Titan Accelerometer

User Guide

Nanometrics INC.
SEISMOLOGICAL INSTRUMENTS

Kanata, Ontario • Canada

Titan Accelerometer Accelerometer User Guide

Applies to model numbers

- TACCL-N1 (16381) Titan Accelerometer
- TACCL-V1 (17285) Titan Accelerometer, Vertical Mount
- TACCL-PH2 (18095) Titan Accelerometer, Posthole

Nanometrics Inc.
250 Herzberg Road
Kanata, Ontario, Canada K2K 2A1
Tel +1 613-592-6776
Fax +1 613-592-5929
Email sales_mkt@nanometrics.ca
www.nanometrics.ca

Part number 16921R7
Release date 2015-08-14

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 16921R7 of this document includes the following changes:

- Added information for configuring SLIP connections. See Configuring SLIP Connections on page 60.
- Updated cable information. See List of cables and accessories on page 4.
- Updated specifications to model number TACCL-PH2, Titan Posthole. See Physical specifications – model TACCL-PH2 on page 47.

This revision of the Titan Accelerometer User Guide applies to units with serial numbers 200 and above. If you have a unit with serial number 199 or below, see revision 16921R1 of the User Guide.

Contents

Tables

Figures

Part 1
Installation

- Getting Started
- Performing a Surface Installation
- Performing a Posthole Installation
- Post-Installation Activities

Chapter 1
Getting Started

1.1 About Titan Accelerometers

Titan Accelerometer is a force balance triaxial accelerometer that provides exceptional performance over a wide frequency range. The Titan is aimed at higher precision strong motion and structural monitoring applications, where scientists and engineers require exceptional dynamic range and low hysteresis.

There are three variations of the Titan Accelerometer. The Titan Accelerometer (model TACCL-N1) is the model upon which this guide is based and is intended to be installed on a horizontal surface. The Titan Accelerometer, Vertical Mount, (model TACCL-V1) and the Titan Accelerometer, Posthole (model TACCL-PH2) are intended to be installed vertically. See Appendix B "Information Specific to the Titan Vertical Mount" for features, installation instructions, and functionality specific to the Titan Accelerometer, Vertical Mount. See Appendix C "Information Specific to the Titan Posthole" for features, installation instructions, and functionality specific to the Titan Accelerometer, Posthole.

Model TACCL-N1 — The Titan Accelerometer is

- a surface accelerometer
- intended for installation on a horizontal surface
- rated to IP-67 in an aluminum enclosure

Model TACCL-V1 — The Titan Accelerometer, Vertical Mount (Titan Vertical Mount) is

- a surface accelerometer
- intended for installation on a vertical surface
- rated to IP-67 in an aluminum enclosure

Model TACCL-PH2 — The Titan Accelerometer, Posthole (Titan Posthole) is

- a posthole accelerometer
- intended for installation in a cased or uncased hole
- rated to IP-68 in a stainless steel enclosure with a waterproof shroud cable

The Titan Accelerometer is the first accelerometer to incorporate digitally selectable full-scale range and offset zeroing capabilities. These features make it ideal for a wide variety of applications where the instruments are difficult to access or where site visits need to be kept to a minimum.

The triaxial sensor and electronics are housed in a rugged, compact aluminum case that features a single bolt anchoring slot, adjustable levelling screws, and an integrated bubble level. The electronic interface eliminates the need to open the case, avoiding any risk of contaminating the mechanism. There are no jumpers to install or trimpots to adjust.

The Titan Accelerometer has an integrated Web server that is accessible using a standard Web browser and the RS-232 serial interface available on the Titan Accelerometer connector (see Chapter 8, "Using the Web Interface"). Use Serial Line Internet Protocol (SLIP) to browse into the Titan Accelerometer and perform management and configuration tasks (see Appendix A "Configuring SLIP Connections" for instructions on configuring a SLIP connection on a Microsoft Windows® XP computer). 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 Titan Accelerometer remotely, even with the unit in service.

Browsing to the Titan Accelerometer home page, users can configure the full-scale range (Z channel independently of the X and Y channels), precisely and automatically zero the offset of each channel, examine instrument state-of-health, obtain factory hardware information and the nominal sensor response, update the firmware, and store or retrieve user calibration response data.

Users can also use the control pin on the connector of the Titan Accelerometer to enable calibration, initiate automatic offset zeroing, or to perform a unit self-test.

For circumstances where a SLIP connection is not practical, a basic command-line interface using the serial RS-232 connection provides an alternative way to change the default configuration of the Titan Accelerometer (see Chapter 9, "Using the Titan Accelerometer Command-Line Interface").

1.2 Unpacking and Handling a Titan Accelerometer

The shipping box and packing for Titan accelerometers have been designed and tested to protect these accelerometers against the impact of accidental drops during hand-carrying and from vibration and shock during shipping. To maintain warranty protection, Titan accelerometers must always be transported in packaging approved by Nanometrics. Save the original packaging and reuse it any time you are transporting a Titan Accelerometer. If custom packaging is required for a particular application, please consult Nanometrics (see Contacting Nanometrics on page 71).

After delivering a Titan Accelerometer 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.

1.3 Cables and Accessories

Table 1-1 lists cables and accessories for the Titan Accelerometer that can be purchased separately.

Table 1-1 List of cables and accessories

Name	Part Number	Description
Models TACCL-N1 (16381) and TACCL-V1 (17285)		
Cable, Titan Accelerometer 14-Pin Straight to Nanometrics digitizer	16774–nM (*n* is the length of cable in metres)	Double-shielded, ultra-flexible cable with Titan accelerometer straight connector on one end and Nanometrics digitizer connector on the other end for connecting a Nanometrics digitizer. Custom cable lengths are available upon request.
Cable, Titan Accelerometer 14-Pin Straight to Open-end	16845–nM (*n* is the length of cable in metres)	Double-shielded, ultra-flexible cable with Titan accelerometer straight connector on one end and open-ended at the other end for attaching the connector of a third-party digitizer. Custom cable lengths are available upon request.
Cable, Titan Accelerometer to third party digitizer	Contact Nanometrics	Double-shielded, ultra-flexible cable with Titan accelerometer straight 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 71) for a full listing of cables with connectors to third party digitizers.
Cable, 14-Pin Straight to Serial/Power, Molded	16978–2M	Cable to provide power to the Titan accelerometer and enable serial communications between the Titan Accelerometer and a laptop. Standard cable length is 2 m. Custom cable lengths are available upon request.

Table 1-1 List of cables and accessories

Models TACCL-PH2 (17784)		
Cable, Posthole Seismometer, Trillium Compact/Titan to Nanometrics Digitizer, PU Jacket	17768-xxM (*xx* is the length of cable in metres)	A cable that connects the Titan Accelerometer, Posthole to a Nanometrics digitizer. This cable has a rugged polyurethane jacket suitable for direct burial to depths of 300 m.
Cable, Posthole Seismometer, Trillium Compact/Titan to Open Ended, PU Jacket	18005-xxM (*xx* is the length of cable in metres)	A cable with a glass reinforced epoxy connector on one end that connects to the Titan Accelerometer, Posthole connector and is open-ended at the other end. This cable has a rugged polyurethane jacket suitable for direct burial to depths of 300 m.
Cable, Posthole, Seismometer, Trillium Compact/Titan to Third Party digitizer	Contact Nanometrics	A cable with a glass reinforced epoxy connector on one end that connects to the Titan Accelerometer, Posthole connector, and the connector for a common thirdparty digitizer, such as a Q330 or REFTEK D130, on the other end. Contact Nanometrics (see Contacting Nanometrics on page 71) for a full listing of cables with connectors to third party digitizers
Models TACCL-V1 (17285) and TACCL-PH2 (17784)		
Bubble Level	MSC0225	For applications where precise levelling is required, the bubble level is placed on top of the accelerometer during installation.

1.4 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 photographs of the site and the 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 71) to obtain an RMA number.

The Titan Accelerometer mechanical and electronic elements have been designed to be robust and reliable to ensure that 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.

1.4.1 Recording Your Serial Number and IP Address

Before installing your Titan Accelerometer, 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, at the end opposite of the connector.

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 its Web interface. See Chapter 8 "Using the 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 7.3 "Calculating the IP Address" on page 33 for instructions.

1.5 Performing the Initial Configuration Before Deployment

Each Titan Accelerometer has a default factory configuration that addresses the most common use cases. This means that most units will require minimal pre-installation configuration. Before deploying any Titan Accelerometer units in the field, you should ensure that the units are configured to meet your needs. Table 1-2 provides the default configuration settings and references to sections in this guide that provide instructions for changing these settings.

Table 1-2 Titan Accelerometer default factory configuration

Parameter	Default setting	Reference sections of this guide
Full-scale range	4 *g* on horizontal and vertical channels	Section 8.6 "Mode" on page 37 in Chapter 8 "Using the Web Interface" -OR- Section 9.3 "Using the Titan Accelerometer Command-Line Interface" on page 41
Control line	All functions enabled ◆ (HOLD) Calibration Enable / (PULSE) Self-test + Auto-zero	Section 8.7 "Control Lines" on page 37 in Chapter 8 "Using the Web Interface" -OR- Section 9.3 "Using the Titan Accelerometer Command-Line Interface" on page 41

It is recommended that if configuration changes are required, that these changes be done in batches, before the units are deployed in the field.

Chapter 2

Performing a Surface Installation

The contents of this chapter are applicable to the Titan Accelerometer (model TA) and the Titan Vertical Mount (model TA-VM).

2.1 Evaluating the Installation Site

When deciding where to install a Titan accelerometer, it is important to understand the expected range of motion at the site and to evaluate the available installation surfaces.

To achieve accurate measurements, Titan accelerometers installed at sites that are expected to experience motion greater than 0.1 *g* should be anchored to a hard, unyielding surface, such as concrete, masonry, or metal. Anchoring the unit to the installation surface is required because motion of 0.1 *g* or more could cause an unsecured Titan Accelerometer to shift and produce inaccurate measurements. Titan accelerometers are shipped with the necessary hardware to secure the units to concrete, masonry, or metal surfaces (see also, Section 2.3 "Secure Installations" on page 8).

At sites where less than 0.1 g of motion is expected, a Titan Accelerometer can be placed unsecured on the installation surface (see also, Section 2.4 "Freestanding Installations" on page 12). For all installations, regardless of the expected ground motion, the installation surface should be flat, level, and free of debris and obstacles.

Also important when selecting an installation site is to consider how the units will be oriented. Options include orienting the accelerometer with the directions of the compass (north-south or east-west), or aligning it with the primary axis of the structure where it is being installed. See Section 2.2 "Orientation, Placement, and Levelling Features" on page 7 and Figure 13-1 "Front view of Titan Accelerometer features and dimensions" on page 55 for information on the orientation features of the Titan Accelerometer.

2.2 Orientation, Placement, and Levelling Features

Titan accelerometers have several features that aid in the orientation, secure placement, and levelling of the units during installation. Chapter 13 "Physical Features and Dimensions" provides illustrations that show these features in front, back, side, and bottom views.

a) Orientation

To aid in the proper orientation of your accelerometer, each Titan Accelerometer has X (east), Y (north), and Z (vertical) directional arrows on the base and corresponding guidelines on the top of the case. Use these guides to orient the unit with directional lines placed on the installation surface. The long straight sides of the base can be used with a straightedge to align in the Y direction.

Titan accelerometers are factory configured to provide near zero readings when installed level on a horizontal surface. Changing the orientation of the unit will offset these readings.

b) Placement

To securely place your accelerometer on the installation surface, each Titan Accelerometer has a mounting slot in the back of the unit. The Titan Accelerometer slides over the head of a bolt or a nut set into the installation surface (see also, Section 2.3 "Secure Installations" on page 8).

c) Levelling

For levelling purposes, each Titan accelerometer is equipped with:

- Three adjustable-height locking screws.
- A levelling bubble on the cover.

It is easy to test that the unit is reading acceleration properly before installation. Simply connect it to a digitizer or access its Web interface through a serial connection (see Chapter 8, "Using the Web Interface") and observe the changes in the readings as you tilt it about the X, Y, and Z axes.

2.3 Secure Installations

If the installation site is expected to experience ground motion that exceeds 0.1 *g*, the Titan Accelerometer should be secured to the installation surface. Securing the Titan Accelerometer to the surface will prevent the unit from shifting, which can cause inaccurate measurements.

Titan accelerometers ship with the necessary hardware to secure the units to concrete, masonry, or metal surfaces. For a list of the tools and hardware required to secure a Titan Accelerometer to the installation surface, see Section 2.3.1 "What You Need to Secure a Titan Accelerometer to the Installation Surface" on page 9.

For instructions on how to attach a Titan Accelerometer to the installation surface, and to properly level, orient, and secure it to that surface, continue with

- Section 2.3.2 "Preparing the Installation Surface" on page 10
- Section 2.3.3 "Attaching the Titan Accelerometer to the Installation Surface" on page 10
- Section 2.3.4 "Orienting, Levelling, and Securing the Titan Accelerometer" on page 12

2.3.1 What You Need to Secure a Titan Accelerometer to the Installation Surface

You will need the following to properly orient, securely mount, and level a Titan Accelerometer on a concrete, masonry, or steel surface:

Table 2-1 Tools needed to secure a Titan Accelerometer to the installation surface

Item	Supplied by	Notes
Compass	Installer	If orienting the Titan Accelerometer to north-south or east-west
Drawing tools	Installer	To mark the installation surface
Drill and bit	Installer	To drill hole in installation surface
Hardware (anchor or bolt)	Nanometrics (included in Titan Accelerometer installation kit)	Concrete or masonry surface (only one anchor or bolt is required, two options are provided) ◆ One 1/4 in. threaded (1/4-20) masonry wedge expansion anchor stud with a 7/32 in. high nut (see note below) ◆ One 5/16 in. masonry sleeve anchor bolt with 11/64 in. head height (see note below) Metal surface ◆ One M6x25 hex bolt with M6 hex nut Alternatively you can use a 1/4-20 bolt (not included) and the 7/32 in. high 1/4-20 nut included with the anchor stud.
3 mm hex screwdriver	Nanometrics (included in Titan Accelerometer installation kit)	For locking the levelling screws
Adjustable wrench or 10 mm wrench	Installer	For locking the levelling screws

Washers with the 1/4 in. threaded (1/4-20) masonry wedge expansion anchor stud and the 5/16 in. masonry sleeve anchor bolt are not required and can be discarded. The blue sleeve included with the 5/16 in. masonry sleeve anchor bolt can also be discarded.

2.3.2 Preparing the Installation Surface

Perform the following steps to prepare the installation surface for installing and orienting the Titan Accelerometer:

1. Select an installation location that is flat and level and ensure that it is clean and free of obstacles.
2. Determine the desired orientation of the Titan Accelerometer, such as aligned with true north or in line with the primary axis of the structure.
3. If using a directional orientation, use the compass and drawing tools to draw a line on the concrete parallel to the selected orientation direction. If you are using a magnetic compass, account for the local magnetic declination when drawing the line.

   -OR-

   If aligning the Titan Accelerometer along the primary axis of the structure, draw a line parallel to this axis.
4. Indicate the drilling location by marking the desired location on the orientation line. When adding this mark, ensure there is a radius of 20 cm around it that is free of obstacles and debris. The mark represents the centre point of the Titan Accelerometer and is the location where the anchor or bolt that will hold the Titan Accelerometer in place will be set into the surface.

2.3.3 Attaching the Titan Accelerometer to the Installation Surface

Perform the following steps to set the anchor or bolt into the installation surface and attach the Titan Accelerometer to it.

1. Select the anchor or bolt you will use to attach the Titan Accelerometer to the installation surface. Table 2-1 "Tools needed to secure a Titan Accelerometer to the installation surface" on page 9 identifies the hardware that ships with each Titan Accelerometer.
2. Drill a hole at the drilling location marked on the installation surface (see step 4 in Section 2.3.2 "Preparing the Installation Surface" on page 10). Use an appropriate drill bit for the surface type and the selected anchor or bolt.

Table 2-2 Suggested drilling guidelines for hardware supplied by Nanometrics

Hardware	Surface Type	Drill Bit	Hole Depth
1/4 in. threaded (1/4-20) masonry wedge expansion anchor stud	Concrete or masonry	1/4 in. concrete drill bit	50 mm (2 in.) (see Figure 2-1)
5/16 in. masonry sleeve anchor bolt	Concrete or masonry	5/16 in. concrete drill bit	40 mm (1.5 in) (see Figure 2-1)
M6x25 hex bolt	Metal (tapped)	Drill and tap for M6 thread	20 mm drilled and tapped for M6 thread (see Figure 2-2)
M6x25 hex bolt	Metal (through hole)	6.5 mm or as desired for M6 clearance hole	Through hole (see Figure 2-2)

Figure 2-1 Stud and bolt anchors set in a concrete or masonry surface

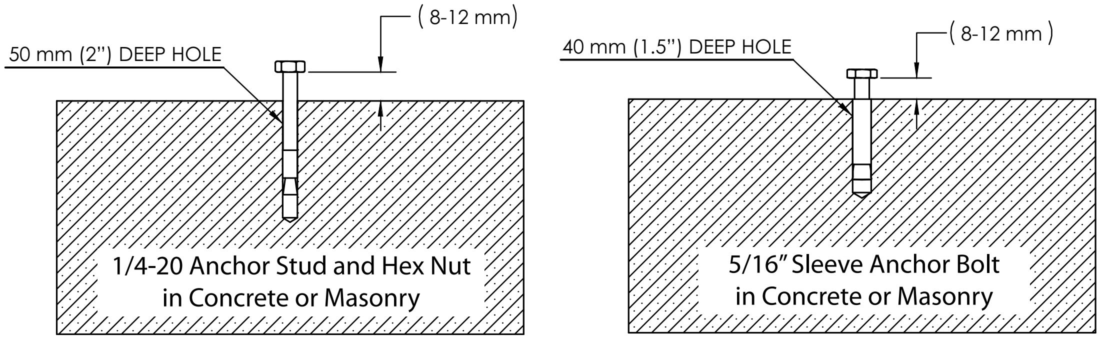
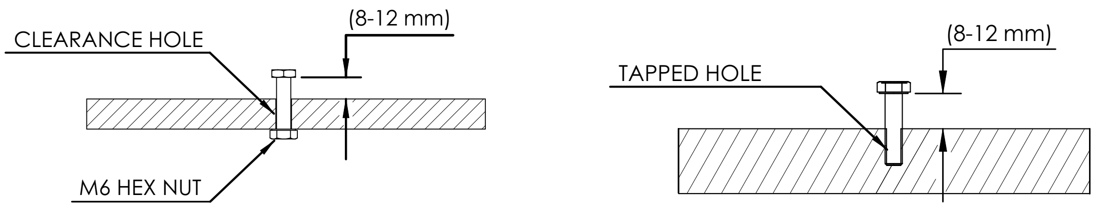


Figure 2-2 M6x25 bolt set in clearance and tapped holes of metal surface



3. Important: clear all debris from the hole.
4. Insert the selected anchor or bolt into the hole. Ensure that the head of the anchor or bolt is 8 mm to 12 mm above the surface.

For the 1/4-20 anchor stud and hex nut in concrete or masonry

- Thread the nut onto the bolt so it is flush with the top of the bolt.

For the 5/16 in. sleeve anchor bolt in concrete or masonry

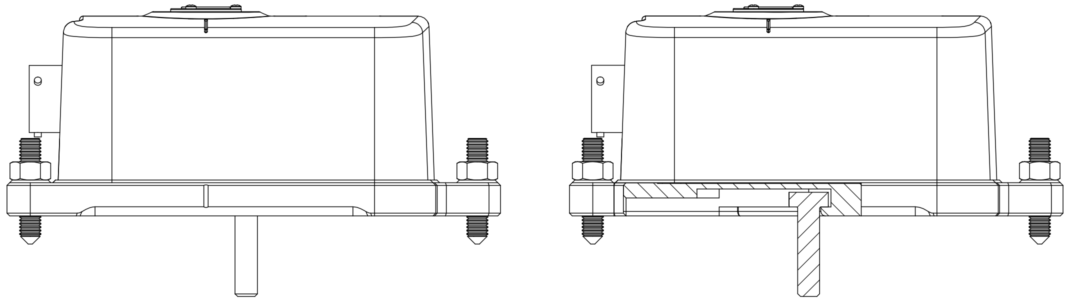
- Ensure that the sleeve of the anchor bolt is flush with the installation surface.

See Figure 2-1 "Stud and bolt anchors set in a concrete or masonry surface" on page 11.

5. Using the guide in the bottom of the Titan Accelerometer, fit the Titan Accelerometer over the head of the anchor or bolt.

   Figure 2-3 illustrates how the slot in the back of the Titan Accelerometer fits over the head of the anchor or bolt set into the installation surface. For a full view of the back of the Titan Accelerometer, see Figure 13-2 "Back view of Titan Accelerometer features and dimensions" on page 55.

Figure 2-3 Example of Titan Accelerometer fitted over the head of an anchor or bolt



2.3.4 Orienting, Levelling, and Securing the Titan Accelerometer

Perform the following steps to orient and level the Titan Accelerometer, and to secure it to the installation surface.

1. To orient the Titan Accelerometer, turn it so that its Y directional marker is aligned with the line drawn on the installation surface. See step 3 in Section 2.3.2 "Preparing the Installation Surface."
2. Adjust the levelling screws until
   a) The levelling bubble is in the centre of the black ring.
   b) The levelling screws are extended to the maximum extent permitted by the anchor or bolt. As the levelling screws are turned into the surface, the Titan Accelerometer is lifted away from it, creating a secure connection between the Titan Accelerometer and the head of the anchor or bolt.

For installations on concrete or masonry surfaces, over-tightening the levelling screws may pull the anchor or bolt out of the installation surface.

3. Lock each of the levelling screws by inserting the 3 mm hex screwdriver into the screw to stop it from rotating and using a wrench to firmly tighten the lock nut.
4. Ensure that the levelling bubble is still indicating that the unit is level. If the unit is not level, level it again.

2.4 Freestanding Installations

If the installation site is expected to experience ground motion of less than 0.1 *g* the Titan Accelerometer can be placed unsecured on the installation surface. As with all Titan Accelerometer installations, the installation surface must be as flat and level as possible and the levelling screws and levelling bubble on the Titan Accelerometer will be used to accurately level the unit. For detailed instructions, see Section 2.4.2 "Installation Instructions for Freestanding Installations" on page 13.

2.4.1 What You Need for a Freestanding Installation

To properly orient and level a Titan Accelerometer in a freestanding installation you will need the following:

Table 2-3 Tools needed for a freestanding Titan Accelerometer installation

Item	Supplied by	Notes
Compass	Installer	To orient the Titan Accelerometer to north-south or east-west
Drawing tools	Installer	To mark the installation surface
3 mm hex screwdriver	Nanometrics (included in Titan Accelerometer installation kit)	For tightening the levelling screws
Adjustable wrench or 10 mm wrench	Installer	For tightening the levelling screws

2.4.2 Installation Instructions for Freestanding Installations

Perform the following steps to properly orient and level a Titan Accelerometer in a freestanding installation:

1. Select an installation location that is flat and level and ensure that it is clean and free of obstacles.

   When selecting your installation location, ensure there is a radius of 20 cm around the intended centre point of the Titan Accelerometer that is free of obstacles.

2. Determine the desired orientation of the Titan Accelerometer, either directional or in line with the primary axis of the structure.
3. If using a directional orientation, use the compass and drawing tools to draw a line on the surface parallel to the selected orientation direction. If you are using a magnetic compass, account for the local magnetic declination when drawing the line.

   -OR-

   If aligning the Titan Accelerometer along the primary axis of the structure, draw a line parallel to this axis.
4. Place the Titan Accelerometer in the desired location on the line drawn on the surface.
5. Adjust the levelling feet until the levelling bubble is in the centre of the black ring.
6. Lock the levelling screws so the unit remains level by inserting the 3 mm hex screwdriver into one of the screws to stop it from rotating and using a wrench to firmly tighten the lock nut.
7. Repeat the above step for the remaining two levelling screws.
8. Ensure that the levelling bubble is still indicating that the unit is level. If the unit is not level, level it again.

2.5 Thermal Insulation

A Titan accelerometer that is not thermally insulated will produce reasonably good data if it is installed in a thermally stable, draft-free environment. However, to obtain the best performance with the lowest possible noise, especially when recording weak motion, the Titan Accelerometer should be thermally insulated. The best method is to make a freestanding cover out of rigid foam insulation that is sealed against air drafts, does not touch the accelerometer, and minimizes the volume of air trapped between the insulating box and the accelerometer (see also Section 2.5.1).

2.5.1 Insulating a Titan Accelerometer with a Rigid Foam Box

Use the following recommendations as a guide when constructing a thermal insulating box for your Titan Accelerometer:

When installing a Titan Accelerometer in a rigid foam insulating box, follow the best practices for levelling the accelerometer that are outlined in the installation instructions for your type of installation.

- Construct a five-sided box that is large enough to house the accelerometer without touching the sides of the accelerometer 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 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 installation surface. Adhesive weatherstripping that is 1.25cm (0.5 in.) thick creates a good seal.
- Ensure the thermal insulating 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 accelerometer. Tie-wraps with tie-wrap anchors or a heavy object are effective tools for achieving strain relief.

2.6 Installation Checklist

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

- ❑ Installation surface is clear of debris
- ❑ Titan Accelerometer Y direction is aligned to true north (accounting for the magnetic declination), or with the primary axis of the structure
- ❑ Titan Accelerometer is level
- ❑ Levelling screws are extended and tensioned against the anchor bolt
- ❑ Levelling screws are locked
- ❑ Serial number and IP address are noted
- ❑ Cable is connected to the Titan Accelerometer and the digitizer
- ❑ Cable is strain-relieved to the installation surface
- ❑ Cable is not touching the Titan Accelerometer case
- ❑ If used, thermal insulation is in place
- ❑ If used, thermal insulation is not touching the Titan Accelerometer or cables
- ❑ If used, thermal insulation is securely fastened to the installation surface
- ❑ X, Y, and Z channels are zeroed using the auto-zero function, if desired

Chapter 3

Performing a Posthole Installation

The contents of this chapter are applicable to the Titan Posthole (model TACCL-PH2).

3.1 Installing a Titan Posthole

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

1. Prepare the hole for the installation.

   Regardless of whether the hole is uncased or cased, ensure that the bottom of the hole is sufficiently level for your application. For best results, the accelerometer should be as level as possible. For deep holes, this may require the use of self-levelling cement or other methods.

   - 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 accelerometer, which has a diameter of 97 mm. The minimum hole depth will allow the accelerometer 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 accelerometer, which has a diameter of 97 mm.

     A cased hole must be covered at the top to protect the accelerometer 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 accelerometer.

2. Connect the cable to the accelerometer and digitizer.

   Nanometrics cable 17768-nM (where *n* is the length of the cable in metres) can be used to connect a Titan Posthole to a Nanometrics digitizer. Alternatively, if you are connecting your Titan Posthole to a third-party digitizer, contact Nanometrics to inquire about the availability of a cable for a specific digitizer (see Contacting Nanometrics on page 71), or use cable 18005-nM (where *n* is the length of the cable in metres), which is open-ended at the digitizer end, allowing you to attach the connector of your digitizer.

   See Chapter 6, "Configuring Your System" for information on configuring your Nanometrics digitizer for a Titan Posthole and also refer to the digitizer manual.

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

> The recommended practices for aligning a Titan Posthole vary based on the depth of the hole where the unit is installed.
>
> (1) For recommendations on aligning a Titan Posthole in a shallow hole of 2 m or less, see 3.2.1 "Using a Surface Line" on page 17.
>
> (2) For recommendations on aligning a Titan Posthole in a deeper hole, see 3.2.2 "Using a Surface Accelerometer" on page 18.

4. Level and stabilize the accelerometer using an appropriate technique to ensure that it is solidly coupled to the surrounding substrate and will not shift or move.
5. Power the accelerometer.
6. Verify a level installation by checking that the seismic outputs are 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. Recheck the seismic outputs to verify that the unit is undisturbed.

3.2 Aligning a Titan Posthole

There are two typical methods for aligning a Titan Posthole. The method used is usually determined by the depth of the hole where the accelerometer is installed.

For shallow holes,

- Align the north-south guide on the top of the Titan Posthole to a surface line. See Section 3.2.1 for details.

For deeper holes,

- Correlate the output of the accelerometer with that of a temporarily installed surface-based accelerometer that is aligned to true north or with the structure being monitored in order to calculate their relative orientation. See Section 3.2.2 for details.

3.2.1 Using a Surface Line

The surface line method of aligning a Titan Posthole can only be used in shallow holes (usually 2 m or less) where the top of the accelerometer is visible and it can be turned by hand after being lowered into the hole.

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

To use a surface line to align a Titan Posthole to north or to align it with the primary axis of a structure being monitored

1. Place a ruler or stake a line across the hole that is aligned to true north, if using a directional orientation; or align the line with the primary axis of the structure being monitored, if aligning to a physical structure.

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

3.2.2 Using a Surface Accelerometer

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

When you install the reference accelerometer on the surface, ensure that you align it carefully in a known orientation. After both accelerometers have been installed, configure each instrument to 0.25 *g* mode and 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.

To avoid clipping in 0.25 *g* mode, the Titan Posthole must be no more than ±14° from vertical.

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 71) for more information on using this method of alignment.

3.3 Titan Posthole Orientation

To aid in the proper orientation of your accelerometer, the Titan Posthole has X, Y, and Z directional arrows and guidelines on the top of the case. See Section C.4 “XYZ Output Signals” on page 67 for information on how to use these markers.

Titan accelerometers are factory configured to provide near zero readings when installed level on a horizontal surface. Changing the orientation of the unit will offset these readings.

Chapter 4

Post-Installation Activities

4.1 Connecting the Digitizer

See Chapter 6, "Configuring Your System" for information on configuring your Nanometrics digitizer for a Titan Accelerometer and also refer to the digitizer manual. See also Chapter 8, "Using the Web Interface" for information on using the SLIP connection and the Titan Accelerometer Web interface and Chapter 9, "Using the Titan Accelerometer Command-Line Interface" for information on using the command-line interface.

4.2 Grounding the Digitizer and Titan Accelerometer

The digitizer and accelerometer cases must have a low-resistance path to ground for safety. However, directly earthing both instruments will result in a ground loop. Where it is possible to leave the accelerometer isolated from earth ground, it is preferred to make the earth connection at the digitizer. However in some applications it may be inevitable that the accelerometer be grounded, so in these situations an effort should be made to isolate the digitizer. For more details on earthing the digitizer and accelerometer, refer to the user guide for your digitizer.

4.3 Allowing the Titan Accelerometer to Settle

For most applications it is not necessary to wait for Titan accelerometers to settle after installation. However, for the most accurate readings, allow the unit to settle for one hour before auto-zeroing (see also Section 4.4).

4.4 Auto-Zeroing the Titan Accelerometer

Titan accelerometers are factory configured to provide near zero readings on the X, Y, and Z channels when installed level on a horizontal surface. The Z channel is designed with a built in offset of 1 *g* to compensate for earth's gravity. Different temperatures or small variations in tilt may cause the average or DC channel outputs to have an offset from zero. Initiating the auto-zeroing function of the Titan Accelerometer automatically measures and then compensates for DC offsets, resulting in near-zero DC levels on all channels. This fixed offset removal is permanently stored in the Titan Accelerometer, and is changed only when auto-zeroing is initiated again. Offsets may be subsequently introduced if the unit is moved, reinstalled, if its ambient temperature has changed, or if its full-scale range has been changed, creating the need to auto-zero again.

Auto-zeroing allows you to remove small offsets. See Table 10-2 "Performance specifications – all models" on page 44 for the effective range of the trimming circuit. The Titan Accelerometer should be installed, levelled, and not subject to significant motion when auto-zeroing is performed. After auto-zeroing the channels, the acceleration readings for each channel should be near zero.

You can use a digitizer or the Titan Accelerometer Web interface to initiate auto-zeroing. If you are using a digitizer, refer to Section 5.2 "Digital Control Input Signal" on page 23 for information on the digital input signal and control line used for enabling and initiating auto-zeroing. Also refer to the digitizer user guide for instruction on how to set the control lines. If you are using the Titan Accelerometer Web interface, see Chapter 8, "Using the Web Interface" for instruction on setting up the Serial Line Internet Protocol (SLIP) connection and Section 8.5 "Offset Trimming" on page 36 for instruction on how to perform auto-zeroing through the Web interface.

4.5 Troubleshooting Your Installation

Table 4-1 lists common types of noise that may occur with a Titan accelerometer and reasons why the noise may be present.

Table 4-1 Types of noise and possible causes

Noise Type	Possible Cause
Spikes on horizontal channels	◆ The feet of the Titan Accelerometer are not locked or properly tensioned against the anchor bolt. ◆ There is a force pulling on the cable. ◆ There is something touching the sides of the Titan Accelerometer.
Continuous low frequency drift (random or periodic)	◆ The Titan Accelerometer is exposed to air drafts or large temperature changes. Install an insulating cover over the unit.
Spikes on all channels simultaneously	◆ 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.
Drift on startup	◆ A small amount of drift is normal as the Titan Accelerometer is coming to equilibrium temperature. It should stabilize within 1 hour.

4.6 Site Record

Use the following table to record information about the installation and site. This information will be helpful in identifying changes to the site over time.

Table 4-2 Record of installation details

Site name (full name / station code / network code, for example, Yellowknife / YKN / CN):	**Latitude:**
	Longitude:
	Elevation:
	Date of installation (mm/dd/yyyy):
Description of installation site (for example, name of building, location of Titan Accelerometer within building, depth of hole, other):	**Length of installation:** Permanent or temporary: If temporary, expected time frame (mm/dd/yyyy to mm/dd/yyyy):
Installation surface type (for example, concrete floor, steel beam, buried (include type of strata) other):	**Titan Accelerometer orientation:** Orientation of X arrow ____________ Orientation of Y arrow ____________ Orientation of vertical (Z) ____________
Is the Titan Accelerometer secured to this surface? Yes / No	**Expected range of motion at the site:** ________ *g* to ________ *g*
Notes:	

Part 2

Operation

- Input and Output Signals
- Configuring Your System
- Setting Up Serial Port Communications
- Using the Web Interface
- Using the Titan Accelerometer Command-Line Interface

Chapter 5

Input and Output Signals

5.1 XYZ Output Signals

To account for the source impedance, see Table 10-2 "Performance specifications – all models" on page 44.

See Table 5-1 for the polarities of the X, Y, and Z outputs and the correspondence of each to the directions of the compass. The X, Y, and Z outputs are differential signals with a 40 V peak-to-peak range.

You can use the Web interface or command-line interface of the Titan Accelerometer to select the full-scale range of the output signal (see Section 8.1 "About the Web Interface" on page 34 or Section 9.3 "Using the Titan Accelerometer Command-Line Interface" on page 41). The available options are ±4 *g* (factory default), ±2 *g*, ±1 *g*, ±0.5 *g*, and ±0.25 *g*. The Z (vertical) axis range can be set independently of the X and Y (horizontal) axis range setting.

Table 5-1 Axis orientation and polarity of XYZ outputs

Axis	Orientation	Positive Voltage
X	east-west	represents case motion to the east (direction of X arrow)
Y	north-south	represents case motion to the north (direction of Y arrow)
Z	vertical	represents upward case motion (direction of Z arrow)

5.2 Digital Control Input Signal

The Titan accelerometer has one digital control input signal, CTRL, which is pin D on the connector. The CTRL signal is a multi-purpose control line that can be configured to do some or all of enabling calibration, initiating auto-zeroing, and enabling self-test. See Section 8.7 "Control Lines" on page 37 or Section 9.3 "Using the Titan Accelerometer Command-Line Interface" on page 41 for details.

The input is optically isolated from the input voltage, the output signals, and the calibration input signals. Therefore, signals applied to this pin must be referenced to DGND rather than ±PWR or AGND (see Section 12.1 "Connector Pinouts" on page 51).

The control input signal is an active-high signal. 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. The input can tolerate at least ±15V. The control line is shared with the serial RS-232 port (see Section 5.3). It is recommended that you use +12 V to activate the control line 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 Titan Accelerometer automatically senses when valid serial communication on the RX line is being received, and turns on the TX line to transmit. The RX signal shares pin D on the connector with the CTRL control input. When serial communications are occurring on the RX line, the control line signal (CTRL) that shares this pin is not effective. For more details, see Section 5.2 "Digital Control Input Signal" on page 23 and Section 12.1 "Connector Pinouts" on page 51.

The Titan Accelerometer features two styles of user interface using the serial communications port: a full-featured Web interface and a basic command-line interface. For more information on these interfaces, see Chapter 7, "Setting Up Serial Port Communications", Chapter 8, "Using the Web Interface", and Chapter 9 "Using the Titan Accelerometer Command-Line Interface."

5.4 Calibration Input Signal

A calibration input signal is provided to allow for relative calibration of the Titan Accelerometer transfer function. All of the axes use a common calibration input signal, CAL_SIG, as indicated in Section 12.1 "Connector Pinouts" on page 51. The calibration input sensitivity is given in Section 11.1 "Sensitivities" on page 48.

Measuring the output amplitude and phase of the Titan Accelerometer in response to calibration signals at various frequencies allows the nominal transfer function, given in Section 11.2 "Frequency Response" on page 48, to be verified, or more precisely determined, for individual units.

5.5 Status Output Signal

The status output signal indicates the operational status of the Titan Accelerometer. If the signal is high, the unit is operating normally and is able to measure seismic signals. The status output is set to low to indicate one of the following conditions:

- the unit is powering up or rebooting
- the firmware is rebooting or being updated
- the unit is performing auto-zeroing or trim circuit calibration
- calibration is enabled
- the unit is performing a self-test
- the unit has failed a self-test, auto-zero operation, or trim circuit calibration

The status output being low does not indicate the unit is defective or non-operational, but that it is in a state in which it may not produce reliable seismic output signals. Some of these states are transition states that automatically clear, such as when the Titan Accelerometer is powering up, performing a self-test, or auto-zeroing. The status output is set low when calibration is enabled to indicate the possibility that non-seismic signals may be induced by the calibration input. Auto-zeroing or trim circuit calibration may fail if the Titan Accelerometer is not sufficiently level or subject to seismic or calibration signals.

If the status output is persistently low, perform the following, in order, until the signal remains high:

- Ensure calibration is not enabled
- Re-initiate auto-zeroing
- Perform a self-test
- Reboot the Titan Accelerometer firmware
- Power cycle the Titan Accelerometer

Test results are cleared on reboot or power cycle. If the self-test repeatedly fails even with the Titan level, consult Nanometrics technical support.

5.6 Power Consumption

Following are power consumption scenarios typical of Titan accelerometers:

- Under normal operation (the Titan Accelerometer is level, there is a low seismic signal, the Titan Accelerometer has settled for at least 30 minutes, and the RS-232 serial port is not transmitting), power consumption is approximately 1.1 W.
- When experiencing acceleration exceeding clip level on all three channels, the Titan Accelerometer may draw up to 3.2 W.

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

Chapter 6
Configuring Your System

6.1 Choosing the System Clip Level

A seismic monitoring system must be configured so that it will not clip for the largest magnitude events expected.

Figure 6-1 "Titan Accelerometer systems and typical events" on page 27 shows typical event magnitudes plotted against the available system clip levels and Titan Accelerometer noise floors and the low- and high-noise models (NLNM and NHNM) of Peterson[1].

Event magnitudes are taken from Clinton and Heaton[2] who constructed them from octave bandpassed records of tens of events in each magnitude-epicentral distance category. After filtering, the geometric means of the absolute maxima for all records of each event type were computed. The exception is the curve labelled **M7+ max at 10 km**, which was constructed from the maxima rather than the means of all of the absolute maxima.

Titan Accelerometer self-noise and low-noise model power spectral densities were converted to equivalent peak motion using an octave bandwidth and a crest factor of 3, allowing for direct comparisons to event amplitudes and system clip levels. System clip levels have been reduced by a factor of 2 for comparison to event magnitudes to account for the fact that the event magnitudes were generated from octave-bandpassed data, as per Clinton and Heaton[3]. Figure 6-1 "Titan Accelerometer systems and typical events" on page 27, therefore, yields dynamic range estimates for a crest factor of 6.

Assuming there are no local ground motion amplification effects, it is clear that a system with a 2 *g* clip level is "unlikely to clip in the event of most conceivable Earth motions."[4] Furthermore, there are many regions of the earth where even an M7.5 event is unlikely to ever occur in a reasonable time frame, say 1000 years.

Figure 6-1 "Titan Accelerometer systems and typical events" on page 27 shows that the system noise floor can be made lower, and more small events detected, if the clip level is not set higher than necessary. Therefore, it is recommended that the system clip level be set no higher than the largest expected event at the site where it is to be installed.

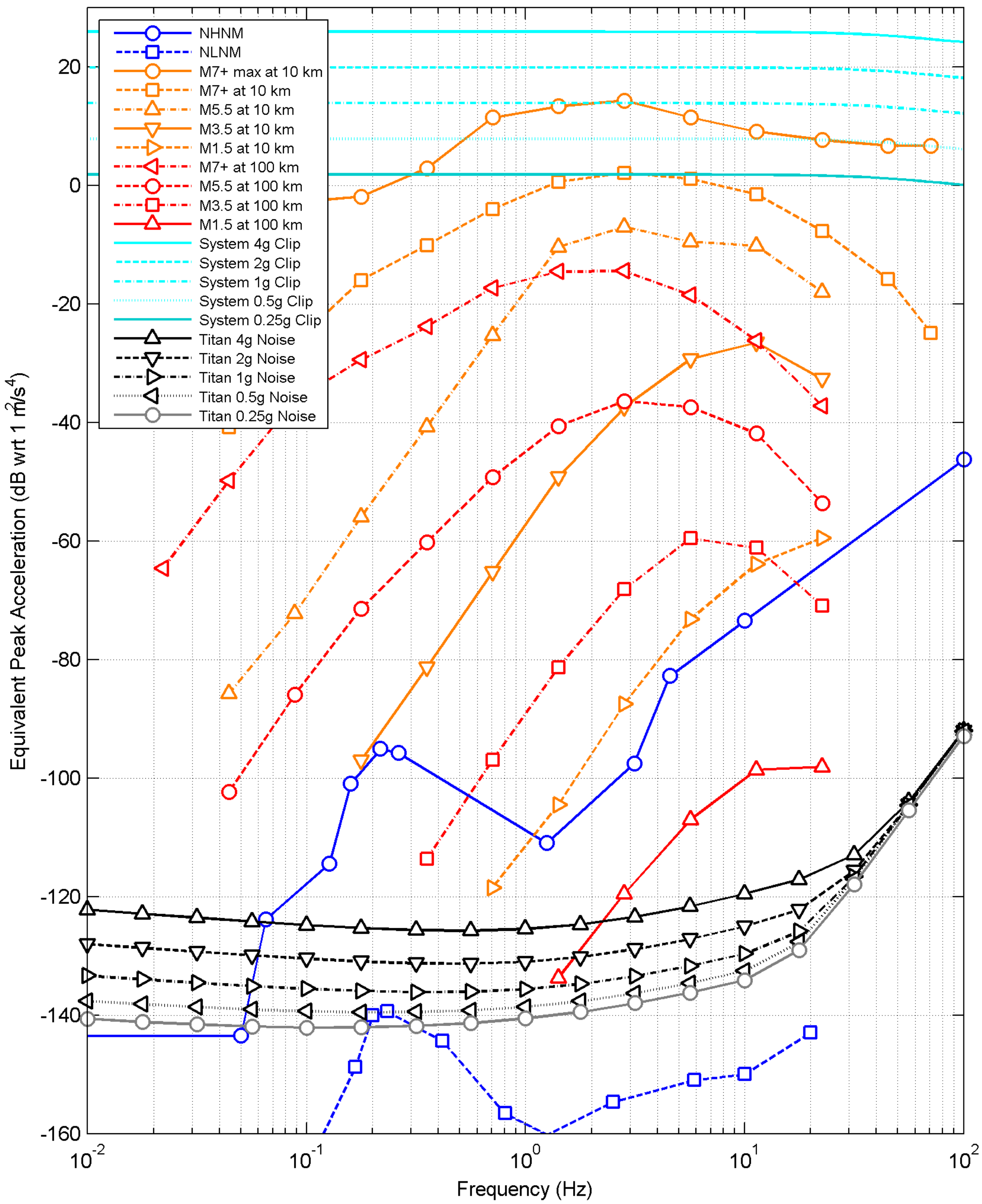
---

1. Jon Peterson, *Observations and Modeling of Seismic Background Noise, Open-File Report 93-322* (Albuquerque, New Mexico: U.S. Department of Interior Geological Survey, 1993).
2. 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.
3. Ibid.
4. Ibid, 337.

The best procedure for choosing the right system clip level is to

1. Obtain an estimate of the seismic hazard for the area where the sensor is to be installed.
2. Estimate site and structural ground motion magnification effects.
3. Choose a system clip level that is larger than the largest expected motion by a generous safety margin.

Figure 6-1 Titan Accelerometer systems and typical events



6.2 Choosing the Digitizer Full-Scale Setting

The available combinations of sensor and digitizer configurations, along with the resulting system sensitivities and clip levels are shown in Table 6-1 and Table 6-2 respectively. The recommended configurations are those in the cells that are not shaded.

Table 6-1 System sensitivity results from Titan Accelerometer and digitizer sensitivity combinations

System Sensitivity (counts/μm/s^2)		Sensor Sensitivity ($V \cdot s^2/m$)				
		0.51	**1.02**	**2.04**	**4.08**	**8.16**
Digitizer Sensitivity (count/μV)	**0.4**	0.204	0.408	0.816	1.632	3.264
	1	0.51	1.02	2.04	4.08	8.16
	2	1.02	2.04	4.08	8.16	16.32
	4	2.04	4.08	8.16	16.32	32.64
	8	4.08	8.16	16.32	32.64	65.28

Table 6-2 System clip level results from Titan Accelerometer and digitizer clip level combinations

System Clip Level (*g*)		Titan Accelerometer Nominal Clip Level (±*g*)				
		4	**2**	**1**	**0.5**	**0.25**
Digitizer Full-Scale (V)	**40**	4	2	1	0.5	0.25
	16	1.6	0.8	0.4	0.2	0.1
	8	0.8	0.4	0.2	0.1	0.05
	4	0.4	0.2	0.1	0.05	0.025
	2	0.2	0.1	0.05	0.025	0.0125

When there are multiple combinations of digitizer and Titan Accelerometer full-scale settings which yield nearly the same system sensitivities, in most applications, the preferred combination is the one where the Titan Accelerometer and digitizer saturate at the same level. Should the digitizer saturate at a lower level than the Titan Accelerometer, any excess range the Titan Accelerometer may have serves no purpose, and as discussed below, such a system will likely result in a higher system noise floor. Furthermore, when the Titan Accelerometer is configured for minimum full-scale, there is no benefit in terms of reduced system noise floor when the digitizer full-scale is set to less than 16 Vpp.

An exception to the above rule is when the Titan Accelerometer is being tested for self-noise. In this case, the digitizer should be set for the highest convenient sensitivity so that the contribution of digitizer noise to the total system noise is minimized.

Figure 6-2 shows the Titan Accelerometer and digitizer noise floors for a few of the available modes.

Figure 6-2 Titan Accelerometer system noise floors

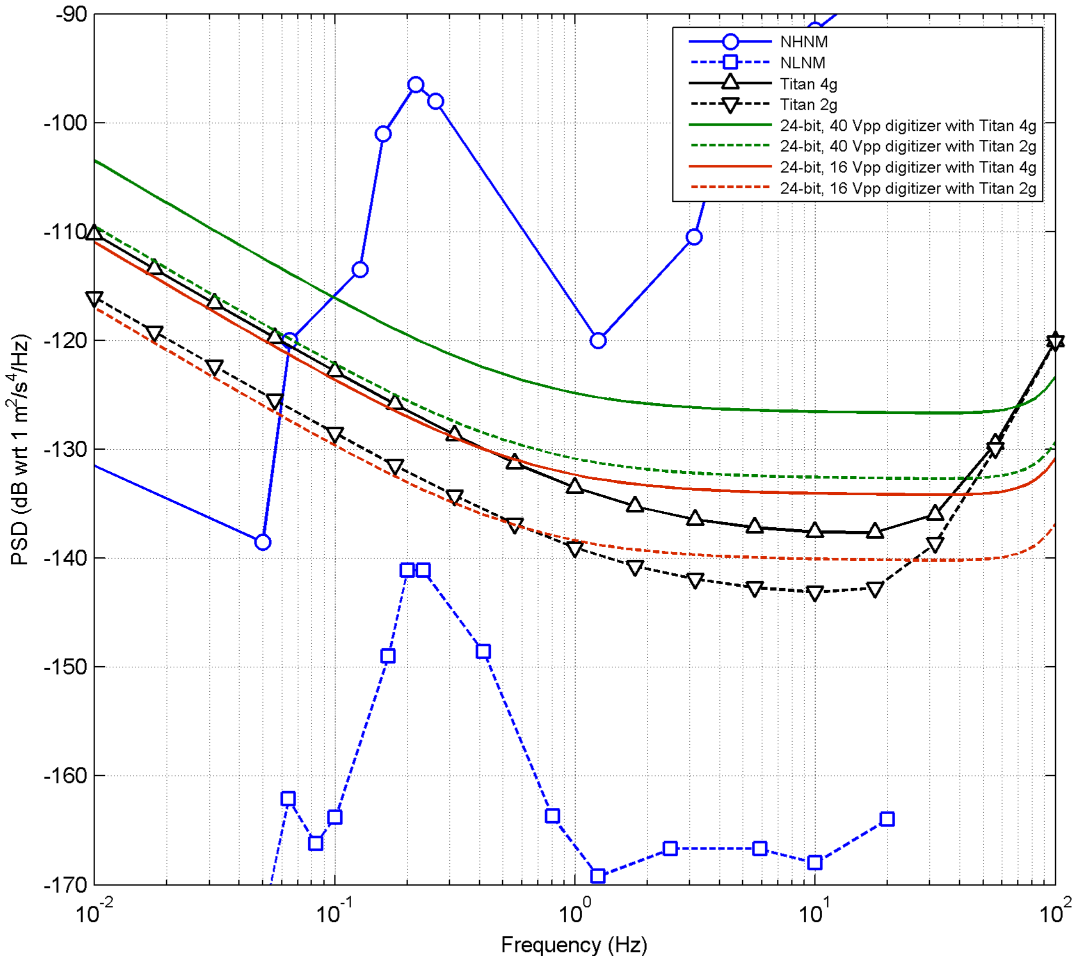


Table 6-2 "System clip level results from Titan Accelerometer and digitizer clip level combinations" on page 28 shows that the following configurations give very nearly the same system clip level:

System A: Titan in 4 *g* mode and digitizer with 16 Vpp full-scale clips at 1.6 *g*

System B: Titan in 2 *g* mode and digitizer with 40 Vpp full-scale clips at 2 *g*

However, Figure 6-2 shows that given the noise performance of a typical 24-bit digitizer, the System A configuration will give a higher system noise floor, particularly below 0.5 Hz, because the noise contribution from the sensor is larger in 4 *g* mode. Since the total self-noise of System A is greater than that of System B, the System B configuration is preferred.

6.3 Selecting the Titan Accelerometer Configuration for a Nanometrics Instrument

The method for selecting the default Titan Accelerometer 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 6-3 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 6-3 Configuring a Nanometrics instrument for a Titan Accelerometer

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 Titan Accelerometer** 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 Titan Accelerometer. 2. Log into the Taurus. 3. Select **Advanced Configuration** from the **Status** menu. 4. Select **Browse** and navigate to the **Titan Accelerometer.cfg** file. 5. Select **Upload**. 6. When the upload is complete, **Apply** and **Commit**.

6.4 Using a Trident Digitizer with a Titan Accelerometer

Refer to the user guide for your Trident digitizer for complete instructions on using it with a Titan accelerometer. Nanometrics cable 16774-nM (where n is the length of the cable in metres) can be used to connect a Titan Accelerometer to a Trident digitizer. See Table 1-1 “List of cables and accessories” on page 4 for a description of this cable.

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 Titan accelerometer.

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	See Section 6.1 “Choosing the System Clip Level” on page 26 and Section 6.2 “Choosing the Digitizer Full-Scale Setting” on page 28.
Sensor Control	High Voltage Level	+12 V	
	Calibration Mode	Voltage (active-high)	
	Line 1 Level (TX, Pin J)	Low	
	Line 2 Level (CTRL/RX, Pin D)	Low	Low is equivalent to disabling the functionality, and High is equivalent to enabling the functionality on all three axes. See Section 8.7 “Control Lines” on page 37 or Section 9.3 “Using the Titan Accelerometer Command-Line Interface” on page 41, and Section 8.4 “Calibration Enable” on page 35 for details on pin configuration and functionality.
	Line 3 Level	Not used	

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

```
TypeName = TitanOpen         // name of this prototype - may be same as model
Model = TitanOpen            // sensor model name
SensitivityUnits = M/S**2    // units of ground motion: M, M/S or M/S**2
Sensitivity = 2.04e5         // counts per unit of ground motion
SensitivityFreq = 1.0        // Frequency at which sensitivity is correct
CalibrationUnits = VOLTS     // calibration input units: VOLTS or AMPS
CalCoilResistance = 432000   // calibration coil resistance in ohms
CalCoilConstant = -11.43     // Calibration units per m/s/s
CalEnable = 1                // digital enable signal for calibration
CalRelay = 0                 // analog relay for calibration (0 = use channel number)
MassCenterEnable = 2         // digital enable signal for Titan auto-zeroing/self-test
MassCenterDuration = 2       // duration of Titan auto-zeroing signal in seconds
CalSource = Trident          // gives the source of the Cal signal
```

Chapter 7

Setting Up Serial Port Communications

7.1 About Serial Communications

The Titan Accelerometer has an integrated Web server that is available using a standard Web browser and the Serial Line Internet Protocol (SLIP) RS-232 serial interface provided on the Titan Accelerometer connector. The Titan Accelerometer Web interface is used to retrieve information about the accelerometer, access state-of-health information and control features, and configure the accelerometer.

The simplest way to connect to the sensor's web page is to use a Nanometrics digitizer, such as Centaur (release 3.4 or greater) (see Section 7.2 "Connecting through a Nanometrics Digitizer" on page 32). The web page is accessed through the Web interface of the digitizer . The Web Interface(see Chapter 8 "Using 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 Titan Accelerometer 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. (See Appendix A, "Configuring 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 or instructions on building your own SLIP appliance, go to support.nanometrics.ca.

7.2 Connecting through a Nanometrics Digitizer

Nanometrics digitizers such as Centaur support the Titan Accelerometer Web interface, allowing you to access the Web-based features of the Titan Accelerometer through a seamless integration with the Web interfaces of those instruments. This integration allows you to access the unit remotely, even while it is in service, without requiring a breakout cable and a SLIP connection on a co-located computer.

See the documentation for your Nanometrics digitizer (release 3.4 or greater) for details on how to access the Titan Accelerometer Web interface through these instruments. See Section 8.1 "About the Web Interface" on page 34 for descriptions of each page.

7.3 Calculating the IP Address

You will need the IP address if you are not using a Nanometrics digitizer to access the sensor's Web interface (see Chapter 8 "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 Titan Accelerometer is 2.24.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 = 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 Titan Accelerometer is 2.24.x.yl, 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 Titan Accelerometer with a serial number of 800 is 2.24.3.32.

7.4 Configuring a Serial Connection for the Web Interface

To access the Web interface of a Titan Accelerometer using a direct serial connection, you have to use a breakout cable to connect a computer to the Titan Accelerometer and then configure a Serial Line Internet Protocol (SLIP) connection on that computer.

For information on how to do this, see Appendix A, "Configuring SLIP Connections".

Chapter 8
Using the Web Interface

8.1 About the Web Interface

The Titan Accelerometer has an integrated browser-based Web interface that can be used for operation and configuration:

- Operation
  - State-of-Health (see Section 8.2 on page 35)
  - Real-time Output (see Section 8.3 on page 35)
  - Calibration Enable (see Section 8.4 on page 35)
  - Offset Trimming Section 8.5 on page 36)
- Configuration
  - Mode (see Section 8.6 on page 37)
  - Control Lines (see Section 8.7 on page 37)
  - Sensor Response (see Section 8.8 on page 38)
  - Hardware Information (see Section 8.9 on page 38)
  - Firmware (see Section 8.10 on page 38)

Ensure that the proxy server is disabled when using a Web browser with a Titan Accelerometer.

The simplest way to access the sensor's Web Interface is to use a Nanometrics digitizer. See Section 7.2 "Connecting through a Nanometrics Digitizer" on page 32.

If you're not using a Nanometrics digitizer, 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 7.1 "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 Titan Accelerometer Web interface through the Web interface of the Centaur (release 3.4 or greater) digitizers, 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 Titan Accelerometer.

8.2 State-of-Health

The SOH page provides internal voltage readings for the internal power supplies of the unit as well as the approximate unit temperature. Together these values provide the health of the unit. Click the **Refresh** button at any time to reload the page with the latest information.

The Status column of the Internal Power table indicates OK or FAIL. If the status of all voltages are reported as OK, the unit is functioning properly. If the status of any of the voltages is FAIL, disconnect the unit if possible, and contact Nanometrics Technical Support for assistance (see Contacting Technical Support on page 71).

8.3 Real-time Output

The Real-time Output page provides real-time readings of the X, Y, and Z channel outputs in units of gravity. These readings are low-resolution approximate readings for informational purposes, and are limited to about 60 percent of the full-scale range. When the page loads, the X, Y, and Z accelerations will be changing as the Web interface receives data from the Titan Accelerometer in real-time. When receiving data from the Titan Accelerometer, the button below the table will be labelled **Streaming**. The real-time stream of data will continue for approximately 60 s to 90 s. Click the **Resume** button to begin streaming data again.

If you want to navigate to another page before the data finishes streaming, click the **Home** link at the bottom of the page.

If one or more of the table cells is highlighted in yellow it means that the value is nearing the maximum that this page can report, which is about 60 percent of the selected full-scale range. The point at which a cell will be highlighted is when its value is at or near the maximum. If you are seeing cells highlighted in yellow, check the analog X, Y, or Z output signals for the actual readings.

For instance, if the selected full-scale range is 2 *g*, an acceleration exceeding 1.25 *g* will result in the table cell being highlighted. Check the analog output signal for the actual reading.

8.4 Calibration Enable

Use the Calibration Enable page to turn calibration on or off through the user interface, or to set the unit to use the configuration selected on the Control Lines page (see Section 8.7 “Control Lines” on page 37)of the Web interface (default). The Calibration Enable setting reverts to the default (Use control line configuration) each time the unit is rebooted or power cycled.

The **On** and **Off** options on the page override the calibration settings on the Control Lines page. Setting the Calibration Enable page to **On** means that calibration is enabled and that the unit can be calibrated at any time. Setting the Calibration Enable page to **Off** means that the unit cannot be calibrated.

When calibration is enabled the Titan Accelerometer is able to receive a calibration signal (CAL_SIG). See Chapter 11, “Performance” for sensitivity and frequency response information. See Section 5.4 "Calibration Input Signal" on page 24 for information on the calibration signal.

Note that turning calibration on will cause the status output signal to be set low (see Section 5.5 "Status Output Signal" on page 24).

8.5 Offset Trimming

Use the Offset Trimming page to automatically or manually set the coarse and fine trim values to compensate for offsets and bring the channel output DC levels very near zero. See Table 10-2 "Performance specifications – all models" on page 44 for the effective range of the trimming circuit. See Section 4.4 "Auto-Zeroing the Titan Accelerometer" on page 19 for more information on the purpose and function of the automatic trimming feature.

The Coarse Trim column of the table accepts values from 0 to 7 and these values represent large incremental changes in the amount of trim. The Fine Trim column accepts values from 0 to 4095 and represents smaller increments. A fine trim change from 0 to 4095 would amount to a little more than one step up in the coarse trim value.

Use the following steps to auto-zero the Titan Accelerometer:

The minimum value for coarse/fine trim is 0/2048, and the maximum value is 7/2048. Values from 0/0 to 0/2047 and from 7/2049 to 7/4095 are not valid.

1. If the mode has changed or if this is the first time auto-zeroing is being performed on the unit, click **Calibrate Trim** to have the Titan Accelerometer calibrate the trimming circuit for the current mode and range selection. Calibrating the trim circuit completes in 30 s or less.
2. Click **Auto-Zero** to zero the channels. Auto-zeroing completes in 30 s or less.

Notes:

(1) If you performed the auto-zero (see step 2) without calibrating the trimming circuit (see step 1), and receive an error message that calibration is required, return to the Offset Trimming page and perform step 1 and step 2.

(2) When trim calibration or auto-zeroing is being performed, non-seismic signals will be evident on the X, Y, and Z output channels as the offset circuit is being exercised.

When complete, the Coarse Trim and Fine Trim columns indicate the degree of trimming used to zero the channels. Coarse and fine trim values of 0/2048 or 7/2048 indicate that the amount of trimming required was beyond the maximum level allowed, and the channel could not be zeroed.

If you choose to manually adjust the trim, edit the values for the desired channels in the Coarse Trim and Fine Trim columns of the table and click **Apply Trim** to apply those trim values to the channels. The readings for the output acceleration and voltages displayed on this page will change in response to adjustments of the trim circuit.

8.6 Mode

Use the Mode page to select the mode for the horizontal (X and Y) and vertical (Z) channels. The modes you can select for the full-scale range are ±4 *g*, ±2 *g*, ±1 *g*, ±0.5 *g*, and ±0.25 *g*. The modes for the horizontal and vertical channels are independently selectable. Once you have made your mode selections, click **Apply** to commit the changes. If you want to discard your changes and reload the page, click **Cancel**.

8.7 Control Lines

Use the Control Lines page to select the desired configuration for the CTRL input signal (see Section 12.1 “Connector Pinouts” on page 51 for connector pinout and pin functionality). The Control Lines page is divided into two sections: CTRL Line Function and Maximum Pulse Width.

The CTRL Line Function section of the page allows you to select the desired functionality for the CTRL digital input signal (pin D on the connector). The options and relevant functionality are as follows:

- Calibration Enable

  Configures the unit to perform a calibration the moment pin D is held high.

- Self-test + Auto-zero

  Configures the unit to perform a self-test followed by an auto-zero the moment pin D is held high.

- Self-test

  Configures the unit to perform a self-test the moment pin D is held high.

- (HOLD) Calibration Enable / (PULSE) Self-test + Auto-zero

  This is the default setting.

  Configures the unit to perform a calibration when pin D is held high for a period longer than the maximum pulse width (see the Maximum Pulse Width section of the Control Lines page), or to perform a self-test followed by an auto-zero if the pin is pulsed high for a period less than the maximum pulse width.

- (HOLD) Calibration Enable / (PULSE) Self-test selected

  Configures the unit to perform a calibration when pin D is held high for a period longer than the maximum pulse width (see the Maximum Pulse Width section of the Control Lines page), or to perform a self-test if the pin is pulsed for a period less than the maximum pulse width.

The Maximum Pulse Width section of the page allows you to set the maximum pulse duration (in seconds). The options are 5, 10, and 15 seconds, with 5 being the default. To pulse the pin, it must be held high for a period shorter than the selected period, otherwise the pin is considered to be held high.

The calibration enable settings on this page can be overridden with the settings on the Calibration Enable page (see Section 8.4 “Calibration Enable” on page 35). A setting of **On** on the Calibration Enable page means that calibration is enabled regardless of the setting on the Control Lines page. A setting of **Off** on the Calibration Enable page means that calibration is disabled, regardless of the setting on the Control Lines page.

8.8 Sensor Response

Use the Sensor Response page to view (or export to a text file) the factory stored nominal frequency response data for this model and version of the Titan Accelerometer, including its present sensitivity setting. Users can also import, view, and export a text file of user-created information, such as accelerometer response data created by calibrating the Titan Accelerometer. The maximum file size that can be imported is 2559 bytes.

8.9 Hardware Information

The Hardware Information link displays a page that allows you to export or view detailed factory information, such as the unit model number, serial number, and version and serial number information for subcomponents. When exporting this information it is exported to a text file (.txt) and can is useful for record keeping or for transmitting to Nanometrics for technical support purposes.

8.10 Firmware

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 Titan Accelerometer, wait 20 s and return to the home page using the IP address.

To update to a new version of the Titan Accelerometer firmware you need to access the Titan Accelerometer bootloader Web page and upload the firmware. This Web page is only accessible for a small window of time (10 s) as the Titan Accelerometer starts up. Follow the steps for uploading new firmware carefully to ensure you reach this Web page.

Use the following steps to upload new firmware to the Titan Accelerometer:

1. Place the new firmware file provided by Nanometrics in a local or network accessible location.
2. Open a new browser window and type the URL of the bootloader Web page, but do not go to the web page yet. You will go to the Web page in step 4. The URL to the bootloader Web page is as follows:
   - http://<IP address>/firmware/bootloader, where <IP address> is the IP address used to access the Titan Accelerometer home page

> Opening a browser window and typing the URL to the bootloader Web page before restarting the Titan Accelerometer will save time during the short 10 s window that is available to access the web page.

3. Restart the Titan Accelerometer using one of the following methods:
   a) Click Reboot on the Firmware page and wait 10 s as the unit shuts down and restarts
   b) Manually power-cycle the unit

4. Immediately return to the browser window you opened in step 2 and go to the bootloader Web page.

If you do not access the bootloader Web page before the Titan Accelerometer firmware starts, the browser will report that the URL cannot be found and the process of rebooting or power cycling must be repeated.

5. Use the bootloader Web page to upload the new firmware file provided by Nanometrics (see step 1).

Chapter 9

Using the Titan Accelerometer Command-Line Interface

9.1 About the Titan Accelerometer Command-Line Interface

The Titan Accelerometer command-line interface is a simplified configuration tool that can be used instead of the Web interface (see Chapter 8, "Using the Web Interface") if a Serial Line Internet Protocol (SLIP) connection is not desired or possible. The command-line interface does not provide the full range of operation and configuration options that are available in the Web interface, but does provide a fast and simple way to change the mode, control line configuration, and maximum pulse width.

Use a serial terminal application (such as HyperTerminal or PuTTY) and an RS-232 serial connection between a computer and the Titan Accelerometer to access the command-line interface. The optional cable 16978–2M (see Table 1-1 "List of cables and accessories" on page 4 for a description of the cable) provides the necessary connectors for creating the connection between an RS-232 port on a computer and the connector on a Titan Accelerometer.

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 Titan Accelerometer.

9.2 Creating the Serial Port Connection

Use the following steps to connect the Titan Accelerometer to the serial port of a computer and configure serial port communications.

1. Connect a computer with a serial port to the Titan Accelerometer connector.
2. Open the serial terminal application on the computer and configure the serial connection with the following settings:

Parameter	Setting
Speed	9600 baud
Data bits	8
Parity	None
Stop bits	1
Flow control	None

9.3 Using the Titan Accelerometer Command-Line Interface

The Titan Accelerometer command-line interface allows you to change the following configuration settings:

- Mode

  Select the mode for the horizontal (X and Y) and vertical (Z) channels. The modes you can select for the full-scale range are ±4 *g*, ±2 *g*, ±1 *g*, ±0.5 *g*, and ±0.25 *g*. The modes for the horizontal and vertical channels are independently selectable.

- Control line configuration

  Select the desired functionality for the CTRL digital input signal (pin D on the connector, see Section 12.1 "Connector Pinouts" on page 51 for connector pinout and pin functionality).

- Maximum pulse width

  Set the maximum pulse duration (in seconds) for the CTRL digital input signal (pin D). The options are 5, 10, and 15 seconds, with 5 being the default. To pulse the pin, it must be held high for a period shorter than the selected period, otherwise the pin is considered to be held high.

To change the configuration using the command-line interface

1. Open a serial terminal window on the computer.
2. Press ENTER. The Titan Accelerometer will respond by displaying the current mode, control line, and maximum pulse width settings.
3. Type the appropriate code (only one code can be input per command line) followed by ENTER to change that setting (see Table 9-1 "Titan Accelerometer command-line codes" on page 42 for the codes and a description of each).

   Upon pressing ENTER the change is committed and the new configuration will be displayed. There is no need to restart the unit. When finished using the command-line interface, simply close the serial terminal window.

Use Table 9-1 as a guide when entering the codes.

Table 9-1 Titan Accelerometer command-line codes

Command Format and Example	Code	Description
Mode		
Format: xy#z# **Example:** xy9z8 <ENTER> (Sets the horizontal channels to 4 *g* mode and the vertical channel to 2 *g* mode.)	9	Set the channel(s) to 4 *g* mode (default setting).
	8	Set the channel(s) to 2 *g* mode.
	7	Set the channel(s) to 1 *g* mode.
	6	Set the channel(s) to 0.5 *g* mode.
	5	Set the channel(s) to 0.25 *g* mode.
Control line		
Format: c# **Example:** c3 <ENTER>	0	Calibration Enable Configures the unit to perform a calibration the moment pin D is held high.
	1	Self-test + Auto-zero Configures the unit to perform a self-test followed by an auto-zero the moment pin D is held high.
	2	Self-test Configures the unit to perform a self-test the moment pin D is held high.
	3	(HOLD) Calibration Enable / (PULSE) Self-test + Auto-zero Configures the unit to perform a calibration when pin D is held high for a period longer than the maximum pulse width, or to perform a self-test followed by an auto-zero if the pin is pulsed high for a period less than the maximum pulse width (default setting).
	4	(HOLD) Calibration Enable / (PULSE) Self-test selected Configures the unit to perform a calibration when pin D is held high for a period longer than the maximum pulse width, or to perform a self-test if the pin is pulsed for a period less than the maximum pulse width.
Maximum pulse width		
Format: p# **Example:** p0 <ENTER>	0	Set the maximum pulse width to 5 seconds (default setting).
	1	Set the maximum pulse width to 10 seconds.
	2	Set the maximum pulse width to 15 seconds.

Part 3
Reference

Chapter 10
Specifications

10.1 Technology

Table 10-1 Technology specifications – all models

Topology	Triaxial, horizontal-vertical
Feedback	Force balance with capacitive displacement transducer
Centring	Automated electronic offset zeroing Can be initiated via control line or serial port
Full-scale range	Electronically selectable Independent vertical and horizontal configuration

10.2 Performance

Table 10-2 Performance specifications – all models

Available full-scale ranges	±4 *g*, ±2 *g*, ±1 *g*, ±0.5 *g*, or ±0.25 *g*
Sensitivity accuracy	±0.5%
Bandwidth (-3 dB)	DC to 430 Hz
Dynamic Range (octave bandwidth, assumed crest factor of 3)	Greater than 150 dB from 0.01 Hz to 10 Hz Greater than 155 dB at 1 Hz
Offset	Electronically zeroed to within ±0.005 *g* Offset trimming range ±0.05 *g*
Linearity	0.03% typical total harmonic distortion at full-scale amplitude
Hysteresis	Less than 0.005% of full-scale
Cross-axis sensitivity	Less than 0.5% total
Offset temperature coefficient	Horizontal sensor: 60 μ*g*/°C, typical Vertical sensor: 320 μ*g*/°C, typical

10.3 Hardware Interface

Table 10-3 Hardware interface specifications – Titan Accelerometer

Connector	14-pin Shell size 12 MIL-C-26482 Series I Mounted on side of case
Acceleration output	40 Vpp differential
Output impedance	2 x 100 Ω
Calibration input	Single voltage input, all channels enabled together
Control input	Single control signal can be configured to initiate auto-zero, initiate self-test, or enable calibration
Status output	Asserted: Unit OK, output signal valid Deasserted: Self-test in progress or failed, auto-zeroing in progress, calibration enabled, or starting up
Serial port	9600 Baud RS-232 compatible

Table 10-4 Hardware interface specifications – Titan Accelerometer, Posthole

Connector	16-pin SubConn Marine Mounted on top of case
Acceleration output	40 Vpp differential
Output impedance	2 x 100 Ω
Calibration input	Single voltage input, all channels enabled together
Control input	Single control signal can be configured to initiate auto-zero, initiate self-test, or enable calibration
Status output	Asserted: Unit OK, output signal valid Deasserted: Self-test in progress or failed, auto-zeroing in progress, calibration enabled, or starting up
Serial port	9600 Baud RS-232 compatible

10.4 Digital Command and Control Interface

Table 10-5 Digital command and control Interface specifications – all models

Digital interface	Onboard web server standard HTTP RS-232 compatible Serial Line Internet Protocol (SLIP) RS-232 command-line interface
Commands	Gain range selection Auto-zero, or set to specific offset Self-test Calibration enable State-of-health request Firmware updates
Data outputs	Sampled XYZ outputs (in volts and *g)* Instrument temperature Trimmer settings Instrument serial number Hardware assemblies and firmware revisions

10.5 Power

Table 10-6 Power specifications – all models

Supply voltage	9 to 36 V DC isolated input
Power consumption	1.1 W typical quiescent See Section 5.6 "Power Consumption" on page 25 for power consumption scenarios
Protection	Reverse-voltage and over-voltage protected Self-resetting over-current protection

10.6 Environmental

Table 10-7 Environmental specifications – all models

Humidity	0 to 100%
Operating temperature	-40°C to +60°C
Storage temperature	-65°C to 75°C
Weather resistance	Models TACCL-N1 and TACCL-V1: rated to IP-67 Model TACCL-PH2: rated to IP-68

10.7 Physical

Table 10-8 Physical specifications – models TACCL-N1 and TACCL-V1

Size	Length: 14 cm (5.5”) Width: 8.5 cm (3.3”) Height: 5.8 cm (2.3”)
Weight	960 g (2.1 lb)
Housing	Aluminum Surface resistant to corrosion, scratches, and chips
Mounting	Single bolt keyhole mount
Levelling	Integrated bubble level (model TA only) Adjustable locking levelling screws
Alignment	Case-top north-south and east-west alignment markers
Orientation	XYZ orientation marker on base

Table 10-9 Physical specifications – model TACCL-PH2

Size	Height: 169 mm (6.7”) Diameter: 96.4 mm (3.8”)
Weight	3 Kg (6.6 lb)
Housing	Stainless steel Surface resistant to corrosion, scratches, and chips
Alignment	Case-top north-south guide for straight-edge, line, or laser level
Orientation	Case-top XYZ orientation marker

Chapter 11
Performance

11.1 Sensitivities

The sensitivity of a Titan accelerometer varies according to the operating mode selected, as shown in Table 11-1. The calibration input sensitivity is 0.049 m/($s^2 \cdot$ V) ±10%, so the combined calibration sensitivity at 1 Hz in 1 *g* mode, for example, is close to unity.

Table 11-1 Titan accelerometer sensitivity

Clip Level (*g*)	Sensitivity ($V \cdot s^2/m$)	Nominal Sensitivity (V/*g*)
4	0.510	5
2	1.02	10
1	2.04	20
0.5	4.08	40
0.25	8.16	80

The nominal sensitivity assumes standard gravity, where g = 9.80665 m/s^2. With standard gravity, it is easy to interpret calibration results at places where local acceleration due to gravity is close to this value, such as at mid-latitudes near sea level. That is, if you apply 1 *g* by inverting the accelerometer in 4 *g* mode, you can expect close to 5 V output. However, it is the sensitivity stated in units of $V \cdot s^2$/m that will remain constant as the accelerometer is moved to different latitudes and elevations.

11.2 Frequency Response

The accelerometer sensitivity, poles, and zeros define the transfer function according to the following equation:

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

Where the normalization factor is defined by the following equation, and is given for informational purposes only.

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

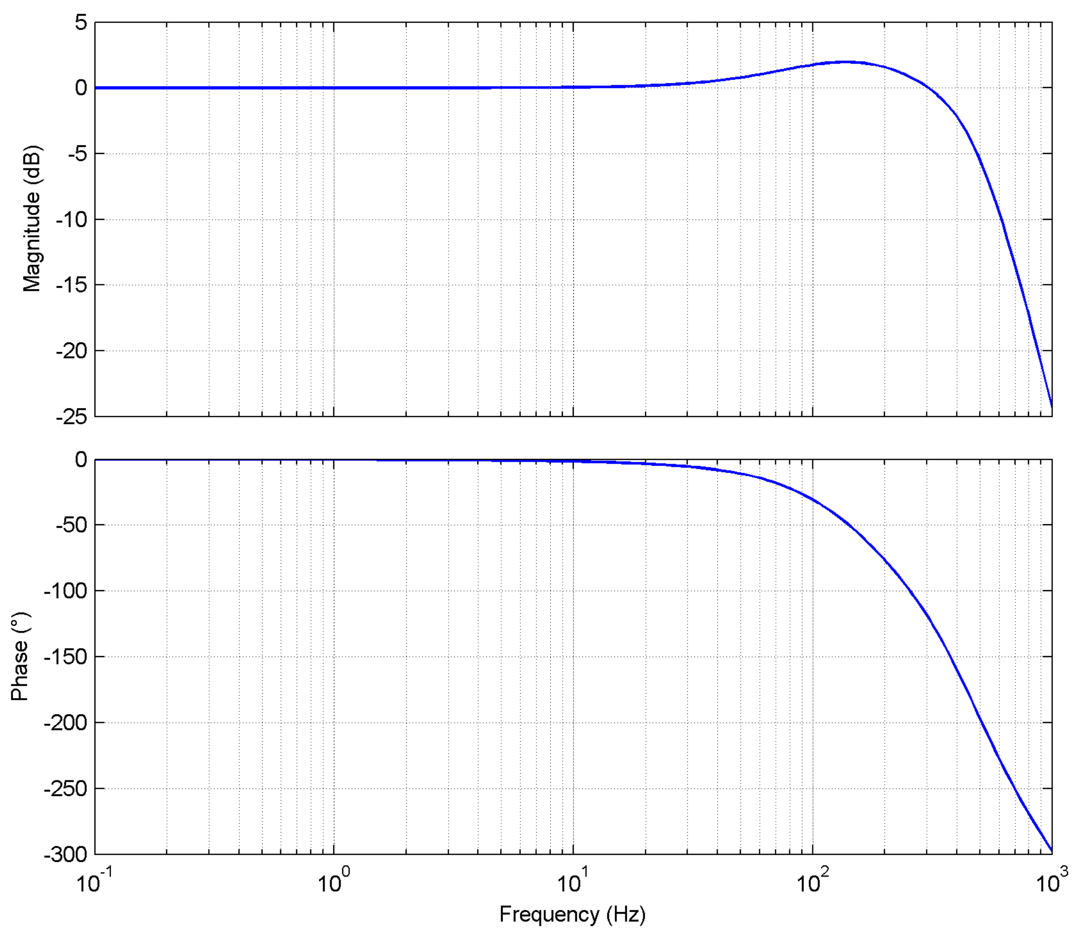
Table 11-1 on page 48 provides the Titan accelerometer sensitivity S_{sens} for the various modes. Table 11-2 provides the poles and zeros for Titan accelerometers.

Table 11-2 Titan accelerometer poles and zeros

Symbol	Parameter	Nominal Values	Units
z_n	Zeros	–515	rad/s
p_n	Poles	–977 ±328i –1486 ±2512i –5736 ±4946i	rad/s
k	Normalization factor	1.0077×10^{18}	$(rad/s)^5$
f_0	Normalization frequency	1	Hz

The nominal response is illustrated in Figure 11-1. The plot is normalized to the sensitivity at 1 Hz. The transfer function of a Titan accelerometer does not substantially vary as the clip level is changed.

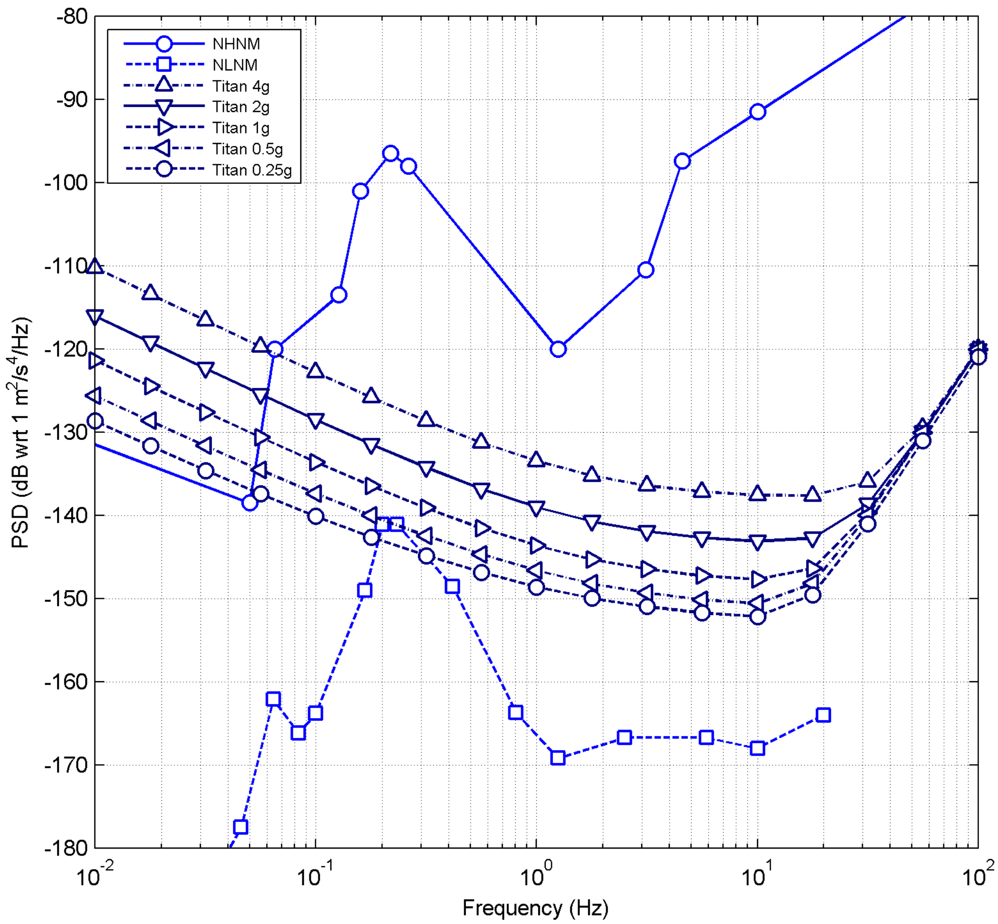
Figure 11-1 Normalized transfer function



11.3 Self-Noise

Figure 11-2 plots typical self-noise for Titan accelerometers. Two curves are included for reference: the NLNM and NHNM, Peterson[1]. The noise floor shown is the typical level of instrument self-noise assuming proper installation.

Figure 11-2 Titan Accelerometer typical self-noise



1. Jon Peterson, *Observations and Modeling of Seismic Background Noise, Open-File Report 93-322* (Albuquerque, New Mexico: U.S. Department of Interior Geological Survey, 1993).

Chapter 12
Connector and Cables

12.1 Connector Pinouts

Table 12-1 provides the connector pinout for the Titan Accelerometer. Table 12-2 provides the connector pinout for the Titan Accelerometer, Posthole.

Table 12-1 Connector Pinout for the Titan Accelerometer

Pin	Name	Function	Type
B	X+	X axis output (east)	40 Vpp differential
C	X-	X axis output (east)	40 Vpp differential
F	Y+	Y axis output (north)	40 Vpp differential
H	Y-	Y axis output (north)	40 Vpp differential
L	Z+	Z axis output (vertical)	40 Vpp differential
M	Z-	Z axis output (vertical)	40 Vpp differential
K	CAL_SIG	Calibration signal input	±12 V maximum
R	STATUS	Titan Accelerometer state-of-health output* *See Section 5.5 "Status Output Signal" on page 24 for details.	+3.3 V or 0 V
D	CTRL/RX	◆ Calibration enable, auto-zero, self-test input* -OR- ◆ Serial RS-232 receive input * See Section 8.7 "Control Lines" on page 37 or Section 9.3 "Using the Titan Accelerometer Command-Line Interface" on page 41, and Section 8.4 "Calibration Enable" on page 35 for details on pin configuration and functionality.	±15 V maximum* *See Section 5.2 "Digital Control Input Signal" on page 23 for details.
J	TX	Serial RS-232 transmit	±3.7 V typical
E	AGND	Analog ground	N/A
P	+PWR	Power input	9 V to 36 V DC isolated
N	-PWR	Power return	9 V to 36 V DC isolated
A	DGND	Digital ground	N/A
shell	CHASSIS	For shielding and safety	N/A

Table 12-2 Connector Pinout for the Titan Accelerometer, Posthole

Pin	Name	Function	Type
5	X+	X axis output (east)	40 Vpp differential
6	X-		
7	Y+	Y axis output (north)	
12	Y-		
9	Z+	Z axis output (vertical)	
10	Z-		
8	CAL_SIG	Calibration signal input	±12 V maximum
14	STATUS	Titan Accelerometer state-of-health output* *See Section 5.5 “Status Output Signal” on page 24 for details.	+3.3 V or 0 V
3	CTRL/RX	◆ Calibration enable, auto-zero, self-test input* -OR- ◆ Serial RS-232 receive input * See Section 8.7 “Control Lines” on page 37 or Section 9.3 “Using the Titan Accelerometer Command-Line Interface” on page 41, and Section 8.4 “Calibration Enable” on page 35 for details on pin configuration and functionality.	±15 V maximum* *See Section 5.2 “Digital Control Input Signal” on page 23 for details.
4	TX	Serial RS-232 transmit	±3.7 V typical
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

12.2 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 signal. This is CTRL/RX.
- Use the AGND for the return currents of the analog signals. These are CAL_SIG, STATUS, and the X, Y, and Z signals.

AGND is connected to the Titan Accelerometer case inside the accelerometer. If AGND is connected through the cable, the case of the Titan Accelerometer 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 Titan Accelerometer does not result in a voltage drop along the cable which takes the power supply voltage below the minimum required at the Titan Accelerometer. See Section 5.6 “Power Consumption” on page 25.
- 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 Titan Accelerometer in the desired state.

Chapter 13

Physical Features and Dimensions

13.1 Views of Titan Accelerometer and Titan Vertical Mount

The following figures show various views of the Titan Accelerometer and the Titan Vertical Mount. The only difference in the physical presentation of these two models is that the Titan Vertical Mount does not have the levelling bubble in the case that is shown in Figure 13-1 on page 55.

This section presents the following views of the Titan Accelerometer and Titan Vertical Mount:

- Figure 13-1 “Front view of Titan Accelerometer features and dimensions” on page 55
- Figure 13-2 “Back view of Titan Accelerometer features and dimensions” on page 55
- Figure 13-3 “Side view of Titan Accelerometer features and dimensions” on page 56
- Figure 13-4 “Bottom view of Titan Accelerometer features and dimensions” on page 56

(1) All dimensions in the figures are in millimetres unless otherwise stated.

(2) The Titan Vertical Mount does not have the levelling bubble shown in Figure 13-1 on page 55. This is a feature specific to the Titan Accelerometer.

Figure 13-1 Front view of Titan Accelerometer features and dimensions

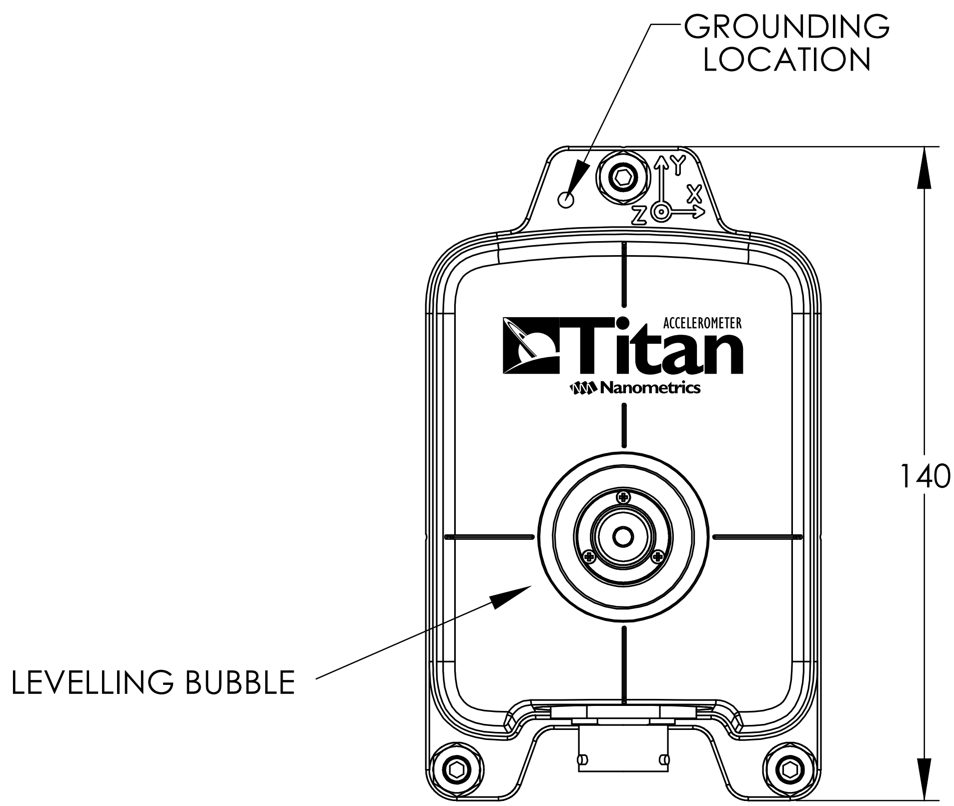


Figure 13-2 Back view of Titan Accelerometer features and dimensions

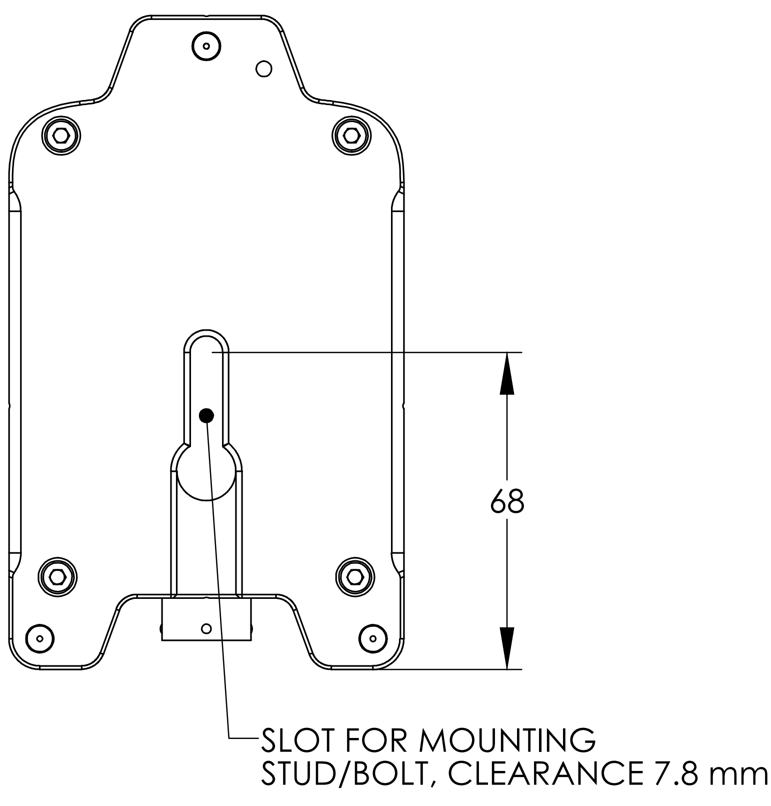
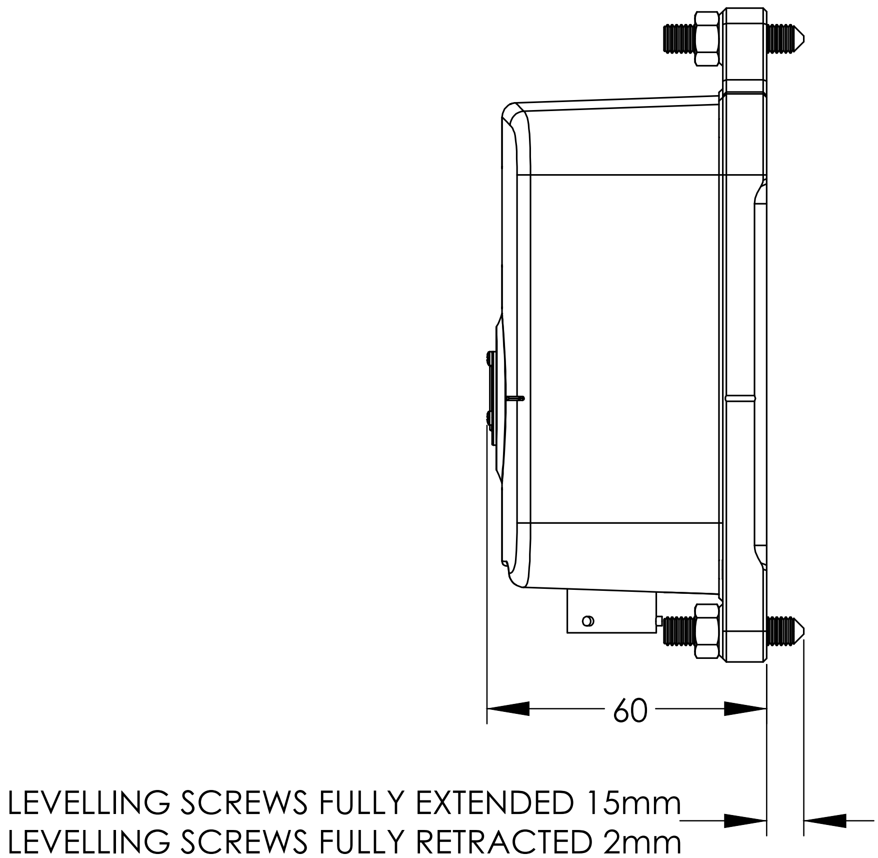
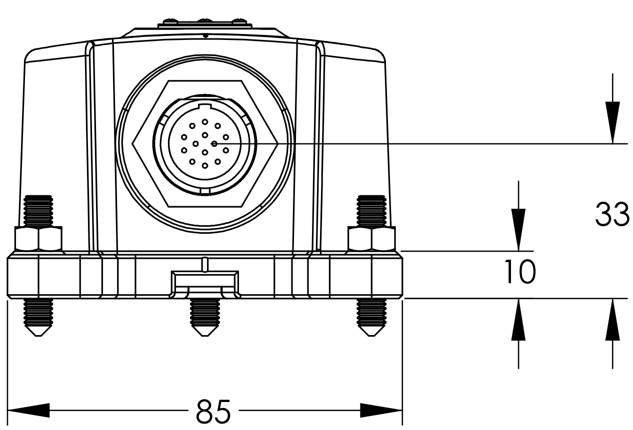


Figure 13-3 Side view of Titan Accelerometer features and dimensions



When the levelling screws are fully retracted, only the cone ends of the screws are visible at the back of the Titan Accelerometer.

Figure 13-4 Bottom view of Titan Accelerometer features and dimensions



13.2 Views of Titan Posthole

This section presents the following views of the Titan Posthole:

- Figure 13-5 "Top view of Titan Posthole" on page 57
- Figure 13-6 "Side view of Titan Posthole" on page 58
- Figure 13-7 "Bottom view of Titan Posthole" on page 59

All dimensions in the figures are in millimetres unless otherwise stated.

Figure 13-5 Top view of Titan Posthole

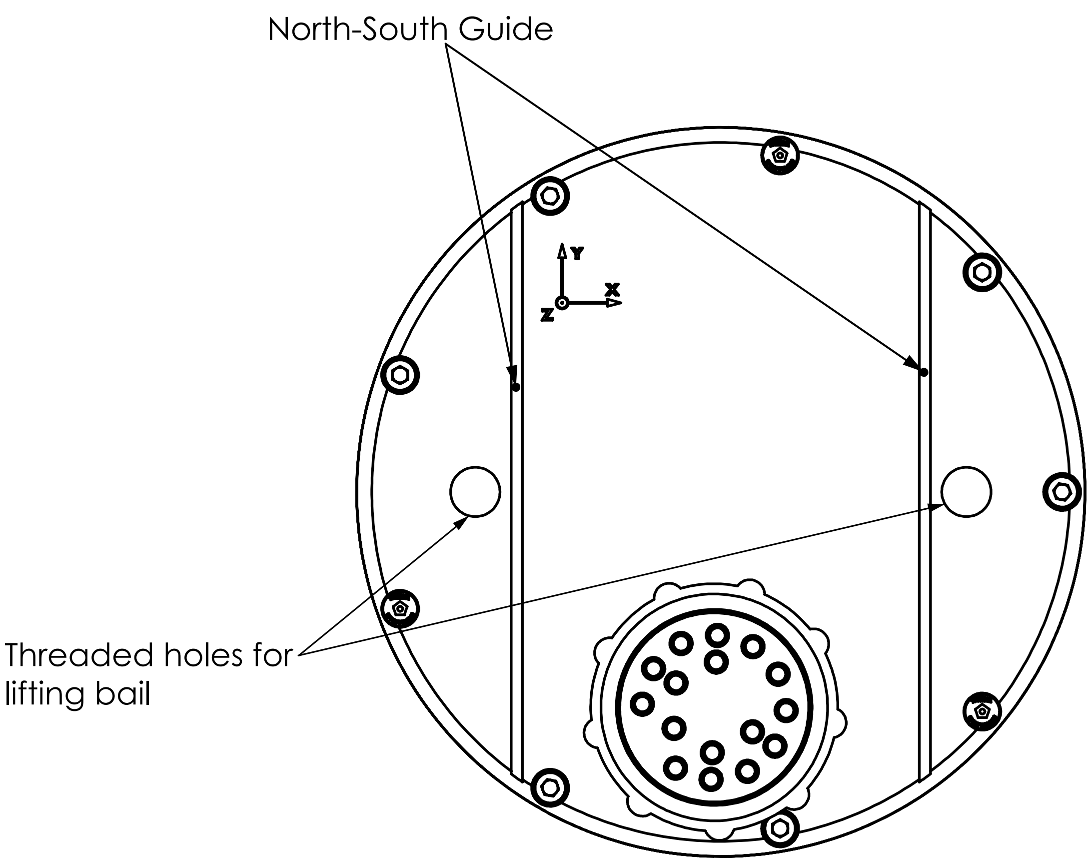


Figure 13-6 Side view of Titan Posthole

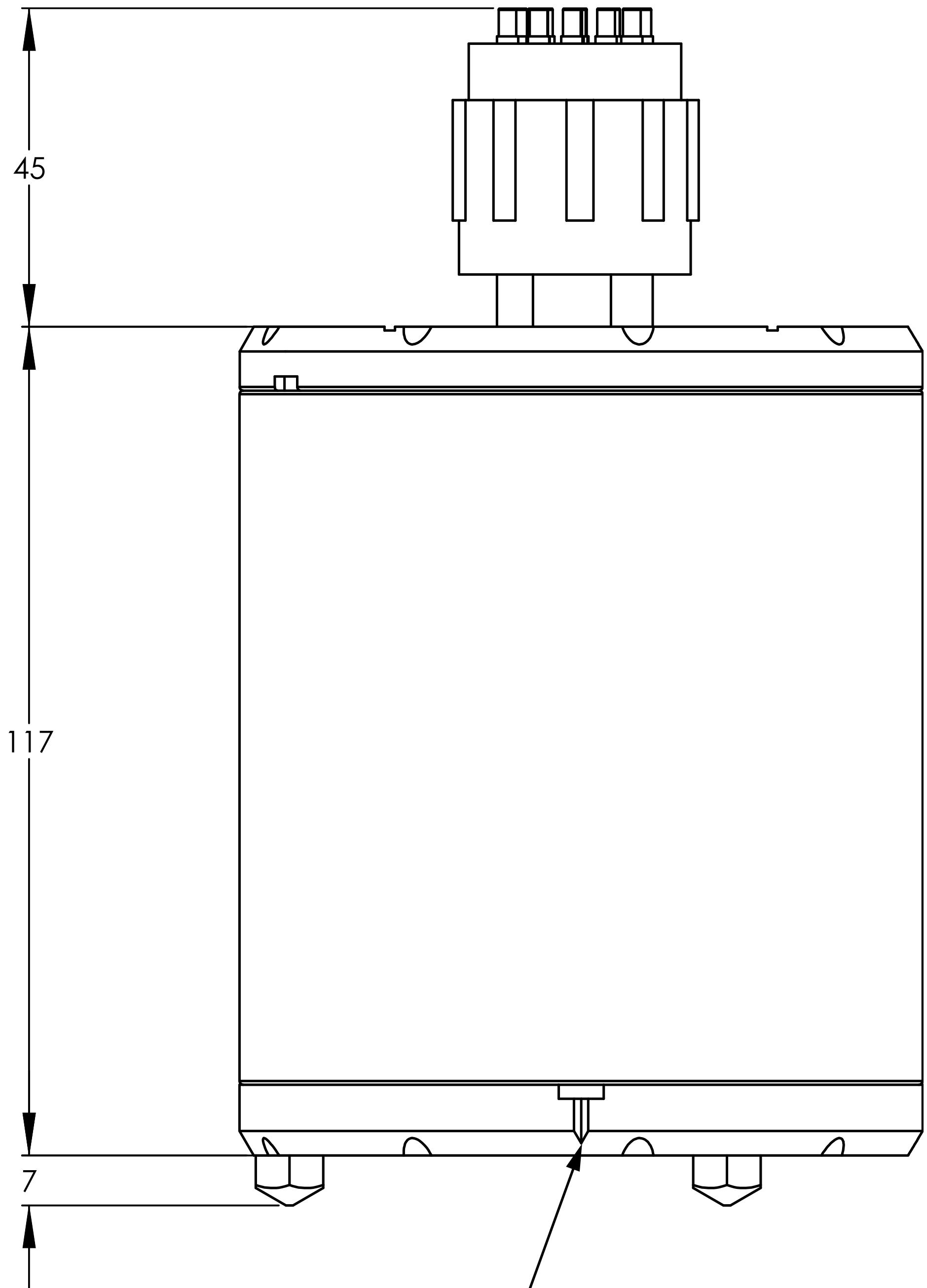
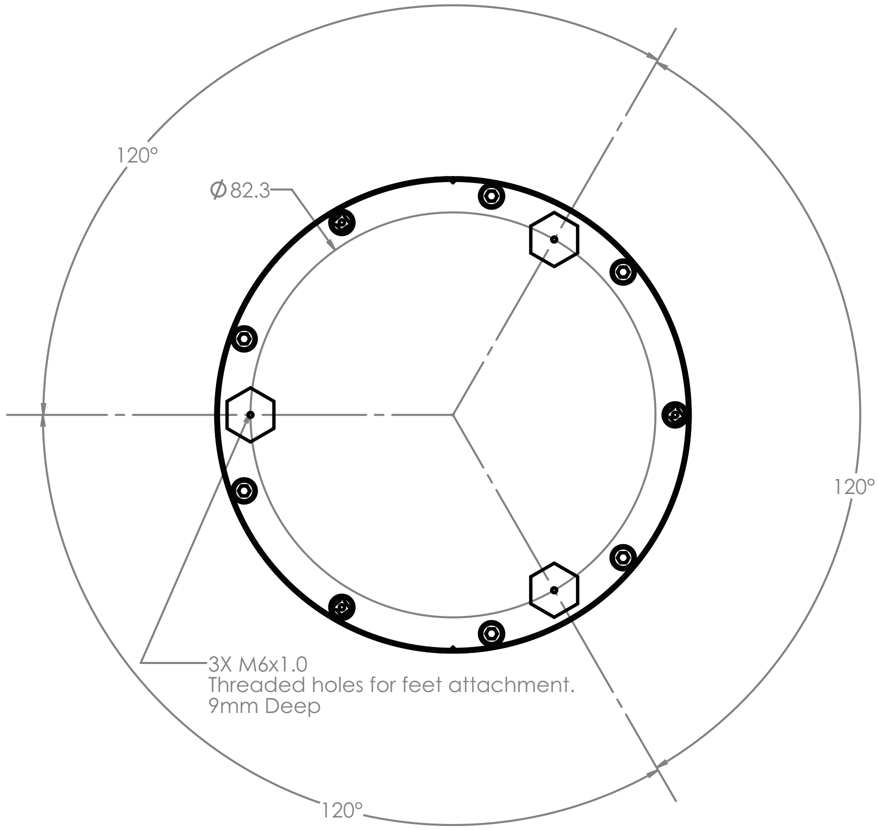


Figure 13-7 Bottom view of Titan Posthole



Appendix A
Configuring SLIP Connections

A.1 Configuring a Serial Connection for the Web Interface

Serial communication should not be active when the highest quality seismic signal is desired because it may cause low levels of noise on the analog output signals.

If you are using a direct serial connection to a computer, you will need to configure a Serial Line Internet Protocol (SLIP) connection on the computer before you can use a Web browser to access the Web interface. See also Section A.1.1 "Creating a SLIP Connection on a Windows XP Computer" on page 61 or Section A.1.2 "Creating a SLIP Connection on a Windows 7 Computer" on page 62 for instructions on configuring this connection.

To use the Web interface of a Titan Accelerometer using a direct serial connection to a computer

1. Use a serial communications breakout cable (Nanometrics part number 16978-2M, see Table 1-1 "List of cables and accessories" on page 4) to connect the serial port of a computer and your power source to the Titan Accelerometer connector.

If the computer is not equipped with a serial port for a direct serial connection, a commercially available USB-to-serial adapter can be used.

2. Start the SLIP connection (see Section A.1.1 "Creating a SLIP Connection on a Windows XP Computer" or Section A.1.2 "Creating a SLIP Connection on a Windows 7 Computer" for instructions on creating the SLIP connection).

   a) Ensure the Titan Accelerometer is connected and powered on.

   b) In Control Panel, select **Network Connections**.

   c) Right-click on the SLIP connection for the Titan Accelerometer 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.

3. Go to the URL of the unit's Home page in a Web browser (which is the IP address of the unit).

   • Open a Web browser on the same computer the Titan Accelerometer is connected to and go to `http://2.24.x.y` (the IP address of the unit) to access the home page.

For example, if the IP address of the Titan Accelerometer is 2.24.1.200, then the URL to access the home page of the instrument is http://2.24.1.200.

The IP address of the unit is provided on the label of your Titan Accelerometer. If you cannot find the IP address, see Section 7.3 "Calculating the IP Address" on page 33 for information on determining the full IP address of the unit.

4. See Section 8.1 "About the Web Interface" on page 34 for descriptions of the pages and instructions on using the Web interface.

A.1.1 Creating a SLIP Connection on a Windows XP Computer

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

You only need to create one SLIP connection per computer for multiple Titan Accelerometer units, assuming the computer's serial port has not been used for another purpose in the interim. To use the SLIP connection with multiple units, simply disconnect the serial connector from one unit, move it to the next unit, and go to the IP address of the new unit in your Web browser. See also Section A.1 "Configuring a Serial Connection for the Web Interface" on page 60.

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 Titan Accelerometer 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 The IP address 2.1.0.0. This is the IP address of the SLIP interface on the computer and it is independent of the IP address for the Titan Accelerometer.
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.

A.1.2 Creating a SLIP Connection on a Windows 7 Computer

The SLIP protocol is available on editions of Microsoft Windows 7 that support XP Mode. Visit the Microsoft Web site (http://www.microsoft.com) to learn about XP Mode and to find a list of the editions of Windows 7 that support it.

When you have determined that you have an edition of Windows 7 that supports XP Mode, download and install XP Mode from Microsoft, and then follow the steps in Section A.1.1 "Creating a SLIP Connection on a Windows XP Computer" on page 61 from your XP Mode virtual machine to configure your SLIP connection.

You will need to map the physical serial port in Windows 7 to the virtual serial port in XP Mode.

Appendix B

Information Specific to the Titan Vertical Mount

B.1 About the Titan Vertical Mount

The Titan Vertical Mount (part number 17286) is a version of the Titan Accelerometer that is intended to be mounted on a vertical surface, such as a wall or structural support. The majority of this user guide is applicable to the Titan Vertical Mount; however, notable differences in features, instructions, and functionality are provided in this section.

Where there are references to horizontal and vertical channels throughout this guide, note that the horizontal channels on a Titan Vertical Mount are X and Z, and the vertical channel is Y.

B.2 Specifications

The specifications of the Titan Vertical Mount only differ from the Titan Accelerometer in that it does not have an integrated bubble level, as indicated in Table 10-8 "Physical specifications – models TACCL-N1 and TACCL-V1" on page 47, Chapter 2 "Performing a Surface Installation", and in images throughout this guide.

B.3 Installation

When installing a Titan Vertical Mount, use the instructions provided in Section 2.3 "Secure Installations" on page 8; however, when aligning and levelling the unit, employ the guidelines in Section B.3.1.

Note the following when preparing for the installation:

- A compass will not be required
- A carpenter's level will be required because the Titan Vertical Mount does not have a bubble level in the cover

B.3.1 Aligning and Levelling a Titan Vertical Mount

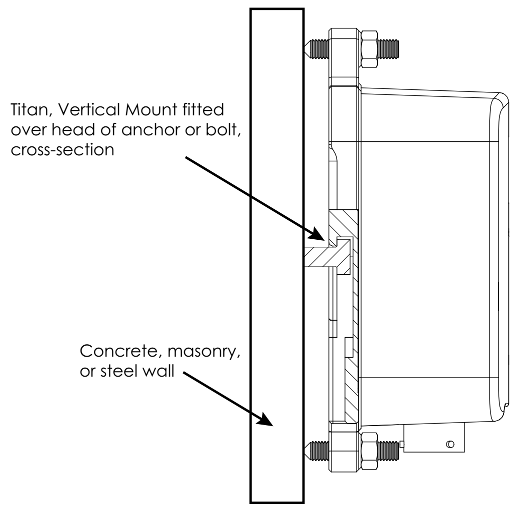
To align the unit vertically, fit it over the head of the anchor or bolt, hold the carpenter's level along the base of the unit, and shift it left or right until the carpenter's level is showing that the unit is vertically aligned.

To level the unit against the installation surface, adjust each of the levelling screws equally, to the maximum extent permitted by the anchor or bolt. As the levelling screws are turned into the surface, the unit is lifted away from it, creating a secure connection between the unit and the head of the anchor or bolt.

For installations on concrete or masonry surfaces, over-tightening the levelling screws may pull the anchor or bolt out of the installation surface.

When finished, lock each of the levelling screws by inserting the 3 mm hex screwdriver into the screw to stop it from rotating and using a wrench to firmly tighten the lock nut.

Figure B-1 Titan, Vertical Mount affixed to wall



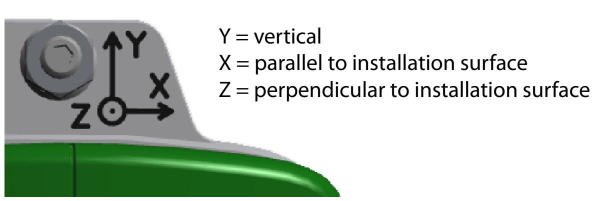
B.4 XYZ Output Signals

Section 5.1 "XYZ Output Signals" on page 23 explains how the axis orientation and polarity of the Titan Accelerometer correspond to the directions of the compass. Instead, the X, Y, and Z outputs on a Titan Vertical Mount correspond with its orientation to the installation surface. See Table B-1 for the polarities of the X, Y, and Z outputs and the correspondence of each to the installation surface. The X, Y, and Z outputs are differential signals with a 40 V peak-to-peak range.

Table B-1 Axis orientation and polarity of Titan Vertical Mount XYZ outputs

Axis	Orientation	Positive Voltage
X	parallel to installation surface	represents case motion to the right (direction of X arrow)
Y	vertical	represents upward case motion (direction of Y arrow)
Z	perpendicular to installation surface	represents outward case motion (direction of Z marker)

Figure B-2 Titan Vertical Mount XYZ orientation markers on base



B.5 Factory Configured Offset of Y Channel

As described in Section 4.4 "Auto-Zeroing the Titan Accelerometer" on page 19, the Z channel of the Titan Accelerometer has a built-in offset of 1 *g* to compensate for earth's gravity. In the Titan Vertical Mount, the Y channel represents vertical motion, and so, the 1 *g* offset is applied to this channel.

Appendix C
Information Specific to the Titan Posthole

C.1 About the Titan Posthole

The Titan Posthole (model TACCL-PH2) is a version of the Titan Accelerometer that is intended to be installed up to 50 m deep in a cased or uncased hole. The majority of this user guide is applicable to the Titan Posthole; however, notable differences in features, instructions, and functionality are provided in this section.

Where there are references to horizontal and vertical channels throughout this guide, note that the horizontal channels on a Titan Posthole are X and Z, and the vertical channel is Y.

C.2 Specifications

The specifications of the Titan Posthole only differ from the Titan Accelerometer in the physical features and dimensions and weather resistance. See Chapter 10 "Specifications" for the specifications of all three models, Table 10-9 "Physical specifications – model TACCL-PH2" on page 47 for the physical specifications specific to the Titan Posthole, and Table 10-7 "Environmental specifications – all models" on page 46 for details on weather resistance.

C.3 Installation

When installing a Titan Posthole, use the instructions provided in Chapter 3 "Performing a Posthole Installation."

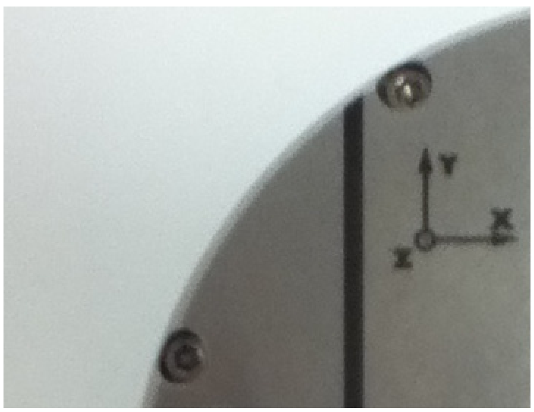
C.4 XYZ Output Signals

Section 5.1 “XYZ Output Signals” on page 23 explains how the axis orientation and polarity of the Titan Accelerometer correspond to the directions of the compass. Instead, the X, Y, and Z outputs on a Titan Posthole correspond with its orientation to the installation surface. See Table C-1 for the polarities of the X, Y, and Z outputs and the correspondence of each to the installation surface. The X, Y, and Z outputs are differential signals with a 40 V peak-to-peak range.

Table C-1 Axis orientation and polarity of Titan Posthole XYZ outputs

Axis	Orientation	Positive Voltage
X	parallel to installation surface	represents case motion to the right (direction of X arrow)
Y	vertical	represents upward case motion (direction of Y arrow)
Z	perpendicular to installation surface	represents outward case motion (direction of Z marker)

Figure C-1 Titan Posthole XYZ orientation markers on base



Appendix D
Glossary

D.1 Glossary of Abbreviations and Terms

A

AWG

American Wire Gauge

E

EMI

Electromagnetic Interference

G

GPS

Global Positioning System

N

NHNM

New High-Noise Model

NLNM

New Low-Noise Model

R

RF

Radio Frequency

RMA

Return Merchandise Authorization

S

SLIP

Serial Line Internet Protocol

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
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.

Contacting Nanometrics

Nanometrics Inc.
250 Herzberg Road
Kanata, Ontario, Canada K2K 2A1
Phone: +1 613-592-6776
Fax: +1 613-592-5929
Email: sales_mkt@nanometrics.ca
Web: www.nanometrics.ca

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