillium Compact firmware

1. Access the Trillium Compact bootloader by
   a) Rebooting the firmware and waiting 10 s (or powering up the seismometer); and then
   b) Immediately accessing the URL of the bootloader at:
      - http://<IP address>/firmware/bootloader, where <IP address> is the IP address used to access the Trillium Compact home page.

There is a 10 s interval to access the bootloader before it starts the seismometer firmware. If this window is missed, the process of rebooting or power cycling must be repeated.

2. Use the bootloader Web page to upload the new firmware file provided by Nanometrics.

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.

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 fize that can be imported is 2559 bytes.

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	See Figure 9-2 "Trillium Compact self-noise" on page 49
Sensitivity	749.1 $V \cdot s/m$ nominal ± 0.5% precision
Off-axis sensitivity	±0.5%
Bandwidth	–3 dB points at 120.2 s and 108 Hz
Transfer function	Lower corner poles within ±0.5% of nominal provided High-frequency poles and zeros within ±5% of nominal provided No peak in response at high frequency See Figure 9-1 "Bode plot for Trillium Compact seismometers" on page 47
Clip level	26 mm/s from 0.1 Hz to 10 Hz
Tilt	Dynamic and operational tilt range of ±2.5°
Parasitic resonances	None below 200 Hz

8.3 Hardware Interface

Table 8-3 Hardware interface specifications

Connector	14-pin Shell size 12 MIL-C-26482 Series I 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 5.6 "Power Consumption" on page 30 for typical power consumption scenarios
Protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection

8.6 Environmental

Table 8-6 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

8.7 Physical

Table 8-7 Physical specifications

Diameter	90 mm
Height	113 mm without levelling feet 128 mm with levelling feet fully retracted 135 mm with levelling feet fully extended
Weight	1.2 kg
Housing	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

Chapter 9
Transfer Function

9.1 Frequency Response

Figure 9-1 is a bode plot that shows the nominal ground motion, calibration input circuit, and combined calibration response for Trillium Compact seismometers. 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.

In this figure:

- The nominal ground motion frequency response of the seismometer is a solid red line.
- The calibration input circuit response is a dash-dotted green line and behaves effectively as a simple low-pass circuit in series with the ground motion response.
- During calibration, the sensor calibration response is the combination of the two lines referenced above and is a dashed blue line.

Figure 9-1 Bode plot for Trillium Compact seismometers

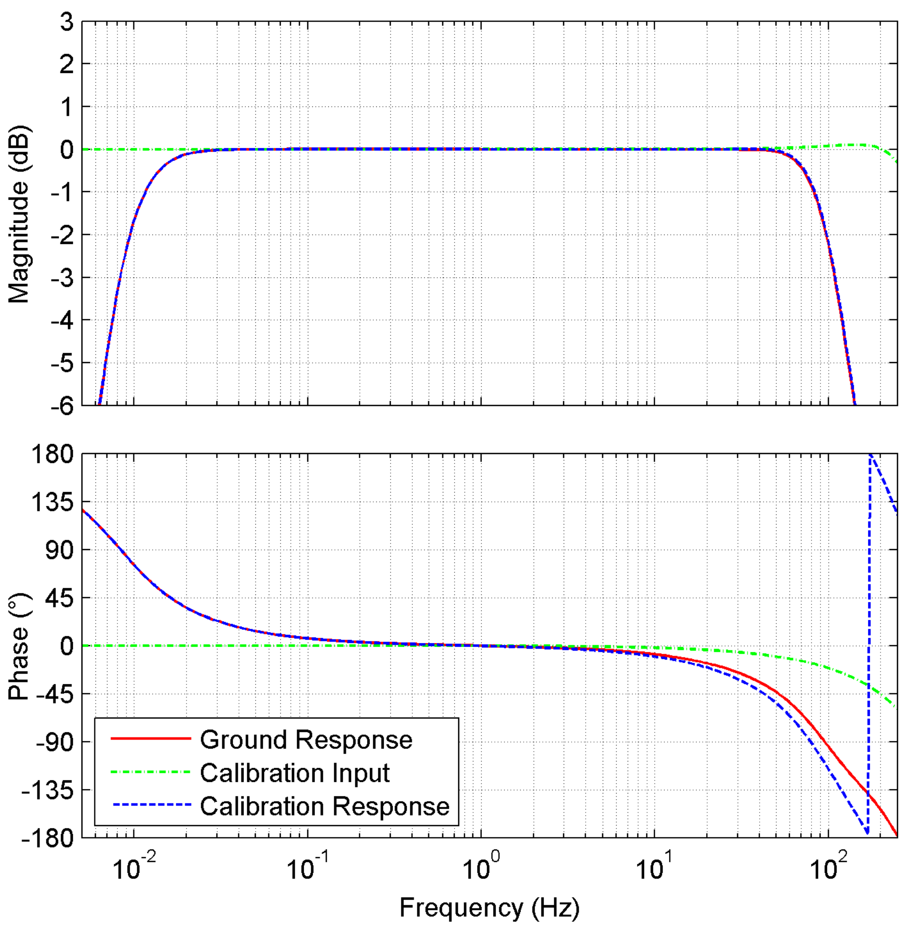


Table 9-1 provides the ground motion response nominal parameters. The ground motion response has –3 dB corners at 120.2 s and 108 Hz. The ground motion sensitivity at f_0 specified in Table 9-1 assumes an infinite input impedance at the digitizer. For digitizers with low input impedance, it will become 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

Symbol	Parameter	Nominal Values	Units
z_n	Zeros	0 0 –434.1	rad/s
p_n	Poles	–0.03691 ±0.03712i –371.2 –373.9 ±475.5i –588.4 ±1508i	rad/s
k	Normalization factor	8.184 x 10^{11}	$(\text{rad/s})^4$
f_0	Normalization frequency	1	Hz
S	Ground motion sensitivity at f_0	749.1	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

$$k = \frac{1}{\dfrac{\prod_n (i2\pi f_0 - z_n)}{\prod_n (i2\pi f_0 - p_n)}} \qquad \text{(EQ 2)}$$

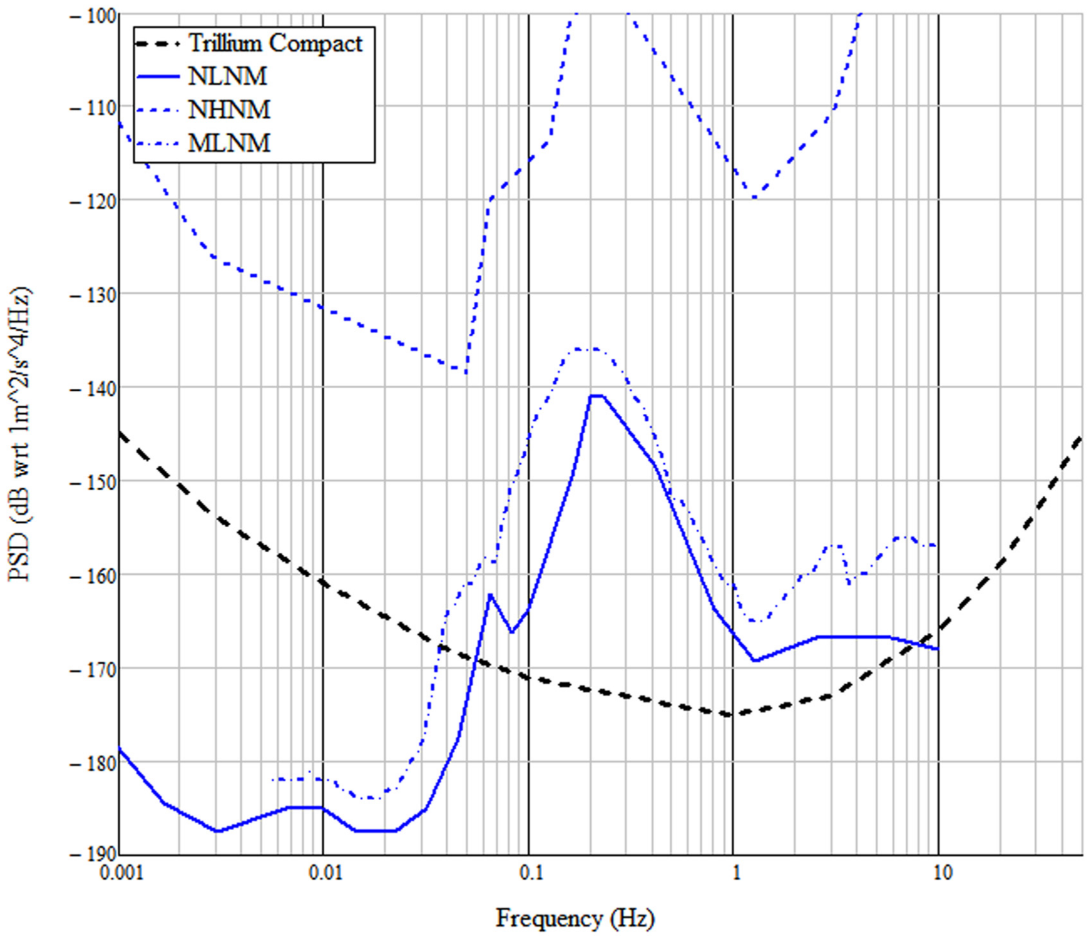
and is given for informational purposes only.

The calibration input sensitivity at 1 Hz is 0.0100 m/(s²·V) ± 7 percent, so the combined calibration sensitivity at 1 Hz is 7.50 rad/s ± 7 percent. 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 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.

9.2 Self-Noise

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, and seismometer installation. See Chapter 2 "Selecting and Preparing a Site" and Chapter 3 "Installing a Trillium Compact."

Figure 9-2 Trillium Compact self-noise



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.

Chapter 10

Connector and Cables

10.1 Connector Pinout

The Trillium Compact connector is a 14-pin male military circular type hermetic connector. Table 10-1 provides the connector pinout.

Table 10-1 Connector Pinout

<table>
<tr><th>Pin</th><th>Name</th><th>Function</th><th>Type</th></tr>
<tr><td>B</td><td>X+/U+</td><td rowspan="2">X axis output (east)</td><td rowspan="2">40 Vpp differential</td></tr>
<tr><td>C</td><td>X-/U-</td></tr>
<tr><td>F</td><td>Y+/V+</td><td rowspan="2">Y axis output (north)</td><td rowspan="2">40 Vpp differential</td></tr>
<tr><td>H</td><td>Y-/V-</td></tr>
<tr><td>L</td><td>Z+/W+</td><td rowspan="2">Z axis output (vertical)</td><td rowspan="2">40 Vpp differential</td></tr>
<tr><td>M</td><td>Z-/W-</td></tr>
<tr><td>K</td><td>CAL_SIG</td><td>Calibration signal input</td><td>• 120 kΩ input impedance nominal
• 0.375 $(m/s^2)/V$ nominal</td></tr>
<tr><td>R</td><td>MAXIMUM MASS POSITION</td><td>Mass position of the axis with the highest absolute mass position</td><td>-4 V to +4 V analog</td></tr>
<tr><td rowspan="2">D*</td><td>CALEN/RX
(Factory default)</td><td>• Input: Calibration enable
-OR-
• Input: Serial RS-232 receive</td><td rowspan="2">• 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

* This input controls calibration enable by default. If desired, you can reconfigure this pin to control short period/long period mode instead. See Section 5.1 "UVW and XYZ Output Signals" on page 27 for details.</td></tr>
<tr><td>SP/RX</td><td>• Input: Change to short period mode from the factory default long period mode
• Input: Serial RS-232 receive</td></tr>
<tr><td>J</td><td>UVW/TX</td><td>• Input: Enable UVW outputs instead of the factory default XYZ outputs
• Output: Serial RS-232 transmit</td><td>• Digital: Active-high 5 V to 15 V (low is equal to open or 0 V)
• Serial transmit: ±3.7 V</td></tr>
<tr><td>E</td><td>AGND</td><td>Analog ground</td><td>N/A</td></tr>
<tr><td>P</td><td>+PWR</td><td>Power input</td><td rowspan="2">9 V to 36 V DC isolated</td></tr>
<tr><td>N</td><td>-PWR</td><td>Power return</td></tr>
<tr><td>A</td><td>DGND</td><td>Digital ground</td><td>N/A</td></tr>
<tr><td>shell</td><td>CHASSIS</td><td>For shielding and safety</td><td>N/A</td></tr>
</table>

10.2 Seismometer Cable Pinout

A seismometer cable may be included with your Trillium Compact. A label with the part number is located on the cable. Use the appropriate pinout table for the appropriate cable as a reference when wiring the seismometer cable to a digitizer connector.

Table 10-2 provides the pinout for part number 16777–nM (where n is the length of the cable in metres), which is a cable with a Trillium Compact seismometer right-angled connector on one end and Nanometrics digitizer connector on the other end for connecting a Taurus or Trident.

Table 10-2 Seismometer cable wiring for cable 16777–nM (for Nanometrics digitizers)

Nanometrics Digitizer			Seismometer			Wire Colour	Run
Connector	**Pin**	**Name**	**Connector**	**Pin**	**Name**		
P1	U	CH1+	P2	L	Z+/W+	Brown	1
P1	C	CH1-	P2	M	Z-/W-	Black	1
P1	B	CH1 GND				DRAIN	1
P1	A	CH2+	P2	F	Y+/V+	Orange	2
P1	S	CH2-	P2	H	Y-/V-	Black	2
P1	T	CH2 GND				DRAIN	2
P1	a	CH3+	P2	B	X+/U+	Yellow	3
P1	P	CH3-	P2	C	X-/U-	Black	3
P1	R	CH3 GND				DRAIN	3
P1	N	CAL1+	P2	K	CAL_SIG	White	
P1	M	CAL2+					
P1	L	CAL3+					
P1	K	EXT_SOH1	P2	R	MAXIMUM MASS POSITION	Orange	
P1	X	EXT_SOH2					
P1	J	EXT_SOH3					
P1	B	CH1 GND	P2	E	AGND	Pink	
P1	F	SEN +12V	P2	P	+PWR	Red	4
P1	D	SEN RTN	P2	N	-PWR	Black	4
P1	b	CHGND				DRAIN	4
P1	H	CTRL1	P2	J	UVW/TX	Blue	
P1	W	CTRL2	P2	D	CALEN/SP/RX	Purple	
P1	V	DGND	P2	A	DGND	Gray	
P1		SHELL	P2		SHELL	Overall/Shield	
P1	G	CTRL3					
P1	Z	CAL1-/CTRL4					
P1	c	CAL2-/CTRL5					
P1	Y	CAL3-/CTRL6					
P1	E	SEN -12V					

Table 10-3 provides the pinout for part number 16865–nM (where n is the length of the cable in metres), which is a cable with a Trillium Compact seismometer right-angled connector on one end and open-ended at the other end for attaching the connector of a third-party digitizer.

Table 10-3 Seismometer cable wiring for cable 16865–nM (open-ended cable)

Seismometer			Digitizer			Wire Colour	Run
Connector	**Pin**	**Name**	**Connector**	**Pin**	**Name**		
P1	L	Z+/W+				Brown	1
P1	M	Z-/W-				Black	1
P1						DRAIN	1
P1	F	Y+/V+				Orange	2
P1	H	Y-/V-				Black	2
P1						DRAIN	2
P1	B	X+/U+				Yellow	3
P1	C	X-/U-				Black	3
P1						DRAIN	3
P1	K	CAL_SIG				White	
P1	R	MAXIMUM MASS POSITION				Orange	
P1	E	AGND				Pink	
P1	P	+PWR				Red	4
P1	N	-PWR				Black	4
P1						DRAIN	4
P1	J	UVW/TX				Blue	
P1	D	CALEN/SP/RX				Purple	
P1	A	DGND				Gray	
P1		SHELL				Overall/Shield	

Additionally, you may have received a cable, Nanometrics part number 16864-3M, that provides power to the Trillium Compact and enables serial communication between the seismometer and a laptop. Table 10-4 provides the pinout for this cable.

Table 10-4 Seismometer cable wiring for cable 16864–3M (serial/power cable)

Seismometer			Serial/Power Connectors			Wire Colour	Run
Connector	**Pin**	**Name**	**Connector**	**Pin**	**Name**		
P1	P	+PWR	P2		BATT	Red	
P1	N	-PWR	P2		BATT_RTN	Black	
P1	J	UVW/TX	P3	2	RX	Red	
P1	D	CALEN/SP/RX	P3	3	TX	Green	
P1	A	DGND	P3	5	DGND	Black	
P1	L	Z+/W+					
P1	M	Z-/W-					
P1	F	Y+/V+					
P1	H	Y-/V-					
P1	B	X+/U+					
P1	C	X-/U-					
P1	K	CAL_SIG					
P1	R	MAXIMUM MASS POSITION					
P1	E	AGND					

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 CALEN/SP/RX (either CALEN/RX or SP/RX, CALEN/RX is the factory default) and UVW/TX.
- Use the AGND for the return currents of the analog signals. These are CAL_SIG and MAXIMUM MASS POSITION.

AGND is connected to CHGND inside the seismometer. If AGND is connected through the cable, the case of the Trillium Compact should be isolated from earth ground to prevent a ground loop.

- 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 44.
- 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.

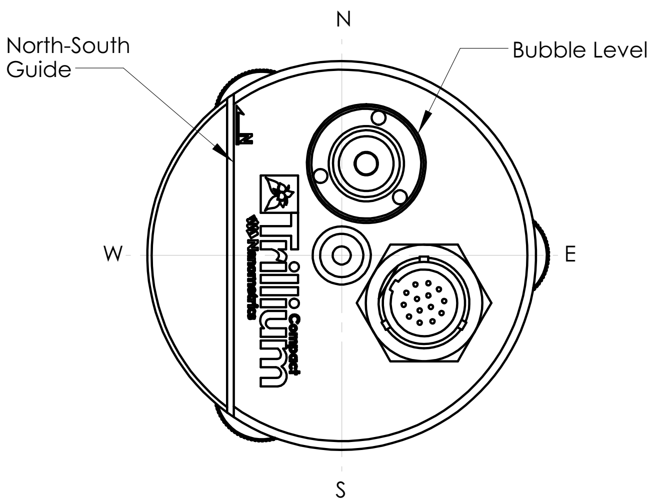
Chapter 11

Alignment Features and Dimensions

11.1 Top View of Alignment Features

Figure 11-1 is an illustration that shows the relative orientation of the north-south alignment features on a Trillium Compact seismometer.

Figure 11-1 Top view of alignment features

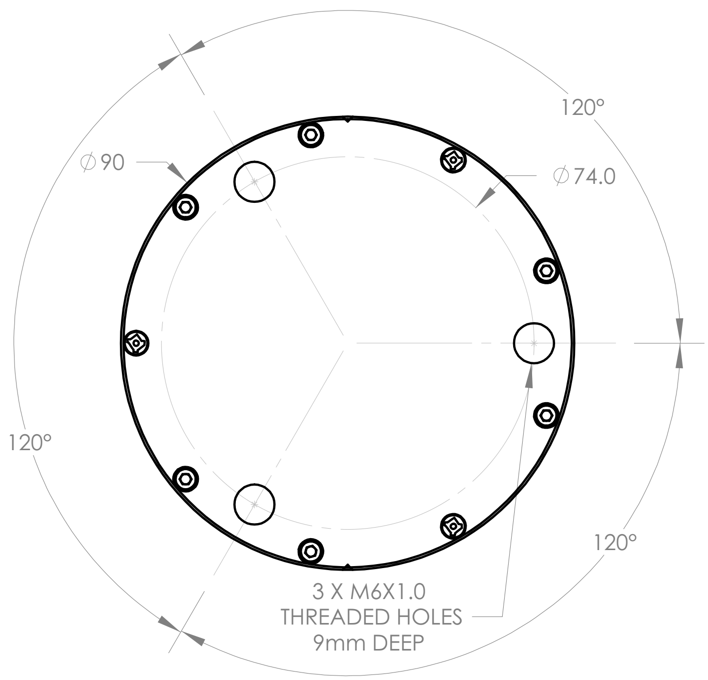


11.2 Bottom View of Alignment Features and Dimensions

Figure 11-2 is an illustration that shows the relative orientation of the north-south alignment features and dimensions for a Trillium Compact seismometer.

All dimensions are in millimetres unless otherwise stated.

Figure 11-2 Bottom view of alignment features and dimensions (feet removed)

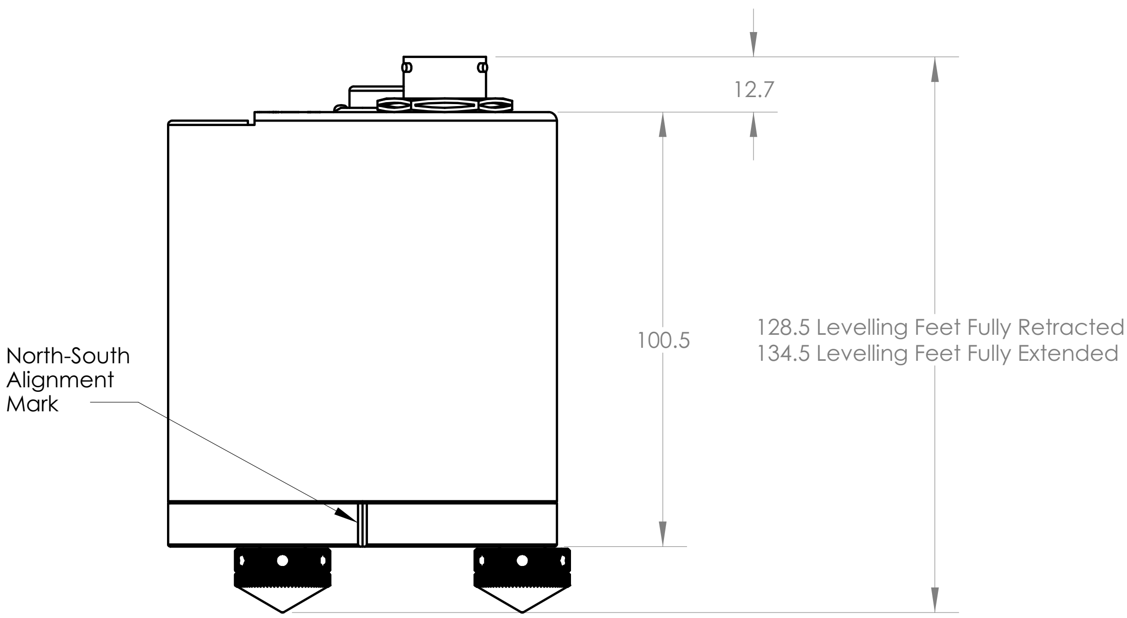


11.3 Side View of DImensions

Figure 11-3 is an illustration that shows the alignment features and dimensions of a Trillium Compact seismometer from the side.

All dimensions are in millimetres unless otherwise stated.

Figure 11-3 Side view of alignment features and dimensions



Appendix A
Glossary

A.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

RMS

Root Mean Squared

S

SLIP

Serial-Over-IP

T

TCP/IP

Transmission Control Protocol/Internet Protocol

A.2 List of Unit Abbreviations and Symbols

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

Table A-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 a world leader in the development of precision instrumentation, network technology, and software applications for seismological and environmental studies. Using Nanometrics technology, our customers establish and grow research networks that are often located in extreme environments such as the frozen Arctic and Antarctic, the arid deserts of the Middle East, the jungles of South America, and the depths of the world's oceans. Many of these are mission-critical national and regional networks that demand the highest possible data quality and availability.

Nanometrics provides end-to-end solutions that include a growing portfolio of broadband and strong motion seismometers, dataloggers and digitizers, satellite ground station systems for remote site data collection, and software applications for data and network analysis and management. To support this portfolio, Nanometrics also provides global systems engineering services for design, installation, and support of complete networks.

Our head office, research and development centre, and production facility are located in the Kanata North Business Park of Ottawa, the high-technology heart of Canada's capital region.

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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