OPERATIONS, MAINTENANCE AND SURVEILLANCE MANUAL: HOPE BAY DORIS TAILINGS IMPOUNDMENT AREA

HOPE BAY, NUNAVUT

Appendix H – Standard Operating Procedures

AGNICO EAGLE

Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 4

Prepared for

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Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 4

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1 Introduction

1.1 Revision Summary

Table 1 provides a summary of the revision history for the North Dam Monitoring Standard Operating Procedures (SOP).

Table 1: Revision History for the North Dam Monitoring SOP

Revision	Status	Date	Major Changes
0	Issued for Use	July 2013	-
1	Issued for Use	September 2013	Updates to Section 6 and 7
2	Issued for Use	August 2017	Monitoring frequency requirements (Section 3.1), data download procedures (Section 4), ground survey monitoring (Section 5), water level monitoring via permanent datalogger (Section 7), addition of more detail on seepage monitoring (Section 9), Primary contact email (throughout) from Hopebay@srk.com to hopebaymonitoring@srk.com
3	Issued for Use	August 2020	Water level monitoring transmission frequency (Section 5), Seepage monitoring (Section 9) adding location TL-5 and the development of a Quality Assurance / Quality Control (QA/QC) program Minor updates to align with the South Dam SOP
4	Issued for Use	December 2022	Updated to reflect change in ownership, updated seepage sampling procedure at North Dam (no longer required)

1.1 Background

The North Dam at Hope Bay has been designed as a water retaining structure. Its successful performance is dependent on maintaining the integrity of the frozen core through preservation of permafrost in the dam foundation (SRK 2007). Because of complex foundation conditions, differential settlement longitudinally and transversely across the dam is expected. To track whether deformations are within the design limits for the dam, a rigorous monitoring program has been established (SRK 2012).

Table 2 lists the North Dam monitoring components and Figure 1 presents a general arrangement of the North Dam.

Table 2: North Dam Monitoring Components

Component	Instrument	Quantity
Thermal	Horizontal ground temperature cables	13
	Vertical ground temperature cables	11
	Thermosyphon monitoring temperature cables	12
Deformation	Deep settlement points	3
	Surficial survey points, located on the downstream shell of the dam	18
	Crest monitoring points, located along the crest of the dam	14
	Inclinometers installed downstream slope of the dam	6
Water level	Pressure transducer installed in Reclaim pond	1
Seepage	Weekly Walkover Survey, sampling as required	n/a
Visual	Weekly Walkover Survey	n/a

1.2 Objectives

Responsibility for implementing the North Dam monitoring program rests with AEMAEM, and the data will be reviewed annually by the Engineer of Record (EOR) as part of the annual geotechnical inspection. This document provides comprehensive Standard Operating Procedures (SOP) for carrying out the required monitoring.

1.3 Layout

Section 2 of this document provides a summary of the instrumentation that has been installed (SRK 2012). The required monitoring frequency and responsibility matrix is provided in Section 3. Sections 4 to 9 contain the specific SOPs.

2 Monitoring Overview

2.1 Thermal Monitoring

2.1.1 Ground Temperature Cables

The frozen core and the underlying foundation have been designed to remain frozen for the life of the structure. The core should at all times be a temperature of at least -2°C, while the underlying foundation soils must be a temperature of at least -8°C (SRK 2007). Thirteen horizontal ground temperature cables have been installed to monitor the core temperature, and eleven vertical ground temperature cables have been installed to monitor the foundation temperature (Figure 1 and 2). One of the horizontal ground temperature cable (ND-HTS-085-33.5) was damaged beyond repair during construction and a replacement could not be installed. Additionally, one vertical ground temperature cable (ND-VTS-060-US) was irreparably damaged prior to datalogger installation. Therefore, these cables are not included in the monitoring program.

All working ground temperature cables are connected to two automated dataloggers via a series of multiplexers, which allow data collection at any pre-programmed frequency. The location of these dataloggers and associated multiplexers are indicated on Figure 2. The SOP for downloading data from these dataloggers is presented in Section 4.

2.1.2 Thermosyphon Monitoring

Horizontal sloped passive thermosyphons are installed in the base of the key trench. These have been designed to promote freezing conditions in the foundation soils. The thermosyphons are sealed pressure vessels and do not have moving parts that require service or maintenance. A thorough physical inspection for signs of corrosion is however required on the exposed portions of the thermosyphon system as part of routine visual inspections.

Each thermosyphon is monitored by a cable connected to one thermistor bead. These are referred to as Thermosyphon Status Thermistors (TSTs) are attached to the riser of each thermosyphon radiator. These TSTs allow monitoring of the thermosyphon operation during the active cooling season. Monitoring is done by measuring the temperature of the radiator pipe where it exits in the ground (this is equivalent to measuring the temperature of the cooling agent in the thermosyphon) and comparing it to the ambient air temperature at the panel. During the active cooling season the cooling agent within the thermosyphon, where it exits in the ground, is expected to be a minimum of 5°C warmer than the air temperature.

The TSTs were attached to the thermosyphon radiators using epoxy resin adhesive. The TST attachments were made as close to the riser elbow as possible and were insulated using spray foam. In total 12 TSTs were installed (one for each radiator). Photos of the installation and a simplified schematic of the thermosyphon radiator layout are shown in Figure 9.

At the north radiator cluster the TST lead cables were connected into Multiplexer #9 in Node E. The leads from the south radiator cluster were routed to Node A and from there fed through the pre-installed metal conduits along the crest of the dam and connected into Multiplexer #9 in Node E (Figures 3 and 4).

2.2 Deformation Monitoring

2.2.1 Survey Point Monitoring

The North Dam is expected to undergo deformation because of creep over its design life; this includes differential longitudinal and transverse settlement. These settlements are expected to result in strains of less than 2% in the frozen core of the dam (SRK 2007). A total of 35 survey monitoring points was installed within the dam to track these deformations such that it can be confirmed that they are within the specified design limits.

The installed monitoring points are illustrated on Figures 1 and 3, and include the following:

- **Primary Survey Control Points:** five permanent survey control points were established on exposed bedrock locations outside of the North Dam peripheral.
- **Deep Settlement Points:** three deep settlement points are located on the downstream slope of the dam. The deep settlement points are intended to track deformation of the foundation soils near the shell. Deep settlement points are located along the downstream face of the dam approximately 7 m from the downstream crest of the dam, and were installed to a depth of 0.5 m below the original ground surface. They consist of 102 mm (4-inch) steel pipes protected by a 152 mm (6-inch) diameter outer steel casing. The top of the steel casing is protected by a fabricated steel cap.
- **Surficial Survey Points:** 18 surficial survey points are located on the downstream shell of the dam. The surficial survey points are intended to track deformation of foundation soils at the location of maximum expected deformation. The surficial survey points were installed by embedding 1 m diameter boulders in a grid pattern into the run-of-quarry material of the dam shell. Once these boulders were seated into the dam shell, holes were drilled and expansion bolts were installed into each boulder.
- **Crest Monitoring Points:** 14 crest monitoring points are located along the crest of the dam. These monitoring points are intended to monitor differential settlement and deformation of the upper portion of the frozen core. The crest monitoring monuments were manufactured on site and are comprised of steel rods attached to base plates. 102 mm (4-inch) steel pipe housing protects the rods, and a steel cap protects the top of each monitoring point housing.

The SOP for completing these manual surveys, are included in Section 5.

2.2.2 Inclinometer Monitoring

Six inclinometers were installed on the downstream slope of the dam. These inclinometers were installed along the zone of the dam expected to undergo the maximum amount of deformation, and thus subject to the maximum strain. The locations of the installed inclinometers are shown on Figure 3. The SOP for taking these readings are included in Section 6.

2.3 Water Level Monitoring

Reclaim pond water level monitoring recorded automatically using a datalogger and georeferenced by monthly survey monitoring during the open water season as described in Section 7.

Between July 2015 and June 2017, a pressure transducer datalogger was used to monitor the depth of water during open water season. This was installed at a depth of approximately 5 m below the Reclaim pond water level of 29.08 masl. The data was downloaded manually and provided to the EOR on an as-requested basis. In June 2017, a new temporary pressure transducer was connected to a Datagarrison data transmitter installed on the shore of the Reclaim pond. The data logger collects a reading every 15 minutes and the data is transmitted to the online portal every 5 days. This pressure transducer was permanently installed for year-round monitoring on September 28, 2017.

The pressure transducer records water level in the Reclaim pond as meters of water (head) above the datalogger and require a known elevation of the datalogger for accurate translation to elevations. Therefore, as part of the monthly survey data collection (Section 5) a survey of the Reclaim pond water level is required to calibrate the pressure transducer readings. The full monitoring SOP is provided in Section 7.

2.4 Visual Monitoring

Visual inspection must be carried out for the North Dam and all its components, looking for obvious signs of distress.

During the initial years of dam operations several depressions were identified on the shell of the dam. These depressions are likely due to settlement of shell material after construction; however, the known depressions and any future depressions must be monitored to ensure that they are not signs of larger issues or instability. Monitoring will continue until stability of the depression can be confirmed.

Additional details on the primary focus areas for the visual monitoring is presented in Section 8.

2.5 Seepage Monitoring

Previously water has been noted at the toe of the dam. When noted, additional monitoring is required. The SOP for seepage monitoring is provided in Section 9.

3 Monitoring Protocols

3.1 Monitoring Frequency/Responsibility

A summary of the monitoring requirements and associated responsibility is listed in Table 3. These monitoring requirements can be revised at any time under the direction of the North Dam EOR, or the qualified Licensed Geotechnical Engineer carrying out the annual geotechnical inspection after consultation with the North Dam EOR.

Table 3: Summary of Monitoring Requirements

Element	Item	Method	Responsibility	Frequency
Thermal	Ground Temperature Cables	Dataloggers	AEM	Daily readings, monthly downloads
	Thermosyphons	Dataloggers	AEM	Daily readings, monthly downloads
Deformation	Downstream Deep Settlement	Manual	AEM	Monthly, May to November(1)
	Downstream Surface Settlement	Manual	AEM	
	Crest Settlement	Manual	AEM	
	Depression	Manual	AEM	
	Inclinometers	Manual	AEM	Monthly
Water Balance	Water Level	Datalogger	AEM	Daily readings (online portal)
	Water Level	Manual	AEM	Monthly, when Reclaim pond is not frozen
	Seepage Monitoring	Per Section 9	AEM	Weekly when seepage is observed
	TL-5 Geochemical Sampling	Manual	AEM	Monthly
	Geochemical QA/QC	Manual	AEM	Monthly (in conjunction with other sampling)
Visual	Visual Walk over Inspection and Reporting	Manual	AEM	Weekly (below FSL(2)) Daily (at or above FSL)
	Geotechnical Inspection	Manual	Independent Qualified Licensed Geotechnical Engineer	Annually
Maintenance	Datalogger Primary Batteries	Manually recharge	AEM	Annually
	Datalogger Backup Batteries	Manually replace	AEM	5-year cycle
	Datalogger Recalibration	Manual	AEM	5-year cycle
	Desiccant Packs Replace	Manual	AEM	As required

Note(s)

(1) Deformation monitoring is not required during the winter months when the ground is frozen, if thermal data from the ground temperature cables does not indicate any cause for concern.

(2) FSL: Full Service Level

3.2 Monitoring Data Management Protocols

All monitoring data collected must be stored electronically. Manual notes must be scanned and the raw data saved together with any transposed or processed data. All data must be reviewed by appropriate qualified staff immediately following collection to confirm integrity of the instrumentation, as well as to ensure that dam performance is consistent with expectations. If staff is not qualified to draw such conclusions, the EOR must be contacted to perform these duties.

Reporting requirements are specified in each section typically via email, however where appropriate, agreed upon shared drives can be used for file transfer, but a notification email should be sent once the inspection is uploaded. Currently a South Dam monitoring shared folder is stored here:

https://van.files.srk.com/nextcloud/index.php/s/EERtAo85KZLocdy?path=%2FTIA%20Monitoring

4 Datalogger Standard Operating Procedures

For the thermal monitoring instrumentation, SOPs have been developed for the datalogger downloads. The dataloggers are connected to the ground temperature cables and permanent TSTs.

Figure 2 shows the location of the ground temperature cables and TSTs while Figures 4 and 5 show the general layout of the data acquisition system and associated monitoring nodes.

The Operator's manuals for the dataloggers (CR1000) and associated Compact Flash Module (CFM100) are provided in Appendix A1, and A2. The wiring diagrams for the dataloggers, multiplexers and ground temperature cables are presented in Appendix B, and for completeness Appendix C presents an overview of the CR1000 datalogger programming.

4.1 Objective

The datalogger SOP has been developed to provide AEM staff with clear instructions on how to maintain and operate the two North Dam dataloggers. These dataloggers are used to record ground temperature and thermosyphon radiator performance data.

4.2 Overall Procedure

The datalogger SOP can be summarized by the following procedures:

1. **Field Data Extraction.** Data collection requires that the data either be downloaded directly from the datalogger or the exchange of the flash card with a blank flash card. Complete details of this field procedure are described in Section 4.3.
2. **Data Download and Processing.** Complete details on these office procedures are described in Sections 4.4 and 4.4.3. This task involves extraction of data from the memory flash cards and subsequent forwarding of this data to the EOR.
3. **Maintenance**. This field procedure defines basic maintenance procedures necessary for the ongoing successful operation of the dataloggers (Section 4.5).

4.3 Field Data Extraction (Direct Download or Card Exchange Procedure)

4.3.1 Direct Download

This is the preferred download procedure as over time it has led to fewer card errors and download issues. This procedure uses the PC200W software. Prior to any download the particular datalogger has to be initialized in the software. The current field computer is set up for this, however should the datalogger be renamed after recalibration or PC200W be reinstalled, communication to each datalogger will need to be re-initialized on the computer (Appendix A1). Once installed and set up, the download procedure is as follows and screenshots are provided in Figure 7:

- **Step 1:** Connect the dedicated data transfer cable to the RS 232 port of the datalogger. Connect the cable to the field computer using either a serial port or a USB port through a Serial-USB adapter.
- **Step 2:** Open PC200W.
- **Step 3:** From the stations list on the left of the window select the appropriate datalogger. Ensure the selection the same datalogger being downloaded from, otherwise the file names will be misleading.
- **Step 4:** Click "Connect". Once this is finished, select the "Download all data" button. This should start the download.
- **Step 5:** Switch to "Collect Data" tab.
- **Step 6:** Select "All data from datalogger (Overwrite data files)" option is selected; this enables the download of all data stored in the datalogger's memory. Tick off all the files in the list of files for the complete download. Click "Collect". Data collection may take 20 minutes or more if the datalogger is full. If the cables get disconnected for any reason, you have to restart the download.
- **Step 7:** Take note of the path to the downloaded files. The computer defaults to the main drive (C:\ drive for most computers) where it creates a "Campbellsci" folder. Once back to the office, these will be the files sent to SRK.
- **Step 8:** Click "disconnect". **IMPORTANT,** If you close without disconnecting, next time you open PC200W it will be looking for the datalogger that was last connected, causing various problems with the laptop.
- **Step 9:** Disconnect the cables from the datalogger and from the field laptop.

4.3.2 Card Exchange (Alternative Method)

This should be completed as required, i.e., when the direct download method is not working. Steps 1 through 5 below explain the procedure for exchanging the memory flash cards for each of the two dataloggers:

- **Step 1:** Open each of the two weatherproof enclosures containing the dataloggers. Their physical locations, and key elements within the weatherproof enclosures are shown on Figure 6.
- **Step 2:** Push the removal button on the CFM100 Compact Flash Module, which is connected to the CR1000 datalogger. Wait for a green light. The removal button is located on the upper left corner of the unit, as illustrated in Figure 6. Note that it may take a few seconds for the green light to illuminate.
- **Step 3:** Once the solid green light is on, open the flash card cover hinged door (Figure 6). To do this, loosen the securing screw with manual finger effort (no need for hand tools).
- **Step 4:** Press the card release button and remove the flash card (Figure 6). The card release button is the small square button immediately above the flash card.

- **Step 5:** Place the exchange card into the flash card slot (it can only go in one way). Make sure that the correct card (marked as CR1000 #1 or CR1000 #2) is placed into the appropriate individual datalogger.
  - *Warning: Installing the wrong card will cause an error in the program which will prevent transfer of data to the card.*
- **Step 6:** Close and secure the hinged door by hand-tightening the securing screw (no need for any tools).

4.4 Data Download Procedure

4.4.1 Direct Download

For the direct download method, the steps above result in the files saved on the computer. Please ensure the file name generated by the datalogger. The naming convention includes

- File 1 – 8: NorthDamCR1000#n_m

Where: *n* = datalogger number (either CR1000 #1 or CR1000 #2)

m = file type (Daily_Samples, Public, StationStatus or Status)

Once back in the office, email all eight downloaded files to SRK as listed in Section 4.4.4 below.

4.4.2 Card Exchange (Alternative Method)

If the card exchange method is used in place of the Direct Download, follow the steps below to extract the data from the cards:

- **Step 1:** Insert the memory flash card into the appropriate slot of the Media Reader (Figure 8).
- **Step 2:** Connect the reader to a computer.
- **Step 3:** Copy the two files from each of the two cards and save to the hard drive.
- **Step 4:** Once copied, email all four files to SRK as listed in Section 4.4.4 below.

Please note that the two files from each card should automatically follow the following naming convention, and should not be altered:

- File #1: "HB_NorthDam_CR1000_#n.Daily_Samples_YYYY_MM_DD_HHmm.dat"
- File #2: "HB_NorthDam_CR1000_#n.StationStatus_YYYY_MM_DD_HHmm.dat"

Where: *n* = datalogger number (either CR1000 #1 or CR1000 #2)

YYYY = calendar year

MM = calendar month

DD = calendar date

HHmm = time

Note: the data and timestamp in the filename will correspond to the time and data that was first transferred onto the card, i.e., when the card was placed into the datalogger.

4.4.3 Data Pre-Processing Procedure

If the files collected during the card exchange procedure are too large to be sent by email, some pre-processing will be required. Typically, this will not be required unless files sizes exceed 10 megabytes (MB). Steps 1 through 5 below describe these data processing procedures:

- **Step 1**: Open the LoggerNet software and choose the "**Card Convert**" option from the "**Data**" menu.
- **Step 2:** Select the correct card drive by clicking on the "**Select Card Drive**" button and navigating to the appropriate computer drive. Select the files to be pre-processed.
  - *Note:* there will always be two files created at the same time (see Section 4.4.2). Select both files.
- **Step 3:** Select the output directory for the processed files. It is recommended that a folder directory be created and dedicated to the field data on the C:\ drive. That way the data can always be backed up by the download computer.
- **Step 4:** Click on the "**Destination Files Options**" button. From the pop-up window, select the "**ASCII Table Data (TOA5)**" format for the output file. Make sure to tick off the "**TimeDate Filenames**", "**Create New Filenames**", and "**Store Time Stamp**" options.
- **Step 5:** Email the *.TOA5 output files to SRK as listed in Section 4.4.4 below.

Figure 7 provides example software screenshots from the key steps above.

4.5 Maintenance Procedure

4.5.1 Battery Maintenance

The two 12-volt batteries (Node B and Node D as shown on Figures 3 to 5) powering the data acquisition system must be charged at least once every year. They can be charged with an automotive / car battery charger (typically in the range of 2 to 6 amps for 12-volt lead acid batteries). This should ideally be done in the fall, in preparation for winter operation.

When not connected to the 12-volt battery the datalogger has an internal battery to ensure that the internal clock/ time is maintained. The rest of the electronics are solid state so upon re-hooking up the 12-volt battery the data gathering will resume.

Twenty-four hours after the 12-volt batteries are recharged or replaced and reconnected to the data acquisition system, a data download (Section 4.4) is required. This check is required to ensure that the system is operational.

4.5.2 Datalogger Re-Calibration

Every five years the CR1000 dataloggers must be re-calibrated and the internal battery replaced. This work must be done by a qualified person approved by the EOR. Additional details on datalogger (CR1000) care and maintenance can be found in Appendix A1.

4.5.3 Desiccant Pack Maintenance

Desiccant packs have been placed in each datalogger and multiplexer housing (i.e., Nodes A to E as shown in Figures 3 to 5). These packs absorb condensation moisture inside the housings to protect the internal electronics. Desiccant packs must be replaced or oven dried (standard vented oven at 93ºC [200ºF]) when moisture inside the readout housing is visible, or when the desiccant status indicators are flagged (Figure 6). Damaged desiccant packs must be replaced.

4.6 Reporting Procedure

Any manually downloaded data should be provided in the required format as listed above. Any additional observations (such as noted damage or issues with the datalogger or cables) that may assist with data interpretations should be recorded and sent along with the compiled data downloads or the Visual Monitoring reports (Section 8). SRK should also be informed when battery recharges or other maintenance occurs.

All data or observations should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

5 Ground Survey Standard Operating Procedure

5.1 Objective

Ground surveys of the control points, deep settlement points, surficial survey points and crest settlement monitoring points are required. Figure 1 shows a general arrangement, along with primary survey control points, and Figure 3 presents a plan view of the instrumentation layout, including location names and UTM coordinates. Figure 10 shows a typical layout for the installed North Dam deformation monitoring instrumentation while Figure 11 shows additional details on the deep settlement points and surficial survey points.

5.2 Survey Procedures

The ground surveys/deformation monitoring should be completed with survey instruments that have accuracy in the range of ± 2 mm (horizontal and vertical). Likely these surveys will be completed by a Total Station survey; however, if the specified is maintained, other appropriate survey methods may be adopted by a qualified sub-contractor or AEM surveyor. Additional details on “suggested guidelines of surveying at the North Dam”, with a Total Station, are presented in Appendix D (from Cornelissen 2013). Specifically, these guidelines discuss:

- Expected manpower and time allocation;
- Equipment and accessories;
- Metadata/control points;
- Station set-ups; and
- General surveying and survey error reduction.

For the deep settlement points and crest monitoring points a steel cap / top was fabricated to protect the monitoring points. Any accumulated dirt or ice around these protective caps should be removed and the caps removed to access the protected points. Before leaving the North Dam area, after the monthly ground survey, all caps should be cleaned. If the caps are moist, it is suggested that the insides of the caps be dried prior to being placed back over the monitoring points to avoid jamming or freezing. Any damage noted to any of the survey / monitoring points should be recorded and submitted with the survey data.

In addition to the monitoring points, the water level of the TIA reclaim pond should be surveyed to correlate the water level data (from the pressure transducer) with an elevation.

5.3 Reporting Procedures

The survey data is expected to be supplied in Excel or csv format. Any additional observations (such as noted damage) that may assist with data interpretations should be noted and sent along with the compiled survey data. All data should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

6 Slope Inclinometer Standard Operating Procedure

6.1 Objective

Six inclinometers were installed on the downstream slope of the dam, along the dam area that is expected to undergo the maximum amount of deformation. Procedures for taking, reading and transferring the collected inclinometer data using the dedicated software is outline below. Additional details and photographs of the inclinometer instrumentation are presented in Figures 12 to 14.

6.2 Procedure

6.2.1 Instrument Description

The inclinometer instrumentation (Figure 12) is comprised of the following parts:

- Inclinometer probe (manual provided in Appendix A3);
- Digitilt DataMate readout box (manual provided in Appendix A4);
- Control cable (on a spool); and
- Inclinometer casing (installed permanently on the dam).

The inclinometer probe is transported and stored in a plastic carry case (see Figure 12). The probe is a very sensitive instrument, and must be protected from shocks and vibrations as much as possible, i.e., transport it on the seat inside the cab, opposed to the cargo box or platform of the truck.

6.2.2 Measurement Procedure

The following steps should be followed when taking a measurement:

- **Step 1:** Connect the readout to the probe using the control cable. Avoid over-tightening the connector at the probe end, which would reduce the effectiveness of the O-ring seal.
- **Step 2:** Remove the steel cap off the inclinometer casing, exposing the top of the inner (blue) guide casing.
- **Step 3:** Turn the readout box ON. This will power up the servo-accelerometers inside the probe, making them less vulnerable to shocks.
  – *Note:* the switch lever must be pulled up slightly when turning the readout on or off.
- **Step 4:** Cup the wheels of the probe with one hand and lower the probe in the casing. Make sure the upper wheel is aligned with the groove facing upstream (southeast/towards the reclaim pond and approximately perpendicular to the dam centerline), as shown in Figure 13.
  – *Note:* To avoid the need for data corrections, care should be taken to ensure that for the first set of readings at each location, the orientation of the upper inclinometer wheel is positioned in the groove towards the upstream.

– *Note:* After long periods between collecting inclinometer measurements (more than two months), the inclinometer holes should first be measured with a weighted tape measure to better determine an expected maximum reading depth. If water, soil or rock can make it within the plastic acrylonitrile butadiene styrene (ABS) casing, the maximum reading depth may be affected.

- **Step 5:** Lower the probe slowly to the bottom of the casing, making sure not to strike the bottom of the hole. The probe will therefore be about 15 cm past the deepest expected measurement marker on the control cable (expected depths provided in Table 4).

  – *Note:* To assist in estimating the total depth, the measurement beads on the inclinometer cable should be counted as they are lowered down hole. Total depth estimate in meters, can then determined by multiplying the counted number of beads by 0.5 m (or divide the number of beads lowered down the hole by two).

- **Step 6:** Wait ten minutes to allow the probe temperature to equilibrate with the temperature in the hole.

  – *Note:* If multiple holes/locations are being completed in one day, as long as the probe is not removed from the ambient air temperatures (i.e., moved or temporarily stored within a vehicle or heated container), then the temperature equilibration time can be reduced to five minutes for subsequent holes (i.e., 10 minutes equilibration on the first hole and then five minute equilibration on the remaining holes).

- **Step 7:** Once the probe has equilibrated, the arrows on the readout box should be used to move the cursor to select "**Read**" from the menu screen. Press "**Enter**" to complete the selection.

- **Step 8:** Next "**Record**" should be selected from the menu screen. Again "**Enter**" should be pushed for selection. From the installation list that comes up, select the station location that matches the location the current reading is being taken at. Press "**Enter**" to step past each parameter, as no edits should be needed. The complete list of locations is provided in Table 4.

Table 4: Inclinometer Installation and Measurement Details

Site Name	Installation	Minimum Reading Depth (m)	Maximum Expected Reading Depth* (m)	Reading Intervals (m)
N. Dam	070-1	0.5	14.5	0.5
N. Dam	070-2	0.5	14.0	0.5
N. Dam	070-3	0.5	12.5	0.5
N. Dam	120-1	0.5	12.0	0.5
N. Dam	120-2	0.5	11.0	0.5
N. Dam	120-3	0.5	4.5	0.5

*Based on initial set of readings completed / gather by SRK on September 8 and 9, 2012

- **Step 9:** The next screen will show the start depth (e.g., bottom reading for each hole, for example 14.5 for N.Dam:120-1) and the first readings for the A and B axis (A0 and B0 respectively). Figure 12 shows the designation of the A, B, A0 and B0 axes.
  - *Troubleshooting Note:* If there are discrepancies between what is pre-programmed into the readout box and what is measured in the field as the maximum reading depth, then one of the following options should be completed before proceeding to Step 10:
    1. Scroll up on the readout box until the measured maximum depth is reached; or
    2. Repeatedly press "**Enter**" on the readout box to input a 'dummy' or/stand-in value for the bottom intervals until the desired field measured maximum reading depth is reached. Notes should be taken to reflect which depths have 'dummy' numbers recorded in them.
- **Step 10:** Slowly raise the probe off the bottom of the inclinometer casing to the first measurement mark on the control cable. The range of measurement depths for each inclinometer station is provided in Table 4. Hold the top of the marker aligned with the top of the casing, as shown in Figures 13 and 14. The cable has yellow markers at 0.5 m intervals and red markers at 1 m intervals, i.e. alternating red and yellow markers.
- **Step 11:** Allow the readings to stabilize. A diamond will be displayed next to each number when the readings are stable. Press "**Enter**" to record the readings. The recorded readings will be marked with a star and shown on the bottom line of the display. The new depth will appear on the top line.
  - *Note:* every reading should be taken from the same point/location on the top of the inclinometer casing to limit measurement errors and discrepancies. These errors are often later apparent as large A & B checksum values when the data is downloaded, see Section 6.2.3. For best measurement repeatability, the location where measurements are being taken from should be marked on the top of the inclinometer casing with a permanent marker or tape.
- **Step 12:** If the readings do not seem to stabilize, record the average of the shown readings manually in your field book and then skip the level using the UP arrow. One average should be recorded for each A0 and B0 respectively.
- **Step 13:** Pull the cable up until the next measurement mark on the cable is aligned with the top of the inclinometer casing (at the same measurement location as used in Step 11). Record the reading when the numbers have stabilized.
  - *Note:* If any of the reading measurement markers are overshot then the probe should be lowered back to the previous level and then raised again to the exact marker depth. To ensure consistent measurements the probe must be drawn upward before each reading.
- **Step 14:** Repeat the process for each mark on the cable, until the probe is at the top of the casing (i.e., last reading will be at the 0.5 m mark on the cable).
- **Step 15:** After the last reading, the readout will display a menu screen. Select "**Continue**" from the menu options.

- **Step 16:** Carefully lift out the probe, cupping the wheel assemblies with your hand to prevent them from snapping open.
- **Step 17:** Holding the probe upright, slowly rotate it 180 degrees (do not flip), and re-insert the probe into the inner inclinometer casing. This time the upper wheel will be facing downstream (northwest/toward the camp or slightly west of the Doris Creek Bridge location).
  - Note: It is important that the probe is rotated 180 degrees and not into the inclinometer casing groves that are only 90 degrees from the initial groves. A full 180-degree rotation of the probe is required so that readings are taken both ways down the hole. This 180-degree rotation allows for a second set of measurements to be recorded which can then be later used to eliminate potential small errors in calibration. A reading should be taken from the same marked location at the top of the inclinometer casing, as outlined in Step 11.
- **Step 18:** Allow the probe to re-equilibrate for five minutes then repeat Steps 4 through 14. Parameters A and B will change to A180 and B180.
  - *Note:* These readings will be marked with the pi sign (π).
- **Step 19:** After the last reading select "**Done**" from the menu and move to the next station.
- **Step 20:** Make sure the blue protective cap for the inclinometer casing is placed back on and is secured. Before moving to the next inclinometer location, the steel cover should be re-placed back over the steel protective housing.

  Refer to the user manuals of the Digitilt Inclinometer (Appendix A3) and the Digitilt DataMate II (Appendix A4) for further details, if/as needed. Figure 2 shows the physical location of each inclinometer station.

6.2.3 Data Transfer

Once the data has been recorded, it is stored in the internal memory of the readout box. The data can be retrieved from the readout by connecting the readout box to a personal computer running a Windows operating system. Once connected, the Digitilt's DataMate Manager (DMM), DigiPro or DigiPro 2 program (all versions of the Durham Geo Slope Indicator software) can be used to complete the data transfer. A manual for the DMM for Windows, DigiPro and DigiPro 2 for Windows software is presented in Appendix A5, A6 and A7 respectively. The following steps should be followed to allow for a successful data transfer:

- **Step 1:** Download and install the DMM, DigiPro or DigiPro2 software (Slope Indicator software) from the Slope Indicator website (www.slopeindicator.com/downloads/dmm-download-page.html).
- **Step 2:** Start the Slope Indicator software program.
- **Step 3:** Power up the readout.
- **Step 4:** Connect the readout to the PC using the USB cable provided.
- **Step 5:** On the readout box, choose "**Comm**" from the main menu.

- **Step 6:** Open the Slope Indicator software. Go to "**File**" on the menu bar and then select "**New**" to create a new file or "**Open**" to navigate and open and existing database file.
  - Note: only once you have created or selected an existing database file will you be able to access the "DataMate" menu bar outlined in Step 7.
- **Step 7:** In the Slope Indicator software, select the "**DataMate**" drop-down menu.
- **Step 8:** Select the appropriate "**Comm Port**" (communication port) from the drop-down menu.
  - *Note:* each port (such as USB port) on your computer may have a different "Communication Port" number designation. Make sure you select the right Communication Port number for the installed cable driver. If the selected Communication Port is not responding, then you may need to try a different Communication Port number. If all ports do not work, you may need to download a new driver for the cable by connecting to the internet then connecting the port to your computer. Alternately drivers can be downloaded from www.slopeindicator.com.
- **Step 9:** From the main menu of the Slope Indicator software, select "DataMate" and then pick "Retrieve All" from the drop-down menu (Figure 14).
  - *Note:* different retrieved surveys may be dragged and dropped into a saved / compiled project database (i.e., a database with all the data for each round of measurements saved into it). Alternately you can go to "**File**" then "Import" on the drop-down menu to add in additional field data, if/as desired, to a compiled site inclinometer database.
- **Step 10:** From the main menu of the Slope Indicator software, select "**File**" and then pick "**Save As**" from the fly-down menu (for the older DMM or DigiPro software). Alternately if you are using DigiPro2 create a backup database by selecting "**File**" and then "**Backup Database**" from the fly-down menu (Figure 14).
  - *Note:* once the inclinometer survey / field data is received into the Slope Indicator software it can be viewed by clicking the drop-down sections / inclinometer location groupings on the left-hand side of the screen. Note that each of the individual field surveys can then be viewed by again clicking / expanding the file tree list below each inclinometer location / grouping.
    - When viewing the raw field data, the "**A_Checksum**" and "**B_Checksum**" columns can be used to check the quality of the survey data. Typically, these A and B checksum values (unit less) should be $\pm$ 50 or less, and with no more than two values for any given survey location being between 50 and 100; excluding the top 0.5 m depth rows / readings. Checks on the data quality will be done by the EOR however; the steps outlined above can proactively be completed by site personnel to limit the chance of re-surveys being asked for.
- **Step 11:** Save the data as a project database (or backup database) to the computer's desktop. The file can then be moved and stored for archiving after it has been e-mailed to the EOR.

The primary component of the file name is the date the data was collected on. The file names should be similar to the example “Copy of DataMate_*YYYY_MM_DD*.mdb” Where:

YYYY – calendar year

MM – calendar month

DD – calendar date

- **Step 12:** Close the software and turn off the readout.
- **Step 13:** Send the data to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.. Any additional field notes that outline details about how the inclinometer field survey was completed or about conditions at the time of this survey should be supplied with the updated database file.

6.3 Instrument Maintenance

6.3.1 General

When all measurements are complete, disconnect the control cable from the probe and the readout. Wipe the probe and the cable clean and replace the protective caps of the readout and the probe for transport.

Once back inside (e.g., office), open the probe carry case and remove all protective caps of the probe and the readout to allow the instruments and the connectors to dry for a few hours.

Before initially heading out to the field, the probe should be connected to the readout and tested in the office to ensure that a proper connection between the probe and DataMate is being made.

6.3.2 Battery Maintenance

The Digitilt DataMate battery should be charged overnight prior to collecting the survey data. The Digitilt DataMate has an AC main socket for the battery charger attachment or for external power if/as required. Battery levels can be checked by going to the ‘**Utilities**’ menu, then by choosing ‘**Batt**’. A new, fully charged battery should show approximately 6.6 volts with a full charge. The battery should be recharged if below 6 volts. It is best to charge the battery overnight if possible.

6.3.3 Desiccant Pack Maintenance

The desiccant is located inside the Digitilt DataMate. To check the moisture level in the DataMate go to the ‘**Utilities**’ menu and choose ‘**Temp**’. The DataMate displays humidity and temperature. Humidity levels from 20% to 60% are normal and if the humidity exceeds 75%, replace the desiccant (Appendix A4, page 16 of Digitilt DataMate manual).

7 Water Level Monitoring Standard Operating Procedure

7.1 Objective

Performance monitoring of the North Dam can only be properly done in conjunction with an accurate determination of the water level behind the dam. Water levels are recorded and transmitted to the online portal on regular basis.

7.2 Measurement Procedures

The water level measurements are recorded at TIA-2 using a permanent data logger (Instrumentation Northwest Inc.) paired with a HOBO Energy Pro Datalogger (Onset Computer Corp.). The data is then transmitted by a solar-powered iridium satellite transceiver where it can be accessed on the online portal. There is also a back-up datalogger installed but is not part of the regular monitoring SOP (Appendix F)

The data logger is configured to collect a reading every 15 minutes and the data is transmitted to an online portal on a regular basis (currently every 5 days). The login details are as follows:

https://datagarrison.com/
Username: 300234010417660
Password: hobo

Water level data will be monitored by SRK from the online portal. If modification to the datalogger-transmitter configuration are made, provide details to SRK at hopebaymonitoring@srk.com.

Water levels are measured as meters of water (head) above the data logger and require a known elevation of the datalogger or, more easily acquired, a surveyed water level for accurate translation to elevations for comparison to critical dam elevations. When initially installed by ERM (September 2017) a constant of 27.761 m was to be added for conversion to an elevation (Appendix F). As such, the only steps for active monitoring of the water level are as follows:

- **Step 1:** Regularly inspect the datalogger-transmitter setup at TIA-2 to confirm no damage or modification has occurred. Possible causes could be ice movement, human modification or animal interaction.
- **Step 2:** If damage or modification is noted, it must be reported with the time, date, detailed observations and at least one photo to SRK at hopebaymonitoring@srk.com.
- **Step 3:** As part of the monthly survey data collection (Section 5) a survey point of the water level must be collected.
- **Step 4:** In addition, ERM proposes to complete bi-annual water level surveys of the TIA reclaim pond to update the water level conversion constant, when received, these must also be provided to SRK to ensure agreement between surveys.

7.3 Reporting Procedures

Water level data recorded by the TIA-2 logger-transmitter system will be downloaded from the online portal discussed in this section. The water level survey data is expected to be supplied in Excel compatible format and would be sent along with the ground survey data (Section 5). Any observed changes to the TIA-2 configuration should be sent to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

8 Visual Monitoring Standard Operating Procedure

8.1 Objective

Formal visual (walk over) inspections of the South Dam, and immediate surrounding area, is required to act as an early notification for potential issues in areas not directly monitored by the installed instrumentation or other monitoring activities. Two levels of inspection are proposed:

1) Daily monitoring to identify issues or observations that may adversely impact the dam.

2) Full weekly visual (walk over) inspections.

8.2 Daily Visual Inspection

It is expected that the tailings deposition operations are monitored daily by qualified site staff at the TIA. The daily inspections are not intended to be an intensive exercise, rather it should include a walking or driving from one end of the dam to the other inspecting for major changes that have the potential to compromise its performance between weekly inspections. These inspections should include:

1. Settlement, depressions, sinkholes, cracking or signs of movement along the crest, the downstream or upstream face of the dam;

2. Significant changes in the observed seepage conditions compared to the prior weekly inspection;

3. Rapidly changing erosion conditions at the interface of the dam and the tundra;

4. Any other atypical conditions observed that are concerning or have the potential to compromise the dam performance.

There is no reporting requirement for the daily visual inspections and should be conducted as part of a daily ‘round’ at the TIA.

8.3 Weekly Visual (Walk Over) Inspection and Reporting

The upstream and downstream slopes and crests of the dams should be the focus during the walk over visual inspections. Specifically, the following should be noted:

1. Erosion

   (a) Any erosion over 5 cm in depth should be noted. Erosion locations should be recorded (using a handheld GPS or survey) and photographed.

   (b) If erosion is notable then it should be monitored carefully to ensure that conditions do not worsen (i.e., getting larger, deeper, to greater extent).

   (c) If erosion can be measured, then simple visual estimates or measurements with a tape measure should be completed on the larger erosional features.

2. Settlements / Depressions / Sinkholes.

   (a) If observed, then locations should be recorded (with GPS), photographed and the dimension / extents estimated.

3. Cracks/ Movements

   (a) If signs of cracking or movement are apparent then the crest on the upstream and downstream should be noted, photographed and the approximate crack dimension should be estimated or measured.

4. Debris and Vegetation

   (a) Any debris or vegetation growing on the upstream and downstream slopes of the dam should be noted.

   (b) Materials should not be stockpiled on the dam surface. Any debris on the dam should be removed to assist with better performing visual inspections over these areas.

   (c) Snow can affect thermal performance of the dam. Natural snow drifting over 1.0 m should be noted.

5. Ponding or Potential Seepage

   (a) Seepage is defined as water in contact with and flowing downstream of the dam. Walk the full length of the downstream dam toe to identify and currently flowing seepage locations or location that appear to have evidence of past seepage (which can be monitored going forward).

   (b) If seepage water is found, note the location (by dam chainage/station or GPS), photograph and provide a preliminary estimate the seepage rate if possible.

   (c) Ponded water exists only at the lowest point at the downstream toe of the dam. If new ponded areas are observed along the downstream toe, note the location and approximate extent on the inspection form and photograph.

   (d) Notify the on-site environmental coordinator to assess and conduct seepage monitoring (Section 9).

6. Instrumentation

   (a) Look for visual damage to instrumentation (i.e., does all instrumentation appear to be intact or has it been damaged by equipment, animals or personnel?).

   (b) If damage is noted, then photographs and notes / observations should be collected to assist with determining if repair of the instrumentation is possible.

7. Thermosyphon Radiators

   (a) Look for visual damage or corrosion to thermosyphon radiators (i.e., is any rust notable, is any physical damage notable, and is the thermosyphon radiators generally still upright).

(b) If damage is noted, then photographs and notes / observations should be collected.

A monitoring checklist is presented in Appendix E. This inspection form, along with any photos or notes from the inspection should be formally recorded and submitted to the EOR jkurylo@srk.com, Peter Luedke, pluedke@srk.com, and the SRK team at hopebaymonitoring@srk.com.

The EOR should be notified immediately after any inspection where notable changes to any of the areas / items listed above are observed. The EOR will work with AEM to provide further guidance on monitoring or sampling requirements and to determine if mitigation measures are required.

9 Seepage Monitoring Standard Operating Procedure

9.1 Objective

Seepage or contact water flowing from the toe of the North Dam has been observed since dam construction. With deposition of tailings ongoing, seepage monitoring is required to confirm that the source is not seepage from the TIA.

This procedure must be conducted when potential seepage is identified during the Visual Monitoring (Section 8) or **monthly** once potential seepage has been identified.

In 2022, it was determined that seepage sampling is no longer required at the North Dam. If seepage is identified during the visual site inspections, seepage sampling will resume per this SOP.

9.2 Procedure

Seepage is defined as water flowing from the toe of the North Dam. Monitoring and sample collection are to be performed by on-site environmental personnel, who are trained in seepage identification and sample collection methods. Seepage monitoring of the North Dam toe specifically is described as follows:

1. Complete a walk over survey on foot. This will consist of walking the full length of the downstream dam toe to identify any currently flowing seepage locations or location that appear to have evidence of past seepage (which can be monitored going forward). Ponded water should be inspected for seepage feeding into the ponded water, if none, no sampling is required.
2. At each flowing seepage location, collect water samples for the parameters listed in the laboratory analytical suite (LAS) listed in this section and record the following field data:
   - GPS coordinates,
   - Photographs (upstream and downstream shots),

   (a) Volumetric flow rate

   1. Volumetric flow rates determined as follows:

      For samples collected at the v-notch weir:

      o The height of the water in the weir reservoir, relative to the bottom of the v-notch itself, should be measured. The level should not be measured in the v notch (this could be done as a check but should not be the primary measurement).

      o For calibration of the v-notch weir, a container of known volume should be filled from the flow passing through the v-notch. The time required to fill the entire container (of a know volume – e.g. 1L) should be recorded. This should be repeated three times per sampling event. This is most critical during the first sampling events of the year.

- o All seepage that reports the v-notch weir area should be directed through the weir. Where a large proportion of the seepage is flowing around the weir, the percentage of total seepage flowing through the weir should be estimated and reported with the field notes.

For samples collected at the toe of the dam (not at the v-notch weir):

- o Flow volume and velocity can be estimated by taking a container of a known volume and recording the time it takes for the seepage to fill the known volume. Alternatively, estimate the cross-sectional area of the flow and using a stop watch visually estimate the velocity of the water (time for identifiable debris to travel a known distance through the estimated cross-sectional area). To help improve accuracy of the estimate / measurement, at least three iterations of the estimate should be completed.

(b) Field measurements: temperature, pH, electrical conductivity (EC), chloride, and oxidation reduction potential (ORP),

(c) Date and time,

(d) Name of sampler, and

The seepage sampling frequency is **once per week** while seepage is occurring or at the discretion of the EOR.

3. For every seepage sampling event, collect additional samples at the following locations:

   (a) SNP station TL-1 (Reclaim Barge)

      1. Field measurements (temperature, pH, EC, chloride, ORP), and
      2. Water samples for lab parameters listed below (LAS).

   (b) Upstream side of the North Dam (reservoir touching the upstream slope)

      1. Field measurements (temperature, pH, EC, chloride, ORP), and
      2. Water samples are not required at this location.

4. **Once per month**, collect the following QA/QC samples to validate the geochemical data set:

   (a) One field duplicate, one travel blank and one field blank for lab parameters listed below (LAS); and

   (b) For the field duplicate only, field measurements (temperature, pH, EC, chloride, ORP).

5. **Once per month** during routine sampling of SNP station TL-5 (tailings supernatant discharge from the mill), collect samples for the analysis of:

   (a) Field measurements (temperature, pH, EC, chloride, ORP), and

   (b) Water samples for lab parameters listed below (LAS).

(c) This monthly sampling of TL-5 satisfies the TL-5 monitoring requirements outlined in the South Dam SOP (SRK, 2020).

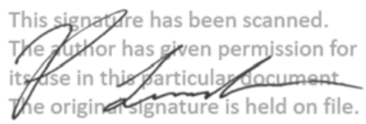
The laboratory analytical suite (LAS) for North Dam Seepage Monitoring Program is as follows:

- Lab pH and EC
- SO_4, Cl
- Alkalinity
- Ammonia, NO_3, NO_2, Total N
- Total CN, Free CN
- SCN, CNO
- Total metals (including sulphur and mercury)
- Dissolved metals (including sulphur and mercury)

9.3 Sample Shipment and Reporting Procedure

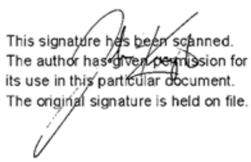
Water samples are to be shipped to ALS Environmental. When samples are shipped, the appropriate Chain of Custody (COC) form and the field data should be sent to SRK, and the Engineer of Record (EOR) should be notified that the sample have been collected and shipped. Upon receipt of the lab results, these should also be sent to SRK. All documentation and results should be sent to Lbarazzuol@srk.com (Lisa Barazzuol) rcocuaco@srk.com (Rosie Cocuaco), mting@srk.com (Maritess Ting) and Hopebaymonitoring@srk.com (SRK Hope Bay monitoring account).

This report, “Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 3Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 3Hope Bay Project, North Dam Monitoring: Standard Operating Procedures – Revision 3”, was prepared by SRK Consulting (Canada) Inc.

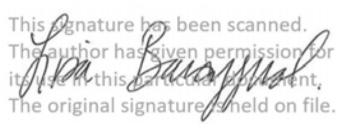


Peter LuedkePeter LuedkePeter Luedke, EITEITEIT
Consultant

and reviewed by:



John Kurylo, MEng PEngMEng PEngMEng PEng
Senior Consultant



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Principal Consultant (Geochemistry)

All data used as source material plus the text, tables, figures, and appendices of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

10 References

Cornelissen, G. 2013. Suggested Guidelines for Surveying at the North Dam. PDF notes supplied by True North Geomatics Ltd. / Nuna Logistics to SRK Consulting (Canada) Inc. September.

National Oceanic and Atmospheric Administration (NOAA) / John Lipe. Accessed July 2013 online at: http://www.srh.noaa.gov/srh/dad/hydro/Doingasurvey.html.

SRK Consulting (Canada) Inc. 2007. Design of the Tailings Containment Area, Doris North Project, Hope Bay, Nunavut, Canada. Report prepared for Miramar Hope Bay Ltd. Project Number: 1CM014.008.165. March 2007.

SRK Consulting (Canada) Inc. 2012. Hope Bay Project, North Dam As-Built Report. Nunavut, Canada. Report prepared for Hope Bay Mining Ltd. Project Number: 1CH008.058. October 2012.

SRK Consulting (Canada) Inc. 2020. Hope Bay Project, South Dam Monitoring: Standard Operating Procedures – Revision 01. Report prepared for AEM Resources Inc. Project Number: 1CT022.036. July 2020.

Appendix A - Operator's Manuals

Appendix A1 - CR1000 Measurement and Control System

OPERATOR'S MANUAL

CR1000 Measurement and Control System

Revision: 7/11

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. (“CSC”) to be free from defects in materials and workmanship under normal use and service for **thirty-six (36) months** from date of shipment unless specified otherwise. **** Batteries are not warranted.** ** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

CAMPBELLSCIENTIFIC
CANADA CORP.
11564 - 149 street - edmonton - alberta - T5M 1W7
tel 780.454.2505 fax 780.454.2655
www.campbellsci.ca

PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

Select Sections extracted from CR100 Measurement and Control System (Revision: 7/11) Operator's Manual.

Full manual can be found online at: http://s.campbellsci.com/documents/us/manuals/cr1000.pdf

Table of Contents

Section 1. Introduction

Whether in extreme cold in Antarctica, scorching heat in Death Valley, salt spray from the Pacific, micro-gravity in space, or the harsh environment of your office, Campbell Scientific dataloggers support research and operations all over the world. Our customers work a broad spectrum of applications, from those more complex than any of us imagined, to those simpler than any of us thought practical. The limits of the CR1000 are defined by our customers. Our intent with the CR1000 manual is to guide you to the tools you need to explore the limits of your application.

You can take advantage of the CR1000's powerful analog and digital measurement features by spending a few minutes working through the *Quickstart Tutorial* (p. 3) and the *Overview* (p. 27). For more demanding applications, the remainder of the manual and other Campbell Scientific publications are available. If you are programming with CRBASIC, you will need the extensive Help available with the CRBASIC Editor software. Formal CR1000 training is also available from Campbell Scientific.

This manual is organized to take you progressively deeper into the complexity of CR1000 functions. You may not find it necessary to progress beyond the *Quickstart Tutorial* (p. 3) or *Overview* (p. 27) sections. *Quickstart Tutorial* (p. 3) gives a cursory view of CR1000 data acquisition and walks you through a first attempt at data acquisition. *Overview* (p. 27) reviews salient topics, which are covered in-depth in subsequent sections and appendices.

More in-depth study requires other Campbell Scientific publications, most of which are available on-line at *www.campbellsci.com*. Generally, if a particular feature of the CR1000 requires a peripheral hardware device, more information is available in the manual written for that device. Manuals for Campbell Scientific products are available at *www.campbellsci.com*.

If you are unable to find the information you need, please contact us at 435-753-2342 to speak with an applications engineer. Or, you can email us at *support@campbellsci.com*.

Section 2. Quickstart Tutorial

This tutorial gives a cursory look at CR1000 data acquisition.

2.1 Primer - CR1000 Data Acquisition

Data acquisition with the CR1000 is the result of a step wise procedure involving the use of electronic sensor technology, the CR1000, a telecommunications link, and *datalogger support software* (p. 439, p. 490).

2.1.1 Components of a Data Acquisition System

A typical data acquisition system is conceptualized in *FIGURE. Data Acquisition System Components* (p. 4). A CR1000 is only one part of a data acquisition system. To acquire good data, suitable sensors and a reliable data retrieval method are required. A failure in any part of the system can lead to "bad" data or no data.

2.1.1.1 Sensors

Suitable sensors accurately and precisely transduce environmental change into measurable electrical properties by outputting a voltage, changing resistance, outputting pulses, or changing states.

Read More! *APPENDIX. Accuracy, Precision, and Resolution* (p. 454)

2.1.1.2 Datalogger

CR1000s can measure almost any sensor with an electrical response. CR1000s measure electrical signals and convert the measurement to engineering units, perform calculations and reduce data to statistical values. Every measurement does not need to be stored. The CR1000 will store data in memory awaiting transfer to the PC via external storage devices or telecommunications.

2.1.1.3 Data Retrieval

The products of interest from a data acquisition system are data in data files, usually stored on and accessible by a PC.

Data are copied, not moved, from the CR1000 to the PC. Multiple users may have access to the same CR1000 without compromising data or coordinating data collection activities.

RS-232 and CS I/O ports are integrated with the CR1000 wiring panel to facilitate data collection.

On-site serial communications are preferred if the datalogger is near the PC, and the PC can dedicate a serial (COM) port for the datalogger. On-site methods such as direct serial connection or infrared link are also used when the user visits a remote site with a laptop or PDA.

In contrast, telecommunications provide remote access and the ability to discover problems early with minimum data loss. A variety of devices, and combinations of devices, such as telephone modems, radios, satellite transceivers, and TCP/IP network modems are available for the most demanding applications.

FIGURE 1.   Data Acquisition System Components

2.1.2   CR1000 Module and Power Supply

The CR1000 module integrates electronics within a sealed stainless steel clamshell, making it economical, small, and very rugged.

2.1.2.1   Wiring Panel

The CR1000 module connects to the wiring panel. As shown in *FIGURE. CR1000 Wiring Panel* (p. 5), the wiring panel provides terminals for connecting sensors, power and communications devices. Internal surge protection is incorporated with the input channels.

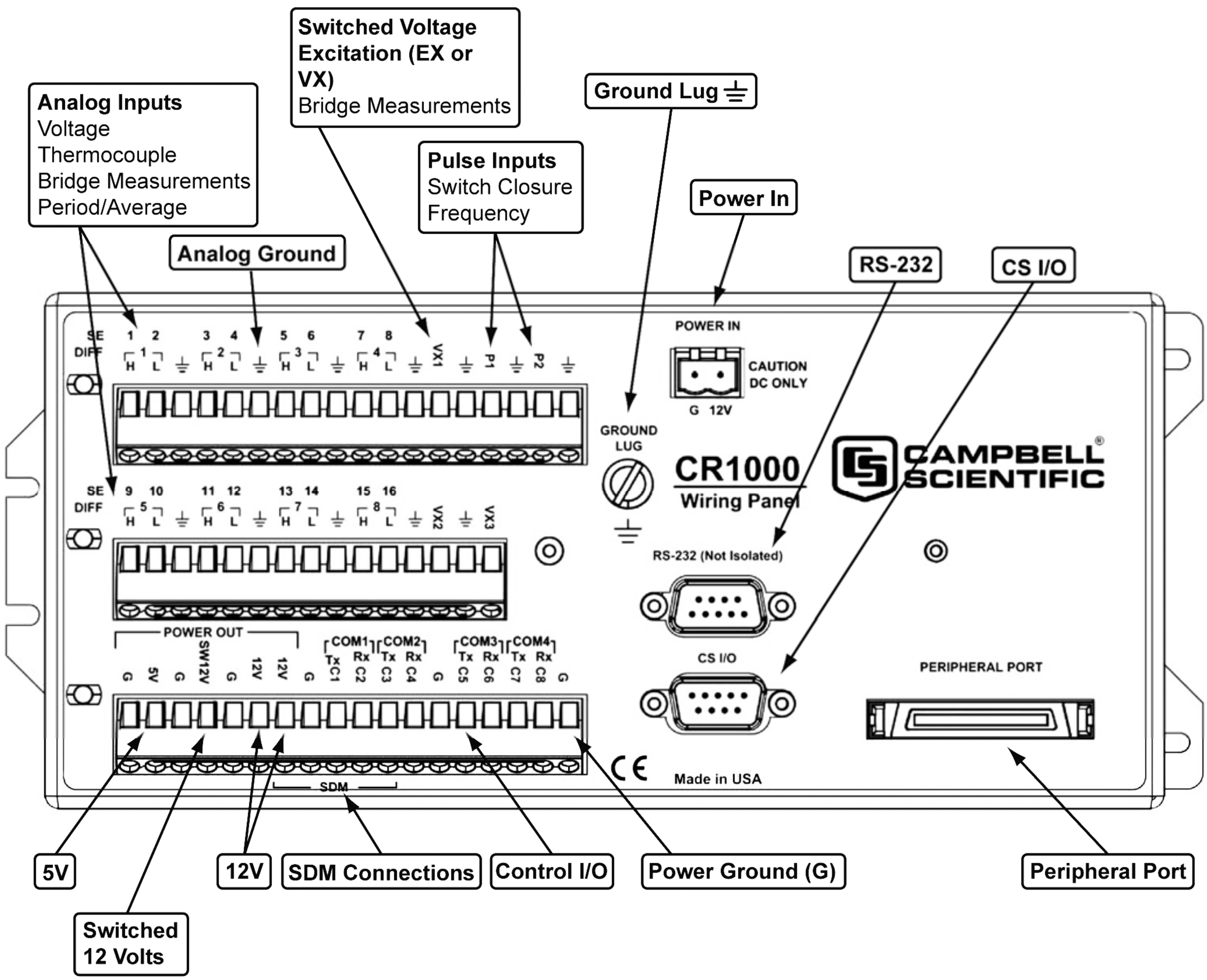


FIGURE 2. Wiring Panel

2.1.2.2 Power Supply

The CR1000 is powered by a nominal 12 Vdc source. Acceptable power range is 9.6 to 16 Vdc.

External power connects through the green "POWER IN" on the face of the CR1000. The "POWER IN" connection is internally reverse polarity protected.

2.1.2.3 Backup Battery

A lithium battery backs up the CR1000 clock, program, and memory in case of power loss. See *SECTION. Internal Battery* (p. 41)

2.1.3 Sensors

Most electronic sensors, whether or not manufactured or sold by Campbell Scientific, can be interfaced to the CR1000. Check for on-line content concerning interfacing sensors at *www.campbellsci.com*, or contact a Campbell Scientific applications engineer for assistance.

2.1.3.1 Analog Sensors

Analog sensors output continuous voltages that vary with the phenomena measured. Analog sensors connect to analog terminals. Analog terminals are configured as single-ended, wherein sensor outputs are measured with respect to ground (*FIGURE. Analog Sensor Wired to Single-Ended Channel #1* (p. 6)) or configured as differential, wherein high sensor outputs are measured with respect to the low output (*FIGURE. Analog Sensor Wired to Differential Channel #1* (p. 6)). *TABLE. Single-ended and Differential Input Channels* (p. 6) lists channel assignments.

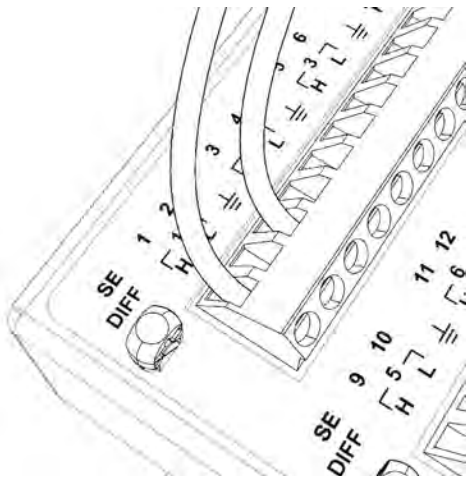


FIGURE 3.   Analog Sensor Wired to Single-Ended Channel #1

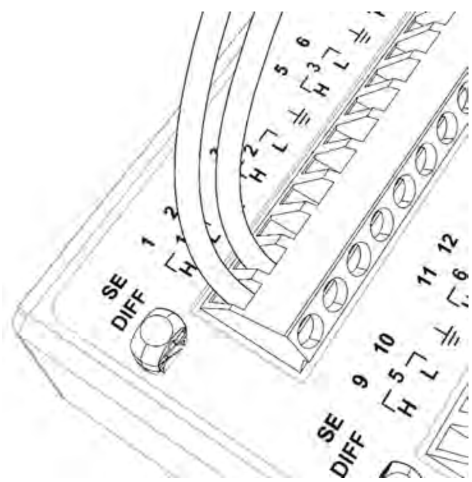


FIGURE 4.   Analog Sensor Wired to Differential Channel #1

TABLE 1. Single-ended and Differential Input Channels

Differential Channel	***Single-Ended Channel***
1H 1L	1 2
2H 2L	3 4
3H 3L	5 6
4H 4L	7 8
5H 5L	9 10
6H 6L	11 12
7H 7L	13 14
8H 8L	15 16

2.1.3.2 Bridge Sensors

Many sensors use a resistive bridge to measure phenomena. Pressure sensors and position sensors commonly use a resistive bridge. For example, a specific resistance in a pressure transducer strain gage correlates to a specific water pressure. A change in resistance in a wind vane potentiometer correlates to a change in wind direction.

2.1.3.2.1 Voltage Excitation

Bridge resistance can be determined by measuring the difference between a known voltage applied to a bridge and the measured return voltage. The CR1000 supplies a precise scalable voltage excitation via excitation terminals. Return voltage is measured on analog terminals. Examples of bridge sensor wiring using voltage excitation are illustrated in *FIGURE. Half Bridge Wiring -- Wind Vane Potentiometer* (p. 8) and *FIGURE. Full Bridge Wiring -- Pressure Transducer* (p. 8).

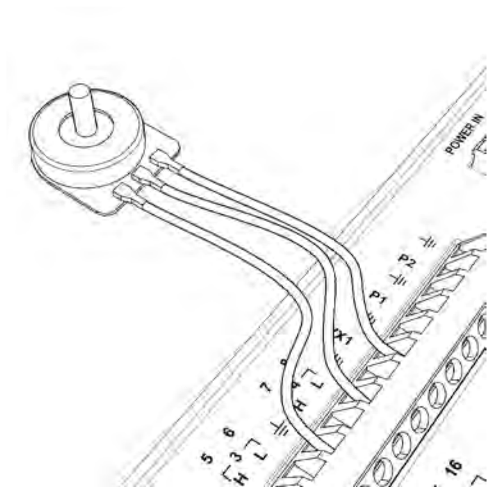


FIGURE 5. Half Bridge Wiring -- Wind Vane Potentiometer

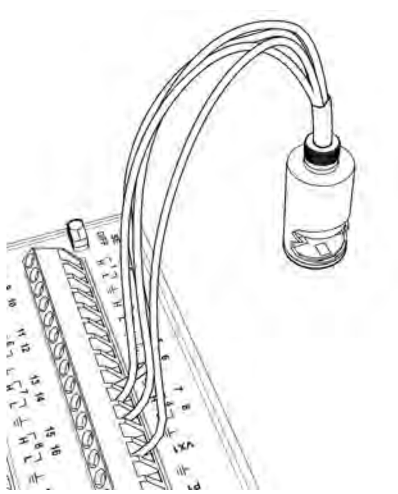


FIGURE 6. Full Bridge Wiring -- Pressure Transducer

2.1.3.3 Pulse Sensors

Pulse sensors are measured on CR1000 pulse measurement channels. The output signal generated by a pulse sensor is a series of voltage waves. The sensor couples its output signal to the measured phenomenon by modulating wave frequency. The CR1000 detects each wave as the wave transitions between voltage extremes (high to low or low to high). This is termed "state transition". Measurements are processed and presented as counts, frequency, or timing data.

Note Period averaging sensors, while technically frequency output sensors, are typically connected to single-ended analog channels and measured with the PeriodAverage() instruction.

2.1.3.3.1 Pulses Measured

FIGURE. Pulse Sensor Output Signal Types (p. 9) illustrates three pulse sensor output signal types.

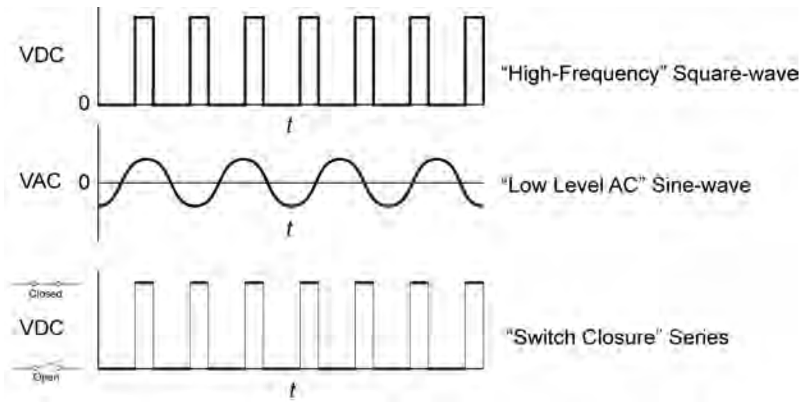


FIGURE 7. Pulse Sensor Output Signal Types

2.1.3.3.2 Pulse Input Channels

TABLE. Pulse Input Channels and Measurements (p. 9) lists devices, channels and options for measuring pulse signals.

TABLE 2. Pulse Input Channels and Measurements

Channels Available for Pulse Input	***Input Types***	***Data Option***	***CRBASIC Instruction***
P1, P2	High Frequency Low-Level ac Switch Closure	Counts Frequency Run Avg of Freq	PulseCount ()
C1, C2, C3, C4, C5, C6, C7, C8	High Frequency Switch Closure Low-Level ac (with LLAC4 Low-Level AC Conversion Module)	Counts Frequency Run Avg of Freq Interval Period State	PulseCount () TimerIO ()

2.1.3.3.3 Pulse Sensor Wiring

Wiring a pulse sensor to a CR1000 is straight forward, as shown in *FIGURE. Pulse Input Wiring -- Anemometer Switch* (p. 10). Pulse sensors have two active wires, one of which is always ground. Connect the ground wire to a ⏚ channel. Connect the other wire to a pulse channel. Sometimes the sensor will require power from the CR1000, so there will be two more wires – one of which is always ground. Connect power ground to a G channel. Do not confuse the pulse wire with the positive power wire, or damage to the sensor or CR1000 may result. Some switch closure sensors may require a pull-up resistor. Consult *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86) for information on use of pull-up resistors.

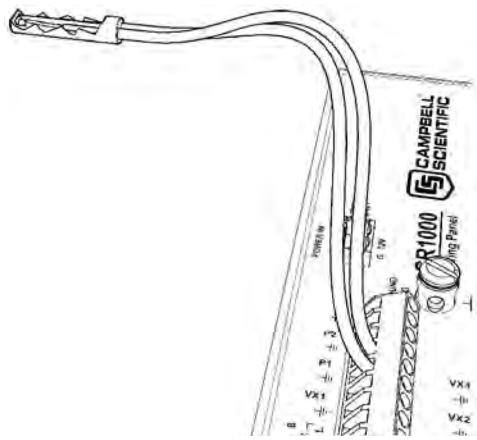


FIGURE 8.   Pulse Input Wiring -- Anemometer Switch

2.1.3.4 RS-232 Sensors

The CR1000 has 6 ports available for RS-232 input as shown in *FIGURE. Location of RS-232 Ports* (p. 10). As indicated in *FIGURE. Use of RS-232 and Digital I/O when Reading RS-232 Devices* (p. 10), RS-232 sensors can be connected to the RS-232 port or to digital I/O port pairs. Ports can be set up with various baud rates, parity options, stop bit options, and so forth as defined in CRBASIC Help.

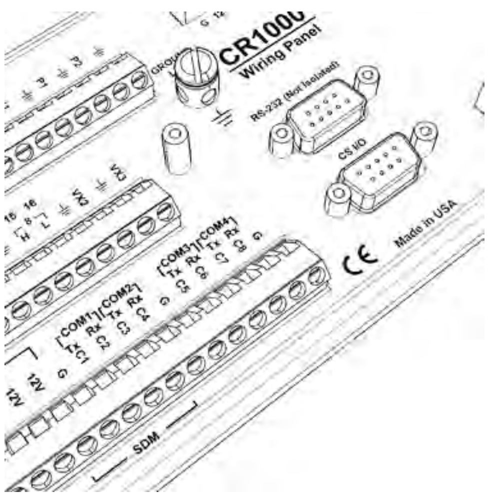


FIGURE 9.   Location of RS-232 Ports

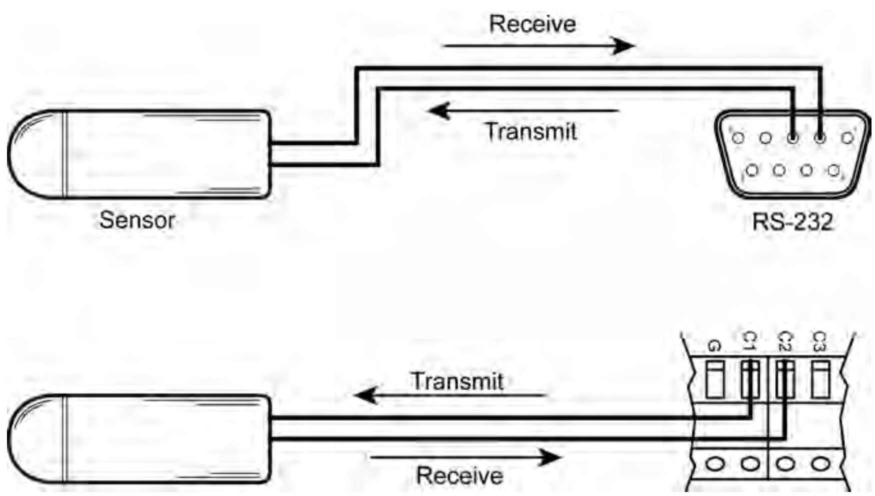


FIGURE 10. Use of RS-232 and Digital I/O when Reading RS-232 Devices

2.1.4 Digital I/O Ports

The CR1000 has 8 digital I/O ports selectable as binary inputs or control outputs. These are multi-function ports. Edge timing, switch closure, and high frequency pulse functions are introduced in *SECTION. Pulse Sensors* (p. 8) and discussed at length in *SECTION. Pulse Measurements* (p. 81). Other functions include device driven interrupts, asynchronous communications and SDI-12 communications. *FIGURE. Control and Monitoring with Digital I/O* (p. 12), illustrates a simple application wherein digital I/O ports are used to control a device and monitor the state (whether on or off) of the device.

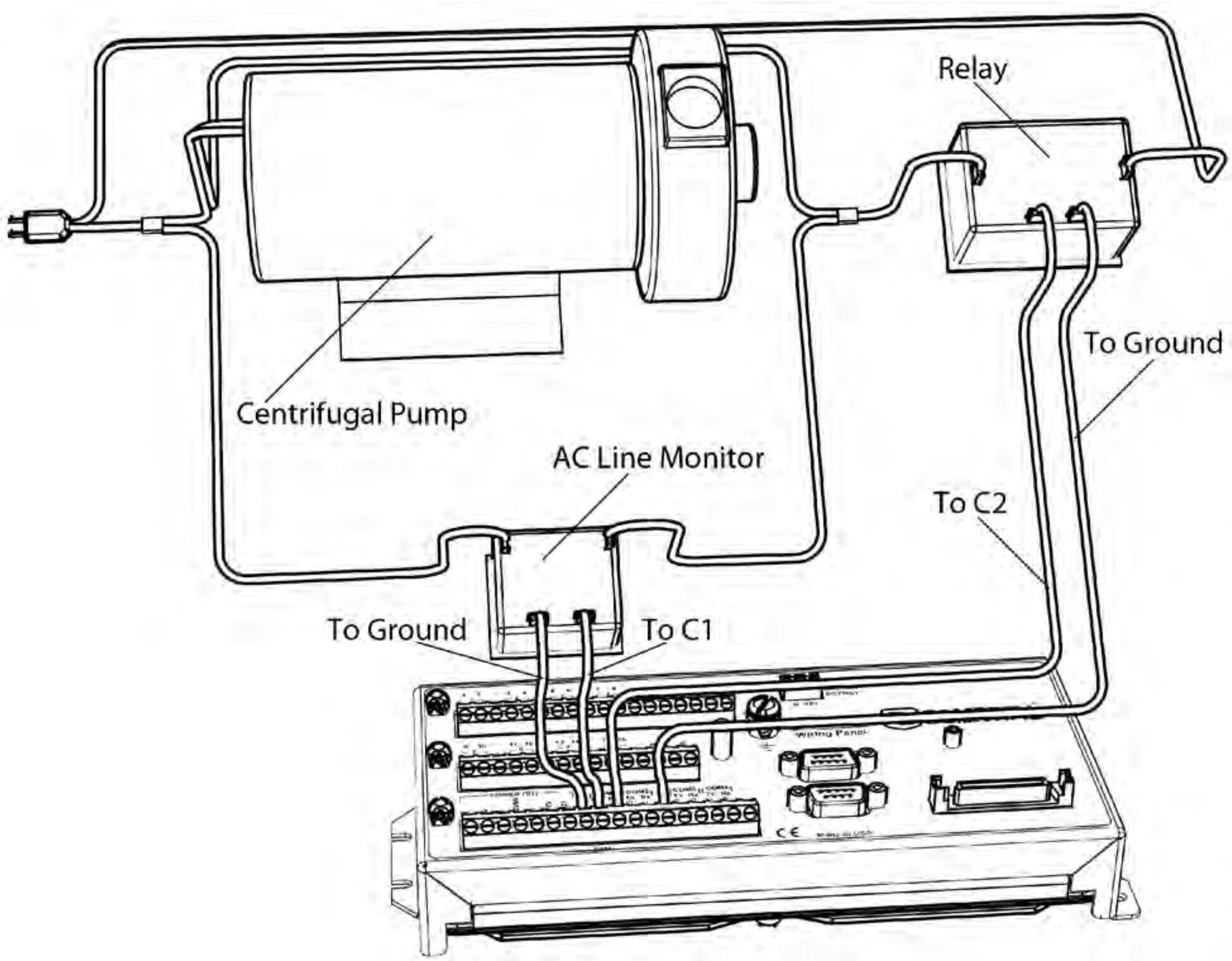


FIGURE 11. Control and Monitoring with Digital I/O

2.1.4.1 SDM Channels

SDM devices and a brief description of the their uses can be found in *APPENDIX. Sensors and Peripherals* (p. 495).

Digital I/O ports C1, C2 and C3 are used for SDM (Serial Device for Measurement) communications.

2.1.5 Input Expansion Modules

Modules are available from Campbell Scientific to expand the number of input and digital I/O ports on the CR1000. *APPENDIX. Digital I/O Expansion* (p. 498) lists available modules.

2.2 Exercise - Measuring a Thermocouple

This tutorial is designed to illustrate the function of the CR1000. During the exercise, the following items will be described.

- Attaching a thermocouple to analog differential terminals
- Creating a program for the CR1000
- Making a simple thermocouple measurement
- Sending data from the CR1000 to a PC
- Viewing the data from the CR1000

2.2.1 What You Will Need

The following items are needed to complete this exercise.

- Campbell Scientific CR1000 datalogger
- Campbell Scientific PS100 12 Vdc power supply (or other compatible power supply) with RED and BLACK wire leads.
- Thermocouple (included with the CR1000)
- Personal Computer (PC) with an available RS-232 serial port. A USB to RS-232 cable may be used if an RS-232 port is not available.
- RS-232 cable (included with the CR1000).

Note If the PC is to be connected to the RS-232 port for an extended period, use Campbell Scientific's SC32B interface to provide optical isolation. This protects low level analog measurements from outside interference.

- PC200W software. This software is available on the Campbell Scientific Resource CD or at www.campbellsci.com.

2.2.2 Hardware Set-Up

Note The thermocouple is attached to the CR1000 later

2.2.2.1 External Power Supply

With reference to *FIGURE. Power and RS-232 Connections* (p. 14),

1. Remove the green power connector from the CR1000.
2. Verify the RED wire on the PS100 is attached to a PS100 12V terminal, and the BLACK wire is attached to a PS100 G terminal.

3. Verify the On/Off switch on the PS100 is in the Off position.

4. Attach the RED wire from the PS100 to the terminal labeled 12V on the green connector.

5. Attach the BLACK wire from the PS100 to the terminal labeled G on the green connector.

6. After confirming the correct polarity on the wire connections, insert the green power connector into its receptacle on the CR1000.

7. Connect the RS-232 cable between the RS-232 port on the CR1000 and the RS-232 port on the PC (or to the USB to RS-232 cable).

8. Move the On/Off switch on the PS100 to the On position.

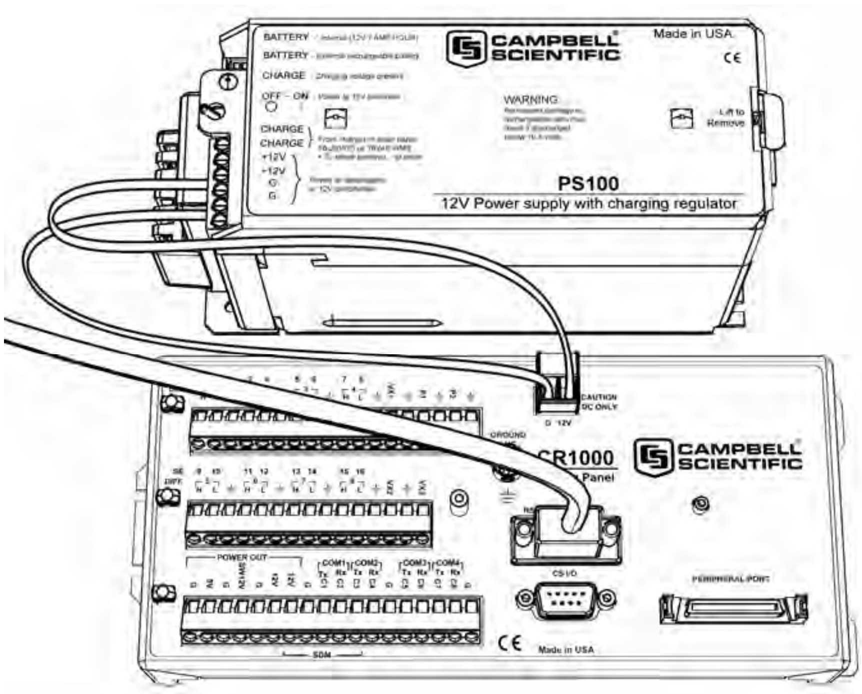


FIGURE 12. Power and RS-232 Connections

2.2.3 PC200W Software Setup

1. Install the PC200W software onto a PC. Follow the on-screen prompts during the installation process for the Program Folder and Destination Location.

2. Open the PC200W software (*FIGURE. PC200W Main Window* (p. 15)). When the software is first run, the EZSetup Wizard will be run automatically in a new window. This will configure the software to communicate with the CR1000. *TABLE. PC200W EZSetup Wizard Example Selections* (p. 15) indicates what information needs to be entered

on each screen. Click on Next at the bottom of the screen to advance to the next screen.

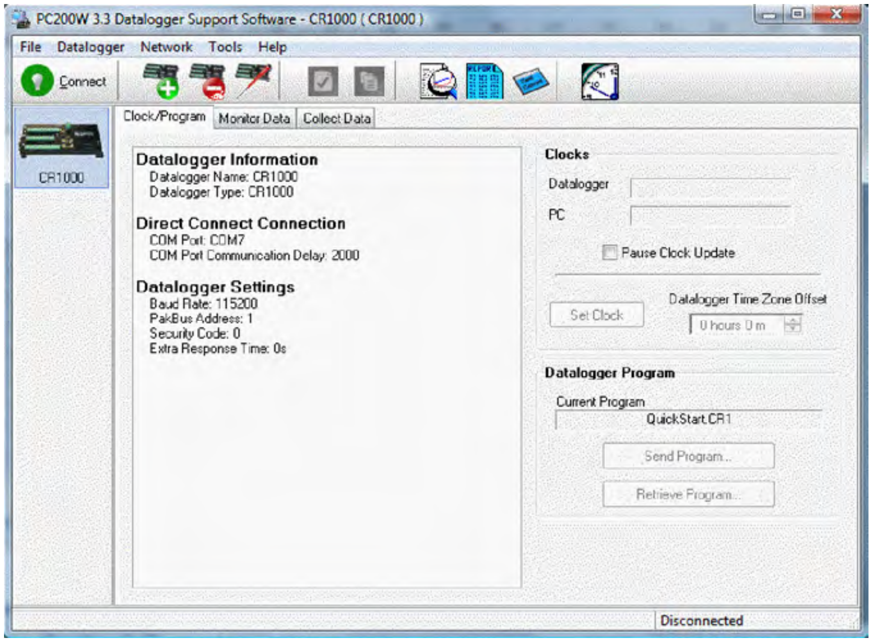


FIGURE 13. PC200W Main Window

TABLE 3. PC200W EZSetup Wizard Example Selections.

Start the wizard to follow table entries

Screen Name	***Information Needed***
Introduction	Provides and introduction to the EZSetup Wizard along with instructions on how to navigate through the wizard.
Datalogger Type and Name	Select the CR1000 from the scroll window. Accept the default name of "CR1000."
COM Port Selection	Select the correct COM port for RS-232 connection. Typically, this will be COM1. Other COM numbers are possible, especially when using a USB to serial cable. Leave the COM Port Communication Delay at "00 seconds." Note: When using a USB to serial cable, the COM number may change if the cable is moved to a different USB port. This will prevent data transfer between the software and CR1000. Should this occur, simply move the USB cable back to the original port. If this is not possible, it will be necessary to close the PC200W software and open it a second time to refresh the available COM ports. Click on "Edit Datalogger Setup" and change the COM port to the new port number.
Datalogger Settings	Used to configure how the CR1000 communicates through the COM port. For this tutorial, accept the default settings.

TABLE 3. PC200W EZSetup Wizard Example Selections.	
Start the wizard to follow table entries	
Screen Name	***Information Needed***
Communication Setup Summary	Provides a summary of the settings made in previous screens.
Communications Test	A communications test between the CR1000 and PC can be performed in this screen. For this tutorial, the test is not required. Press Finish to exit the Wizard.

After exiting the wizard, the main PC200W window becomes visible. The window has several tabs available. By Default, the Clock/Program tab is visible. This tab displays information on the currently selected datalogger along with clock and program functions. The Monitor Data or Collect Data tabs may be selected at any time.

A number of icons are available across the top of the window. These access additional functions available to the user.

2.2.4 Write Program with Short Cut

Short Cut Programming Objectives:

This portion of the tutorial will use Short Cut to create a program that measures the CR1000 power supply voltage, wiring panel temperature, and ambient air temperature. The CR1000 will take samples once per second and store averages of these values at one minute intervals.

2.2.4.1 Procedure: (Short Cut Steps 1-6)

1. Click on the Short Cut icon in the upper-right corner of the PC200W window. The icon resembles a clock face.

2. A new window will appear showing the option to create a new program or open an existing program. Select **New Program**.

3. A drop-down list will appear showing different dataloggers. Select the CR1000.

4. The program will now ask for the scan interval. Set the interval to 1 second and click on okay.

Note The first time Short Cut is run, a prompt will appear asking for a choice of "ac Noise Rejection." Select "60 Hz" for the United States and other countries using 60 Hz ac voltage. Select "50 Hz" for Europe and other countries operating on 50 Hz ac voltage.

5. A second prompt will ask for a choice of "Sensor Support." Select "Campbell Scientific, Inc."

6. Under Available Sensors, expand the "Sensors" folder by clicking on the "+" symbol. This shows several sub-folders. Expand the "Temperature" folder to view the available sensors.

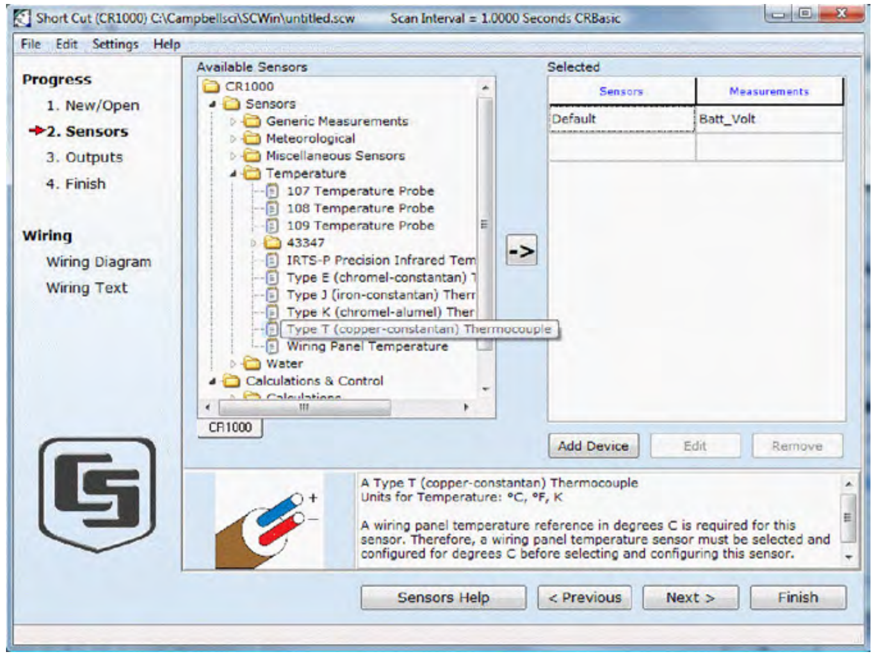


FIGURE 14. Short Cut Temperature Sensor Folder

2.2.4.2 Procedure: (Short Cut Steps 7-9)

7. Double-click the Wiring Panel Temperature sensor to add it to the Selected category. Alternatively, highlight the Wiring Panel Temperature sensor by clicking on it once, and then click on the arrow between Available Sensors and Selected to add it to the Selected sensors.

8. Double-click the Type T Thermocouple to add it to the Selected category. A prompt will appear asking for the number of sensors. Change this value to "1." A second prompt screen will appear. Set the Reference Temperature Measurement to "Ptemp_C," and then click OK to close the prompt.

9. Click on the Wiring Diagram link to view the sensor wiring diagram. Attach the Type T Thermocouple to the CR1000 as shown in the diagram.

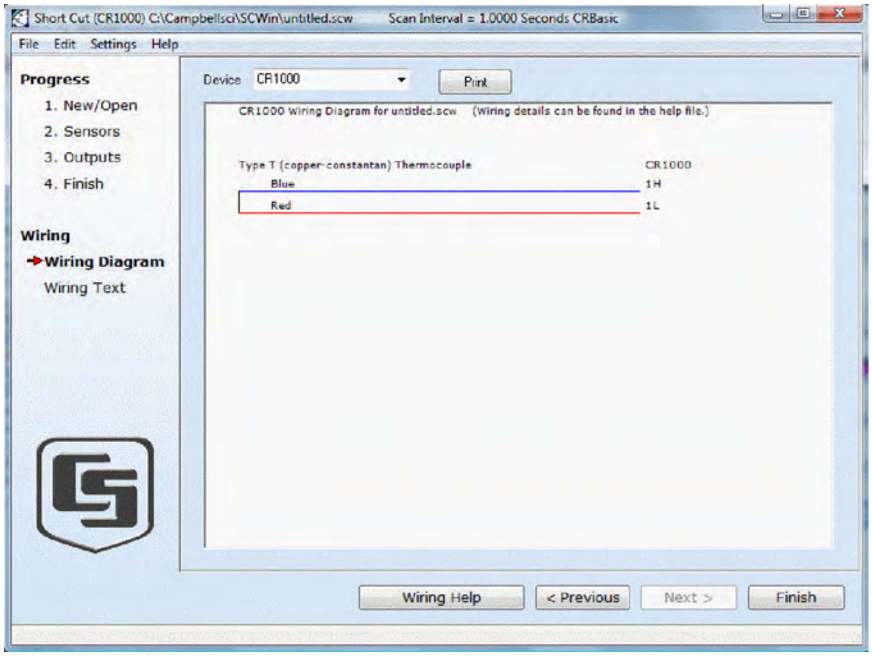


FIGURE 15. Short Cut Thermocouple Wiring

2.2.4.3   Procedure: (Short Cut Steps 10-11)

Historical Note In the space race era, a field thermocouple measurement was a complicated and cumbersome process incorporating a thermocouple wire with three junctions, a micro-voltmeter, a vacuum flask filled with an ice slurry, and a thick reference book. One thermocouple junction was connected to the micro-voltmeter. Another sat in the vacuum flask. The third was inserted into the location of the temperature of interest. When the temperature settled out, the micro-voltmeter was read. This value was then looked up on the appropriate table in the reference book to determine the temperature.

Then along came Eric and Evan Campbell. Campbell Scientific designed the first CR7 datalogger to make thermocouple measurements without the need of vacuum flasks, third junctions, or reference books. Now, there's an idea!

Nowadays, a thermocouple consists of two wires of dissimilar metals, such as copper and constantan, joined at one end. The joined end is the measurement junction; the junction that is created when the thermocouple is wired to the CR1000 is the reference junction.

When the two junctions are at different temperatures, a voltage proportional to the temperature difference is induced into the wires. The thermocouple measurement requires the reference junction temperature to calculate the measurement junction temperature using proprietary algorithms in the CR1000 operating system.

10. Click on Outputs to advance to the next step.

11. The Outputs window displays a list of selected sensors on the left, and data storage Tables on the right.

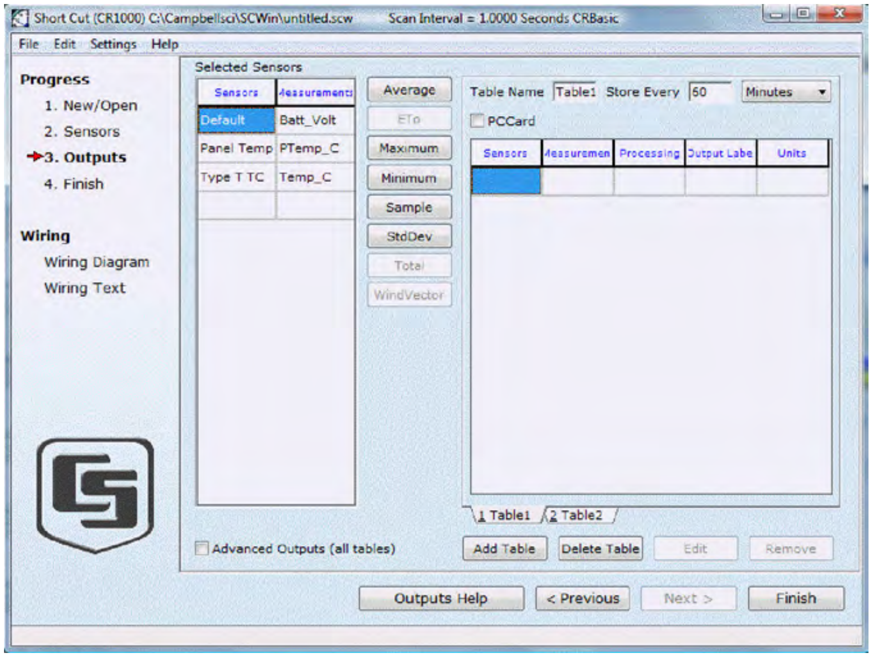


FIGURE 16. Short Cut Outputs Tab

2.2.4.4 Procedure: (Short Cut Steps 12-16)

12. By default, there are two Tables initially available. Both Tables have a Store Every field along with a drop-down box to select the time units. These are used to set the time interval when data is stored.

13. Only one Table is needed for this tutorial, so Table 2 can be removed. Select Table 2 by clicking on its tab, and then click on Delete Table.

14. Change the Table Name to OneMin, and then change the interval to 1 minute (Store Every 1 Minutes).

15. Adding a measurement to the table is done by selecting the measurement under Selected Sensors, and then clicking on one of the processing buttons in the center of the window.

16. Apply the Average function to the Batt_Volt, PTemp_C, and Temp_C measurements.

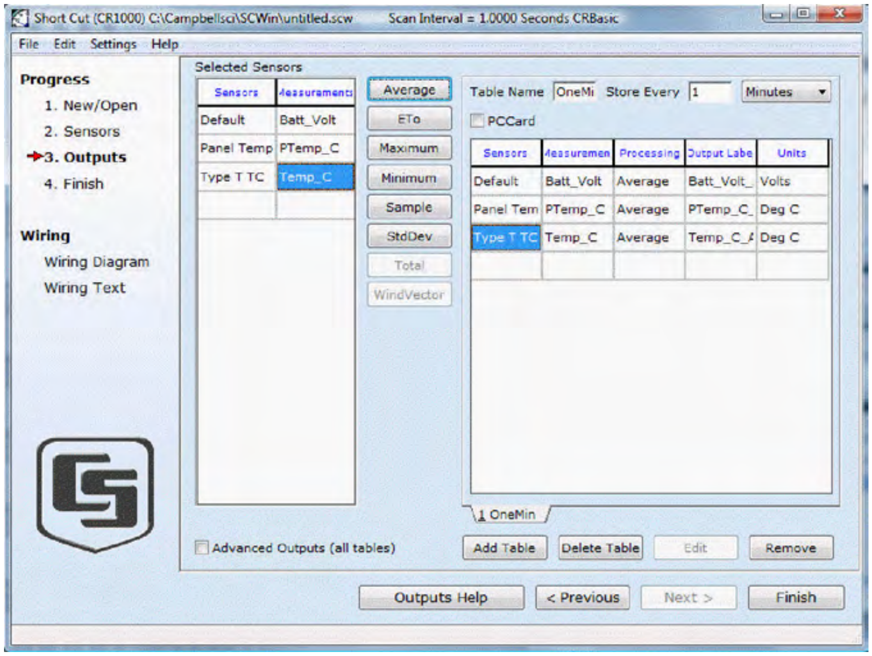


FIGURE 17. Short Cut Output Table Definition

2.2.4.5 Procedure: (Short Cut Steps 17-18)

17. Click on **Finish** to compile the program. Give the program the name "QuickStart." A summary screen will appear showing the compiler results. Any errors during compiling will also be displayed.

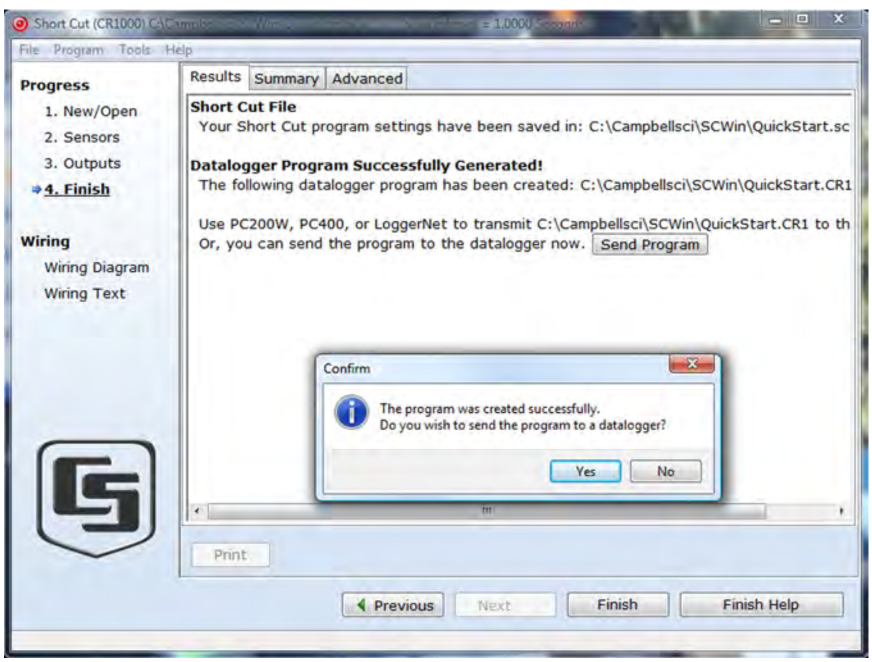


FIGURE 18. Short Cut Compile Confirmation

18. Close this window by clicking on the "X" in the upper right corner.

2.2.5 Send Program and Collect Data with PC200W

PC200W Support Software Objectives:

This portion of the tutorial will use PC200W to send the program to the CR1000, collect data from the CR1000, and store the data to the PC

2.2.5.1 Procedure: (PC200W Step 1)

1. From the PC200W Clock/Program tab, click on the *Connect* button to establish communications with the CR1000. When communications have been established, the text on the button will change to Disconnect.

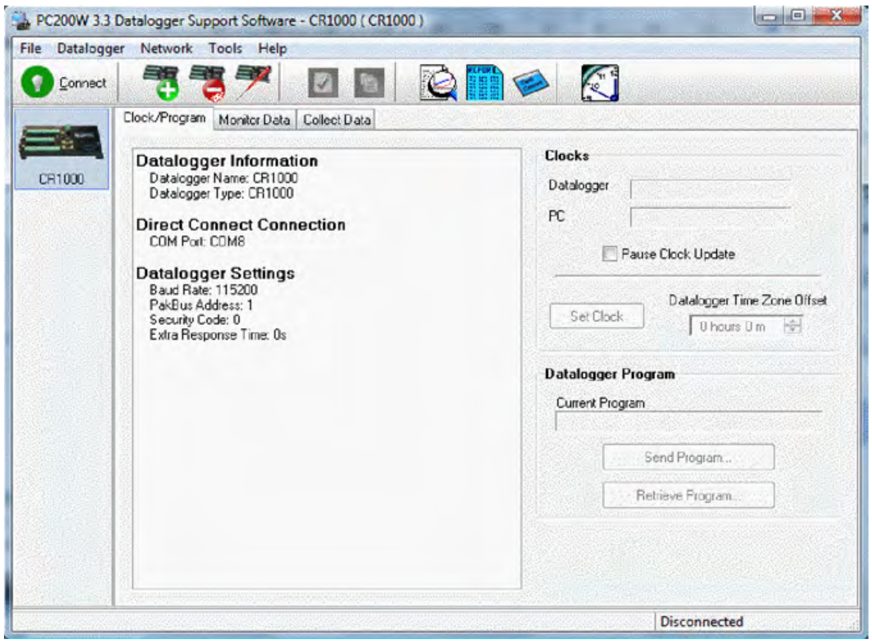


FIGURE 19. PC200W Connect Button

2.2.5.2 Procedure: (PC200W Steps 2-4)

2. Click the Set Clock button to synchronize the datalogger's clock with the computer's clock.

3. Click on the Send Program button. A window will appear warning that data on the datalogger will be erased. Answer "yes" to the prompt. Another window will open. Browse to the C:\CampbellSci\SCWin folder, select the QuickStart.CR1 file, and then click the Open button. A status bar will appear while the program is sent to the CR1000 followed by a confirmation that the transfer was successful. Click OK to close this window.

4. After sending a program to the CR1000, a good practice is to monitor the measurements to ensure they are reasonable. Select the Monitor Data tab. The window now displays data found in the Public Table coming from the CR1000. To view the OneMin table, select an empty cell in the display area, and then click on the Add button.

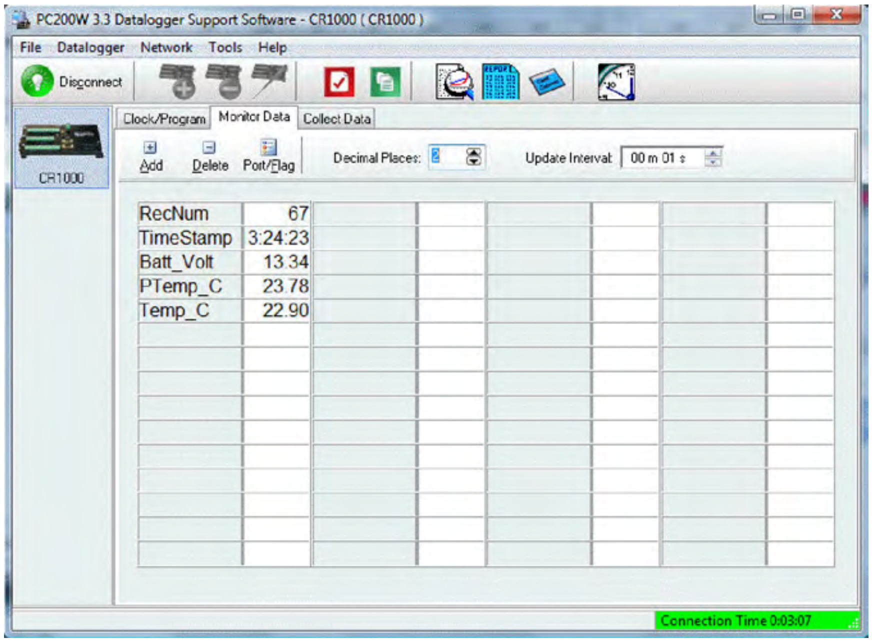


FIGURE 20. PC200W Monitor Data Tab - Public Table

2.2.5.3 Procedure: (PC200W Step 5)

5. In the Add Selection window, click on the OneMin table, and then click Paste. The OneMin table is now displayed in the main display.

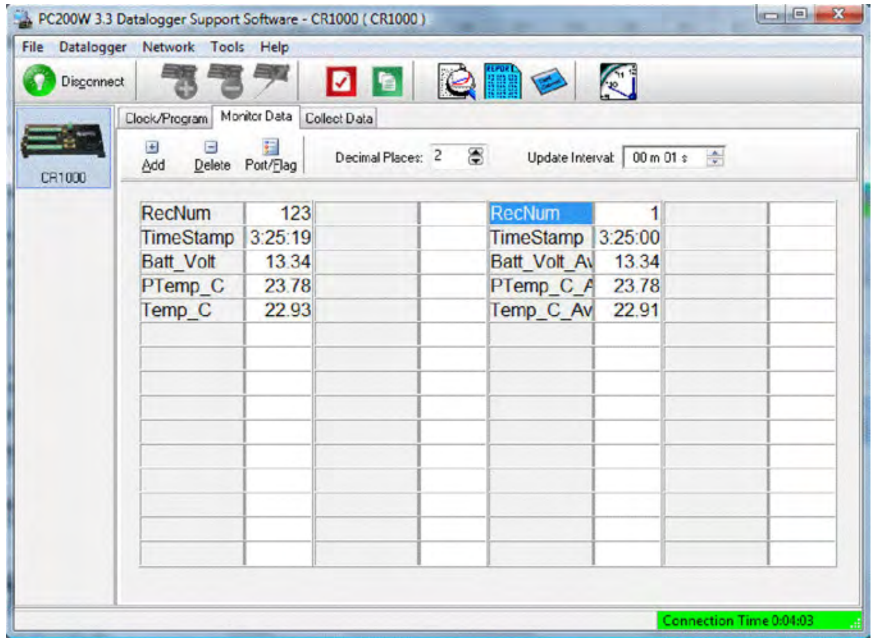


FIGURE 21. PC200W Monitor Data Tab - Public and OneMin Tables

2.2.5.4 Procedure: (PC200W Step 6)

6. Click on the Collect Data tab. From this window, data is chosen to be collected as well as the location where the collected data will be stored.

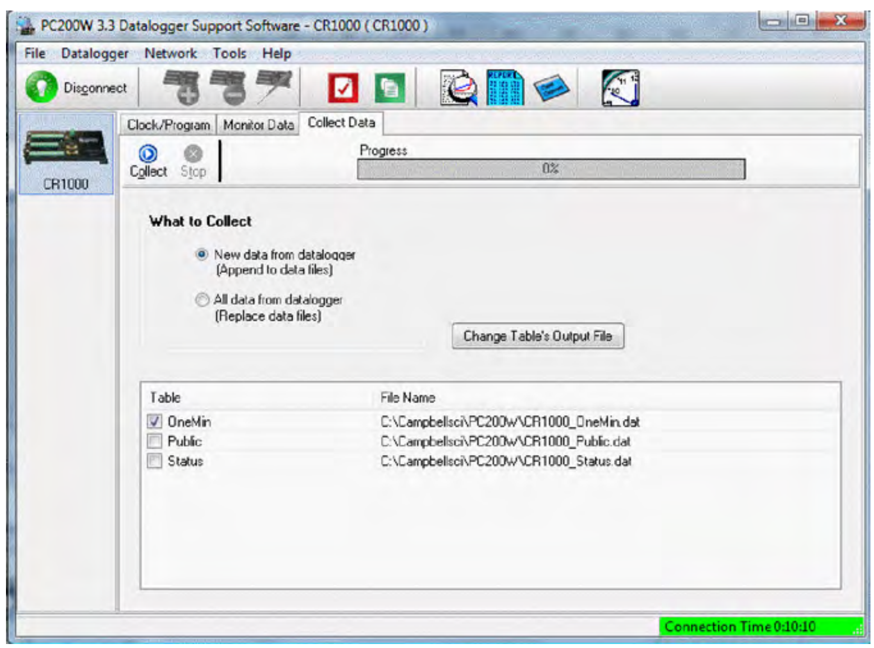


FIGURE 22. PC200W Collect Data Tab

2.2.5.5 Procedure: (PC200W Steps 7-9)

7. Click the OneMin box so a check mark appears in the box. Under the "What to Collect" heading, select "New data from datalogger." This selects which data will be collected.

8. Click on the Collect button. A requester box will appear, prompting for a filename. Click on Save to accept the default filename of "CR1000_OneMin.dat." A progress bar will appear as the data is collected, followed by the message, "Collection Complete." Click OK to continue.

9. To view the data, click on the View icon at the top of the window. This opens a new window.

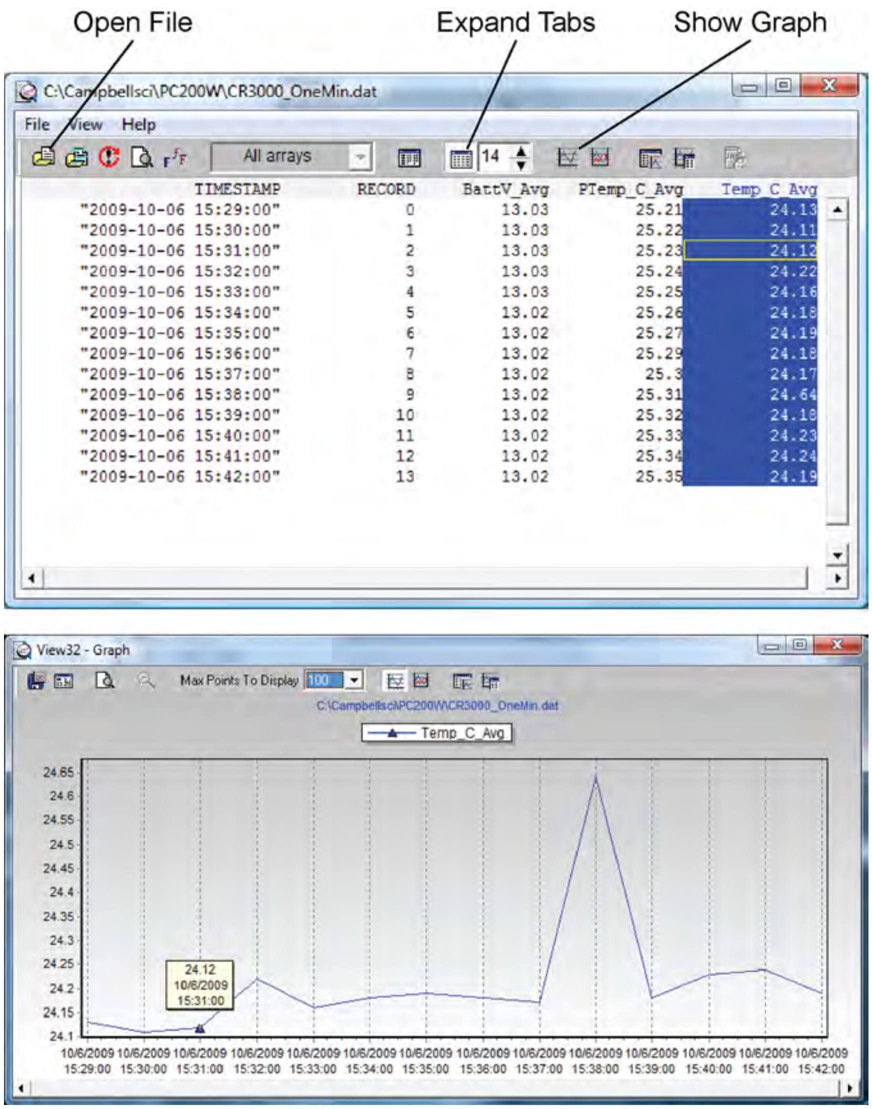


FIGURE 23. PC200W View Data Utility

2.2.5.6 Procedure: (PC200W Steps 10-11)

10. Click on the Open File icon to open a file for viewing. Select the "CR1000_OneMin.dat" file and click on Open. The collected data is now shown.

11. Click on Expand Tabs to display the data in columns with column headings.

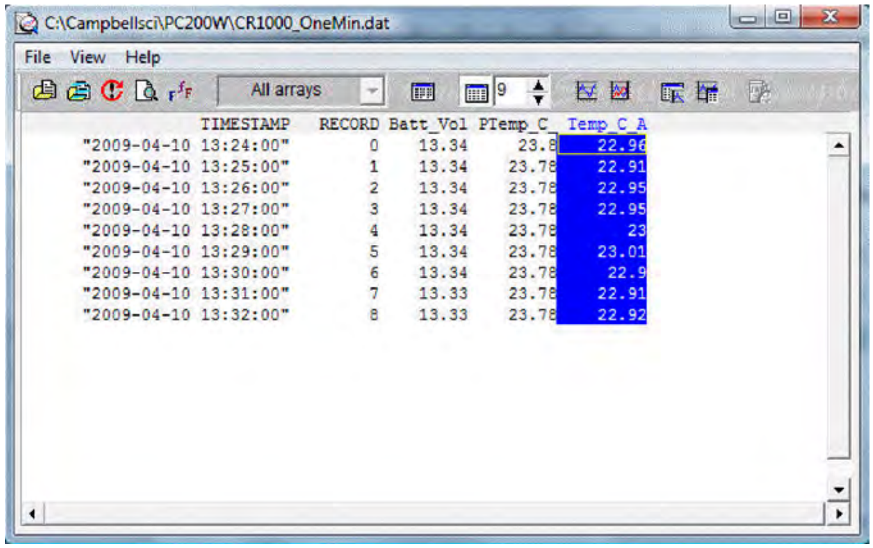


FIGURE 24. PC200W View Data Table

2.2.5.7 Procedure: (PC200W Steps 12-13)

12. Select any data column by clicking on it. To display the data in graphical form, click on one of the Show Graph buttons. A graph with one Y-axis or two Y-axes will be generated.

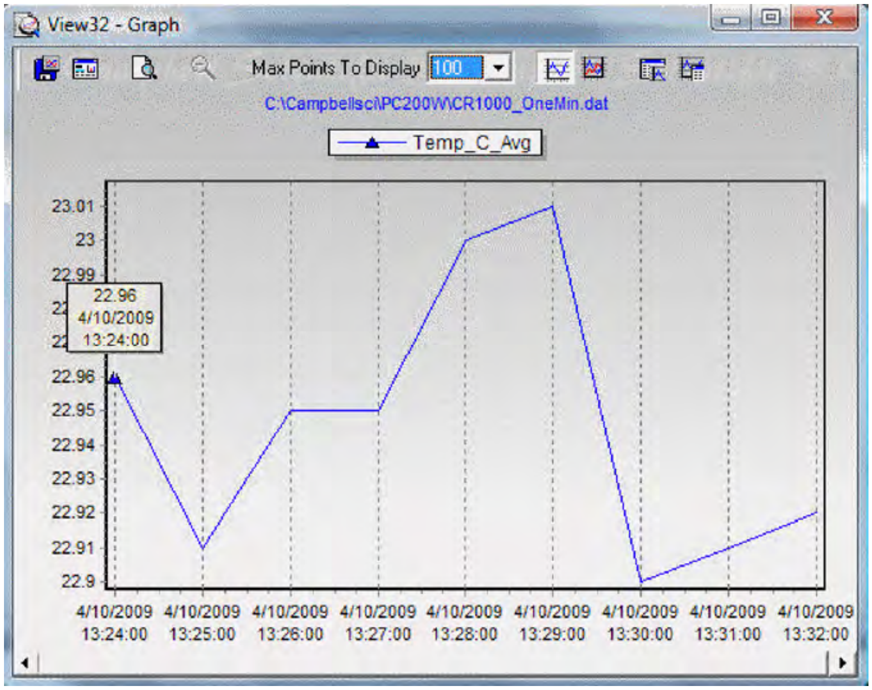


FIGURE 25. PC200W View Data Graph

13. Close the Graph and View windows, and then close the PC200W program.

Section 3. System Overview

A data acquisition system consists of hardware, user entered programs, and datalogger support software. *FIGURE. Features of a Data Acquisition System* (p. 27) illustrates a common CR1000-based data acquisition system.

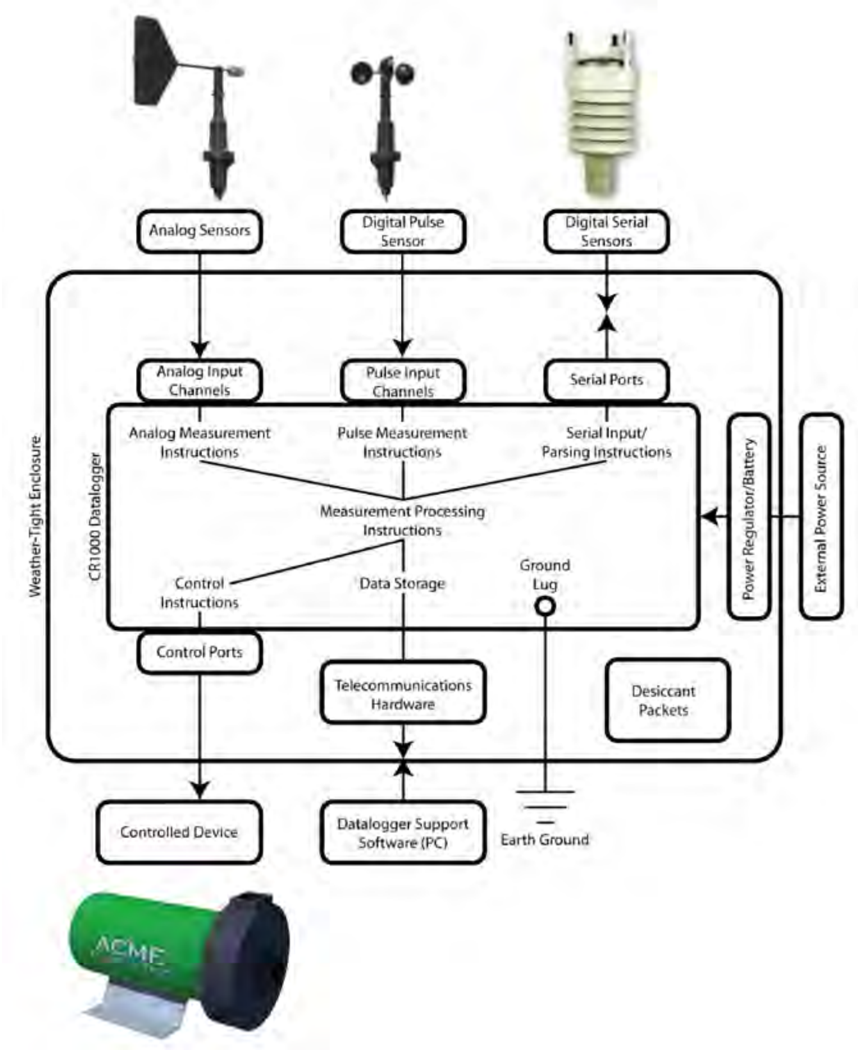


FIGURE 26. Features of a Data Acquisition System

3.1   CR1000 Datalogger

The CR1000 Datalogger is a precision instrument designed for demanding low-power measurement applications. CPU, analog and digital inputs, analog and digital outputs, and memory are controlled by the operating system in conjunction with the user program. The user program is written in CRBASIC, a programming language that includes data processing and analysis routines and a standard BASIC instruction set. Campbell Scientific's datalogger support software facilitates program generation, editing, data retrieval, and real-time data monitoring (see *SECTION. Support Software* (p. 395)).

The CR1000 is a multimeter with memory and timekeeping. It is one part of a data acquisition system. To acquire quality data, suitable sensors and reliable telecommunications devices are also required.

Sensors transduce phenomena into measurable electrical forms, outputting voltage, current, resistance, pulses, or state changes. The CR1000, sometimes with the assistance of various peripheral devices, can measure nearly all electronic sensors.

The CR1000 measures analog voltage and pulse signals, representing the magnitudes numerically. Numeric values are scaled to the unit of measure such as milliVolts and pulses, or in user specified engineering units such as wind direction and wind speed. Measurements can be processed through calculations or statistical operations and stored in memory awaiting transfer to a PC via external storage or telecommunications.

The CR1000 has the option of evaluating programmed instructions sequentially, or in pipeline mode, wherein the CR1000 decides the order of instruction execution.

3.1.1 Sensor Support

Read More! See *SECTION. Sensor Support* (p. 43).

The following sensor types are supported by the CR1000 datalogger. Refer to *APPENDIX. Sensors* (p. 495) for information on sensors available from Campbell Scientific.

- Analog voltage
- Analog current (with a shunt resistor)
- Thermocouples
- Resistive bridges
- Pulse output
- Period output
- Frequency output
- Serial smart sensors
- SDI-12 sensors

A library of sensor manuals and application notes are available at *www.campbellsci.com* to assist in measuring many sensor types. Consult with a Campbell Scientific applications engineer for assistance in measuring unfamiliar sensors.

3.1.2 CR1000 Wiring Panel

The wiring panel of the CR1000 is the interface to all CR1000 functions. Most CR1000 functions are best introduced by reviewing features of the CR1000 wiring panel. *FIGURE. CR1000 Wiring Panel* (p. 5) illustrates the wiring panel and some CR1000 functions accessed through it.

Read More! Expansion accessories increase the input / output capabilities of the wiring panel. Read *SECTION. Measurement and Control Peripherals* (p. 95) for more information.

3.1.2.1 Measurement Inputs

Measurements require a physical connection with a sensor at an input channel and CRBASIC programming to instruct the CR1000 how to make, process, and store the measurement. The CR1000 wiring panel has the following input channels:

Analog Voltage: 16 channels (Diff 1 - 8 / SE 1 - 16) configurable as 8 differential or 16 single-ended inputs.

- Input voltage range: -5000 mV to +5000 mV.
- Measurement resolution: 0.67 µV to 1333 µV

Period Average: 16 channels (SE 1 -16)

- Input voltage range: -2500 mV to +2500 mV.
- Maximum frequency: 200 kHz
- Resolution: 136 ns

Note Both pulse count and period average measurements are used to measure frequency output sensors. Yet pulse count and period average measurement methods are different. Pulse count measurements use dedicated hardware -- pulse count accumulators, which are always monitoring the input signal, even when the CR1000 is between program scans. In contrast, period average measurement instructions only monitor the input signal during a program scan. Consequently, pulse count scans can usually be much less frequent than period average scans. Pulse counters may be more susceptible to low frequency noise because they are always "listening", whereas period averaging may filter the noise by reason of being "asleep" most of the time. Pulse count measurements are not appropriate for sensors that are powered off between scans, whereas period average measurements work well since they can be placed in the scan to execute only when the sensor is powered and transmitting a correct signal.

Period average measurements utilize a high-frequency digital clock to measure time differences between signal transitions, whereas pulse count measurements simply accumulate the number of counts. As a result, period average measurements offer much better frequency resolution per measurement interval, as compared to pulse count measurements. The frequency resolution of pulse count measurements can be improved by extending the measurement interval by increasing the scan interval and by averaging.

Pulse: 2 channels (P1 - P2) configurable for counts or frequency of the following signal types:

- High level 5V square waves
- Switch closures
- Low-level A/C sine waves

Digital I/O: 8 channels (C1 - C8) configurable for serial input, SDM, SDI-12, state, frequency, pulses, edge counting and edge timing.

- C1 - C8: state, frequency, pulse, edge counting and edge timing measurements.
- Edge Timing Resolution: 540 ns
- C1, C2 and C3: Synchronous Devices for Measurement (SDM) input / output.
- C1, C3, C5, C7: SDI-12 input / output.
- C1 & C2, C3 & C4, C5 & C6, C7 & C8: serial communication input / output.

9-Pin RS-232: 1 port (Computer RS-232) configurable for serial input.

Refer to *APPENDIX. Digital I/O Expansion* (p. 498), *APPENDIX. Pulse / Frequency Input Expansion Modules* (p. 498), and *APPENDIX. Serial Input / Output Peripherals* (p. 499) for information on available input expansion modules.

3.1.2.2 Voltage Outputs

The CR1000 has several terminals capable of supplying switched voltage and current to peripherals, sensors, or control devices.

Read More! See *SECTION. Control Output* (p. 95).

- **Switched Analog Output (Excitation)**: three channels (VX1 - VX3) for precise voltage excitation ranging from -2500 mV to +2500 mV. These channels are regularly used with resistive bridge measurements. Each channel will source up to 25 mA.
- **Digital I/O**: 8 channels (C1 - C8) configurable for on / off and pulse output duration.
- **Switched 12 Volts dc (SW-12)**: One terminal controls (switch on / off) primary voltage under program control for control of external devices requiring 12 Vdc, such as humidity sensors. SW-12 can source up to 900 mA. See *TABLE. Current Sourcing Limits* (p. 102).
- **Continuous Analog Output**: available by adding a peripheral analog output device available from Campbell Scientific. Refer to *APPENDIX. CAO Modules* (p. 498) for information on available output expansion modules.

3.1.2.3 Grounding Terminals

Read More! See *SECTION. Grounding* (p. 105).

Proper grounding will lend stability and protection to a data acquisition system. It is the easiest and least expensive insurance against data loss-and the most neglected. The following terminals are provided for connection of sensor and datalogger grounding:

- **Signal Grounds**: 12 ground terminals (⏚) used as reference for single-ended analog inputs, pulse inputs, excitation returns, and as a ground for sensor shield wires. Signal returns for pulse inputs should use ⏚ terminals located next to pulse inputs.
- **Power Grounds**: 6 terminals (G) used as returns for 5V, SW-12, 12V, and C1-C8 outputs. Use of G grounds for these outputs minimizes potentially large current flow through the analog voltage measurement section of the wiring panel, which can cause single-ended voltage measurement errors.
- **Ground Lug**: 1 terminal (⏚), the large ground lug is used to connect a heavy gage wire to earth ground. A good earth connection is necessary to secure the ground potential of the datalogger and shunt transients away from electronics. Minimum 14 AWG wire is recommended.

3.1.2.4 Power Terminals

Read More! See *SECTION. CR1000 Power Supply* (p. 99).

Power In

Note: Refer to *APPENDIX. Power Supplies* (p. 495) for information on available power supplies.

- **External Power Supply**: One green plug (POWER IN): for connecting power from an external power source to the CR1000. This is the only terminal used to input power; other 12V terminals and the SW-12 terminal are output only terminals for supplying power to other devices. Review power requirements and power supply options in *SECTION. CR1000 Power Supply* (p. 99) before connecting power.

Power Out

- See *SECTION. Powering Sensors* (p. 100)
- **Peripheral 12 Vdc Power Source**: 2 terminals (12V) and associated grounds (G) supply power to sensors and peripheral devices requiring nominal 12 Vdc. This supply may drop as low as 9.6 Vdc before datalogger operation stops. Precautions should be taken to minimize the occurrence of data from underpowered sensors.
- **Peripheral 5 Vdc Power Source**: 1 terminal (5V) and associated ground (G) supply power to sensors and peripheral devices requiring regulated 5 Vdc.

3.1.2.5 Communications Ports

Read More! See *SECTION. RS-232 and TTL Recording* (p. 91), *SECTION. Telecommunications and Data Retrieval* (p. 369) and *SECTION. PakBus Overview* (p. 373).

The CR1000 is equipped with 6 communications ports. Communication ports allow the CR1000 to communicate with other computing devices, such as a PC, or with other Campbell Scientific dataloggers.

Note RS-232 communications normally operate well up to a transmission cable capacitance of 2500 picofarads, or approximately 50 feet of commonly available serial cable.

- **9-pin RS-232**: 1 DCE port for communicating with a PC through the supplied serial cable, serial sensors, or through 3rd party serial telecommunications devices. Acts as a DTE device with a null-modem cable.

Read More! See *APPENDIX. Serial Port Pin Outs* (p. 479).

Note The 9-pin RS-232 port is not electrically isolated. "Isolation" means isolated, by means of optical isolation components, from the communications node at the other end of the connection. Optical isolation prevents some electrical problems such as ground looping, which can cause significant errors in single-ended analog measurements. Campbell Scientific offers a peripheral optically isolated RS-232 to CS I/O interface as a CR1000 accessory. Refer to *APPENDIX. Serial Input / Output Peripherals* (p. 499) for model information.

- **9-pin CS I/O port**: 1 port for communicating through Campbell Scientific telecommunications peripherals. Approved CS I/O telecommunication interfaces are listed in *APPENDIX. Serial Input / Output Peripherals* (p. 499).

- **2-pin RS-232**: 4 ports configurable from Control I/O ports for communication with serial sensors or other Campbell Scientific dataloggers.

- **Peripheral**: 1 port for use with some Campbell Scientific CF memory card modules and IP network link hardware. See *SECTION. Data Table Declarations* (p. 177) for CF card precautions.

3.1.3 Power Requirements

Read More! See *SECTION. CR1000 Power Supply* (p. 99).

The CR1000 operates from a dc power supply with voltage ranging from 9.6 to 16 V, and is internally protected against accidental polarity reversal. The CR1000 has modest input power requirements. In low power applications, it can operate for several months on non-rechargeable batteries. Power systems for longer-term remote applications typically consist of a charging source, a charge controller, and a rechargeable battery. When ac line power is available, an ac/ac or ac/dc wall adapter, a charge controller, and a rechargeable battery can be used to construct a UPS (uninterruptible power supply). Contact a Campbell Scientific applications engineer for assistance in acquiring the items necessary to construct a UPS.

Applications requiring higher current requirements, such as satellite or cellular phone communications, should be evaluated by means of a power budget with a knowledge of the factors required by a robust power system. Contact a Campbell Scientific applications engineer if assistance is required in evaluating power supply requirements.

Common power devices are:

- Batteries
    - Alkaline D-cell - 1.5 Vdc / cell
    - Rechargeable Lead-Acid battery
- Charge Sources
    - Solar Panels
    - Wind Generators
    - ac/ac or ac/dc wall adapters

Refer to *APPENDIX. Power Supplies* (p. 495) for specific model numbers of approved power supplies.

3.1.4 Programming

The CR1000 is a highly programmable instrument, adaptable to the most demanding measurement and telecommunications requirements.

3.1.4.1 Firmware: OS and Settings

Read More! See *SECTION. CR1000 Configuration* (p. 111).

Firmware consists of the operating system (OS) and durable configuration settings. OS and settings remain intact when power is cycled.

Note The CR1000 is shipped factory ready with all settings and firmware necessary to communicate with a PC via RS-232 and to accept and execute user application programs. OS upgrades are occasionally made available at *www.campbellsci.com*.

For more complex applications, some settings may need adjustment. Adjustments are accomplished with DevConfig Software (*DevConfig* (p. 111)), the optional keyboard display (see *SECTION. Using the Keyboard Display* (p.

395)), or through datalogger support software (see *APPENDIX. Software* (p. 489)).

OS files are sent to the CR1000 with DevConfig or through the program Send button in datalogger support software. When the OS is sent via DevConfig, most settings are cleared, whereas, when sent via datalogger support software, most settings are retained.

OS files can also be sent to the CR1000 with a CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).

Read More! See *SECTION. Programming* (p. 129) and *SECTION. CRBASIC Programming Instructions* (p. 175) and CRBASIC help for more programming assistance.

A CRBASIC program directs the CR1000 how and when sensors are to be measured, calculations made, and data stored. A program is created on a PC and sent to the CR1000. The CR1000 can store a number of programs in memory, but only one program is active at a given time. Three Campbell Scientific software applications, Short Cut, CRBASIC Editor, and Transformer Utility create CR1000 programs.

- Short Cut creates a datalogger program and wiring diagram in four easy steps. It supports most sensors sold by Campbell Scientific and is recommended for creating simple programs to measure sensors and store data.

- Programs generated by Short Cut are easily imported into CRBASIC Editor for additional editing. For complex applications, experienced programmers often create essential measurement and data storage code with Short Cut, then edit the code with CRBASIC Editor. Note that once a Short Cut generated program has been edited with CRBASIC Editor, it can no longer be modified with Short Cut.

3.1.5 Memory and Data Storage

Read More! See *SECTION. Memory and Data Storage* (p. 349).

CR1000 memory size is posted in the Status Table (*APPENDIX. Status Table and Settings* (p. 457)).

The CR1000 stores these data:

- Operating system. Held in up to 2 Mbytes Flash EEPROM.

- Settings. Held in 512 K Flash.

- Programs, system data, and measurement data. Held in 4 Mbytes SRAM.

Note -- Maximum memory allowed for program storage is 490 kbytes.

Programs are stored as files on the automatically partitioned CPU: drive. Photographic images and measurement data files are stored on the USR: drive, which is partitioned by the user from data storage memory (See *APPENDIX. Cameras* (p. 504)). TableFile() instruction output files are usually stored on USR:. TableFile() also stores files on a USB: drive (*APPENDIX. Mass Storage Devices* (p. 504)). Data formats available for storage by TableFile() include TOA5, TOB1, CSIXML, CSIJSON.

Note CR1000s with serial numbers smaller than 11832 were usually supplied with only 2 Mbytes of SRAM.

Additional final data storage is available by using the optional CompactFlash® card with a CompactFlash® module listed in *APPENDIX. Card Storage Modules* (p. 503), or with a mass storage device (*APPENDIX. Mass Storage Devices* (p. 504)).

3.1.6 Data Retrieval

Data tables are transferred to PC files through a telecommunications link (*SECTION. Telecommunications and Data Retrieval* (p. 369)) or by transporting a CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) to the PC.

3.1.6.1 Via Telecommunications

Data are usually transferred through a telecommunications link to an ASCII file on the supporting PC using Campbell Scientific datalogger support software (*APPENDIX. Software* (p. 489)). See also the manual and Help for the software package being used.

3.1.6.2 Via Mass Storage Device

Caution When removing a CS mass storage device (thumb drive) from the CR1000, do so only when the LED is not lit or flashing. Removing a CS mass storage device from the CR1000 while the device is active can cause data corruption.

Data stored on CS mass storage devices are retrieved through a telecommunication link to the CR1000 or by removing the device, connecting it to a PC, and copying / moving files using Windows Explorer.

3.1.6.3 Via CF Card

Caution When installing a CF card module, first turn off the CR1000 power.

Before removing a CF card module from the datalogger, disable the card by pressing the "removal button" (NOT the eject button), wait for the green LED, then turn CR1000 power off.

Removing a card or card module from the CR1000 while the CF card is active can cause garbled data and can damage the card.

Sending a program to the CR1000 may erase all SRAM and CF card data. To prevent losing data, collect data from the CF card before sending a program to the datalogger.

The CR1000 manages data on a CF card as final storage table data, accessing the card as needed to fill data collection requests initiated with the Collect button in *datalogger support software* (p. 439, p. 490). If desired, binary data can be collected using the File Control utility in *datalogger support software* (p. 439, p. 490). Before collecting data this way, stop the CR1000 program to ensure data are not written to CF while data are retrieved, other wise, data corruption and confusion will result.

Data stored on CF cards are retrieved through a telecommunication link to the CR1000 or by removing the card, carrying it to a computer, and retrieving the data via a third party CF adaptor. Retrieving data, especially large files, is much faster through a CF adaptors than via telecommunications.

The format of data files collected via a CF adaptor is different than the format created by *datalogger support software* (p. 489). Data files read from the CF card via a CF adaptor can be converted to a Campbell Scientific format using CardConvert. CardConvert is included with mid- and top-level *datalogger support software* (p. 489). Consult the software manual for more CardConvert information.

3.1.6.4 Data File Formats in CR1000 Memory

Routine CR1000 operations store data in binary data tables. However, when the TableFile() instruction is used, data are also stored in one of several formats in discrete text files in internal or external memeory. See *SECTION. Data Storage* (p. 352) for more information on the use of the TableFile() instruction.

3.1.6.5 Data Format on Computer

CR1000 data stored on a PC via support software is formatted as either ASCII or Binary depending on the file type selected in the support software. Consult the software manual for details on the various available data file formats.

3.1.7 Communications

Read More! See *SECTION. Telecommunications and Data Retrieval* (p. 369).

The CR1000 communicates with external devices to receive programs, send data, or act in concert with a network. The primary communication protocol is PakBus. Modbus and DNP3 communication protocols are also supported. Refer to *APPENDIX. Telecommunications Hardware* (p. 501) for information on available communications devices.

3.1.7.1 PakBus

Read More! See *SECTION. PakBus Overview* (p. 373).

The CR1000 communicates with Campbell Scientific support software, telecommunication peripherals, and other dataloggers via PakBus, a proprietary network communications protocol. PakBus is a protocol similar in concept to IP (Internet protocol). By using signatured data packets, PakBus increases the number of communications and networking options available to the CR1000. Communication can occur via RS-232, CS I/O, or digital I/O ports.

Advantages of PakBus:

- Simultaneous communication between the CR1000 and other devices.
- Peer-to-peer communication-no PC required.
- Other PakBus dataloggers can be used as "sensors" to consolidate all data into one CR1000.
- Routing - the CR1000 can act as a router, passing on messages intended for another logger. PakBus supports automatic route detection and selection.
- Short distance networks with no extra hardware-A CR1000 can talk to another CR1000 over distances up to 30 feet by connecting transmit, receive and ground wires between the dataloggers. PC communications with a PakBus datalogger via the CS I/O port, over phone modem or radio, can be routed to other PakBus dataloggers.
- Datalogger to datalogger communications-special CRBASIC instructions simplify transferring data between dataloggers for distributed decision making or control.
- In a PakBus network, each datalogger is set to a unique address before being installed in the network. Default PakBus address is 1. To communicate with the CR1000, the datalogger support software (see *SECTION. Telecommunications and Data Retrieval* (p. 369)) must know the CR1000's PakBus address. The PakBus address is changed using the optional keyboard display, DevConfig software, CR1000 status table, or PakBus Graph software.

3.1.7.2 Modbus

Read More! See *SECTION. Modbus* (p. 388).

The CR1000 supports Modbus Master and Modbus Slave communication for inclusion in Modbus SCADA networks.

3.1.7.3 DNP3 Communication

Read More! See *SECTION. DNP3* (p. 385).

The CR1000 supports DNP3 Slave communication for inclusion in DNP3 SCADA networks.

3.1.7.4 Keyboard Display

Read More! See *SECTION. Using the Keyboard Display* (p. 395).

The optional keyboard display is a powerful tool for field use. It allows complete access to most datalogger tables and function, allowing the user to monitor, make modifications, and troubleshoot a datalogger installation conveniently and in most weather conditions.

3.1.7.4.1 Custom Menus

Read More! To implement custom menus, see CRBASIC Help for the DisplayMenu() instruction.

CRBASIC programming in the CR1000 facilitates creation of custom menus for the optional keyboard display.

FIGURE. Custom Menu Example (p. 39) shows windows from a simple custom menu named "DataView". "DataView" appears as the main menu on the keyboard display. DataView has menu item, "Counter", and submenus "PanelTemps", "TCTemps", and "System Menu". "Counter" allows selection of 1 of 4 values. Each submenu displays two values from CR1000 memory. PanelTemps shows the CR1000 wiring panel temperature at each scan, and the one minute sample of panel temperature. TCTemps displays two thermocouple temperatures.

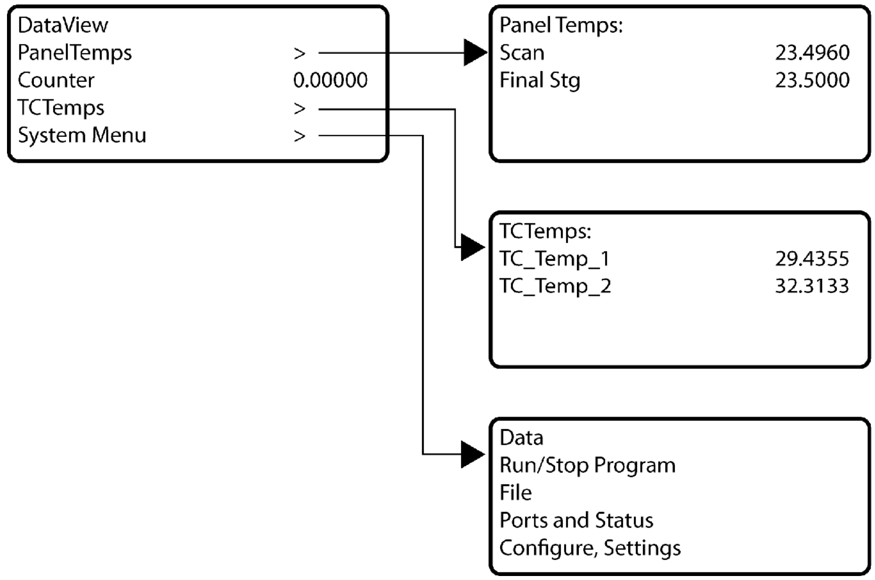


FIGURE 27. Custom Menu Example

3.1.8 Security

CR1000 applications may include collection of sensitive data, operation of critical systems, or networks accessible by many individuals. CR1000 security provides means by which partial or complete lock-out can be accomplished in the CRBASIC program code.

Up to three levels of security can be set in the datalogger. Level 1 must be set before Level 2. Level 2 must be set before Level 3. If a level is set to 0, any level greater than it will also be set to 0 (e.g., if Level 2 is 0, Level 3 is 0). Valid security codes are 1 through 65535 (0 is no security). Each level must have a unique code. If security is set to a negative code in the CR1000, a positive code must be entered to unlock the CR1000. That positive code = 65536 + (negative security code). For example, a security code of -1111 must be entered as 64425 to unlock the CR1000.

Security can be enabled using DevConfig, the optional keyboard display, Status Table, or the SetSecurity () instruction.

Note -- If SetSecurity () is used in the CRBASIC program, the security settings persist if a new program that has no SetSecurity () instruction is sent to the CR1000.

Functions affected by each level of security are:

- **Level 1**: collecting data, setting the clock, and setting variables in the Public table are unrestricted. Enter level 1 password to change or retrieve the datalogger program or set variables in the Status table.

- **Level 2**: collecting data are unrestricted. Enter level 2 password to set the clock or change variables in the public table. Enter level 1 password to change the datalogger program or non-read-only postings in the status table.
- **Level 3**: Enter level 3 password to collect data. Enter level 2 password to collect data, set public variable and set the clock. Enter level 1 password to open all datalogger functions to unrestricted use.

In addition to passwords, recording and monitoring program signatures are important components of a security scheme. Read more about use of program signatures in *SECTION. System Signatures* (p. 173).

3.1.9 Maintenance

Read More! See *SECTION. Care and Maintenance* (p. 409).

With reasonable care, the CR1000 should give many years of reliable service.

3.1.9.1 Protection from Water

The CR1000 and most of its peripherals must be protected from moisture. Moisture in the electronics will seriously damage, and probably render un-repairable, the CR1000. Water can come from flooding or sprinkler irrigation, but most often comes as condensation. In most cases, protecting from water is as easy as placing the CR1000 in a weather tight enclosure with desiccant and elevating the enclosure above the ground. The CR1000 is shipped with desiccant to reduce humidity. Desiccant should be changed periodically. Do not completely seal the enclosure if lead acid batteries are present; hydrogen gas generated by the batteries may build up to an explosive concentration. Refer to *APPENDIX. Enclosures* (p. 497) for information on available weather tight enclosures.

3.1.9.2 Protection from Voltage Transients

Read More! See *SECTION. Grounding* (p. 105).

The CR1000 must be grounded to minimize the risk of damage by voltage transients associated with power surges and lightning induced transients. Earth grounding is required to form a complete circuit for voltage clamping devices internal to the CR1000. Refer to *APPENDIX. Voltage Transient Suppressors* (p. 503) for information on available surge protection devices.

3.1.9.3 Calibration

Read More! See *SECTION. Self-Calibration* (p. 60).

The CR1000 uses an internal voltage reference to routinely calibrate itself. To maintain electrical specifications, Campbell Scientific recommends factory recalibration every two years. For calibration services, contact Campbell Scientific to obtain a Return Materials Authorization (RMA) prior to shipping.

3.1.9.4 Internal Battery

Caution -- Misuse of the lithium battery or installing it improperly can cause severe injury. Fire, explosion, and severe burn hazard! Do not recharge, disassemble, heat above 100°C (212°F), solder directly to the cell, incinerate, nor expose contents to water. Dispose of spent lithium batteries properly.

The CR1000 contains a lithium battery that operates the clock and SRAM when the CR1000 is not externally powered. In a CR1000 stored at room temperature, the lithium battery should last approximately 3 years (less at temperature extremes). In installations where the CR1000 is powered most of the time, the lithium cell should last much longer. Lithium battery voltage can be monitored from the CR1000 Status Table. Operating range of the battery is 2.7 to 3.6 Vdc. Replace the battery as directed in *SECTION. Replacing the Internal Battery* (p. 411) when the voltage is below 2.7 Vdc.

3.2 PC Support Software

Read More! See *SECTION. Support Software* (p. 395).

Several datalogger support software products for Windows are available. Software for datalogger setup and simple applications, PC200W and Short Cut, are available at no cost at *www.campbellsci.com*. For more complex programming, telecommunications, networking, and reporting features, full-featured products are available from Campbell Scientific.

- PC200W Starter Software is available at no charge at *www.campbellsci.com*. It supports a transparent RS-232 connection between PC and CR1000, and includes Short Cut for creating CR1000 programs. Tools for setting the datalogger clock, sending programs, monitoring sensors, and on-site viewing and collection of data are also included.
- PC400 supports a variety of telecommunication options, manual data collection, and data monitoring displays. Short Cut, CRBASIC Editor, and Transformer Utility are included for creating CR1000 programs. PC400 does not support complex communication options, such as phone-to-RF, PakBus® routing, or scheduled data collection.
- LoggerNet supports combined telecommunication options, customized data monitoring displays, and scheduled data collection. It includes Short Cut, CRBASIC Editor, and Transformer Utility programs for creating CR1000 programs. It also includes tools for configuring, trouble-shooting, and managing datalogger networks. LoggerNet Admin and LoggerNet Remote are also available for more demanding applications.

3.3 CR1000 Specifications

SPECIFICATIONS valid from -25° to +50°C, non-condensing environment, unless otherwise specified. Recalibration recommended every two years. Critical specifications and system configuration should be confirmed with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE
(10) ms to 1 day @ 10 ms increments

ANALOG INPUTS (SE 1-16 or DIFF 1-8)
(8) differential (DF) or 16 single-ended (SE) individually configured input channels. Channel expansion provided by optional analog multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. Resolution of DF measurements with input reversal is half the Basic Res.

Range (mV)[1]	DF Res (µV)[2]	Basic Res (µV)
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1] Range overhead of ≈9% on all ranges guarantees full-scale voltage will not cause over-range.
[2] Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset),-55° to 85°C(-XT only)

[3] Accuracy does not include sensor and measurement noise. Offsets are defined as:

Offset for DF w/input reversal = 1.5 x Basic Res+1.0 µV
Offset for DF w/o input reversal = 3 x Basic Res+2.0 µV
Offset for SE = 3 x Basic Res + 3.0 µV

ANALOG MEASUREMENT SPEED:

Integration Type Code	Integration Time	Settling Time	----Total Time[5]---- SE w/ No Rev	DF w/ Input Rev
250	250µs	450µs	≈1ms	≈12ms
_60Hz[4]	16.67ms	3ms	≈20ms	≈40ms
_50Hz[4]	20.00ms	3ms	≈25ms	≈50ms

[4] AC line noise filter
[5] Includes 250 µs for conversion to engineering units

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range (digital resolution dominates for higher ranges).

250 µs Integration: 0.34 µV RMS
50/60 Hz Integration: 0.19 µV RMS

INPUT LIMITS: ±5 Vdc

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

PERIOD AVERAGE: Any of the 16 SE analog inputs can be used for period averaging. Accuracy is ±(0.01% of reading + resolution), where resolution is 136 ns divided by the specified number of cycles to be measured.

Input amplitude and frequency:

Voltage Gain	± Input Range mV	Signal Peak-Peak[6] Min mV	Max V	Min Pulse Width µs	Max[7] Freq kHz
1	250	500	10	2.5	200
10	25	10	2	10	50
33	7.5	5	2	62	8
100	2.5	2	2	100	5

[6] With signal centered at CR1000 ground.
[7] The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

ANALOG OUTPUTS (Vx 1-3)
(3) switched voltage outputs sequentially active only during measurement.

RANGES / RESOLUTION:

Chan	Range	Resolution	Current Source / Sink
V_X	±2.5V	0.67mV	±25 mA

spacer
spacer
V_X ACCURACY
±(0.06% of setting + 0.8 mV, 0° to 40°C
±(0.12% of setting + 0.8 mV, -25° to 50°C
±(0.18% of setting + 0.8 mV,-55° to 85°C(-XT only)

V_X FREQUENCY SWEEP FUNCTION: Switched outputs provide a programmable swept frequency, 0 to 2500 mV square waves for exciting vibrating wire transducers.

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS
MEASUREMENT TYPES: Ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation for voltage excitation eliminates DC errors. Offset values are reduced by a factor of 2 when excitation reversal is used.

VOLTAGE RATIO ACCURACY[8]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error:

±(0.04% of reading + offset)/V_X

[8] Accuracy does not include sensor and measurement noise. Offsets are defined as:

Offset for DF w/input reversal = 1.5 x Basic Res + 1.0 µV
Offset for DF w/o input reversal = 3 x Basic Res + 2.0 µV
Offset for SE = 3 x Basic Res + 3.0 µV

PULSE COUNTERS (P 1-2)
(2) inputs individually selectable for switch closure, high frequency pulse, or low-level ac. Independent 24-bit counters for each input.

MAXIMUM COUNTS PER SCAN: 16.7 x 10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 µs time constant.

LOW LEVEL AC MODE: Internal ac coupling removes dc offsets up to ±0.5 Vdc.

Input Hysteresis: 12 mV RMS @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	Range (Hz)
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS (C 1-8)
(8) ports software selectable as binary inputs or control outputs. Provide edge timing, subroutine interrupts / wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UARTs), SDI-12 communications, and SDM communications

HIGH FREQUENCY MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

EDGE TIMING RESOLUTION: 540 ns

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 16 V; low -8.0 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE:
100 kohms with inputs <6.2 Vdc
220 ohm with inputs ≥ 6.2 Vdc

SERIAL DEVICE/RS-232 SUPPORT: 0 to 5 Vdc UART

SWITCHED 12 Vdc (SW-12)
(1) independent 12 Vdc unregulated source is switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

CE COMPLIANCE
STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

COMMUNICATION
RS-232 PORTS:
9-pin: DCE (not electrically isolated) for computer or non-CSI modem connection.
COM1 to COM4: Four independent Tx/Rx pairs on control ports (non-isolated); 0 to 5 Vdc UART
Baud Rate: Selectable from 300 to 115.2 kbps.
Default Format: 8 data bits; 1 stop bits; no parity.
Optional Formats: 7 data bits; 2 stop bits; odd, even parity.

CS I/O PORT: Interface with CSI telecommunications peripherals.

SDI-12: Digital control ports 1, 3, 5 or 7 are individually configurable and meet SDI-12 Standard version 1.3 for datalogger mode. Up to ten SDI-12 sensors are supported per port.

PERIPHERAL PORT: 40-pin interface for attaching CompactFlash or Ethernet peripherals.

PROTOCOLS SUPPORTED: PakBus, Modbus, DNP3, FTP, HTTP, XML, POP3, SMTP, Telnet, NTCIP, NTP, SDI-12, and SDM.

SYSTEM
PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core, running at 7.3 MHz)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and final data storage.

RTC CLOCK ACCURACY: ±3 min. per year. Correction via GPS optional.

RTC CLOCK RESOLUTION: 10 ms

SYSTEM POWER REQUIREMENTS
VOLTAGE: 9.6 to 16 Vdc

EXTERNAL BATTERIES: 12 Vdc nominal (power connection is reverse polarity protected)

INTERNAL BATTERIES: 1200 mAhr lithium battery for clock and SRAM backup typically provides 3 years of back-up.

TYPICAL CURRENT DRAIN: Sleep Mode: ≈0.6 mA
1 Hz Sample Rate (one fast SE meas.): 1 mA
100 Hz Sample Rate (one fast SE meas.): 16.2 mA
100 Hz Sample Rate (one fast SE meas. w/ RS-232 communications): 27.6 mA
optional keyboard display on: add 7 mA to current drain
Backlight on: add 100 mA to current drain

PHYSICAL
DIMENSIONS: 239 x 102 x 61 mm (9.4 x 4.0 x 2.4 in); additional clearance required for cables and leads.

MASS/WEIGHT (datalogger + base):

MASS: 1.0 kg
WEIGHT: 2.1 lbs

WARRANTY
(3) years against defects in materials and workmanship.

Section 4. Measurements

Several features give the CR1000 the flexibility to measure many sensor types. Contact a Campbell Scientific applications engineer if assistance is required in assessing CR1000 compatibility to a specific application or sensor type. Some sensors require precision excitation or a source of power. See *SECTION. Powering Sensors and Devices* (p. 100).

4.1 Time

Measurement of time is an essential function of the CR1000. Time measurement with the on-board clock enables the CR1000 to attach time stamps to data, measure the interval between events, and time the initiation of control functions.

4.1.1 Time Stamps

A measurement without an accurate time reference has little meaning. Data on the CR1000 are stored with time stamps. How closely a time stamp corresponds to the actual time a measurement is taken depends on several factors.

The time stamp in common CRBASIC programs matches the time at the beginning of the current scan as measured by the real time clock in the CR1000. If a scan starts at 15:00:00, data output during that scan will have a time stamp of 15:00:00 regardless of the length of the scan or when in the scan a measurement is made. The possibility exists that a scan will run for some time before a measurement is made. For instance, a scan may start at 15:00:00, execute time consuming code, then make a measurement at 15:00:00.51. The time stamp attached to the measurement, if the CallTable () instruction is called from within the Scan ... NextScan construct, will be 15:00:00, resulting in a time stamp skew of 510 ms.

Time stamp skew is not a problem with most applications because,

- program execution times are usually short, so time stamp skew is only a few milliseconds. Most measurement requirements allow for a few milliseconds of skew.
- data processed into averages, maxima, minima, etc are composites of several measurements. Associated time stamps only reflect the time the last measurement was made and processing calculations were completed, so the significance of the exact time a specific sample was measured diminishes.

Applications measuring and storing sample data wherein exact time stamps are required can be adversely affected by time stamp skew. Skew can be avoided by

- Making measurements early in a scan interval, before time consuming code.

- Programming the CR1000 such that the time stamp reflects the system time rather than the scan time. When CallTable () is executed from within the Scan ... NextScan construct, as is normally done, the time stamp reflects scan time. By executing the CallTable () instruction outside the Scan ... NextScan construct, the time stamp will reflect system time instead of scan time. *CRBASIC EXAMPLE. Time Stamping with System Time* (p. 44) shows the basic code requirements.

CRBASIC EXAMPLE 1. Time Stamping with System Time

```
'Declare Variables
Public value

'Declare Data Table
DataTable(Test,True,1000)
    Sample(1,Value,FP2)
EndTable

SequentialMode

BeginProg
    Scan(1,Sec,10,0)

        'Delay -- in an operational program, delay may be caused by other code
        Delay(1,500,mSec)

        'Measure Value -- can be any analog measurement
        PanelTemp(Value,0)

        'Immediately call SlowSequence to execute CallTable()
        TriggerSequence(1,0)

    NextScan
    'Allow data to be stored 510 ms into the Scan with a s.51 timestamp
    SlowSequence
        Do: WaitTriggerSequence: CallTable(Test): Loop

EndProg
```

Other time processing CRBASIC instructions are governed by these same rules. Consult CRBASIC Editor Help for more information on specific instructions.

4.2 Voltage

The CR1000 incorporates a programmable gain input instrumentation amplifier (PGIA), as illustrated in *FIGURE. PGI Amplifier* (p. 45). The voltage gain of the instrumentation amplifier is determined by the user selected range code associated with voltage measurement instructions. The PGIA can be configured to measure either single-ended (SE) or differential (DIFF) voltages. For SE measurements, the voltage to be measured is connected to the H input while the L input is internally connected to signal ground (⏚). CRBASIC instructions BrHalf (), BrHalf3W (), TCSE (), Therm107 (), Therm108 (), Therm109 (), and VoltSE () perform SE voltage measurements. For DIFF measurements, the voltage to be measured is connected between the H and L inputs on the PGIA. CRBASIC instructions BrFull (), BrFull6W (), BrHalf4W (), TCDiff (), and VoltDiff () instructions perform DIFF voltage measurements.

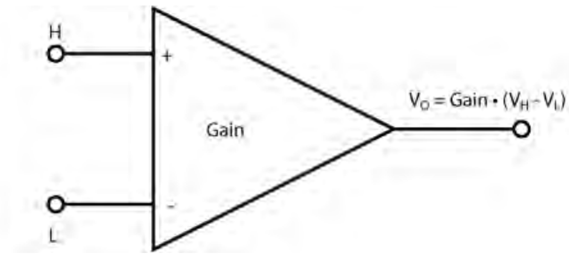


FIGURE 28. PGI Amplifier

A PGIA processes the difference between the H and L inputs, while rejecting voltages that are common to both inputs. *FIGURE. PGIA with Input Signal Decomposition* (p. 45), illustrates the PGIA with the input signal decomposed into a common-mode voltage (V_{cm}) and a DIFF mode voltage (V_{dm}). The common-mode voltage is the average of the voltages on the V_H and V_L inputs, i.e., $V_{cm} = (V_H + V_L)/2$, which can be viewed as the voltage remaining on the H and L inputs with the DIFF voltage (V_{dm}) equal to 0. The total voltage on the H and L inputs is given as $V_H = V_{cm} + V_{dm}/2$, and $V_L = V_{cm} – V_{dm}/2$, respectively.

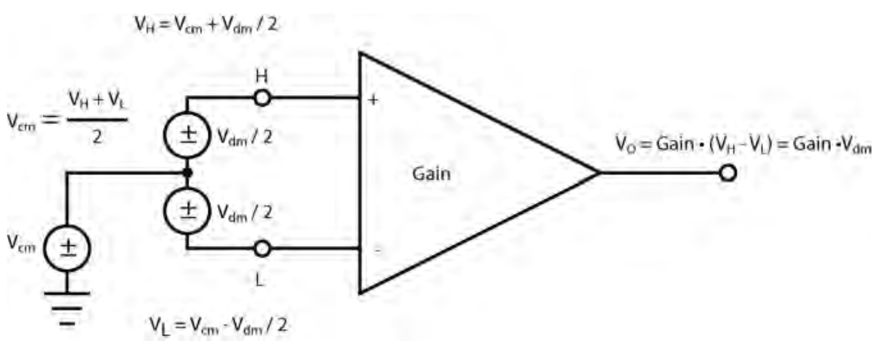


FIGURE 29. PGIA with Input Signal Decomposition

4.2.1 Input Limits

The Input Limits specifies the voltage range, relative to CR1000 ground, which both H and L input voltages must be within to be processed correctly by the PGIA. Input Limits for the CR1000 are ±5 Vdc. Input voltages in which V_H or V_L are beyond the ±5 Vdc Input Limits may suffer from undetected measurement errors. The term “Common-mode Range”, which defines the valid range of common-mode voltages, is often used instead of “Input Limits.” For DIFF voltages that are small compared to the Input Limits, Common-mode Range is essentially equivalent to Input Limits. Yet from *FIGURE. PGIA with Input Signal Decomposition* (p. 45),

Common-mode Range = ± | Input Limits – $V_{dm}/2$ |, indicating a reduction in Common-mode Range for increasing DIFF signal amplitudes. For example, with a 5000 mV DIFF signal, the Common-mode Range is reduced to ±2.5 Vdc, whereas Input Limits are always ±5 Vdc. Hence for non-negligible DIFF signals, "Input Limits" is more descriptive than "Common-mode Range."

Note Two sets of numbers are assigned to analog channels. For differential measurements, analog channels are numbered 1 - 8. Each differential channel as two inputs: high (H) and low (L). For single-ended measurement, analog channels are numbered 1-16.

Note Sustained voltages in excess of ±16 V input to the analog channels will damage CR1000 circuitry.

4.2.2 Reducing Error

Read More! Consult the following White Papers at *www.campbellsci.com* for in-depth treatment of the advantages of differential and single-ended measurements: "Preventing and Attacking Measurement Noise Problems", "Benefits of Input Reversal and Excitation Reversal for Voltage Measurements", and "Voltage Measurement Accuracy, Self-Calibration, and Ratiometric Measurements.

Deciding whether a differential or single-ended measurement is appropriate for a particular sensor requires sorting through trade-offs of accuracy and precision, available measurement hardware, and fiscal constraints.

In broad terms, analog voltage is best measured differentially because these measurements include noise reduction features, listed below, not included in single-ended measurements.

- Passive Noise Rejection
    - No voltage reference offset
    - Common-mode noise rejection
        - Rejects capacitively coupled noise
- Active Noise Rejection
    - Input reversal
        - Review *SECTION. Input and Excitation Reversal* (p. 53) for details
        - Doubles input reversal signal integration time

Reasons for using single-ended measurements, however, include:

- Sensor is not designed for differential measurement.
- Sensor number exceeds available differential channels.

Sensors with a high signal-to-noise ratio, such as a relative humidity sensor with a full scale output of 0 to 1000 mV, can normally be measured single-ended without a significant reduction in accuracy or precision.

Sensors with low signal-to-noise ratio, such as thermocouples, should normally be measured differentially. However, if the measurement to be made does not require high accuracy or precision, such as thermocouples measuring brush fire temperatures, a single-ended measurement may be appropriate. If sensors require differential measurement, but adequate input channels are not available, an analog multiplexer should be acquired to expand differential input capacity. Refer to *APPENDIX. Analog Multiplexers* (p. 497) for information concerning available multiplexers.

Because a single-ended measurement is referenced to CR1000 ground, any difference in ground potential between the sensor and the CR1000 will result in an error in the measurement. For example, if the measuring junction of a copper-constantan thermocouple being used to measure soil temperature is not insulated, and the potential of earth ground is 1 mV greater at the sensor than at the point where the CR1000 is grounded, the measured voltage will be 1 mV greater than the thermocouple output, or approximately 25°C high. A common problem with ground potential difference occurs in applications wherein external signal conditioning circuitry is powered by the same source as the CR1000, such as an ac mains power receptacle. Despite being tied to the same ground, differences in current drain and lead resistance may result in a different ground potential between the two instruments. Hence, a differential measurement should be made on the analog output from an external signal conditioner. Differential measurements MUST be used when the low input is known to be different from ground.

4.2.3 Measurement Sequence

The CR1000 measures analog voltage by integrating the input signal for a fixed duration, then holding the integrated value during the successive approximation analog-to-digital (A/D) conversion. The CR1000 can make and store measurements from up to 8 differential or 16 single-ended channels at the minimum scan rate of 10 ms (100 Hz) using the burst mode voltage measurement (*SECTION. Burst* (p. 310)). The maximum conversion rate is 2000 per second for measurements made on a single channel.

The timing of CR1000 measurements is precisely controlled. The measurement schedule is determined at compile time and loaded into memory. This schedule sets interrupts that drive the measurement task.

Using two different voltage measurement instructions with the same voltage range takes the same measurement time as using one instruction with two repetitions.

Note This is not the case with legacy CR10(X), 21X, CR23X, and CR7(X) dataloggers. Using multiple measurement "reps" in these dataloggers reduced overall measurement time.

Several parameters in CRBASIC voltage measurement instructions VoltDiff () and VoltSE () vary the sequence and timing of measurements. *TABLE.*

CRBASIC Parameters Varying Measurement Sequence and Timing (p. 48) lists these parameters.

TABLE 4. CRBASIC Parameters Varying Measurement Sequence and T

CRBASIC Parameter	***Description***
MeasOfs	Correct ground offset on single-ended measurements.
RevDiff	Reverse high and low differential inputs.
SettlingTime	Sensor input settling time.
Integ	Duration of input signal integration.
RevEx	Reverse polarity of excitation voltage.

4.2.4 Measurement Accuracy

CR1000 analog measurement error is calculated as

Error = Gain Error (%) + Offset Error

Gain error is expressed as ±% and is a function of input voltage and CR1000 temperature. It is minimized by factory calibration and increases with component temperature and aging. Between 0°C and 40°C, gain error is ±0.06% of input voltage.

Offset error is expressed as

Offset Error = Resolution + 1 μV

where

Resolution = published resolution of the programmed input voltage range (see *SECTION. Specifications* (p. 42)).

FIGURE. Voltage Measurement Accuracy (0° to 40°C) (p. 49) illustrates that as magnitude of input voltage decreases, measurement error decreases.

Note The accuracy specification includes only the CR1000's contribution to measurement error. It does not include the error of sensors.

For example, assume the following (see *SECTION. Specifications* (p. 42)):

- Input Voltage: +2500 mV
- Programmed Input Voltage Range: ±2500 mV
- Programmed Measurement Instruction: VoltDiff()
- Input Measurement Reversal = True
- CR1000 Temperature: Between 0°C and 40°C

Accuracy of the measurement is calculated as follows:

Error = Gain Error + Offset Error,

where

Gain Error = ± (2500 * 0.0006)

= ±1.5 mV

and

Offset Error = Differential (DF) Resolution + 1 μV

= 333 μV + 1 μV

= 334 μV

Therefore,

Error = Gain Error + Offset Error

= ±1.5 mV + 334 μV.

= ±1.834 mV

In contrast, the error for a 500 mV input under the same constraints is ± 0.634 mV.

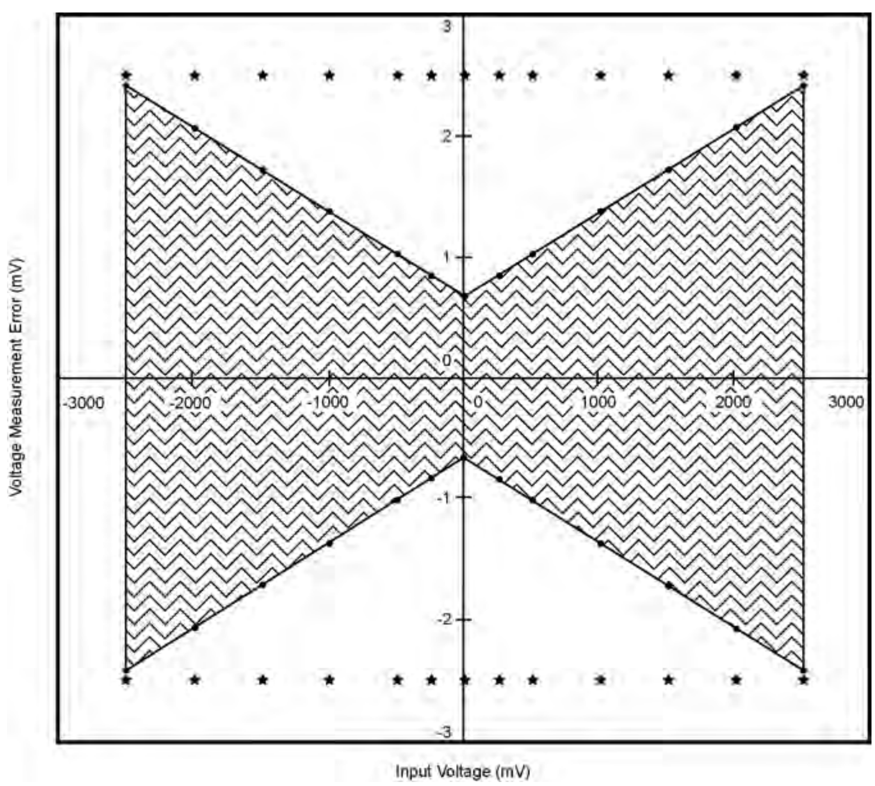


FIGURE 30. Voltage Measurement Accuracy (0° to 40° C)

4.2.5 Voltage Range

In general, a voltage measurement should use the smallest fixed input range that will accommodate the full scale output of the sensor being measured. This results in the best measurement accuracy and resolution. The CR1000 has fixed input ranges for voltage measurements and an auto range to automatically determine the appropriate input voltage range for a given measurement. *TABLE. Analog Voltage Input Ranges with CMN / OID* (p. 50) lists input voltage ranges and range codes.

4.2.5.1 AutoRange

For signals that do not fluctuate too rapidly, AutoRange allows the CR1000 to automatically choose the voltage range to use. AutoRange makes two measurements. The first measurement determines the range to use, and is made with the 250 µs integration on the ±5000 mV range. The second measurement is made using the appropriate range with the integration specified in the instruction. Both measurements use the settling time programmed in the instruction. AutoRange optimizes resolution but takes longer than a measurement on a fixed range, because of the two measurements required.

An AutoRange measurement will return NAN (Not-A-Number) if the voltage exceeds the range picked by the first measurement. To avoid problems with a signal on the edge of a range, AutoRange selects the next larger range when the signal exceeds 90% of a range.

AutoRange is recommended for a signal that occasionally exceeds a particular range, for example, a Type J thermocouple measuring a temperature usually less than 476°C (±25 mV range) but occasionally as high as 500°C (±250 mV range). AutoRange should not be used for rapidly fluctuating signals, particularly signals traversing several voltage ranges rapidly. The possibility exists that the signal can change ranges between the range check and the actual measurement.

TABLE 5. Analog Voltage Input Ranges with Options for Common Mod Input Detect (OID)

Range Code	***Description***
mV5000	measures voltages between ±5000 mV
mV2500[1]	measures voltages between ±2500 mV
mV250[2]	measures voltages between ±250 mV
mV25[2]	measures voltages between ±25 mV
mV7_5[2]	measures voltages between ±7.5 mV
mV2_5[2]	measures voltages between ±2.5 mV
AutoRange[3]	datalogger determines the most suitable range

[1] Append with "C" to enable CMN/OID and set excitation to full-scale DAC (~2700 mV)

[2] Append with "C" to enable CMN/OID

[3] Append with "C" to enable CMN/OID on ranges ≤ ±250 mV, CMN on ranges > ±250 mV

4.2.5.2 Fixed Voltage Ranges

An approximate 9% range overhead exists on fixed input voltage ranges. For example, over-range on the ±2500 mV input range occurs at approximately +2725 mV and -2725 mV. The CR1000 indicates a measurement over-range by returning a NAN (Not-A-Number) for the measurement.

4.2.5.3 Common Mode Null / Open Input Detect

For floating differential sensors such as thermocouples, nulling of any residual common-mode voltage prior to measurement pulls the H and L input amplifier (IA) inputs within the ±5 V Input Limits. Appending a “C” to the range code (i.e. "mV2_5C") enables the nulling of the common-mode voltage prior to a differential measurement on the ±2.5 mV, ±7.5 mV, ±25 mV, and ±250 mV input ranges. Another useful feature for both SE and DIFF measurements is the detection of open inputs due to a broken or disconnected sensor wire, to prevent otherwise undetectable measurement errors. Range codes ending with “C” also enable open detect for all input ranges, except the ±5000 mV input range (See *TABLE. Analog Voltage Input Ranges with CMN / OID* (p. 50)).

On the ±2.5 mV, ±7.5 mV, ±25 mV, and ±250 mV input ranges, the “C” range code option results in a brief 50 microseconds internal connection of the H and L inputs of the IA to 300 mV and ground, respectively, while also connected to the sensor to be measured. The resulting internal common-mode voltage is ±150 mV, which is well within the ±5 V Input Limits. Upon disconnecting the internal 300 mV and ground connections, the associated input is allowed to settle to the desired sensor voltage and the voltage measurement made. If the associated input is open (floating) the input voltages will remain near the 300 mV and ground, resulting in an over range (NAN) on the ±2.5 mV, ±7.5 mV, ±25 mV, and the ±250 mV input range. If the associated sensor is connected and functioning properly, a valid measured voltage will result after the input settling associated with open input detect.

On the ±2500 mV input range the “C” option (i.e. mV2500C) can be used for open input detect with some limitations, as an internal voltage large enough to cause measurement over range is not available. The “C” option for a voltage measurement on the ±2500 mV input range (i.e. mV2500C), results in the H input being briefly connected to a voltage greater than 2500 mV, while the L input is connected to ground. The resulting common-mode voltage is > 1.25 V which is not very helpful in nulling residual common-mode voltage. However, open input detect is still possible by including an If…Then…Else statement in the CRBASIC program to test the measured results. For example, the result of a voltage measurement on the ±2500 mV input range with the “C” option could be tested for > 2500 mV to indicate an open input. For bridge measurements, the returned value X being > 1 would indicate an open input. For example, the BrHalf() instruction returns the value X defined as V1/Vx, where V1 is the measured single-ended voltage and Vx is the user defined excitation voltage having a 2500 mV maximum value. For a BrHalf() measurement utilizing the “C” option on the ±2500 mV input range (i.e. mV2500C), a result of X > 1 indicates an open input for the V1 measurement. The “C” option is not available on the ±5000 mV input range.

Open Input Detect Cautionary Notes

- if the input is not a truly open circuit, such as might occur on a wet cut cable end, the open circuit may not be detected because the input capacitor discharges through external leakage to ground to a normal voltage within the settling time of the measurement. This problem is worse when a long settling time is selected, as more time is given for the input capacitors to discharge to a "normal" level.
- if the open circuit is at the end of a very long cable, the test pulse (300 mV) may not charge the cable (with its high capacitance) up to a voltage that generates NaN or a distinct error voltage. The cable may even act as an aerial and inject noise which also might not read as an error voltage.
- the sensor may "object" to the test pulse being connected to its output, even for 100 microseconds. There is little or no risk of damage, but the sensor output may be kicked into temporary oscillation. Programming a longer settling time in the CRBASIC measurement instruction to allow oscillations to decay before the A/D conversion may mitigate the problem.

4.2.6 Offset Voltage Compensation

Analog measurement circuitry in the CR1000 may introduce a small offset voltage to a measurement. Depending on the magnitude of the signal, this offset voltage may introduce significant error. For example, an offset of 3 μV on a 2500 mV signal introduces an error of only 0.00012%; however, the same offset on a 0.25 mV signal introduces an error of 1.2%.

The primary source of offset voltage is the Seebeck effect, which arises at the junctions of differing metals in electronic circuits. A secondary source of offset voltage are return currents incident to powering external devices through the CR1000. Return currents create voltage drop at the ground terminals that may be used as signal references.

CR1000 measurement instructions incorporate techniques to cancel these unwanted offsets. *TABLE. Analog Measurement Instructions and Offset Voltage Compensation Options* (p. 52) lists available options.

TABLE 6. Analog Measurements and Offset Voltage Compensation				
CRBASIC Voltage Measurement Instruction	***Input Reversal (RevDiff = True)***	***Excitation Reversal (RevEx = True)***	***Measure Ground Reference Offset (MeasOff = True)***	***Background Calibration (RevDiff = False) (RevEx = False) (MeasOff = False)***
VoltDiff()	*			*
VoltSe()			*	*
TCDiff()	*			*
TCSe()			*	*
BrHalf()		*		*
BrHalf3W()		*		*
Therm107()		*		*
Therm108()		*		*
Therm109()		*		*
BrHalf4W()	*	*		*
BrFull()	*	*		*
BrFull6W()	*	*		*
AM25T()	*	*		*

4.2.6.1 Input and Excitation Reversal

Reversing inputs (differential measurements) or reversing polarity of excitation voltage (bridge measurements) cancels stray voltage offsets. For example, if there is a +3 μVolt offset in the measurement circuitry, a 5 mV signal is measured as 5.003 mV. When the input or excitation is reversed, the measurement is -4.997 mV. Subtracting the second measurement from the first and dividing by 2 cancels the offset:

5.003 mV - (-4.997 mV) = 10.000 mV

10.000 mV / 2 = 5.000 mV.

When the CR1000 reverses differential inputs or excitation polarity, it delays the same settling time after the reversal as it does before the first measurement. Thus there are two delays per channel when either RevDiff or RevEx is used. If both RevDiff and RevEx are True, four measurements are performed; positive and negative excitations with the inputs one way and positive and negative excitations with the inputs reversed. To illustrate,

- the CR1000 switches to the channel
- sets the excitation, settles, **measures**,
- reverses the excitation, settles, **measures**,
- reverses the excitation, reverses the inputs, settles, **measures**,
- reverses the excitation, settles, **measures.**

There are four delays per channel measured. The CR1000 processes the four sub-measurements into a single reported value. In cases of excitation reversal, excitation "on time" for each polarity is exactly the same to ensure that ionic sensors do not polarize with repetitive measurements.

Read More! A white paper entitled "The Benefits of Input Reversal and Excitation Reversal for Voltage Measurements" is available at *www.campbellsci.com*.

4.2.6.2 Ground Reference Offset Voltage

When MeasOff is enabled (= True), the CR1000 measures the offset voltage of the ground reference prior to each VoltSe () or TCSe () measurement. This offset voltage is subtracted from the subsequent measurement.

4.2.6.3 Background Calibration (RevDiff, RevEx, MeasOff = False)

If RevDiff, RevEx, or MeasOff is disabled (= False) in a measurement instruction, offset voltage compensation is still performed, albeit less effectively, by using measurements from automatic background calibration. Disabling RevDiff, RevEx, or MeasOff speeds up measurement time; however, the increase in speed comes at the cost of accuracy 1) because RevDiff, RevEx, and MeasOff are more effective techniques, and 2) because background calibrations are performed only periodically, so more time skew occurs between the background calibration offsets and the measurements to which they are applied.

Note Disable RevDiff, RevEx and MeasOff when CR1000 module temperature and return currents are slow to change or when measurement duration must be minimal to maximize measurement frequency.

4.2.7 Integration

Read More! See White Paper "Preventing and Attacking Measurement Noise Problems" at *www.campbellsci.com*.

The CR1000 incorporates circuitry to perform an analog integration on voltages to be measured prior to the A/D conversion. The magnitude of the frequency response of an analog integrator is a SIN(x) / x shape, which has notches (transmission zeros) occurring at 1 / (integer multiples) of the integration duration. Consequently, noise at 1 / (integer multiples) of the integration duration is effectively rejected by an analog integrator. *TABLE. Measurement Integration Times and Codes* (p. 55) lists three integration durations available in the CR1000 and associated CRBASIC codes. If reversing the differential inputs or reversing the excitation is specified, there are two separate integrations per measurement; if both reversals are specified, there are four separate integrations.

TABLE 7. CRBASIC Measurement Integration Times and Codes		
Integration Time (ms)	*CRBASIC Code*	*Comments*
250 µs	250	Fast integration
16.667 ms	_60Hz	filters 60 Hz noise
20 ms	_50Hz	filters 50 Hz noise

4.2.7.1 ac Power Line Noise Rejection

Grid or mains power (50 or 60 Hz, 230 or 120 Vac) can induce electrical noise at integer multiples of 50 or 60 Hz. Small analog voltage signals, such as thermocouples and pyranometers, are particularly susceptible. CR1000 voltage measurements can be programmed to reject (filter) 50 or 60 Hz related noise.

4.2.7.1.1 ac Noise Rejection on Small Signals

The CR1000 rejects ac power line noise on all voltage ranges except mV5000 and mV2500 by integrating the measurement over exactly one ac cycle before A/D conversion as illustrated in *TABLE. ac Noise Rejection on Small Signals* (p. 55) and the full cycle technique of *FIGURE. ac Power Line Noise Rejection* (p. 55).

TABLE 8. ac Noise Rejection on Small Signals		
Applies to all analog input voltage ranges except mV2500 and mV5000.		
ac Power Line Frequency	*Measurement Integration Duration*	*CRBASIC Integration Code*
60 Hz	16.667 ms	_60Hz
50 Hz	20 ms	_50Hz

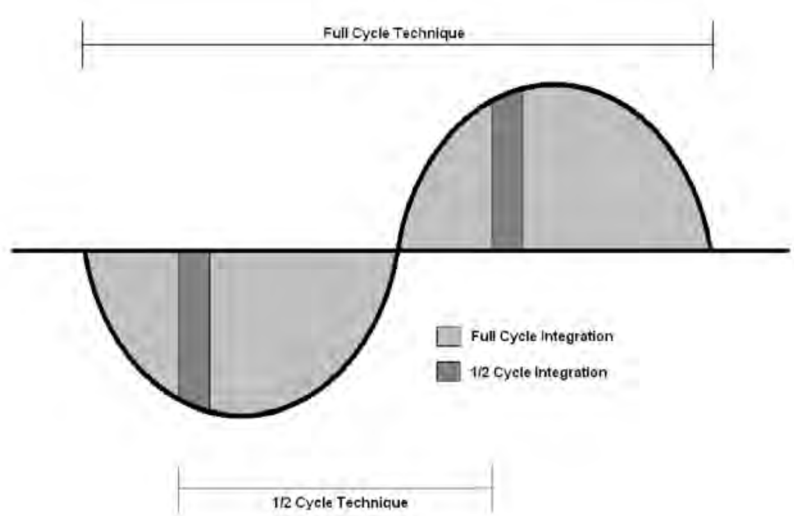


FIGURE 31. ac Power Line Noise Rejection Techniques

4.2.7.1.2 ac Noise Rejection on Large Signals

When rejecting ac noise on the 2500 mV and 5000 mV ranges, the CR1000 makes two fast measurements separated in time by ½ line cycle, as illustrated in *FIGURE. ac Power Line Noise Rejection Techniques* (p. 55). For 60 Hz rejection, ½ line cycle = 8333 µs, meaning that the 2nd measurement must start 8333 µs after the integration for the first measurement was started. The A/D conversion time is approximately 170 µs, leaving a maximum input settling time of approximately 8333 µs - 170 µs = 8160 µs before the 2nd measurement is delayed too long to result in a rejection notch at 60 Hz. For 50 Hz rejection on the mV5000 and mV2500 input ranges, the maximum input settling time of approximately 10,000 - 170 µs = 9830 µs before the 2nd measurement is delayed too long to result in a rejection notch at 50 Hz. The CR1000 does not prevent or warn against setting the settling time beyond the ½ cycle limit. *TABLE. ac Noise Rejection on Large Signals* (p. 56) lists details of the ½ line cycle ac power line noise rejection technique.

TABLE 9. ac Noise Rejection on Large Signals

Applies to analog input voltage ranges mV2500 and mV5000.

ac Power Line Frequency	*Measurement Integration Time*	*CRBASIC Integration Code*	*Default Settling Time*	*Maximum Recommended Settling Time**
60 Hz	250 µs x 2	_60Hz	3000 µs	8330 µs
50 Hz	250 µs x 2	_50Hz	3000 µs	10000 µs

*Excitation time equals settling time in measurements requiring excitation. The CR1000 cannot excite VX/EX excitation channels during A/D conversion. The ½ cycle technique with excitation limits the length of recommended excitation / settling time for the first measurement to ½ cycle. The CR1000 does not prevent or warn against setting a settling time beyond the ½ cycle limit. For example, a settling time of up to 50000 microseconds can be programmed, but the CR1000 will execute the measurement as follows:

1. CR1000 turns excitation on, waits 50000 microseconds, then makes the first measurement.

2. During A/D, CR1000 turns off excitation for ≈ 170 microseconds.

3. Excitation is switched on again for ½ cycle, then the second measurement is made.

Restated, when using the ½ cycle 50 Hz or 60 Hz rejection method, a sensor does not see a continuous excitation of the length entered as the settling time before the second measurement if the settling time entered is greater than ½ cycle. Depending on the sensor used, a truncated second excitation may cause measurement errors.

4.2.8 Signal Settling Time

When the CR1000 switches to an analog input channel or activates excitation for a bridge measurement, a settling time is required for the measured voltage to settle to its true value before being measured. The rate at which the signal settles is determined by the input settling time constant which is a function of both the source resistance and input capacitance.

Rise and decay waveforms are exponential. *FIGURE. Input Voltage Rise and Transient Decay* (p. 57) shows rising and decaying waveforms settling to the true signal level, V_{so}.

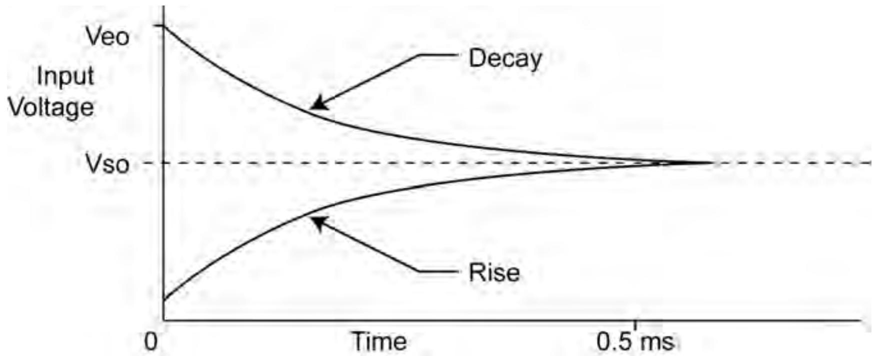


FIGURE 32. Input Voltage Rise and Transient Decay

The CR1000 delays after switching to a channel to allow the input to settle before initiating the measurement. The SettlingTime parameter of the associated measurement instruction is provided to allow the user to tailor measurement instructions settling times with 100 µs resolution up to the maximum settling time of 50000 µs. Default settling times are listed in *TABLE. CRBASIC Measurement Settling Times* (p. 57), and are meant to provide sufficient signal settling in most cases. Additional settling time may be required when measuring high resistance (impedance) sensors and / or sensors connected to the datalogger by long leads. Measurement time of a given instruction increases with increasing settling time. For example, a 1 ms increase in settling time for a bridge instruction with input reversal and excitation reversal results in a 4 ms increase in time for the CR1000 to perform the instruction.

TABLE 10. CRBASIC Measurement Settling Times

Settling Time Entry	*Input Voltage Range*	*Integration Code*	*Settling Time**
0	All	250 µs	450 µs (default)
0	All	_50Hz	3 ms (default)
0	All	_60Hz	3 ms (default)
>100	All	All	µs entered

*Minimum settling time required to allow the input to settle to CR1000 resolution specifications.

A settling time is required for voltage measurements to minimize the effects of the following sources of error:

- A small switching transient occurs when the CR1000 switches to the single-ended or differential channel to be measured.
- A relatively large transient may be induced on the signal conductor via capacitive coupling during a bridge measurement from an adjacent excitation conductor.

- 50 or 60 Hz integrations require a relatively long reset time of the internal integration capacitor before the next measurement due to dielectric absorption.

4.2.8.1 Minimizing Settling Errors

When long lead lengths are required the following general practices can be used to minimize or measure settling errors:

1. DO NOT USE WIRE WITH PVC INSULATED CONDUCTORS. PVC has a high dielectric which extends input settling time.

2. Where possible, run excitation leads and signal leads in separate shields to minimize transients.

3. When measurement speed is not a prime consideration, additional time can be used to ensure ample settling time. The settling time required can be measured with the CR1000.

4.2.8.2 Measuring the Necessary Settling Time

Settling time for a particular sensor and cable can be measured with the CR1000. Programming a series of measurements with increasing settling times will yield data that indicates at what settling time a further increase results in negligible change in the measured voltage. The programmed settling time at this point indicates the true settling time for the sensor and cable combination.

CRBASIC EXAMPLE. Measuring Settling Time (p. 59) presents CRBASIC code to help determine settling time for a pressure transducer utilizing a high capacitance semi-conductor. The code consists of a series of full-bridge measurements (BrFull ()) with increasing settling times. The pressure transducer is placed in steady-state conditions so changes in measured voltage are attributable to settling time rather than changes in the measured pressure. Reviewing *SECTION. Programming* (p. 129) may help in understanding the CRBASIC code in the example.

The first six measurements are shown in *TABLE. First Six Values of Settling Time Data* (p. 60). Each trace in *FIGURE. Settling Time for Pressure Transducer* (p. 59) contains all 20 PT() values for a given record number, along with an average value showing the measurements as percent of final reading. The reading has settled to 99.5% of the final value by the fourteenth measurement, PT(14). This is a suitable accuracy for the application, so a settling time of 1400 μs is determined to be adequate.

CRBASIC EXAMPLE 2. Measuring Settling Time

```
'Program to measure the settling time of a sensor measured with a differential
'voltage measurement

Public PT(20)                                   'Variable to hold the measurements

DataTable(Settle,True,100)
   Sample(20,PT(),IEEE4)
EndTable

BeginProg
   Scan(1,Sec,3,0)

      BrFull(PT(1),1,mV7.5,1,Vx1,1,2500,True,True,100,250,1.0,0)
      BrFull(PT(2),1,mV7.5,1,Vx1,1,2500,True,True,200,250,1.0,0)
      BrFull(PT(3),1,mV7.5,1,Vx1,1,2500,True,True,300,250,1.0,0)
      BrFull(PT(4),1,mV7.5,1,Vx1,1,2500,True,True,400,250,1.0,0)
      BrFull(PT(5),1,mV7.5,1,Vx1,1,2500,True,True,500,250,1.0,0)
      BrFull(PT(6),1,mV7.5,1,Vx1,1,2500,True,True,600,250,1.0,0)
      BrFull(PT(7),1,mV7.5,1,Vx1,1,2500,True,True,700,250,1.0,0)
      BrFull(PT(8),1,mV7.5,1,Vx1,1,2500,True,True,800,250,1.0,0)
      BrFull(PT(9),1,mV7.5,1,Vx1,1,2500,True,True,900,250,1.0,0)
      BrFull(PT(10),1,mV7.5,1,Vx1,1,2500,True,True,1000,250,1.0,0)
      BrFull(PT(11),1,mV7.5,1,Vx1,1,2500,True,True,1100,250,1.0,0)
      BrFull(PT(12),1,mV7.5,1,Vx1,1,2500,True,True,1200,250,1.0,0)
      BrFull(PT(13),1,mV7.5,1,Vx1,1,2500,True,True,1300,250,1.0,0)
      BrFull(PT(14),1,mV7.5,1,Vx1,1,2500,True,True,1400,250,1.0,0)
      BrFull(PT(15),1,mV7.5,1,Vx1,1,2500,True,True,1500,250,1.0,0)
      BrFull(PT(16),1,mV7.5,1,Vx1,1,2500,True,True,1600,250,1.0,0)
      BrFull(PT(17),1,mV7.5,1,Vx1,1,2500,True,True,1700,250,1.0,0)
      BrFull(PT(18),1,mV7.5,1,Vx1,1,2500,True,True,1800,250,1.0,0)
      BrFull(PT(19),1,mV7.5,1,Vx1,1,2500,True,True,1900,250,1.0,0)
      BrFull(PT(20),1,mV7.5,1,Vx1,1,2500,True,True,2000,250,1.0,0)

      CallTable Settle

   NextScan
EndProg
```

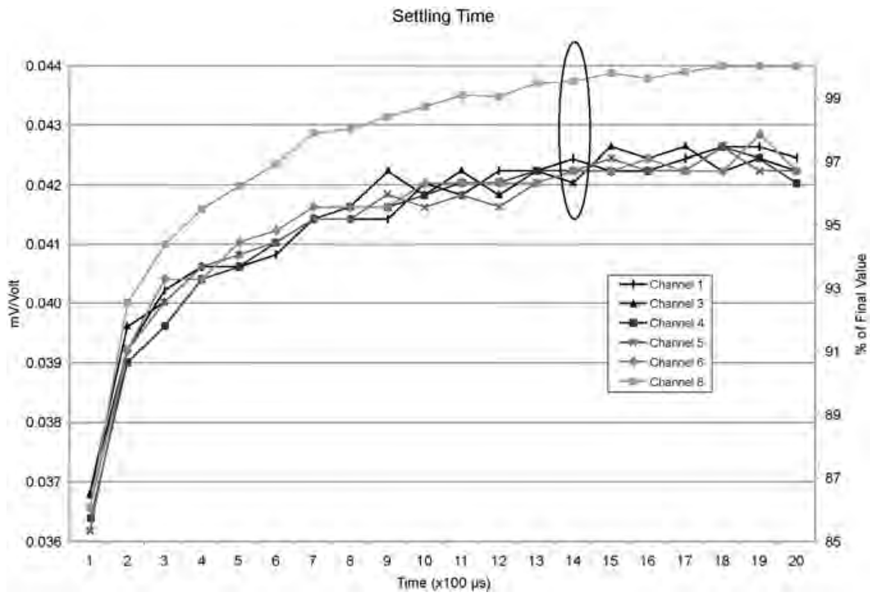


FIGURE 33. Settling Time for Pressure Transducer

TABLE 11. First Six Values of Settling Time Data

TIMESTAMP	*REC*	*PT(1)*	*PT(2)*	*PT(3)*	*PT(4)*	*PT(5)*	*PT(6)*
		Smp	*Smp*	*Smp*	*Smp*	*Smp*	*Smp*
1/3/2000 23:34	0	0.03638599	0.03901386	0.04022673	0.04042887	0.04103531	0.04123745
1/3/2000 23:34	1	0.03658813	0.03921601	0.04002459	0.04042887	0.04103531	0.0414396
1/3/2000 23:34	2	0.03638599	0.03941815	0.04002459	0.04063102	0.04042887	0.04123745
1/3/2000 23:34	3	0.03658813	0.03941815	0.03982244	0.04042887	0.04103531	0.04103531
1/3/2000 23:34	4	0.03679027	0.03921601	0.04022673	0.04063102	0.04063102	0.04083316

4.2.9 Self-Calibration

Read More! Related topics can be found in *SECTION. Offset Voltage Compensation* (p. 52)

The CR1000 self-calibrates to compensate for changes induced by fluctuating operating temperatures and aging. Without self-calibration, measurement accuracy over the operational temperature range is worse by about a factor of 10. That is, over the extended temperature range of -40°C to 85°C, the accuracy specification of ±0.12% of reading can degrade to ±1% of reading with self-calibration disabled. If the temperature of the CR1000 remains the same, there is little calibration drift with self-calibration disabled.

Note -- Self-calibration requires the CR1000 to have an internal voltage standard. The internal voltage standard should periodically be calibrated by Campbell Scientific. When high accuracy voltage measurements are required, a two year calibration cycle is recommended.

Unless a Calibrate() instruction is present in the running CRBASIC program, the CR1000 automatically performs self-calibration during spare time in the background as an automatic *slow sequence* (p. 160), with a segment of the calibration occurring every 4 seconds. If there is insufficient time to do the background calibration because of a scan consuming user program, the CR1000 will display the following warning at compile time: "Warning when Fast Scan x is running background calibration is disabled".

The composite transfer function of the instrumentation amplifier, integrator, and analog-to-digital converter of the CR1000 is described by the following equation:

```
COUNTS = G * Vin + B
```

where COUNTS is the result from an analog-to-digital conversion, G is the voltage gain for a given input range, and B is the internally measured offset voltage.

Automatic self-calibration only calibrates the G and B values necessary to run a given CRBASIC program, resulting in a program dependent number of self-calibration segments ranging from at least 6 to a maximum of 91. A typical number of segments required in self-calibration is 20 for analog ranges and 1 segment for the panel temperature measurement, totaling 21 segments. So, (21 segments) * (4 s / segment) = 84 s per complete self-calibration. The worst-case is (91 segments) * (4 s / segment) = 364 s per complete self-calibration.

During instrument power-up, the CR1000 computes calibration coefficients by averaging 10 complete sets of self-calibration measurements. After power up, newly determined G and B values are low-pass filtered as followed: **Next_Value** = (1/5) * **New** + (4/5) * **Old**. For a step change of the **New** value, the low-pass filter **Next_Value** = (1/5) * **New** + (4/5) * **Old** results in 20% settling for 1 **New** value, 49% settling for 3 **New** values, 67% settling for 5 **New** values, 89% settling for 10 **New** values, and 96% settling for 14 **New** values. If this rate of update for measurement channels is too slow, a user can utilize the Calibrate() instruction. The Calibrate() instruction computes the necessary G and B values every scan without any low-pass filtering.

For a VoltSe() instruction, B is determined as part of self-calibration only if the parameter **MeasOff** = 0. An exception is B for VoltSe () on the ±2500 mV input range with 250 μs integration, which is always determined in self-calibration for use internally. For a VoltDiff () instruction, B is determined as part of self-calibration only if the parameter **RevDiff** = 0.

VoltSe() and VoltDiff() instructions on a given input range with the same integration durations, utilize the same G, but different B values. The 6 input voltage ranges (±5000 mV, ±2500 mV, ±250 mV, ±25 mV, ±7.5 mV, ±2.5 mV) along with the 3 different integration durations (250 μs, _50Hz, and _60Hz) result in a maximum of 18 different gains (G), and 18 offsets for VoltSe() measurements (B), and 18 offsets for VoltDiff() measurements (B) to be determined during CR1000 self-calibration (maximum of 54 values). These values can be viewed in the Status Table, with entries identified as listed in *TABLE. Status Table Calibration Entries* (p. 62).

Automatic self-calibration can be overridden with the Calibrate() instruction, which forces a calibration for each execution, and does not employ any low-pass filtering on the newly determined G and B values. There are two parameters associated with the Calibrate instruction; Dest and CalRange. The CalRange parameter determines whether to calibrate only the necessary input ranges for a given CRBASIC program (Value = 0) or to calibrate all input ranges (Value ≠ 0). The Dest parameter should be of sufficient dimension for all the returned G and B values, which is 2 minimum for the automatic self-calibration of VoltSE () including B (offset) for the ±2500 mV input range with first 250 µs integration, and 54 maximum for all possible integration durations and input voltage ranges chosen.

An example use of the Calibrate() instruction to calibrate all input ranges is given as

```
Calibrate(cal(1),true)
```

where Dest is an array of 54 variables, and Range ≠ 0 to calibrate all input ranges. Results of this command are listed in *TABLE. Calibrate () Instruction Results* (p. 63).

TABLE 12. Status Table Calibration Entries

Status Table Element	*Descriptions of Status Table Elements*			
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*
CalGain(1)		Gain	5000	250 ms
CalGain(2)		Gain	2500	250 ms
CalGain(3)		Gain	250	250 ms
CalGain(4)		Gain	25	250 ms
CalGain(5)		Gain	7.5	250 ms
CalGain(6)		Gain	2.5	250 ms
CalGain(7)		Gain	5000	60 Hz Rejections
CalGain(8)		Gain	2500	60 Hz Rejection
CalGain(9)		Gain	250	60 Hz Rejection
CalGain(10)		Gain	25	60 Hz Rejection
CalGain(11)		Gain	7.5	60 Hz Rejection
CalGain(12)		Gain	2.5	60 Hz Rejection
CalGain(13)		Gain	5000	50 Hz Rejection
CalGain(14)		Gain	2500	50 Hz Rejection
CalGain(15)		Gain	250	50 Hz Rejection
CalGain(16)		Gain	25	50 Hz Rejection
CalGain(17)		Gain	7.5	50 Hz Rejection
CalGain(18)		Gain	2.5	50 Hz Rejection
CalSeOffset(1)	SE	Offset	5000	250 ms
CalSeOffset(2)	SE	Offset	2500	250 ms
CalSeOffset(3)	SE	Offset	250	250 ms
CalSeOffset(4)	SE	Offset	25	250 ms
CalSeOffset(5)	SE	Offset	7.5	250 ms

TABLE 12. Status Table Calibration Entries

Status Table Element	*Descriptions of Status Table Elements*			
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*
CalSeOffset(6)	SE	Offset	2.5	250 ms
CalSeOffset(7)	SE	Offset	5000	60 Hz Rejection
CalSeOffset(8)	SE	Offset	2500	60 Hz Rejection
CalSeOffset(9)	SE	Offset	250	60 Hz Rejection
CalSeOffset(10)	SE	Offset	25	60 Hz Rejection
CalSeOffset(11)	SE	Offset	7.5	60 Hz Rejection
CalSeOffset(12)	SE	Offset	2.5	60 Hz Rejection
CalSeOffset(13)	SE	Offset	5000	50 Hz Rejection
CalSeOffset(14)	SE	Offset	2500	50 Hz Rejection
CalSeOffset(15)	SE	Offset	250	50 Hz Rejection
CalSeOffset(16)	SE	Offset	25	50 Hz Rejection
CalSeOffset(17)	SE	Offset	7.5	50 Hz Rejection
CalSeOffset(18)	SE	Offset	2.5	50 Hz Rejection
CalDiffOffset(1)	Diff	Offset	5000	250 ms
CalDiffOffset(2)	Diff	Offset	2500	250 ms
CalDiffOffset(3)	Diff	Offset	250	250 ms
CalDiffOffset(4)	Diff	Offset	25	250 ms
CalDiffOffset(5)	Diff	Offset	7.5	250 ms
CalDiffOffset(6)	Diff	Offset	2.5	250 ms
CalDiffOffset(7)	Diff	Offset	5000	60 Hz Rejection
CalDiffOffset(8)	Diff	Offset	2500	60 Hz Rejection
CalDiffOffset(9)	Diff	Offset	250	60 Hz Rejection
CalDiffOffset(10)	Diff	Offset	25	60 Hz Rejection
CalDiffOffset(11)	Diff	Offset	7.5	60 Hz Rejection
CalDiffOffset(12)	Diff	Offset	2.5	60 Hz Rejection
CalDiffOffset(13)	Diff	Offset	5000	50 Hz Rejection
CalDiffOffset(14)	Diff	Offset	2500	50 Hz Rejection
CalDiffOffset(15)	Diff	Offset	250	50 Hz Rejection
CalDiffOffset(16)	Diff	Offset	25	50 Hz Rejection
CalDiffOffset(17)	Diff	Offset	7.5	50 Hz Rejection
CalDiffOffset(18)	Diff	Offset	2.5	50 Hz Rejection

TABLE 13. Calibrate() Instruction Results

Array Cal() Element	*Descriptions of Array Elements*				*Typical Value*
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*	
1	SE	Offset	5000	250 ms	±5 LSB
2	Diff	Offset	5000	250 ms	±5 LSB
3		Gain	5000	250 ms	-1.34 mV/LSB
4	SE	Offset	2500	250 ms	±5 LSB
5	Diff	Offset	2500	250 ms	±5 LSB
6		Gain	2500	250 ms	-0.67 mV/LSB
7	SE	Offset	250	250 ms	±5 LSB
8	Diff	Offset	250	250 ms	±5 LSB
9		Gain	250	250 ms	-0.067 mV/LSB
10	SE	Offset	25	250 ms	±5 LSB
11	Diff	Offset	25	250 ms	±5 LSB
12		Gain	25	250 ms	-0.0067 mV/LSB
13	SE	Offset	7.5	250 ms	±10 LSB
14	Diff	Offset	7.5	250 ms	±10 LSB
15		Gain	7.5	250 ms	-0.002 mV/LSB
16	SE	Offset	2.5	250 ms	±20 LSB
17	Diff	Offset	2.5	250 ms	±20 LSB
18		Gain	2.5	250 ms	-0.00067 mV/LSB
19	SE	Offset	5000	60 Hz Rejection	±5 LSB
20	Diff	Offset	5000	60 Hz Rejection	±5 LSB
21		Gain	5000	60 Hz Rejection	-0.67 mV/LSB
22	SE	Offset	2500	60 Hz Rejection	±5 LSB
23	Diff	Offset	2500	60 Hz Rejection	±5 LSB
24		Gain	2500	60 Hz Rejection	-0.34 mV/LSB
25	SE	Offset	250	60 Hz Rejection	±5 LSB
26	Diff	Offset	250	60 Hz Rejection	±5 LSB
27		Gain	250	60 Hz Rejection	-0.067 mV/LSB
28	SE	Offset	25	60 Hz Rejection	±5 LSB
29	Diff	Offset	25	60 Hz Rejection	±5 LSB
30		Gain	25	60 Hz Rejection	-0.0067 mV/LSB
31	SE	Offset	7.5	60 Hz Rejection	±10 LSB
32	Diff	Offset	7.5	60 Hz Rejection	±10 LSB
33		Gain	7.5	60 Hz Rejection	-0.002 mV/LSB
34	SE	Offset	2.5	60 Hz Rejection	±20 LSB
35	Diff	Offset	2.5	60 Hz Rejection	±20 LSB
36		Gain	2.5	60 Hz Rejection	-0.00067 mV/LSB

TABLE 13.   Calibrate() Instruction Results

Array Cal() Element	*Descriptions of Array Elements*				*Typical Value*
	Differential (Diff) Single-Ended (SE)	*Offset or Gain*	*±mV Input Range*	*Integration*	
37	SE	Offset	5000	50 Hz Rejection	±5 LSB
38	Diff	Offset	5000	50 Hz Rejection	±5 LSB
39		Gain	5000	50 Hz Rejection	-0.67 mV/LSB
40	SE	Offset	2500	50 Hz Rejection	±5 LSB
41	Diff	Offset	2500	50 Hz Rejection	±5 LSB
42		Gain	2500	50 Hz Rejection	-0.34 mV/LSB
43	SE	Offset	250	50 Hz Rejection	±5 LSB
44	Diff	Offset	250	50 Hz Rejection	±5 LSB
45		Gain	250	50 Hz Rejection	-0.067 mV/LSB
46	SE	Offset	25	50 Hz Rejection	±5 LSB
47	Diff	Offset	25	50 Hz Rejection	±5 LSB
48		Gain	25	50 Hz Rejection	-0.0067 mV/LSB
49	SE	Offset	7.5	50 Hz Rejection	±10 LSB
50	Diff	Offset	7.5	50 Hz Rejection	±10 LSB
51		Gain	7.5	50 Hz Rejection	-0.002 mV/LSB
52	SE	Offset	2.5	50 Hz Rejection	±20 LSB
53	Diff	Offset	2.5	50 Hz Rejection	±20 LSB
54		Gain	2.5	50 Hz Rejection	-0.00067 mV/LSB

4.2.10 Time Skew Between Measurements

Time skew between consecutive voltage measurements is a function of settling and integration times, A/D conversion, and the number of reps entered into the VoltDiff() or VoltSE() instruction. The relationship is:

> Time Skew = Settling Time + Integration Time + A-D Conversion + Reps/NoReps*

*Reps/No Reps -- If Reps > 1(i.e., multiple measurements by a single instruction), no additional time is required. If Reps = 1 in consecutive voltage instructions, add 15uSec per instruction.

4.3 Bridge Resistance

Many sensors detect phenomena by way of change in a resistive circuit. Thermistors, strain gages, and position potentiometers are examples. Resistance measurements are special case voltage measurements. By supplying a precise, known voltage to a resistive circuit, then measuring the returning voltage, resistance can be calculated.

Read More! Available resistive bridge completion modules are listed in *APPENDIX. Signal Conditioners* (p. 500).

Five bridge measurement instructions are features of the CR1000. *TABLE. Resistive Bridge Circuits -- Voltage Excitation* (p. 66) show circuits that are typically measured with these instructions. In the diagrams, resistors labeled R_s are normally the sensors and those labeled R_f are normally precision fixed (static) resistors. Circuits other than those diagrammed can be measured, provided the excitation and type of measurements are appropriate. Program Code *CRBASIC EXAMPLE. 4 Wire Full Bridge Measurement* (p. 68) shows CR1000 code for measuring and processing four wire full bridge circuits.

All bridge measurements have the option (**RevEx**) to make one set of measurements with the excitation as programmed and another set of measurements with the excitation polarity reversed. The offset error in the two measurements due to thermal EMFs can then be accounted for in the processing of the measurement instruction. The excitation channel maintains the excitation voltage or current until the hold for the analog to digital conversion is completed. When more than one measurement per sensor is necessary (four wire half bridge, three wire half bridge, six wire full bridge), excitation is applied separately for each measurement. For example, in the four-wire half-bridge, when the excitation is reversed, the differential measurement of the voltage drop across the sensor is made with the excitation at both polarities and then excitation is again applied and reversed for the measurement of the voltage drop across the fixed resistor.

Calculating the resistance of a sensor that is one of the legs of a resistive bridge requires additional processing following the bridge measurement instruction. *TABLE. Resistive Bridge Circuits -- Voltage Excitation* (p. 66) lists the schematics of bridge configurations and related resistance equations.

TABLE 14. Resistive Bridge Circuits -- Voltage Excitation

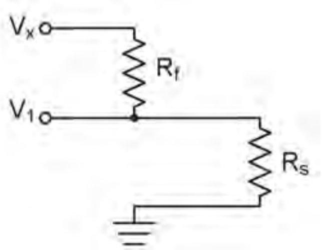
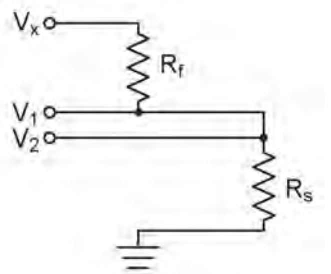
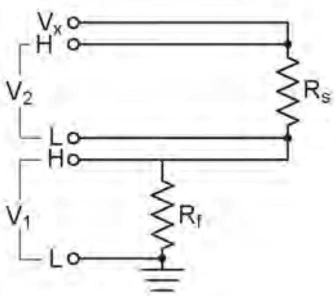
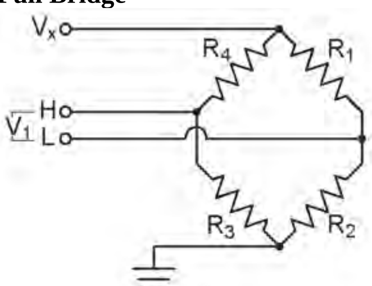
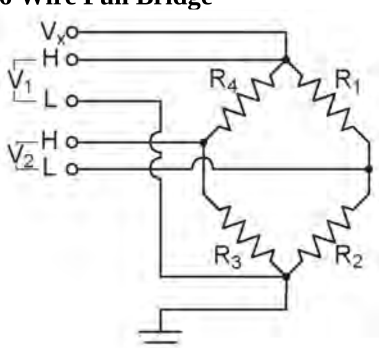
Resistive Bridge Type and Circuit Diagram	*CRBASIC Instruction and Fundamental Relationship*	*Relationships*
Half Bridge[1] 	CRBASIC Instruction: **BrHalf()** Fundamental Relationship[2]: $X = \frac{V_1}{V_x} = \frac{R_s}{R_s + R_f}$	$R_s = R_f \frac{X}{1-X}$ $R_f = \frac{R_s(1-X)}{X}$
3 Wire Half Bridge[1,3]	CRBASIC Instruction: **BrHalf3W()** Fundamental Relationship[2]: $X = \frac{2V_2 - V_1}{V_x - V_1} = \frac{R_s}{R_f}$	$R_f = R_s / X$ $R_s = R_f X$

TABLE 14. Resistive Bridge Circuits -- Voltage Excitation

Resistive Bridge Type and Circuit Diagram	*CRBASIC Instruction and Fundamental Relationship*	*Relationships*
		
4 Wire Half Bridge[1,3] 	CRBASIC Instruction: **BrHalf4W()** Fundamental Relationship[2]: $X = \frac{V_2}{V_1} = \frac{R_s}{R_f}$	$R_s = R_f X$ $R_f = R_s / X$
Full Bridge[1,3] 	CRBASIC Instruction: **BrFull()** Fundamental Relationship[2]: $X = 1000\frac{V_1}{V_x}$ $= 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	These relationships apply to BrFull() and BrFull6W(). $X_1 = \frac{-X}{1000} + \frac{R_3}{R_3+R_4}$ $R_1 = \frac{R_2(1-X_1)}{X_1}$ $R_2 = \frac{R_1 X_1}{1-X_1}$ $X_2 = \frac{X}{1000} + \frac{R_2}{R_1+R_2}$ $R_3 = \frac{R_4 X_2}{1-X_2}$ $R_4 = \frac{R_3(1-X_2)}{X_2}$
6 Wire Full Bridge[1] 	CRBASIC Instruction: **BrFull6W()** Fundamental Relationship[2]: $X = 1000\frac{V_2}{V_1}$ $= 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	

[1]Key: V_x = excitation voltage; V_1, V_2 = sensor return voltages; R_f = "fixed", "bridge" or "completion" resistor; R_s = "variable" or "sensing" resistor.
[2]Where X = result of the CRBASIC bridge measurement instruction with a multiplier of 1 and an offset of 0.
[3]See *APPENDIX. Resistive Bridge Modules* (p. 500) for a list of available terminal input modules to facilitate this measurement.

CRBASIC EXAMPLE 3. 4 Wire Full Bridge Measurement and Processing

```
'Declare Variables
Public X
Public X1
Public R1
Public R2
Public R3
Public R4

Main Program
BeginProg
    R2 = 1000                                  'Resistance of R2
    R3 = 1000                                  'Resistance of R3
    R4 = 1000                                  'Resistance of R4

    Scan(500,mSec,1,0)

        'Full Bridge Measurement:
        BrFull(X,1,mV2500,1,1,1,2500,True,True,0,_60Hz,1.0,0.0)
        X1 = ((-1 * X) / 1000) + (R3 / (R3 + R4))
        R1 = (R2 * (1 - X1)) / X1

    NextScan
EndProg
```

4.3.1 Measurements Requiring ac Excitation

Some resistive sensors require ac excitation. These include electrolytic tilt sensors, soil moisture blocks, water conductivity sensors and wetness sensing grids. The use of dc excitation with these sensors can result in polarization, which will cause erroneous measurement, shift calibration, or lead to rapid sensor decay.

Other sensors, e.g., LVDTs (Linear Variable Differential Transformers), require an ac excitation because they rely on inductive coupling to provide a signal. dc excitation will provide no output.

CR1000 bridge measurements can reverse excitation polarity to provide ac excitation and avoid ion polarization.

Note Sensors requiring ac excitation require techniques to minimize or eliminate ground loops. See *SECTION. Ground Looping in Ionic Measurements* (p. 109).

4.3.2 Strain Calculations

Read More! FieldCalStrain in *SECTION. FieldCa () Demonstration Programs* (p. 230).

A principal use of the four wire full bridge is the measurement of strain gages in structural stress analysis. StrainCalc () calculates microstrain, $\mu\varepsilon$, from an appropriate formula for the particular strain bridge configuration used. All strain gages supported by StrainCalc () use the full bridge electronic configuration. In strain gage parlance, "quarter bridge", "half bridge" and "full bridge" refer to the number of active elements in the full bridge, i.e., 1, 2, or 4 active elements respectively.

StrainCalc() requires a bridge configuration code. *TABLE. StrainCalc() Instruction Equations* (p. 69) shows the equation used by each configuration code. Each code can be preceded by a negative sign (-). Use a positive code when the bridge is configured so the output decreases with increasing strain. Use a negative code when the bridge is configured so the output increases with increasing strain. In the equations in *TABLE. StrainCalc() Instruction Equations* (p. 69), a negative code sets the polarity of V_r to negative (-).

TABLE 15. StrainCalc() Instruction Equations

StrainCalc() BrConfig *Code*	*Configuration*
1	Quarter bridge strain gage: $\mu\varepsilon = \frac{-4 * 10^6 V_r}{GF(1+2V_r)}$
2	Half bridge strain gage. One gage parallel to strain, the other at 90° to strain. $\mu\varepsilon = \frac{-4 * 10^6 V_r}{GF[(1+\nu) - 2V_r(\nu-1)]}$
3	Half bridge strain gage. One gage parallel to $+\varepsilon$, the other parallel to $-\varepsilon$: $\mu\varepsilon = \frac{-2 * 10^6 V_r}{GF}$
4	Full bridge strain gage. Two gages parallel to $+\varepsilon$, the other two parallel to $-\varepsilon$: $\mu\varepsilon = \frac{-10^6 V_r}{GF}$
5	Full bridge strain gage. Half the bridge has to gages parallel to $+\varepsilon$ and $-\varepsilon$, and the other half to $+\nu\varepsilon$ and $-\nu\varepsilon$: $\mu\varepsilon = \frac{-2 * 10^6 V_r}{GF(\nu+1)}$
6	Full bridge strain gage. Half the bridge has two gages parallel to $+\varepsilon$ and $-\nu\varepsilon$, and the other half to $-\nu\varepsilon$ and $+\varepsilon$: $\mu\varepsilon = \frac{-2 * 10^6 V_r}{GF[(\nu+1) - V_r(\nu-1)]}$

where:

- ν: Poisson Ratio (0 if not applicable)
- **GF**: Gage Factor
- $\mathbf{V_r}$: 0.001 (Source-Zero) if BRConfig code is positive (+)
- $\mathbf{V_r}$: -0.001 (Source-Zero) if BRConfig code is negative (-)

where:

- "source": the result of the full Wheatstone bridge measurement ($X = 1000 * V_1 / V_x$) when multiplier = 1 and offset = 0.
- "zero": gage offset to establish an arbitrary zero (see FieldCalStrain in *FieldCal () Demonstration Programs* (p. 230)).

StrainCalc Example: See *SECTION. FieldCalStrain() Demonstration Program* (p. 237)

4.4 Thermocouple

Note Thermocouples are easy to use with the CR1000. They are also inexpensive. However, they pose several challenges to the acquisition of accurate temperature data, particularly when using external reference junctions. Campbell Scientific **strongly encourages** any user of thermocouples to carefully evaluate *SECTION. Error Analysis* (p. 71). An introduction to thermocouple measurements is located in *SECTION. Hands-on Exercise - Measuring a Thermocouple* (p. 13).

The micro-volt resolution and low-noise voltage measurement capability of the CR1000 is well suited for measuring thermocouples. A thermocouple consists of two wires, each of a different metal or alloy, joined at one end to form the measurement junction. At the opposite end, each lead connects to terminals of a voltage measurement device, such as the CR1000. These connections form the reference junction. If the two junctions (measurement and reference) are at different temperatures, a voltage proportional to the difference is induced in the wires. This phenomenon is known as the Seebeck effect. Measurement of the voltage between the positive and negative terminals of the voltage measurement device provides a direct measure of the temperature difference between the measurement and reference junctions. A third metal (e.g., solder or CR1000 terminals) between the two dissimilar metal wires form parasitic thermocouple junctions, the effects of which cancel if the two wires are at the same temperature. Consequently, the two wires at the reference junction are placed in close proximity so they remain at the same temperature. Knowledge of the reference junction temperature provides the determination of a reference junction compensation voltage, corresponding to the temperature difference between the reference junction and 0°C. This compensation voltage, combined with the measured thermocouple voltage, can be used to compute the absolute temperature of the thermocouple junction. To facilitate thermocouple measurements, a thermistor is integrated into the CR1000 wiring panel for measurement of the reference junction temperature by means of the PanelTemp() instruction.

TCDiff() and TCSe() thermocouple instructions determine thermocouple temperatures using the following sequence. First, the temperature (°C) of the reference junction is determined. A reference junction compensation voltage is next computed based on the temperature difference between the reference junction and 0 °C. If the reference junction is the CR1000 analog input terminals, the temperature is conveniently measured with the PanelTemp() instruction. The actual thermocouple voltage is measured and combined with the reference junction compensation voltage. It is then used to determine the thermocouple junction temperature based on a polynomial approximation of NIST thermocouple calibrations.

4.4.1 Error Analysis

The error in the measurement of a thermocouple temperature is the sum of the errors in the reference junction temperature measurement plus the temperature-to-voltage polynomial fit error, the non-ideality of the thermocouple (deviation from standards published in NIST Monograph 175), the thermocouple voltage measurement accuracy, and the voltage-to-temperature polynomial fit error (difference between NIST standard and CR1000 polynomial approximations). The discussion of errors that follows is limited to these errors in calibration and measurement and does not include errors in installation or matching the sensor and thermocouple type to the environment being measured.

4.4.1.1 Panel Temperature Error

The panel temperature thermistor (Betatherm 10K3A1A) is just under the panel in the center of the two rows of analog input terminals. It has an interchangeability specification of 0.1°C for temperatures between 0 and 70°C. Below freezing and at higher temperatures, this specification is degraded. Combined with possible errors in the completion resistor measurement and the Steinhart and Hart equation used to calculate the temperature from resistance, the accuracy of panel temperature is estimated in *FIGURE. Panel Temperature Error Summary* (p. 72). In summary, error is estimated at ± 0.1°C over -0 to 40°C, ± 0.3°C from -25 to 50°C, and ± 0.8°C from -55 to 85°C.

The error in the reference temperature measurement is a combination of the error in the thermistor temperature and the difference in temperature between the panel thermistor and the terminals the thermocouple is connected to. The terminal strip cover should always be used when making thermocouple measurements. It insulates the terminals from drafts and rapid fluctuations in temperature as well as conducting heat to reduce temperature gradients. In a typical installation where the CR1000 is in a weather tight enclosure not subject to violent swings in temperature or uneven solar radiation loading, the temperature difference between the terminals and the thermistor is likely to be less than 0.2°C.

With an external driving gradient, the temperature gradients on the input panel can be much worse. For example, the CR1000 was placed in a controlled temperature chamber. Thermocouples in channels at the ends and middle of each analog terminal strip measured the temperature of an insulated aluminum bar outside the chamber. The temperature of this bar was also measured by another datalogger. Differences between the temperature measured by one of the thermocouples and the actual temperature of the bar are due to the temperature difference between the terminals the thermocouple is connected to and the thermistor reference (the figures have been corrected for thermistor errors). *FIGURE. Panel Temperature Gradients (Low Temperature to High)* (p. 72) shows the errors when the chamber was changed from low temperature to high in approximately 15 minutes. *FIGURE. Panel Temperature Gradients (High Temperature to Low)* (p. 72) shows the results when going from high temperature to low. During rapid temperature changes, the panel thermistor will tend to lag behind terminal temperature because it is mounted deeper in the CR1000.

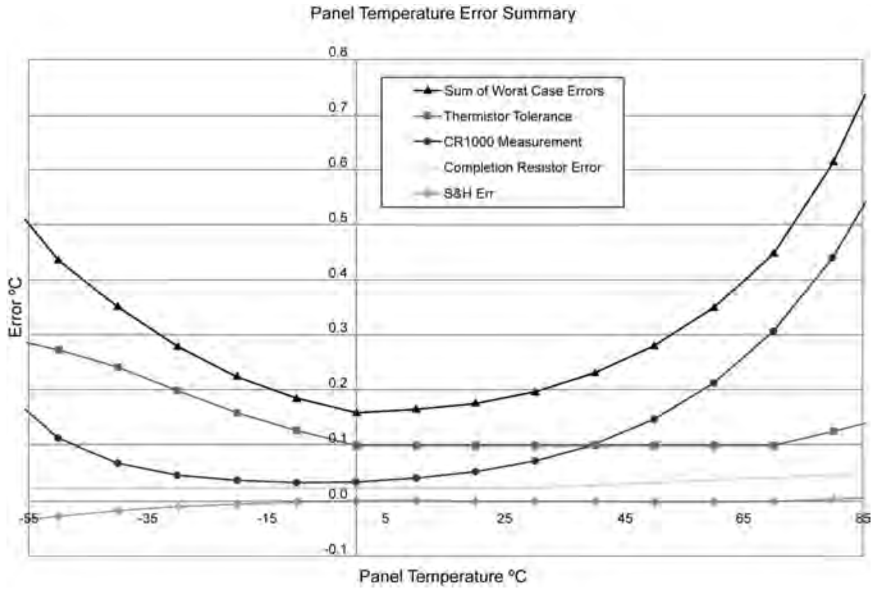


FIGURE 34. Panel Temperature Error Summary

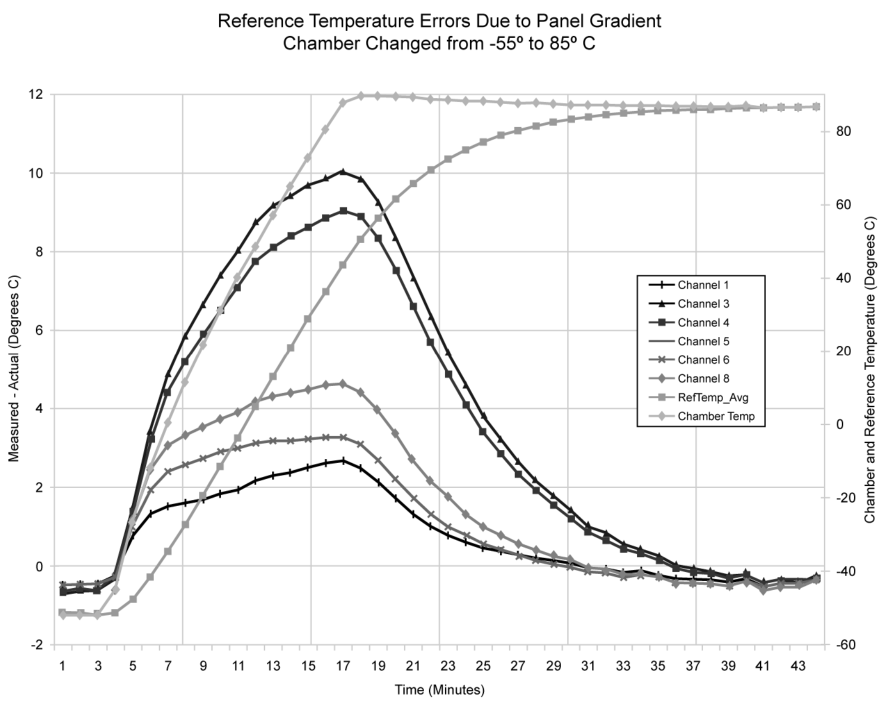


FIGURE 35. Panel Temperature Gradients (Low Temperature to High)

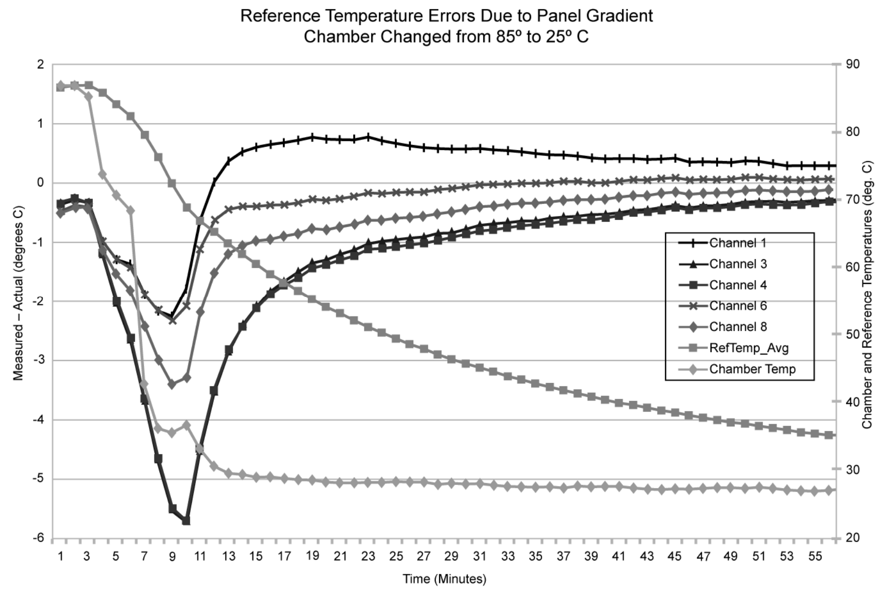


FIGURE 36. Panel Temperature Gradients (High Temperature to Low)

4.4.1.2 Thermocouple Limits of Error

The standard reference that lists thermocouple output voltage as a function of temperature (reference junction at 0°C) is the NIST (National Institute of Standards and Technology) Monograph 175 (1993). ANSI (American National Standards Institute) has established limits of error on thermocouple wire which is accepted as an industry standard (ANSI MC 96.1, 1975). *TABLE. Limits of Error for Thermocouple Wire* (p. 74) gives the ANSI limits of error for standard and special grade thermocouple wire of the types accommodated by the CR1000.

When both junctions of a thermocouple are at the same temperature there is no voltage produced (law of intermediate metals). A consequence of this is that a thermocouple cannot have an offset error; any deviation from a standard (assuming the wires are each homogeneous and no secondary junctions exist) is due to a deviation in slope. In light of this, the fixed temperature limits of error (e.g., ±1.0°C for type T as opposed to the slope error of 0.75% of the temperature) in the table above are probably greater than one would experience when considering temperatures in the environmental range (i.e., the reference junction, at 0°C, is relatively close to the temperature being measured, so the absolute error - the product of the temperature difference and the slope error - should be closer to the percentage error than the fixed error). Likewise, because thermocouple calibration error is a slope error, accuracy can be increased when the reference junction temperature is close to the measurement temperature. For the same reason differential temperature measurements, over a small temperature gradient, can be extremely accurate.

To quantitatively evaluate thermocouple error when the reference junction is not fixed at 0°C limits of error for the Seebeck coefficient (slope of thermocouple voltage vs. temperature curve) are needed for the various thermocouples. Lacking this information, a reasonable approach is to apply the percentage errors, with perhaps 0.25% added on, to the difference in temperature being measured by the thermocouple.

TABLE 16. Limits of Error for Thermocouple Wire (Reference Junction a

Thermocouple	*Temperature*	*Limits of Error (Whichever is greater)*	
Type	*Range°C*	*Standard*	*Special*
T	-200 to 0	± 1.0°C or 1.5%	
	0 to 350	± 1.0°C or 0.75%	± 0.5°C or 0.4%
J	0 to 750	± 2.2°C or 0.75%	± 1.1°C or 0.4%
E	-200 to 0	± 1.7°C or 1.0%	
	0 to 900	± 1.7°C or 0.5%	± 1.0°C or 0.4%
K	-200 to 0	± 2.2°C or 2.0%	
	0 to 1250	± 2.2°C or 0.75%	± 1.1°C or 0.4%
R or S	0 to 1450	± 1.5°C or 0.25%	± 0.6°C or 0.1%
B	800 to 1700	± 0.5%	Not Established.

4.4.1.3 Thermocouple Voltage Measurement Error

Thermocouple outputs are extremely small -- 10 to 70 µV per °C. Unless high resolution input ranges are used when programming the CR1000, accuracy and sensitivity are compromised. *TABLE. Voltage Range for Maximum Thermocouple Resolution* (p. 74) lists high resolution ranges available for various thermocouple types and temperature ranges. The following four example calculations of thermocouple input error demonstrate how the selected input voltage range impacts the accuracy of measurements. *FIGURE. Input Error Calculation* (p. 75) shows from where various values are drawn to complete the calculations. See *SECTION. Measurement Accuracy* (p. 48) for more information on measurement accuracy and accuracy calculations.

When the thermocouple measurement junction is in electrical contact with the object being measured (or has the possibility of making contact) a differential measurement should be made to avoid ground looping.

TABLE 17. Voltage Range for Maximum Thermocouple Resolution (with refe 20°C)

TC Type and Temperature Range (°C)	***Tem-perature Range (°C) for ±2.5 mV Input Range***	***Tem-perature Range (°C) for ±7.5 mV Input Range***	***Tem-perature Range (°C) for ±25 mV Input Range***	***Tem-perature Range (°C) for ±250 mV Input Range***
T: -270 to 400	-45 to 75	-270 to 180	-270 to 400	not used
E: -270 to 1000	-20 to 60	-120 to 130	-270 to 365	>365
K: -270 to 1372	-40 to 80	-270 to 200	-270 to 620	>620
J: -210 to 1200	-25 to 65	-145 to 155	-210 to 475	>475
B: -0 to 1820	0 to 710	0 to 1265	0 to 1820	not used
R: -50 to 1768	-50 to 320	-50 to 770	-50 to 1768	not used
S: -50 to 1768	-50 to 330	-50 to 820	-50 to 1768	not used
N: -270 to 1300	-80 to 105	-270 to 260	-270 to 725	>725

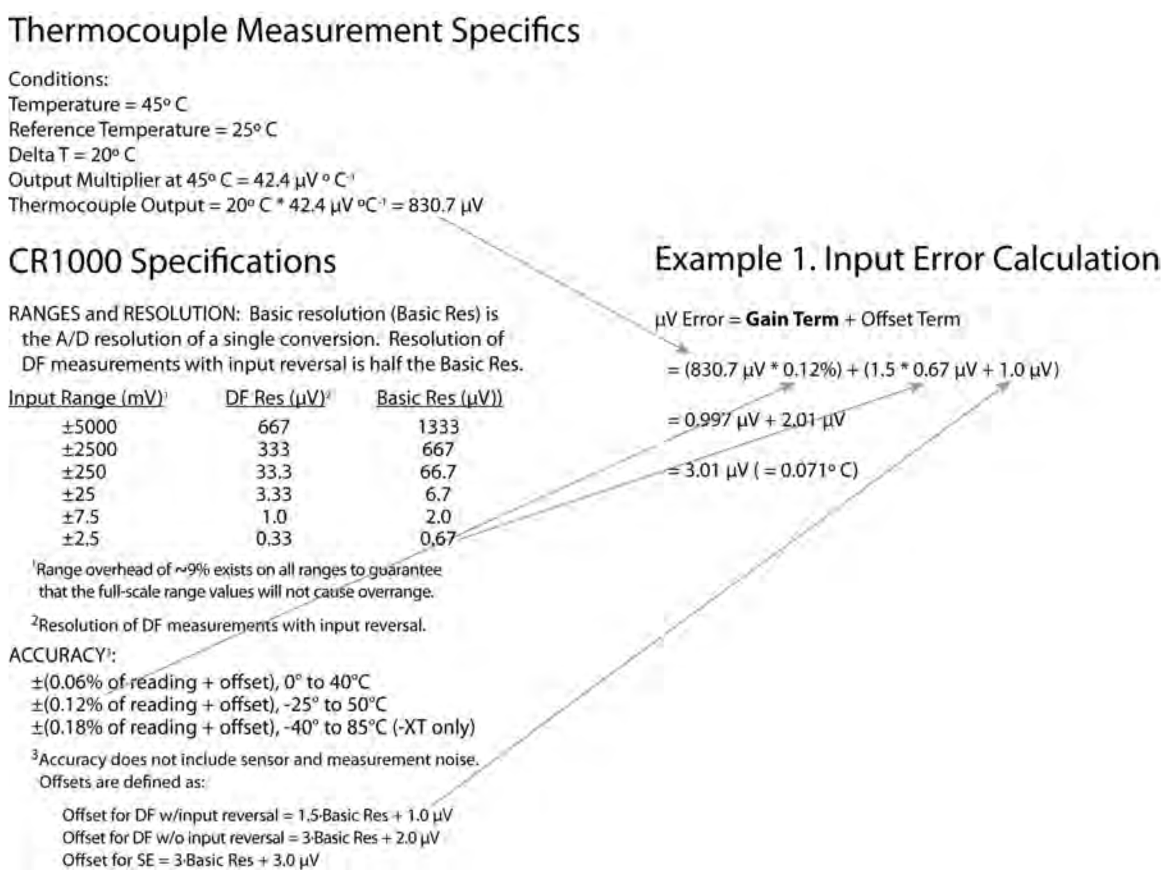


FIGURE 37. Input Error Calculation

4.4.1.3.1 Input Error Examples: Type T Thermocouple @ 45°C

These examples demonstrate that in the environmental temperature range, input offset error is much greater than input gain error because a small input range is used.

Conditions:

CR1000 module temperature between -25 to 50°C

Temperature = 45°C

Reference Temperature = 25°C

Delta T = 20°C

Thermocouple Output Multiplier at 45°C = 42.4 µV $°C^{-1}$

Thermocouple Output = 20°C * 42.4 µV $°C^{-1}$ = 830.7 µV

Input Range = ±2.5 mV

Error Calculations with Input Reversal = True

µV Error = Gain Term + Offset Term

= (830.7 µV * 0.12%) + (1.5 * 0.67 µV + 1.0 µV)

= 0.997 µV + 2.01 µV

= 3.01 µV (= 0.071 °C)

Error Calculations with Input Reversal = False

µV Error = Gain Term + Offset Term

= (830.7 µV * 0.12%) + (3 * 0.67 µV + 2.0 µV)

= 0.997 µV + 4.01 µV

= 5.01 µV (= 0.12 °C)

4.4.1.3.2 Input Error Examples: Type K Thermocouple @ 1300°C

Error in the temperature due to inaccuracy in the measurement of the thermocouple voltage increases at temperature extremes, particularly when the temperature and thermocouple type require using the ±200|250 mV range. For example, assume type K (chromel-alumel) thermocouples are used to measure temperatures around 1300°C.

These examples demonstrate that at temperature extremes, input offset error is much less than input gain error because the use of a larger input range is required.

Conditions

CR1000 module temperature between -25 to 50°C

Temperature = 1300°C

Reference Temperature = 25°C

Delta T = 1275°C

Thermocouple Output Multiplier at 1300°C = 34.9 µV $°C^{-1}$

Thermocouple Output = 1275°C * 34.9 µV $°C^{-1}$ = 44500 µV

Input Range = ±250 mV

Error Calculations with Input Reversal = True

µV Error = Gain Term + Offset Term

= (44500 µV * 0.12%) + (1.5 * 66.7 µV + 1.0 µV)

= 53.4 µV + 101.0 µV

= 154 µV (= 4.41 °C)

Error Calculations with Input Reversal = False

µV Error = Gain Term + Offset Term

= (44500 µV * 0.12%) + (3 * 66.7 µV + 2.0 µV)

= 53.4 µV + 200 µV

= 7.25 µV (= 7.25 °C)

4.4.1.4 Ground Looping Error

When the thermocouple measurement junction is in electrical contact with the object being measured (or has the possibility of making contact) a differential measurement should be made to avoid ground looping.

4.4.1.5 Noise Error

The typical input noise on the ±2.5 mV range for a differential measurement with 16.67 ms integration and input reversal is 0.19 µV RMS. On a type T thermocouple (approximately 40 µV/°C), this is 0.005°C. Note that this is an RMS value; some individual readings will vary by greater than this.

4.4.1.6 Thermocouple Polynomial Error

NIST Monograph 175 gives high order polynomials for computing the output voltage of a given thermocouple type over a broad range of temperatures. To speed processing and accommodate the CR1000's math and storage capabilities, four separate 6th order polynomials are used to convert from volts to temperature over the range covered by each thermocouple type. *TABLE. Limits of Error on CR1000 Thermocouple Polynomials* (p. 78) gives error limits for the thermocouple polynomials.

TABLE 18. Limits of Error on CR1000 Thermocouple Polynomials

TC Type		*Range °C*		*Limits of Error °C Relative to NIST Standards*
T	**-270**	**to**	**400**	
	-270	to	-200	+18 @ -270
	-200	to	-100	±0.08
	-100	to	100	±0.001
	100	to	400	±0.015
J	**-150**	**to**	**760**	±0.008
	-100	to	300	±0.002
E	**-240**	**to**	**1000**	
	-240	to	-130	±0.4
	-130	to	200	±0.005
	200	to	1000	±0.02
K	**-50**	**to**	**1372**	
	-50	to	950	±0.01
	950	to	1372	±0.04

4.4.1.7 Reference Junction Error

Thermocouple instructions TCDiff () and TCSe () include the parameter TRef to incorporate the reference junction temperature into the measurement. A reference junction compensation voltage is computed from TRef as part of the thermocouple instruction, based on the temperature difference between the reference junction and 0°C. The polynomials used to determine the reference junction compensation voltage do not cover the entire thermocouple range, as illustrated in *TABLE. Limits of Error on CR1000 Thermocouple Polynomials* (p. 78) and *TABLE. Reference Temperature Compensation Range and Polynomial Error* (p. 79). Substantial errors in the reference junction compensation voltage will result if the reference junction temperature is outside of the polynomial fit ranges given.

The reference junction temperature measurement can come from a PanelTemp () instruction, or from any other temperature measurement of the reference junction. The standard and extended (-XT) operating ranges for the CR1000 are

-25 to +50 °C and -55 to 85 °C, respectively. These ranges also apply to the reference junction temperature measurement using PanelTemp ().

Two sources of error arise when the reference temperature is out of the polynomial fit range. The most significant error is in the calculated compensation voltage; however a small error is also created by non-linearities in the Seebeck coefficient.

TABLE 19. Reference Temperature Compensation Range and Polynomia Standards

TC Type	Range °C	Limits of Error °C
T	-100 to 100	± 0.001
J	-150 to 296	± 0.005
E	-150 to 206	± 0.005
K	-50 to 100	± 0.01

4.4.1.8 Thermocouple Error Summary

The magnitude of the errors described in *SECTION. Error Analysis* (p. 71) illustrate that the greatest sources of error in a thermocouple temperature measurement are likely due to the limits of error on the thermocouple wire and in the reference temperature. Errors in the thermocouple and reference temperature linearizations are extremely small, and error in the voltage measurement is negligible.

TABLE. Example of Errors in Thermocouple Temperature (p. 79) illustrates the relative magnitude of these errors in the environmental range. It shows a worst case situation where all errors are maximum and additive. A temperature of 45°C is measured with a type T (copper-constantan) thermocouple, using the ±2.5 mV range. The reference thermistor measures 25.1 °C, The terminal the thermocouple is connected to is 0.05°C cooler than the reference thermistor (0.15°C error).

TABLE 20. Example of Errors in Thermocouple Temperature				
	Error: °C : % of Total Error			
	Single Differential 250 µs Integration		*Reversing Differential 50/60 Hz Rejection Integration*	
Source	*ANSI TC Error (1°C)*	*TC Error 1% Slope*	*ANSI TC Error (1°C)*	*TC Error 1% Slope*
Reference Temp.	0.15°:11.5%	0.15°:29.9%	0.15°:12.2%	0.15°:34.7%
TC Output	1.0°:76.8%	0.2°:39.8%	1.0°:81.1%	0.2°:46.3%
Voltage Measurement	0.12°:9.2%	0.12°:23.9%	0.07°:5.7%	0.07°:16.2%
Noise	0.03°:2.3%	0.03°:6.2%	0.01°:0.8%	0.01°:2.3%
Reference Linearization	0.001°:0.1%	0.001°:0.2%	0.001°:0.1%	0.001°:0.25%
Output Linearization	0.001°:0.1%	0.001°:0.2%	0.001°:0.1%	0.001°:0.25%
Total Error	1.302°:100%	0.502°:100%	1.232°:100%	0.432°:100%

4.4.2 Use of External Reference Junction

An external junction in an insulated box is often used to facilitate thermocouple connections. It can reduce the expense of thermocouple wire when measurements are made long distances from the CR1000. Making the external junction the reference junction, which is preferable in most applications, is accomplished by running copper wire from the junction to the CR1000. Alternatively, the junction box can be used to couple extension grade thermocouple wire to the thermocouples, with the PanelTemp () instruction used to determine the reference junction temperature.

Extension grade thermocouple wire has a smaller temperature range than standard thermocouple wire, but meets the same limits of error within that range. One situation in which thermocouple extension wire is advantageous is when the junction box temperature is outside the range of reference junction compensation provided by the CR1000. This is only a factor when using type K thermocouples, since the upper limit of the reference compensation polynomial fit range is 100°C and the upper limit of the extension grade wire is 200°C. With the other types of thermocouples the reference compensation polynomial fit range equals or is greater than the extension wire range. In any case, errors can arise if temperature gradients exist within the junction box.

FIGURE. Diagram of Junction Box (p. 81) illustrates a typical junction box wherein the reference junction is the CR1000. Terminal strips are a different metal than the thermocouple wire. Thus, if a temperature gradient exists between A and A' or B and B', the junction box will act as another thermocouple in series, creating an error in the voltage measured by the CR1000. This thermoelectric offset voltage is also a factor when the junction box is used as the reference junction. This offset can be minimized by making the thermal conduction between the two points large and the distance small. The best solution in the case where extension grade wire is being connected to thermocouple wire is to use connectors which clamp the two wires in contact with each other.

When an external junction box is also the reference junction, the points A, A', B, and B' need to be very close in temperature (isothermal) to measure a valid reference temperature, and to avoid thermoelectric offset voltages. The box should contain elements of high thermal conductivity, which will act to rapidly equilibrate any thermal gradients to which the box is subjected. It is not necessary to design a constant temperature box. It is desirable that the box respond slowly to external temperature fluctuations. Radiation shielding must be provided when a junction box is installed in the field. Care must also be taken that a thermal gradient is not induced by conduction through the incoming wires. The CR1000 can be used to measure the temperature gradients within the junction box.

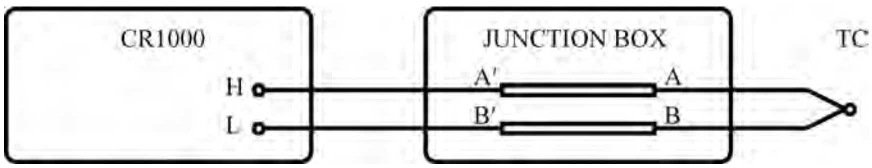


FIGURE 38. Diagram of a Thermocouple Junction Box

4.5 Pulse

FIGURE. Pulse Input Types (p. 9) illustrates pulse input types measured by the CR1000. *FIGURE. Switch Closure Pulse Sensor* (p. 82) is a generalized schematic showing connection of a pulse sensor to the CR1000. The CR1000 features two dedicated pulse input channels, P1 through P2, and eight digital I/O channels, C1 through C8, for measuring frequency or pulse output sensors.

As shown in *TABLE. Pulse Input Channels and Measurements* (p. 9), all CR1000 pulse input channels can be measured with CRBASIC instruction PulseCount (). PulseCount () has various parameters to customize it to specific applications. Digital I/O ports C1 through C8 can also be measured with the TimerIO () instruction. PulseCount () instruction functions include returning counts or frequency on frequency or switch closure signals. TimerIO () instruction has additional capabilities. Its primary function is to measure the time between state transitions.

Note Consult CRBASIC Editor Help for more information on PulseCount () and TimerIO () instructions.

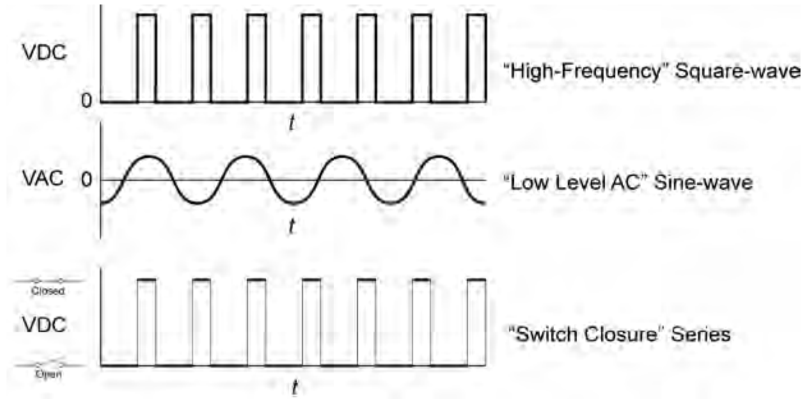


FIGURE 39. Pulse Sensor Output Signal Types

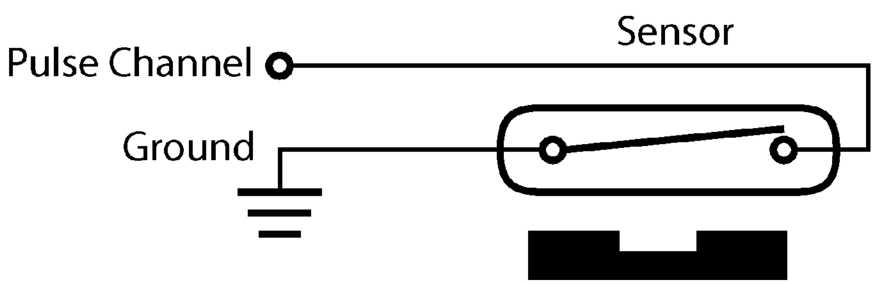


FIGURE 40. Switch Closure Pulse Sensor

TABLE 21.   Pulse Input Channels and Measurements

Channels Available for Pulse Input	***Input Types***	***Data Option***	***CRBASIC Instruction***
P1, P2	High Frequency Low-Level ac Switch Closure	Counts Frequency Run Avg of Freq	PulseCount ()
C1, C2, C3, C4, C5, C6, C7, C8	High Frequency Switch Closure Low-Level ac (with LLAC4 Low-Level AC Conversion Module)	Counts Frequency Run Avg of Freq Interval Period State	PulseCount () TimerIO ()

4.5.1 Pulse Input Channels (P1 - P2)

Read More! Review pulse counter specifications at *SECTION. Specifications* (p. 42). Review pulse counter programming in CRBASIC Editor Help for the PulseCount () instruction.

Dedicated pulse input channels (P1 through P2), as shown in *FIGURE. Pulse Input Channels* (p. 83), can be configured to read high- frequency pulses, low-level ac signals, or switch closures.

Note Input channel expansion devices for all input types are available from Campbell Scientific. Refer to Sensors and Peripherals for more information.

Caution Maximum input voltage on pulse channels P1 through P2 is ±20 V. If pulse inputs of higher than ±20 V need to be measured, third party external signal conditioners should be employed. Contact a Campbell Scientific applications engineer if assistance is needed. Under no circumstances should voltages greater than ±50 V be measured.

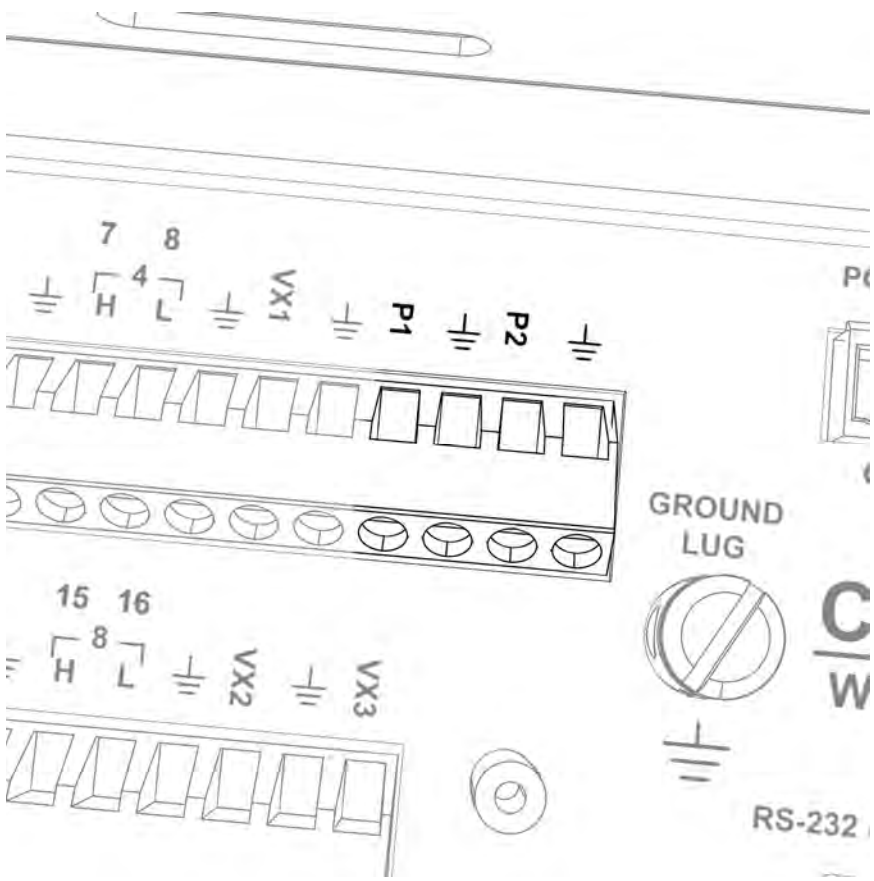


FIGURE 41. Pulse Input Channels

4.5.1.1 High-frequency Pulse (P1 - P2)

High-frequency pulse inputs are routed to an inverting CMOS input buffer with input hysteresis. The CMOS input buffer is an output 0 level with its input ≥ 2.2 V, and an output 1 with its input ≤ 0.9 V. When a pulse channel is configured for high-frequency pulse, an internal 100 kΩ pull-up resistor to 5 Vdc on the P1 or P2 input is automatically employed. This pull-up resistor accommodates open-collector (open-drain) output devices for high-frequency input.

4.5.1.2 Low-Level ac (P1 - P2)

Rotating magnetic pickup sensors commonly generate AC output voltages ranging from milliVolts at low rotational speeds to several volts at high rotational speeds. Pulse channels contain internal signal conditioning hardware for measuring low-level AC output sensors. When configured for low-level AC, P1 through P2 measure signals ranging from 20 mV RMS (±28 mV peak) to 14 V RMS (±20 V peak). Internal AC coupling is incorporated in the low-level AC hardware to eliminate dc offset voltages of up to ±0.5 Vdc.

4.5.1.3 Switch Closure (P1 - P2)

Switch-closure mode measures switch closure events, such as occur with a common tipping bucket rain gage. An internal 100 kΩ pull-up resistor pulls an input to 5 Vdc with the switch open, whereas a switch closure to ground pulls the input to 0 V. An internal 3.3 ms time constant RC debounce filter eliminates multiple counts from a single switch closure event.

4.5.2 Pulse Input on Digital I/O Channels C1 - C8

Read More! Review digital I/O channel specifications in *SECTION. Specifications* (p. 42). Review pulse counter programming with PulseCount () in CRBASIC Help.

Digital I/O channels C1 - C8 can be configured for edge timing or to measure high-frequency or switch closure signals. Input voltage must range between -8.0 and +16 Vdc.

Caution Contact Campbell Scientific for signal conditioning information if a pulse input < -8.0 or > +16 Vdc is to be measured. Under no circumstances should voltages greater than ±50 V be connected to channels C1 - C8.

Low-level ac signals cannot be measured directly by digital I/O channels C1 - C8. Refer to *APPENDIX. Pulse / Frequency Input Expansion Modules* (p. 498) for information on peripheral modules available to convert low-level ac signals to high-frequency square-wave.

4.5.2.1 High-frequency (C1 - C8)

Digital I/O channels C1 - C8 have a small 25 ns input RC filter time constant between the terminal block and the CMOS input buffer, which allows for higher frequency operation (400 kHz maximum) when compared with pulse input channels P1 through P2 (250 kHz maximum).

When configured for input, signals connected to C1 - C8 each go into a digital CMOS input buffer that recognizes inputs ≥ 3.8 V as high and inputs ≤ 1.2 V as low.

Open collector (bipolar transistors) or open drain (MOSFET) sensors are typically measured as high frequency sensors. Condition channels C1 - C8 for open collector or open drain with an external pull-up resistor as shown in *FIGURE. Connecting Switch Closures to Digital IO* (p. 86). The pull-up resistor counteracts an internal 100 kΩ pull-down resistor, allowing inputs to be pulled to > 3.8 V for reliable measurements.

4.5.2.2 Switch Closure (C1 - C8)

Two schemes are available for connecting switch closure sensors to the CR1000. If the switch closes to ground, an external pull-up resistor is used as shown in *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86). If the switch is to close directly to the control port, connect the sensor to the CR1000 as diagramed.

Mechanical switch closures have a tendency to bounce before solidly closing. Bouncing can cause multiple counts. The CR1000 incorporates software switch debounce in switch-closure mode for channels C1 - C8.

Note Maximum switch closure frequency measured is 150 kHz.

4.5.2.3 Edge Timing (C1 - C8)

Time between pulse edges can be measured. Results can be expressed in terms of microseconds or hertz. To read more concerning edge timing, refer to CRBASIC Help for the TimerIO() instruction. Edge timing resolution is 540 ns.

4.5.3 Pulse Measurement Tips

- Activated by the PulseCount() instruction, dedicated 24-bit counters on channels P1 through P2 and C1 through C8 accumulate all counts over the user specified scan interval. Counters are read at the beginning of each scan and cleared. Counters overflow, resulting in erroneous measurements, if accumulated counts exceed 16,777,216.

- Execution of PulseCount() within a scan involves determining the accumulated counts in each dedicated 24-bit counter since execution of the last PulseCount(). Counts are the preferred output option for measuring number of tips from a tipping bucket rain gage, or the number of times a door opens. Many pulse sensors, such as anemometers and flow meters, are calibrated in terms of frequency (Hz or counts / second), and are usually measured with the frequency option.

- Accuracy of PulseCount() is limited by a small scan interval error of ±(3 ppm of scan interval + 10 µs) plus the measurement resolution error of ± 1 Hz. The sum is essentially ± 1 Hz.
- Use the LLAC4 module to convert non-TTL level signals, including low-level ac signals, to TTL levels for input into digital I/O channels C1 through C8.
- When digital I/O channels C1 through C8 measure switch closure inputs, pull-up resistors may be required. *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86) show how pull-up resistors can be incorporated into a wiring scheme.
- As shown *FIGURE. Connecting Switch Closures to Digital I/O* (p. 86), digital I/O inputs, with regard to the 6.2 V Zener diode, have an input resistance of 100 kohms with input voltages < 6.2 Vdc. **For input voltages ≥ 6.2 Vdc, the inputs have an input resistance of only 220 ohms.**

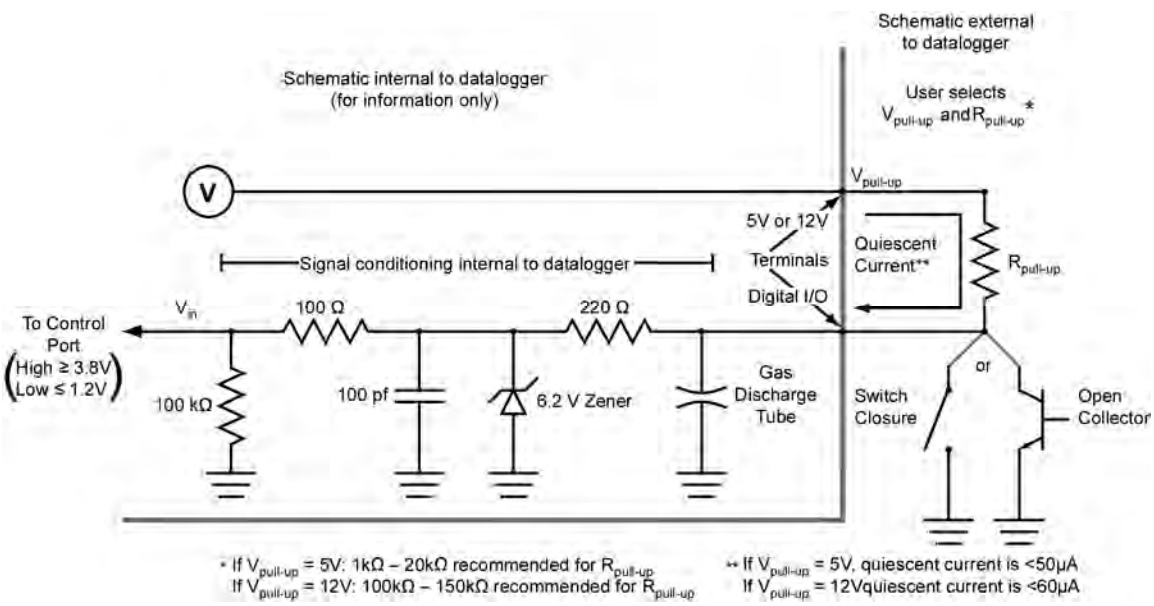


FIGURE 42. Connecting Switch Closures to Digital I/O

4.5.3.1 Frequency Resolution

Resolution of the 24-bit pulse counters is one count. Frequency resolution of a PulseCount () frequency measurement is

$$FR = \frac{1}{S}$$

where:

FR = Resolution of the frequency measurement (Hz)

S = Scan Interval of CRBASIC Program

Resolution of TimerIO () instruction is:

$$FR = \frac{R/E}{P * (P+(R/E))}$$

where:

FR = Frequency resolution of the measurement (Hz)

R = Timing resolution of the period measurement = 540 ns

P = Period of input signal (seconds) = 1 / 1000 Hz = 0.001 s

E = Rising edges per scan = 500 in 0.5 s scan, 5000 in 5.0 s scan)

TimerIO () instruction measures frequencies of ≤ 1 kHz with higher frequency resolution over short (sub-second) intervals. In contrast, sub-second frequency measurement with PulseCount () produce measurements of lower resolution. Consider a 1 kHz input. *TABLE. Frequency Resolution* (p. 87) lists frequency resolution to be expected for a 1 kHz signal measured by TimerIO () and PulseCount() at 0.5 s and 5.0 s scan intervals.

Increasing a 1 s measurement interval to 10 s, either by increasing the scan interval (when using PulseCount()) or by averaging (when using PulseCount() or TimerIO()), improves the resulting frequency resolution from 1 Hz to 0.1 Hz. Averaging can be accomplished by the Average(), AvgRun(), and AvgSpa() instructions. Also, PulseCount() has the option of entering a number greater than 1 in the POption parameter. Doing so enters an averaging interval in milliseconds for a direct running average computation. However, use caution when averaging, Averaging of any measurement reduces the certainty that the result truly represents a real aspect of the phenomenon being measured.

TABLE 22. Frequency Resolution Comparison

	0.5 s Scan	***5.0 s Scan***
PulseCount(), POption 1	FR= 2 Hz	FR = 0.2 Hz
TimerIO(), Function 2	FR = 0.0011 Hz	FR = 0.00011 Hz

4.5.4 Pulse Measurement Problems

4.5.4.1 Pay Attention to Specifications

TABLE. Example of Differing Specifications for Pulse Input Channels (p. 87) compares specifications for pulse input channels to emphasize the need for matching the proper device to application. Take time to understand signals to be measured and compatible channels.

TABLE 23. Example of Differing Specifications for Pulse Input Channels		
	Pulse Channels P1, P2	***Digital I/O Channels C1, C2, C3, C4, C5, C6, C7, C8***
High Frequency Max (kHz)	250	1
Max Input Voltage (Vdc)	20	16
State Transition Thresholds (Vdc)	Count upon transition from <0.9 to >2.2.	Count upon transition from <1.2 to >3.8.

4.5.4.2 Input Filters and Signal Attenuation

Pulse input channels are equipped with input filters to reduce spurious noise that can cause false counts. The higher the time constant (τ) of the filter, the tighter the filter. *TABLE. Time Constants* (p. 88) lists τ values for pulse input channels. So, while TimerIO () frequency measurement may be superior for clean signals, a pulse channel filter (much higher τ) may be required to get a measurement on a dirty signal.

Input filters, however, attenuate the amplitude (voltage) of the signal. The amount of attenuation is a function of the frequency passing through the filter. Higher frequency signals are attenuated more. If a signal is attenuated enough, it may not pass the state transition thresholds (thresholds are listed in *TABLE. Pulse Input Channels and Measurements* (p. 9)) required by the detection device. To avoid over attenuation, sensor output voltage must be increased at higher frequencies. As an example, *TABLE. Filter Attenuation of Frequency Signals* (p. 88) lists low-level ac frequencies and the voltages required to overcome filter attenuation.

For pulse input channels P1 - P2, an RC input filter with an approximate 1 μs time constant precedes the inverting CMOS input buffer. The resulting amplitude reduction is illustrated in *FIGURE. Amplitude Reduction of Pulse-Count Waveform.* (p. 89) For a 0 to 5 Vdc square wave applied to a pulse channel, the maximum frequency that can be counted in high-frequency mode is approximately 250 kHz.

TABLE 24. Time Constants (τ)	
Measurement	*τ*
Pulse Channel, High Frequency Mode	1.2
Pulse Channel, Switch Closure Mode	3300
Pulse Channel, Low-level AC Mode	See *TABLE. Filter Attenuation of Frequency Signals* (p. 88) footnote
Digital I/O, High Frequency Mode	0.025
Digital I/O, Switch Closure Mode	0.025

TABLE 25. Filter Attenuation of Frequency Signals.	
As shown for low-level ac inputs, increasing voltage is required at increasing frequencies to overcome filter attenuation on pulse input channels*.	
ac mV (RMS)	***Maximum Frequency***
20	20
200	200
2000	10,000
5000	20,000
*8.5 ms time constant filter (19 Hz 3 dB frequency) for low-amplitude signals. 1 ms time constant (159 Hz 3 dB frequency) for larger (> 0.7 V) amplitude signals.	

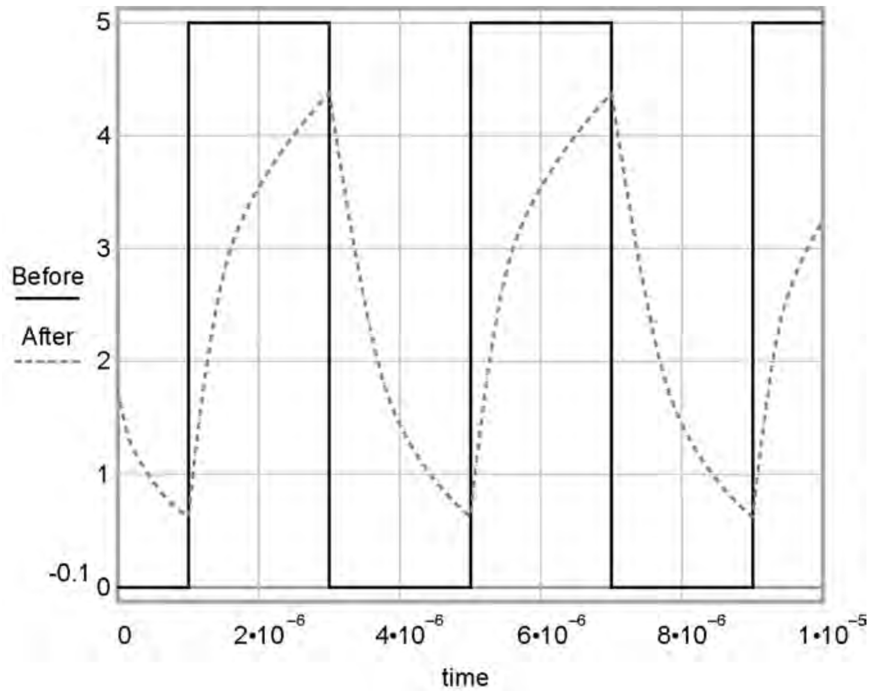


FIGURE 43. Amplitude Reduction of Pulse-Count Waveform (before and after 1 µs time constant filter)

4.6 Period Averaging

The CR1000 can measure the period of a signal on any single-ended analog input channel (SE 1 - 16). The specified number of cycles are timed with a resolution of 136 ns, making the resolution of the period measurement 136 ns divided by the number of cycles chosen.

Low-level signals are amplified prior to a voltage comparator. The internal voltage comparator is referenced to the user-entered threshold. The threshold parameter allows a user to reference the internal voltage comparator to voltages other than 0 V. For example, a threshold of 2500 mV allows a 0 to 5 Vdc digital signal to be sensed by the internal comparator without the need of any additional input conditioning circuitry. The threshold allows direct connection of standard digital signals, but is not recommended for small amplitude sensor signals. For sensor amplitudes less than 20 mV peak-to-peak, a dc blocking capacitor is recommended to center the signal at CR1000 ground (threshold = 0) because of offset voltage drift along with limited accuracy (± 10 mV) and resolution (1.2 mV) of a threshold other than 0. *FIGURE. Input Conditioning Circuit for Period Averaging* (p. 90) shows an example circuit.

The minimum pulse width requirements increase (maximum frequency decreases) with increasing gain. Signals larger than the specified maximum for a range will saturate the gain stages and prevent operation up to the maximum specified frequency. As shown back-to-back diodes are recommended to limit large amplitude signals to within the input signal ranges.

Caution Noisy signals with slow transitions through the voltage threshold have the potential for extra counts around the comparator switch point. A voltage comparator with 20 mV of hysteresis follows the voltage gain stages. The effective input referred hysteresis equals 20 mV divided by the selected voltage gain. The effective input referred hysteresis on the ± 25 mV range is 2 mV; consequently, 2 mV of noise on the input signal could cause extraneous counts. For best results, select the largest input range (smallest gain) that meets the minimum input signal requirements.

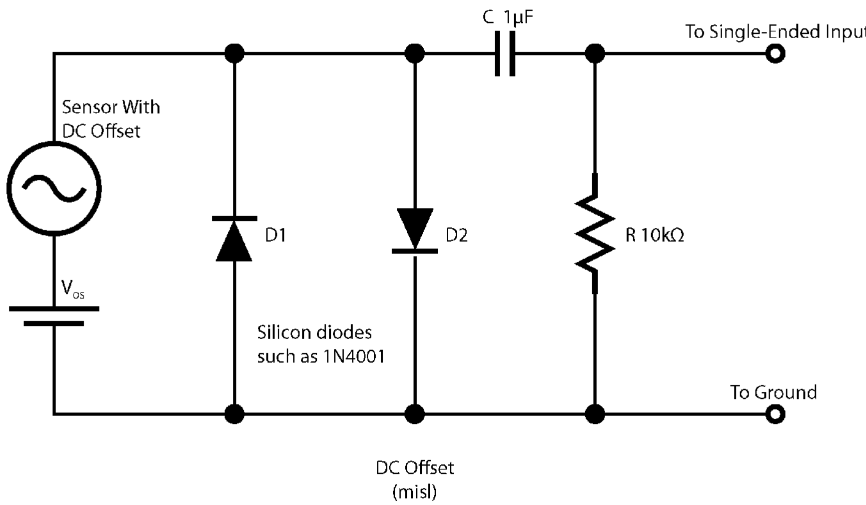


FIGURE 44. Input Conditioning Circuit for Period Averaging

4.7 SDI-12 Recording

Read More! *SECTION. SDI-12 Sensor Support* (p. 249) and *SECTION. Serial Input / Output* (p. 209).

SDI-12 is a communications protocol developed to transmit digital data from smart sensors to data acquisition units. It is a simple protocol, requiring only a single communication wire. Typically, the data acquisition unit also supplies power (12 Vdc and ground) to the SDI-12 sensor. The CR1000 is equipped with 4 SDI-12 channels (C1, C3, C5, C7) and an SDI12Recorder () CRBASIC instruction.

4.8 RS-232 and TTL Recording

Read More! *SECTION. Serial Input / Output* (p. 209) and *SECTION. Serial I/O* (p. 279).

The CR1000 can usually receive and record RS-232 and 0-5V logic data from sensors designed to transmit via these protocols. Data are received through the CS I/O port with the proper interface (*APPENDIX. CS I/O Serial Interfaces* (p. 499)), the RS-232 port, or the digital I/O communication ports (C1 & C2, C3 & C4, C5 & C6, C7 & C8). If additional serial inputs are required, serial input expansion modules (*APPENDIX. Serial Input Expansion Modules* (p. 499)) can be connected to increase the number of serial ports. Serial data are usually captured as strings, which are then parsed (split up) as defined in the user entered program.

Note Digital I/O communication ports (control ports) only transmit 0-5V logic. However, they read most true RS-232 input signals. When connecting serial sensors to an RX control port, the sensor power consumption may increase by a few milliamps due to voltage clamps. An external resistor may need to be added in series to the RX line to limit the current drain, although this is not advisable at very high baud rates. *FIGURE. Circuit to Limit Control Port Input to 5 Volts* (p. 91) shows a circuit that limits voltage input on a control port to 5 Vdc.

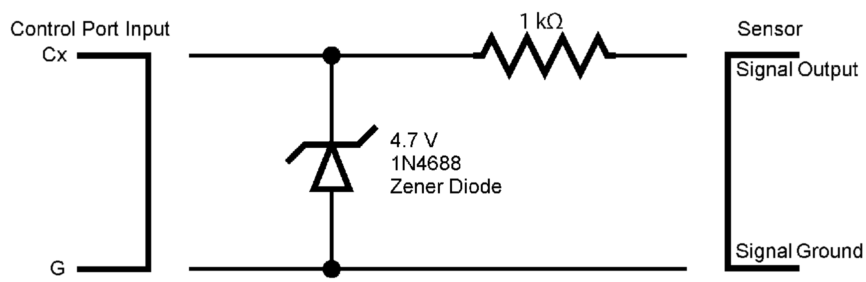


FIGURE 45. Circuit to Limit Control Port Input to 5 Volts

4.9 Field Calibration of Linear Sensor

Read More! *SECTION. Field Calibration of Linear Sensors (FieldCal)* (p. 227) has complete FieldCal information.

Calibration increases accuracy of a measurement device by adjusting its output, or the measurement of its output, to match independently verified quantities. Adjusting a sensor output directly is preferred, but not always possible or practical. By adding FieldCal() or FieldCalStrain() instructions to the CR1000 program, a user can easily adjust the measured output of a linear sensors by modifying multipliers and offsets.

4.10 Cabling Effects

Sensor cabling can have significant effects on sensor response and accuracy. This is usually only a concern with sensors acquired from manufacturers other than Campbell Scientific. Campbell Scientific sensors are engineered for optimal performance with factory installed cables.

4.10.1 Analog Sensor Cables

Cable length in analog sensors is most likely to affect the signal settling time. For more information, see *SECTION. Signal Settling Time* (p. 56).

4.10.2 Pulse Sensors

Because of the long interval between switch closures in tipping bucket rain gages, appreciable capacitance can build up between wires in long cables. A built up charge can cause arcing when the switch closes, shortening switch life. As shown in *FIGURE. Current Limiting Resistor in a Rain Gage Circuit* (p. 92), a 100 ohm resistor is connected in series at the switch to prevents arcing. This resistor is installed on all rain gages currently sold by Campbell Scientific.

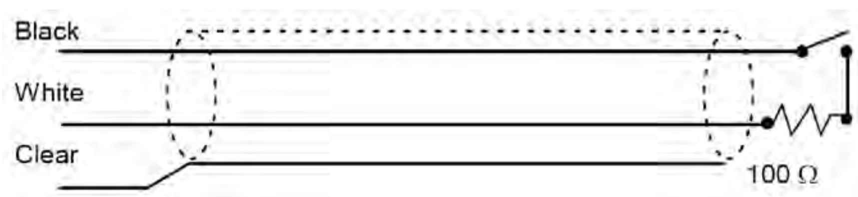


FIGURE 46. Current Limiting Resistor in a Rain Gage Circuit

4.10.3 RS-232 Sensors

RS-232 sensors cable lengths should be limited to 50 feet.

4.10.4 SDI-12 Sensors

The SDI-12 standard allows cable lengths of up to 200 feet. Campbell Scientific does not recommend SDI-12 sensor lead lengths greater than 200 feet; however, longer lead lengths can sometimes be accommodated by increasing the wire gage and/or powering the sensor with a second 12 Vdc power supply placed near the sensor.

4.11 Synchronizing Sensor Measurements

Timing of a measurement is usually controlled relative to the CR1000 clock. When sensors in a sensor network are measured by a single CR1000, measurement times are synchronized, often within a few milliseconds, depending on sensor number and measurement type. Large numbers of sensors, cable length restrictions, or long distances between measurement sites may require use of multiple CR1000s. Techniques outlined below enable network administrators to synchronize CR1000 clocks and measurements in a CR1000 network.

Care should be taken when a clock change operation is planned. Any time the CR1000 clock is changed, the deviation of the new time from the old time may be sufficient to cause a skipped record in data tables. Any command used to synchronize clocks should be executed after any CallTable() instructions and timed so as to execute well clear of data output intervals.

Time Synchronization Techniques:

1. LoggerNet Utility – When reliable telecommunications are common to all CR1000s in a network, LoggerNet's Automated Clock Check provides a simple time synchronization function. Accuracy is limited by the system clock on the PC running the LoggerNet server. Precision is limited by network transmission latencies. LoggerNet compensates for latencies in many telecommunications systems and can achieve synchronies within <100 ms deviation. Errors of 2 – 3 second may be seen on very busy RF connections or long distance internet connections.

Note Common PC clocks are notoriously inaccurate. An easy way to keep a PC clock accurate is to utilize public domain software available at http://tf.nist.gov/service/its.htm.

2. Digital Trigger – A digital trigger, rather than a clock, can provide the synchronization signal. When cabling can be run from CR1000 to CR1000, each CR1000 can catch the rising edge of a digital pulse from the Master CR1000 and synchronize measurements or other functions, using the WaitDigTrig() instructions, independent of CR1000 clocks or data time stamps. When programs are running in pipeline mode, measurements can be synchronized with a few microseconds.

3. PakBus Commands – The CR1000 is a PakBus device, so it is capable of being a node in a PakBus network.. Node clocks in a PakBus network are synchronized using the SendGetVariable(), ClockReport(), or PakBusClock() commands. The CR1000 clock has a resolution of 10 ms, which is the resolution used by PakBus clock sync functions. In networks without routers, repeaters, or retries, the communication time will cause an additional error (typically a few 10s of milliseconds). PakBus clock commands set the time at the end of a scan to minimize the chance of skipping a record to a data table.

An RF401 radio network has an advantage over Ethernet in that ClockReport() can be broadcast to all dataloggers within reach and set their clocks with a single PakBus broadcast from the master. Each datalogger in the network must be programmed with a PakBusClock() instruction.

Note Use of PakBus clock functions re-synchronizes the Scan() instruction. Use should not exceed once per minute. CR1000 clocks drift at a slow enough rate that a ClockReport() once per minute should be sufficient to keep clocks within 30 ms of each other.

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4. GPS – Clocks in CR1000s can be synchronized to within about 10 ms of each other using the GPS () instruction. CR1000s built since October of 2008 (serial numbers >= 20409) can be synchronized within a few microseconds of each other and within ≈ 200 µs of UTC. While a GPS signal is available, the CR1000 essentially uses the GPS as its continuous clock source, so the chance of jumps in system time and skipped records is minimized.

5. Ethernet – Any CR1000 with a network connection (internet, GPRS, private network) can synchronize its clock relative to Coordinated Universal Time (UTC) using the NetworkTimeProtocol () instruction. Precisions are usually maintained to within 10 ms.

Section 6. Power Sources

Reliable power is the foundation of a reliable data acquisition system. When designing a power supply, consideration should be made regarding worst-case power requirements and environmental extremes.

Excessive switching noise or AC ripple present on a DC power supply can increase measurement noise. Noise sources include power transformers, regulators, and grid or mains power inclusively. Using high quality power regulators reduces noise due to power regulation. Utilizing 50 Hz or 60 Hz integration times for voltage measurements (see *SECTION. Sensor Support* (p. 43)) improves rejection of power supply induced noise. The CRBASIC standard deviation instruction, SDEV() can be used to evaluate measurement noise.

Contact Campbell Scientific if assistance in selecting a power supply is needed, particularly with applications in extreme environments.

6.1 Power Requirement

The CR1000 operates on dc voltage ranging from 9.6 to 16 V. It is internally protected against accidental polarity reversal. A transient voltage suppressor (TVS) diode on the 12 Vdc power input terminal provides transient protection by clamping voltages in the range of 19 to 21 V. Sustained input voltages in excess of 19 V can damage the TVS diode.

Caution The 12V and SW-12 terminals on the wiring panel are not regulated by the CR1000; they obtain the same power as that provided by the CR1000 primary power supply. When using the CR1000 wiring panel to source power to other 12 Vdc devices, be sure the power supply regulates the voltage within a the range specified by the manufacturer of the connected device.

6.2 Calculating Power Consumption

Read More! *SECTION. Power Requirements* (p. 32).

System operating time for batteries can be determined by dividing the battery capacity (ampere-hours) by the average system current drain (amperes). The CR1000 typically has a quiescent current draw of 0.5 mA (with display off), 0.6 mA with a 1 Hz sample rate, and >10 mA with a 100 Hz sample rate. With the optional keyboard display on, an additional 7 mA is added to the current drain while enabling the back light for the display adds 100 mA to the current drain.

6.3 Power Supplies

APPENDIX. Power Supplies (p. 495) lists external power supplies available from Campbell Scientific, including alkaline and solar options. Complete power supply information is available in manual or brochure form at *www.campbellsci.com*.

6.3.1 External Batteries

When connecting external power to the CR1000, remove the green POWER IN connector from the CR1000 front panel. Insert the positive 12 Vdc lead into the terminal marked "12V". Insert the ground lead in the terminal marked "G" (ground). The CR1000 is internally protected against, but will not function with, reversed external power polarity.

6.4 Vehicle Power Connections

If a CR1000 is powered by a motor vehicle supply, a second supply may be needed. When starting the motor of the vehicle, the battery voltage may drop below 9.6 V. This causes the CR1000 to stop measurements until the voltage again equals or exceeds 9.6 V. A second supply can be provided to prevent measurement lapses during vehicle starting. *FIGURE. Connecting CR1000 to Vehicle Power Supply* (p. 100) illustrate how a second power supply should be connected to the CR1000. The diode OR connection causes the supply with the largest voltage to power the CR1000 and prevents the second backup supply from attempting to power the vehicle.

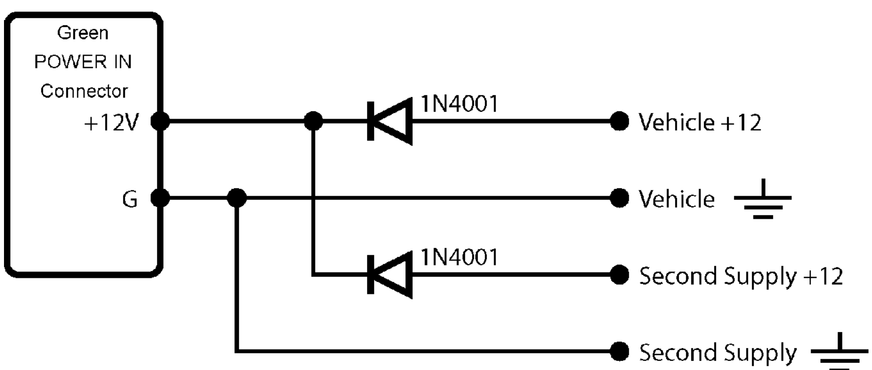

FIGURE 50. Connecting to Vehicle Power Supply

6.5 Powering Sensors and Devices

Read More! See *SECTION. CR1000 Power Supply* (p. 99).

The CR1000 is a convenient distributor of power for sensors and peripherals requiring a 5 or 12 Vdc source. It has 2 continuous 12 Vdc terminals (12V), one program-controlled switched 12 Vdc terminal (SW-12), and one continuous 5 Vdc terminal (5V). SW-12, 12V, and 5V terminals limit current internally for protection against accidental short circuits. Voltage on the 12V and SW-12 terminals will change with the dc supply used to power the CR1000. The 5V terminal is internally regulated to within ±4%, which is typically not adequate accuracy for bridge sensor excitation. *TABLE. Current Sourcing Limits* (p. 102) lists the current limits of 12V and 5V. Greatly reduced output voltages associated with 12V, SW-12, and 5V due to current limiting may occur if the current limits given in the table are exceeded. Information concerning digital I/O control ports is available in *SECTION. Digital I/O Ports* (p. 96).

6.5.1 Switched Excitation

Switched Voltage Excitation

Three switched analog output (excitation) terminals (VX1 - VX3) operate under program control to provide -2500 mV to +2500 mV excitation. Check the accuracy specification of these channels in *SECTION. Specifications* (p. 42) to understand their limitations. Specifications are only applicable for loads not exceeding ±25 mA. CRBASIC instructions that control excitation channels include:

- BrFull ()
- BrFull6W ()
- BrHalf ()
- BrHalf3W ()
- BrHalf4W ()
- ExciteV ()

Note Excitation channels can be configured through the RevEx parameter of bridge instructions to provide a square wave ac excitation for use with polarizing bridge sensors.

6.5.2 Continuous Regulated (5 Volt)

The 5V terminal is regulated and remains near 5 Vdc (±4%) so long as the CR1000 supply voltage remains above 9.6 Vdc. Measurement of the output from 5V (by means of jumpering to an analog input on the same CR1000) enables an accurate bridge measurement if the 5V terminal must be used for excitation.

6.5.3 Continuous Unregulated (Nominal 12 Volt)

Voltage on the 12V terminals will change with CR1000 supply voltage.

6.5.4 Switched Unregulated (Nominal 12 Volt)

SW-12 is often used to control low power devices such as sensors that require 12 Vdc during measurement. Current sourcing must be limited to 900 mA or less at 20°C. See *TABLE. Current Sourcing Limits* (p. 102). Voltage on a SW-12 terminal will change with CR1000 supply voltage. Two CRBASIC instructions, SW12 () and PortSet (), control a SW-12 terminal. Each is handled differently by the CR1000. SW12 () is a processing task instruction. Use it when controlling power to SDI-12 and serial sensors, which use SDI12Recorder () or SerialIn () instructions respectively. CRBASIC programming using IF THEN constructs to control SW-12, such as when used for cell phone control, should also use the SW12 () instruction. PortSet () is a measurement task instruction. Use it when powering analog input sensors that need to be powered just prior to measurement.

A 12 Vdc switching circuit, driven by a digital I/O port, is also available from Campbell Scientific.

Note The SW-12 supply is unregulated and can supply up to 900 mA at 20°C. See *TABLE. Current Sourcing Limits* (p. 102). A resettable polymeric fuse protects against over-current. Reset is accomplished by removing the load or turning off the SW-12 for several seconds.

TABLE 26. Current Source (+) & Sink (-) Limits	
Terminal	***Limit***
Voltage Excitation (VX, EX)[1]	±25 mA Maximum
SW-12[2]	< +900 mA @ 20°C < +630 mA @ 50°C < +450 mA @ 70°C
12V + SW-12 (Combined)[3]	< +3.00 A @ 20°C < +2.34 A @ 50°C < +1.80 A @ 70°C < +1.50 A @ 85°C
5V + CSI/O (Combined)[4]	< +200 mA

[1] Greater magnitude current than stated limits will cause voltage to become unstable. Voltage should stabilize once current is again established under maximum magnitude.

[2] Polyfuse is used to limit power. Result of overload is a voltage drop. To reset, disconnect and allow circuit to cool. Operating at the current limit is OK so long a a little fluctuation can be tolerated.

[3] Polyfuse protected. See 2.

[4] Maximum current is maintained by a current limiting circuit, which holds the current at the maximum by dropping the voltage when the load is too great.

Section 12. Memory and Final Data Storage

12.1 Storage Media

CR1000 memory consists of four non-volatile storage media:

- Internal battery backed SRAM
- Internal Flash
- Internal Serial Flash
- External Flash (optional CSI Flash drive)
- External CompactFlash® (*optional module* (p. 503))

TABLE. CR1000 Memory Allocation (p. 349) and *TABLE. CR1000 SRAM Memory* (p. 350) illustrate how CR1000 memory is structured around these media. The CR1000 utilizes and maintains most memory features automatically. However, users should periodically review areas of memory wherein data files, CRBASIC program files, and image files reside. Review and management of memory are accomplished with LoggerNet / PC400 / RTDAQ / PC200W File Control feature.

TABLE 72. CR1000 Memory Allocation

Memory Sector	Comments
Internal battery-backed SRAM[1] 4 Mbytes*	See *TABLE. CR1000 SRAM Memory* (p. 350) for detail.
Internal Flash[2] 2 Mbytes	Operating system
Internal Serial Flash[3] 12 kbytes: Device Settings 500 kbytes: CPU: drive	Device Settings: A backup of settings such as PakBus Address, Station Name, Beacon Intervals, Neighbor lists, etc. Rebuilt when a setting changes. CPU: Drive: Holds program files, field calibration files, and other files not over written frequently. Slower than SRAM. When a program is compiled and run, it is copied here automatically for loading on subsequent power-ups. Files accumulate until deleted with File Control or the FilesManage() instruction. Use USR: drive to store other file types. Available CPU: memory is reported in Status Table field "CPUDriveFree."

External Flash (Optional) 2 Gbytes: USB: drive	USB: drive: Holds program files. Holds a copy of final storage table data as files when TableFile() instruction is used. USB: data can be retrieved from the storage device with Windows Explorer. Can facilitate use of Powerup.ini.
External CompactFlash (Optional) <= 2 Gbytes: CRD: drive	CRD: drive: Holds program files. Holds a copy of final storage table data as files when CardOut() instruction is used. When data are requested by a PC, data first are provided from SRAM. If the requested records have been overwritten in SRAM, data are sent from CRD:. Alternatively, CRD: data can be retrieved in a binary format using File Control. Binary files are converted using CardConvert software. 10% or 80 kbytes of CF memory (whichever is smaller) is reserved for program storage. Can facilitate use of Powerup.ini.

[1]SRAM

·CR800 series changed from 2 to 4 Mbytes SRAM in Sept 2007. SNs >= 3605 are 4 Mbytes

·CR1000 changed from 2 to 4 Mbytes SRAM in Sept 2007. SNs >= 11832 are 4 Mbytes

·CR3000 has always shipped with a 4 Mbytes SRAM.

[2]Flash is rated for > 1 million overwrites.

[3]Serial Flash is rated for 100,000 overwrites (50,000 overwrites on 128 kbyte units). Care should be taken in programs that do overwrites to use the CRD: or USR: drives so as not to wear-out the CPU: drive.

·The CR800 series changed from 128 to 512 kbytes Serial Flash in May 2007. SNs >=2787 are 512 kbytes

·The CR1000 changed from 128 to 512 kbytes Serial Flash in May 2007. SNs >= 9452 are 512 kbytes

·The CR3000 changed from 128 512 kbytes Serial Flash in May 2007. SNs > 1948 are 512 kbytes

TABLE 73.   CR1000 SRAM Memory

Use	*Comments*
Static Memory	Operational memory used by the operating system regardless of the user program. This sector is rebuilt at power-up, program re-compile, and watchdog events.
Operating Settings and Properties	"Keep" memory. Stores settings such as PakBus address, station name, beacon intervals, neighbor lists, etc. Also stores dynamic properties such as the routing table, communications timeouts, etc.
CRBASIC Program Operating Memory	Stores the currently compiled and running user program. This sector is rebuilt on power-up, recompile, and watchdog events.
Variables & Constants	Stores variables in the user program. These values may persist through power-up, recompile, and watchdog events if the PreserveVariables instruction is in the running program.
Final Storage Data Tables Final Storage is given lowest priority in SRAM memory allocation.	Stores data resulting from CR1000 measurements. This memory is termed "Final Storage." Fills memory remaining after all other demands are satisfied. Configurable as ring or fill and stop memory. Compile error occurs if insufficient memory is available for user allocated data tables.
Communications Memory 1	Construction and temporary storage of PakBus® packets.
Communications Memory 2	Constructed Routing Table: list of known nodes and routes to nodes. Routers use more space than leaf nodes because routes to neighbors must be remembered. Increasing the PakBusNodes field in the Status Table will increase this allocation.
USR: drive <= 3.6 Mbytes (4 Mbyte Mem) <= 1.5 Mbytes (2 Mbyte Mem) Less on older units with more limited memory.	Optionally allocated. Holds image files. Holds a copy of Final Storage when TableFile() instruction used. Provides memory for FileRead / FileWrite operations. Managed in File Control. Status reported in Status Table fields "USRDriveSize" and "USRDriveFree."

12.1.1 Data Storage

Data table SRAM and the CPU: drive are automatically partitioned for use in the CR1000. The USR: drive can be optionally partitioned at programmer discretion.

The USB: drive is automatically partitioned when a CS mass storage device is connected.

TABLE 74. Data Storage Drives

Drive	*Recommended File Types*
CPU:	CR1, .CAL
USR:	.DAT, .JPG
USB:	.DAT
CRD:	Principal use is to expand *Final Storage* (p. 442), but also used to store .JPG, CR1, and .DAT files.

The CRD: drive is automatically partitioned when a CF card is installed.

12.1.1.1 Data Table SRAM

Primary storage for measurement data are those areas in SRAM allocated to data tables as detailed in *FIGURE. CR1000 SRAM Memory* (p. 350). Measurement data can be also be stored as discrete files on USR:, or USB: by using TableFile() instruction.

The CR1000 can be programmed to store each measurement or, more commonly, to store processed values such as averages, maxima, minima, histograms, FFTs, etc. Data are stored periodically or conditionally in data tables in SRAM as directed by the CRBASIC program (see *SECTION. Structure* (p. 133)). The DataTable () instruction allows the user to set the size of a data table. Discrete data files are normally created only on a PC when data are retrieved using *datalogger support software* (p. 439, p. 490).

Data are usually erased from this area when a program is sent to the CR1000. However, options are available in *datalogger support software* (p. 439, p. 490) File Control and CRBASIC Editor to preserve data when downloading programs.

12.1.1.2 CPU: Drive

CPU: is the default drive to which programs and calibration files are stored. Do not store data on CPU: or premature failure of CPU: memory may result.

12.1.1.3 USR: Drive

SRAM can be partitioned to create a FAT32 USR: drive, analogous to partitioning a second drive on a PC hard disk. Certain types of files are stored to USR: to reserve limited CPU: memory for datalogger programs and calibration files. Partitioning also helps prevent interference from data table SRAM. USR: is configured using DevConfig settings or SetStatus() instruction in a CRBASIC program. Partition USR: drive to at least 11264 bytes in 512 byte increments. If the value entered is not a multiple of 512 bytes, the size is rounded up. Maximum size of USR: is the total RAM size less 400 Kbytes; i.e., for a CR1000 with 4 Megabyte memory, the maximum size of USR: is about 3.6 Megabytes.

USR: is not affected by program recompilation or formatting of other drives. It will only be reset if the USR: drive is formatted, a new operating system is loaded, or the size of USR: is changed. USR: size is changed manually using the optional keyboard display or by loading a program with a different USR: size entered in a SetStatus() instruction.

Measurement data can be stored on USR: as discrete files by using the TableFile() instruction. *TABLE. TableFile() Instruction Data File Formats* (p. 355) describes available data file formats.

Note Placing an optional USR: size setting in the user program over-rides manual changes to USR: size. When USR: size is changed manually, the user program restarts and the programmed size for USR: takes immediate effect.

The USR: drive holds any file type within the constraints of the size of the drive and the limitations on filenames. Files typically stored include image files from cameras (see *APPENDIX. Cameras* (p. 504)), certain configuration files, files written for ftp retrieval, html files for viewing via web access, and files created with the TableFile() instruction. Files can be collected by ftp using *datalogger support software* (p. 439, p. 490) File Control utility, or automatically using the LNCMD program supplied exclusively with top-level *datalogger support software* (p. 439, p. 490).

Monitor use of available USR: memory to ensure adequate space to store new files. FileManage() command is used within the CR1000 user program to remove files. Files also can be removed using *datalogger support software* (p. 439, p. 490) File Control utility.

Two status table registers monitor use and size of the USR: drive. Bytes remaining are indicated in register "USRDriveFree." Total size is indicated in register "USRDriveSize." Memory allocated to USR: drive, less overhead for directory use, is shown in *datalogger support software* (p. 439, p. 490) File Control.

12.1.1.4 USB: Drive

USB: drive uses Flash memory on a CS mass storage device (see *APPENDIX. Mass Storage Devices* (p. 504)). Its primary purpose is the storage of ASCII data files. Measurement data can be stored on USB: as discrete files by using the TableFile() instruction. *TABLE. TableFile() Instruction Data File Formats* (p. 355) describes available data file formats.

Caution When removing mass storage devices, do so when the LED is not flashing or lit.

Removing a mass storage device from the CR1000 while the storage device is active can cause data corruption.

CS mass storage devices connect to the CR1000 via the CS I/O port.

CS mass storage devices should be formatted as FAT32.

12.1.1.5 CRD: Drive

CRD: drive uses CompactFlash® memory exclusively. Its primary purpose is the storage of binary data files.

Caution When installing or removing card storage modules, first turn off CR1000 power.

Removing a card from the module while the CF card is active can cause data corruption and may damage the card. Always press the removal button to disable the card and wait for the green LED before removing the card or switching off power prior to removal of the card.

To prevent losing data, collect data from the CF card before sending a program to the datalogger. When a program is sent to the datalogger all data on the CF card may be erased.

CSI CF card modules connect to the CR1000 peripheral port. Each has a slot for Type I or Type II CF cards. A maximum of 30 data tables can be created on a CF card. Refer to *APPENDIX. Card Storage Modules* (p. 503) for information on available CF card modules.

Note CardConvert software, included with mid- and top-level *datalogger support software* (p. 439, p. 490), converts binary card data to the standard Campbell Scientific data format.

When a data table is sent to a CF card, a data table of the same name in SRAM is used as a buffer for transferring data to the card. When the card is present, the status table will show the size of the table on the card. If the card is removed, the size of the table in SRAM is shown.

When a new program is compiled that sends data to the CF card, the CR1000 checks if a card is present and if the card has adequate space for the data tables. If no card is present, or if space is inadequate, the CR1000 will warn that the card is not being used. However, the user program is run and data stored to SRAM. When a card is later inserted, accumulated data is copied to the card.

The CR1000 accepts cards formatted as FAT or FAT32; however, **FAT32 is recommended**. Otherwise, some functionality, such as the ability to manage large numbers of files (>254) is lost. Older CR1000 operating systems formatted cards as FAT or FAT32. Newer operating systems always format cards as FAT32.

See *SECTION. File System Errors* (p. 366) for explanation of error codes associated with CRD: use.

12.1.1.6 Data File Formats

TableFile() instruction data file formats contain time series data and may have an option to include header, timestamp and record number. *TABLE. TableFile() Instruction Data File Formats* (p. 355) lists available formats. For a format to be compatible with *datalogger support software* (p. 439, p. 490) graphing and reporting tools, header, timestamps, and record numbers are usually required. Fully compatible formats are indicated with an asterisk. A more detailed discussion of data file formats is available in the Campbell Scientific publication "LoggerNet Instruction Manual" available at www.campbellsci.com.

TABLE 75. TableFile() Instruction Data File Formats

TableFile() Format Option	*Base File Format*	*Elements Included*		
		Header Information	*Time Stamp*	*Record Number*
0*	TOB1	X	X	X
1	TOB1	X	X	
2	TOB1	X		X
3	TOB1	X		
4	TOB1		X	X
5	TOB1		X	
6	TOB1			X
7	TOB1			
8*	TOA5	X	X	X
9	TOA5	X	X	
10	TOA5	X		X
11	TOA5	X		
12	TOA5		X	X
13	TOA5		X	
14	TOA5			X
15	TOA5			
16*	CSIXML	X	X	X
17	CSIXML	X	X	
18	CSIXML	X		X
19	CSIXML	X		
32*	CSIJSON	X	X	X
33	CSIJSON	X	X	
34	CSIJSON	X		X
35	CSIJSON	X		

*Formats compatible with *datalogger support software* (p. 439, p. 490) data viewing and graphing utilities

12.1.1.6.1 Data File Format Examples

TOB1

TOB1 files may contain an ASCII header and binary data. The last line in the example contains cryptic text which represents binary data.

Example:

```
"TOB1","11467","CR1000","11467","CR1000.Std.20","CPU:file
    format.CR1","61449","Test"
"SECONDS","NANOSECONDS","RECORD","battfivoltfiMin","PTemp"
"SECONDS","NANOSECONDS","RN","",""
"","","","Min","Smp"
"ULONG","ULONG","ULONG","FP2","FP2"
}Ÿp'    E1HŒŸp'    E1H›Ÿp'    E1HªŸp'    E1H¹Ÿp'       E1H
```

TOA5

TOA5 files contain ASCII (American Standard Code for Information Interchange) header and comma separated data.

Example:

```
"TOA5","11467","CR1000","11467","CR1000.Std.20","CPU:file
    format.CR1","26243","Test"
"TIMESTAMP","RECORD","battfivoltfiMin","PTemp"
"TS","RN","",""
"","","Min","Smp"
"2010-12-20 11:31:30",7,13.29,20.77
"2010-12-20 11:31:45",8,13.26,20.77
"2010-12-20 11:32:00",9,13.29,20.8
```

CSIXML

CSIXML files contain header information and data in an XML (eXtensible Markup Language) format.

Example:

```
<?xml version="1.0" standalone="yes"?>
<csixml version="1.0">
<head>
    <environment>
        <station-name>11467</station-name>
        <table-name>Test</table-name>
        <model>CR1000</model>
        <serial-no>11467</serial-no>
        <os-version>CR1000.Std.20</os-version>
        <dld-name>CPU:file format.CR1</dld-name>
    </environment>
    <fields>
        <field name="battfivoltfiMin" type="xsd:float"
            process="Min"/>
        <field name="PTemp" type="xsd:float" process="Smp"/>
    </fields>
</head>
    <data>
        <r time="2010-12-20T11:37:45"
            no="10"><v1>13.29</v1><v2>21.04</v2></r>
        <r time="2010-12-20T11:38:00"
            no="11"><v1>13.29</v1><v2>21.04</v2></r>
```

```
        <r time="2010-12-20T11:38:15"
           no="12"><v1>13.29</v1><v2>21.04</v2></r>
    </data>
</csixml>
```

CSIJSON

CSIJSON files contain header information and data in a JSON (Java Script Object Notation) format.

Example:

```
"signature": 38611,"environment":  {"stationfiname":
    "11467","tablefiname":  "Test","model":
    "CR1000","serialfino":  "11467",
"osfiversion":  "CR1000.Std.21.03","progfiname":  "CPU:file
    format.CR1"},"fields":  [{"name":
    "battfivoltfiMin","type":  "xsd:float",
"process":  "Min"},{"name":  "PTemp","type":
    "xsd:float","process":  "Smp"}]},
"data": [{"time":  "2011-01-06T15:04:15","no":  0,"vals":
    [13.28,21.29]},
{"time":  "2011-01-06T15:04:30","no":  1,"vals":
    [13.28,21.29]},
{"time":  "2011-01-06T15:04:45","no":  2,"vals":
    [13.28,21.29]},
{"time":  "2011-01-06T15:05:00","no":  3,"vals":
    [13.28,21.29]}]}
```

12.1.1.6.2 Data File Format Elements

HEADER

File headers provide metadata that describe the data in the file. A TOA5 header contains the metadata described below. Other data formats contain similar information unless a non-header format option is selected in the TableFile() instruction in the CR1000 CRBASIC program.

Line 1 – Data Origins

Includes the following metadata series: file type, station name, CR1000 model name, CR1000 serial number, OS version, CRBASIC program name, program signature, data table name.

Line 2 – Data Field Names

Lists the name of individual data fields. If the field is an element of an array, the name will be followed by a comma separated list of subscripts within parentheses that identifies the array index. For example, a variable named “values” that is declared as a two by two array, i.e.,

```
Public Values(2,2)
```

will be represented by four field names: “values(1,1)”, “values(1,2)”, “values(2,1)”, and “values(2,2)”. Scalar (non-array) variables will not have subscripts.

Line 3 – Data Units

Includes the units associated with each field in the record. If no units are programmed in the CR1000 CRBASIC program, an empty string is entered for that field.

Line 4 – Data Processing Descriptors

Entries describe what type of processing was performed in the CR1000 to produce corresponding data, e.g., Smp indicates samples, Min indicates minima. If there is no recognized processing for a field, it is assigned an empty string. There will be one descriptor for each field name given on Header Line 2.

TIMESTAMP

Data without timestamps are usually meaningless. Nevertheless, the TableFile() instruction optionally includes timestamps in some formats.

RECORD NUMBER

Record numbers are optionally provided in some formats as a means to ensure data integrity and provide an upcount data field for graphing operations.

12.2 Memory Conservation

One or more of the following memory saving techniques can be used on the rare occasions when a program reaches memory limits:

- Declare variables as DIM instead of Public. DIM variables do not require buffer memory for data retrieval.
- Reduce arrays to the minimum size needed. Each variable, whether or not part of an array, requires about the same amount of memory. Approximately 192000 (4 kbyte memory) or 87000 (2 kbyte memory) variables will fill available memory.
- Use variable arrays with aliases instead of individual variables with unique names. Aliases consume less memory than unique variable names.
- Confine string concatenation to DIM variables.
- Dimension string variables only to the size required.

Read More! More information on string variable memory use and conservation is available in *SECTION. String Operations* (p. 317).

12.3 Memory Reset

Four features are available for complete or selective reset of CR1000 memory.

12.3.1 Full Memory Reset

Full memory reset occurs when an operating system is sent to the CR1000 using DevConfig or when entering "98765" in the status table field "FullMemReset." A full memory reset does the following:

- Clears and Formats CPU: drive (all program files erased)
- Clears SRAM data tables
- Clears Status Table Elements
- Restores settings to default
- Initializes system variables
- Clears communications memory

Full memory reset does not affect the CRD: drive directly. Subsequent user program uploads, however, can affect CRD:.

Operating systems can also be sent using the Program Send feature in *datalogger support software* (p. 439). Beginning with operating system version 16, settings and status are preserved when sending a subsequent OS by this method; data tables are erased. Rely on this feature with caution, however, when sending an OS to CR1000s in remote and difficult to access locations.

12.3.2 Program Send Reset

Final Storage (p. 442) data are erased when user programs are uploaded, unless preserve / erase data options are used. Preserve / erase data options are presented when sending programs from *datalogger support software* (p. 439, p. 490) File Control and CRBASIC Editor Compile | Save | Send. See *SECTION. Preserving Data at Program Send* (p. 131) for a more detailed discussion of preserve / erase data at program send.

12.3.3 Manual Data Table Reset

Data table memory is selectively reset from

- *datalogger support software* (p. 439) Station Status option
- optional keyboard display: Data | Reset Data Tables

12.3.4 Formatting Drives

CPU:, USR:, USB:, and CRD: drives can be formatted individually. Formatting a drive erases all files on that drive. If the currently running user program is found on the drive to be formatted, the program will cease running and any SRAM data associated with the program is erased. Drive formatting is performed through datalogger support software File Control.

12.4 File Management

Files in CR1000 memory (program, data, CAL, image) can be managed or controlled with Campbell Scientific support software as summarized in *TABLE. File Control Functions* (p. 360).

TABLE 76. File Control Functions

File Control Functions	*Accessed Through*
Sending programs to the CR1000.	**Send**[1], File Control[2], DevConfig[3], keyboard with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive)[4], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Setting file attributes. See *File Attributes* (p. 361).	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive)[5], FileManage() instruction[6].
Sending an OS to the CR1000. Reset settings.	DevConfig[3], automatic with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Sending an OS to the CR1000. Preserve settings.	**Send**[1], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) with default.CR1 file.[5]
Formatting CR1000 memory drives.	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Retrieving programs from the CR1000.	Connect[7], File Control[2], keyboard with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[4]
Setting disposition of old CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) files	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Deleting files from memory drives.	File Control[2], power-up with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).[5]
Stopping program execution.	File Control[2].
Renaming a file.	FileRename()[6]
Time stamping a file.	FileTime()[6]
List files.	File Control[2], FileList()[6]

TABLE 76. File Control Functions

File Control Functions	*Accessed Through*
Create a data file from a data table	TableFile()[6]
JPEG files manager	optional keyboard display , LoggerNet | PakBusGraph

[1]*Datalogger support software* (p. 439, p. 490) Program Send Button. See software Help.

[2]*Datalogger support software* (p. 439, p. 490) File Control. See software Help.

[3]Device Configuration Utility (DevConfig). See DevConfig Help.

[4]Manual with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive). See *Data Storage* (p. 352).

[5]Automatic with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) and Powerup.ini. See *Power-up* (p. 363).

[6]CRBASIC commands. See *Data Table Declarations* (p. 177) and *File Management* (p. 215) and CRBASIC Editor Help.

[7]*Datalogger support software* (p. 439, p. 490) Retrieve button. See software Help.

12.4.1 File Attributes

A feature of program files is the file attribute. *TABLE. CR1000 File Attributes* (p. 361) lists available file attributes, their functions, and when attributes are typically used. For example, a program file sent via the **Send** option in *datalogger support software* (p. 439), runs a) immediately ("Run Now") and b) when power is cycled on the CR1000 ("Run on Power-up). This functionality is invoked because **Send** sets two CR1000 file attributes on the program file, i.e., "Run Now" and "Run on Power-up." When together, "Run Now" and "Run on Power-up" are tagged as "Run Always."

Note Activation of the Run on Power-up file can be prevented by holding down the Del key on the optional keyboard display while the CR1000 is being powered up.

TABLE 77. CR1000 File Attributes

Attribute	*Function*	*Attribute for Programs Sent to CR1000 with:*
Run Always (Run on Power-up + Run Now)	Runs now and on power-up	a) **Send**[1] b) File Control[2] with Run Now & Run on Power-up checked. c) CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) power-up[3] using commands 1 & 13 (see *TABLE. Powerup.ini Commands* (p. 364)).
Run on Power-up	Runs only on power-up	a) File Control[2] with Run on Power-up checked. b) CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) power-up[3] using command 2 (see *TABLE. Powerup.ini Commands* (p. 364)).

TABLE 77. CR1000 File Attributes

Attribute	*Function*	*Attribute for Programs Sent to CR1000 with:*
Run Now	Runs only when file sent to CR1000	a) File Control[2] with Run Now checked. b) CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) power-up[3] using commands 6 & 14 (see *TABLE. Powerup.ini Commands* (p. 364)). But, if CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) is left in, program loads again from CompactFlash card (CRD: drive) or CS mass storage media (USB: drive).

[1]*Datalogger support software* (p. 439, p. 490) Program Send Button. See software Help.

[2]*Datalogger support software* (p. 439, p. 490) | File Control. See software Help & *Preserving Data at Program Send* (p. 131).

[3]Automatic on power-up of CR1000 with CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) and Powerup.ini. See *Power-up* (p. 363).

12.4.2 Data Preservation

Associated with file attributes is the option to preserve data in CR1000 memory when a program is sent. This option applies to data table SRAM, CompactFlash(R), and datalogger support software cache data. Depending on the application, retention of data files when a program is downloaded may be desirable. When sending a program to the CR1000 with the datalogger support software Send, data are always deleted before the program runs. When the program is sent using datalogger support software File Control or CRBASIC Editor "Compile, Save, and Send," options to preserve (do not erase) or not preserve (erase) data are presented. The logic in *TABLE. Data Preserve Options* (p. 362) summarizes the disposition of CR1000 data depending on the data preservation option selected.

TABLE 78. Data Preserve Options

```
if "Preserve data if no table changed"
    keep CF data from overwritten program
    if current program = overwritten program
        keep CPU data
        keep cache data
    else
        erase CPU data
        erase cache data
    end if
end if

if "erase CF data"
    erase CF data from overwritten program
    erase CPU data
    erase cache data
end if
```

12.4.3 External Memory Power-up

Uploading a CR1000 operating system file or user program file in the field can be challenging, particularly during weather extremes. Heat, cold, snow, rain, altitude, blowing sand, and distance to hike influence how easily programming with a laptop or palm PC may be. An alternative is to carry the file to field on a light weight external memory device such as a *USB:* (p. 504) or *CRD:* (p. 503) drive. Including a powerup.ini file with the OS / program file on an external drive, connecting the external device to the CR1000, and then cycling power, will result in the file automatically uploading to the CR1000 and running. Powerup.ini options also allows final data storage management comparable to the *datalogger support software* (p. 489) File Control feature. CRD: drive has precedence over USB: drive.

Caution Test Power-up options in the lab before going to the field. Always carry a laptop or palm PC into difficult or expensive to access places.

Power-up functions include

1. Sending programs to the CR1000
2. Setting attributes of CR1000 program files
3. Setting disposition of old CompactFlash card (CRD: drive) or CS mass storage media (USB: drive) files
4. Sending an OS to the CR1000
5. Formatting memory drives
6. Deleting data files

Note Back in the old days of volatile RAM, life was simple. Lost power meant lost programs, variables, and data. The advent of non-volatile memory has saved a lot of frustration in the field, but it requires thought in some applications. For instance, if the CR1000 loses power, do you want it to power back up with the same program, or another one? with variables intact or erased? with data intact or erased?

The powerup.ini file enables the power-up function. The powerup.ini file usually resides on an external drive. It contains a list of one or more command lines. At power-up, the CR1000 searches for a powerup.ini file on a drive and executes the command line(s) prior to compiling a program. Powerup.ini performs three operations:

1. Copies the specified program file to a specified memory drive.
2. Sets a file attribute on the program file.
3. Optionally deletes data left in memory from a just previous, and now overwritten, program.

A powerup.ini file takes precedence during power-up. Although it sets file attributes for the programs it uploads, its presence on a drive does not allow those file attributes to control the power-up process. To avoid confusion, either remove the external drive on which the powerup.ini file resides or delete the file after the powerup.ini operation is complete.

12.4.3.1 Creating and Editing Powerup.ini

A powerup.ini file is created with a text editor on a PC, then saved as "powerup.ini" on a memory drive of the CR1000. The file is saved to the memory drive, along with the operating system or user program file, using the File Control | Send function in *datalogger support software* (p. 489).

Note Some text editors (such as MicroSoft® WordPad®) will attach header information to the powerup.ini file causing it to abort. Check the text of a powerup.ini file in the CR1000 with the optional keyboard display to see what the CR1000 actually sees.

Comments can be added to the file by preceding them with a single-quote character ('). All text after the comment mark on the same line is ignored.

12.4.3.1.1 Syntax

```
Command,File,Device
```

where

- Command = one of the numeric commands in *TABLE. Powerup.ini Commands* (p. 364).
- File = accompanying operating system or user program file. Name can be up to 22 characters.
- Device: the CR1000 memory drive to which the accompanying operating system or user program file is copied (usually CPU:). If left blank or with an invalid option, default device will be CPU:. Use the same drive designation as the transporting external device if the preference is to not copy the file.

TABLE 79. Powerup.ini Commands

Command	*Description*
1*	Run always, preserve data
2	Run on power-up
5	Format
6*	Run now, preserve data
9	Load OS (File = .obj)
13	Run always, erase data
14	Run now, erase files

*By using PreserveVariables() instruction in the CRBASIC program, with commands 1 & 6, data and variables can be preserved.

12.4.3.1.2 Applications

- Commands 1, 2, 6, 13, and 14 (Run Now and / or Run On Power-up). File is copied to Device.
- Command 1, 2, 13 (Run On Power-up). If the copy (first application, above) succeeds, the new Run On Power-up program is accepted. If the copy fails, no change is made to the Run On Power-up program.
- Commands 1, 6, 13, and 14 (Run Now). The Run Now program is changed whether or not the copy (first application, above) occurs. If the copy does succeed, the Run Now program is opened from the device specified.
- Commands 13 and 14 (Delete Associated Data). Since powerup.ini is only processed at power-up, there is not a compiled program to delete associated data for. The information from the last running program is still available for the CR1000 to delete the files used by that program.

12.4.3.1.3 Program Execution

After File is processed, the following rules determine what CR1000 program to run:

- If the Run Now program is changed then it is the program that runs.
- If no change is made to Run Now program, but Run on Power-up program is changed, the new Run on Power-up program runs.
- If neither Run on Power-up nor Run Now programs are changed, the previous Run on Power-up program runs.

12.4.3.1.4 Example Power-up.ini Files

Powerup.ini Example

Code Form / Syntax

```
'Command = numeric power-up command
'File = file associated with the action
'Device = device to which File is copied. Defaults to CPU:

'Command,File,Device
13,Write2CRD_2.cr1,cpu:
```

Powerup.ini Example

Copy program file pwrup.cr1 from the external drive to CPU:. File will run only when CR1000 powered-up later

```
2,pwrup.cr1,cpu:
```

Powerup.ini Example

Format the USR: drive

```
5,,usr:
```

Powerup.ini Example.
Load an operating system (.obj) file into FLASH as the new OS
`9,CR1000.Std.04.obj`

Powerup.ini Example
A program file is carried on an external USB: drive. Do not copy program file from USB:. Run program always, erase data.
`13,toobigforcpu.cr1,usb:`

Powerup.ini Example
Run a program file always, erase data
`13,pwrup_1.cr1,cpu:`

Powerup.ini Example
Run a program file now, erase data now
`14,run.cr1,cpu:`

12.5 File Names

The maximum size of the file name that can be stored, run as a program, or FTP transferred in the CR1000 is 59 characters. If the name is longer than 59 characters an "Invalid Filename" error is displayed. If several files are stored, each with a long filename, memory allocated to the root directory can be exceeded before the actual memory of storing files is exceeded. When this occurs, an "insufficient resources or memory full" error is displayed.

12.6 File System Errors

TABLE. File System Error Codes (p. 366) lists error codes associated with the datalogger file system. Errors can occur when attempting to access files on any of the available drives. All occurrences are rare, but they are most likely to occur when using the CRD: drive.

TABLE 80. File System Error Codes

Error Code	*Description*
1	Invalid Format
2	Device capabilities error
3	Unable to allocate memory for file operation
4	Max number of available files exceeded
5	No file entry exists in directory
6	Disk change occurred

TABLE 80. File System Error Codes

Error Code	*Description*
7	Part of the path (subdirectory) was not found
8	File at EOF
9	Bad cluster encountered
10	No file buffer available
11	Filename too long or has bad chars
12	File in path is not a directory
13	Access permission, opening DIR or LABEL as file, or trying to open file as DIR or mkdir existing file
14	Opening read only file for write
15	Disk full (can't allocate new cluster)
16	Root directory is full
17	Bad file ptr (pointer) or device not initialized
18	Device does not support this operation
19	Bad function argument supplied
20	Seek out of file bounds
21	Trying to mkdir an existing dir
22	Bad partition sector signature
23	Unexpected system ID byte in partition entry
24	Path already open
25	Access to uninitialized ram drive
26	Attempted rename across devices
27	Subdirectory is not empty
31	Attempted write to Write Protected disk
32	No response from drive (Door possibly open)
33	Address mark or sector not found
34	Bad sector encountered
35	DMA memory boundary crossing error
36	Miscellaneous I/O error
37	Pipe size of 0 requested
38	Memory release error (relmem)
39	FAT sectors unreadable (all copies)
40	Bad BPB sector
41	Time-out waiting for filesystem available
42	Controller failure error
43	Pathname exceeds _MAX_PATHNAME

Section 18. Care and Maintenance

Temperature and humidity can affect the performance of the CR1000. The internal lithium battery must be replaced periodically.

18.1 Temperature Range

The CR1000 is designed to operate reliably from -25 to +50°C (-40°C to +85°C, optional) in non-condensing environments.

18.2 Moisture Protection

When humidity tolerances are exceeded and condensation occurs, damage to CR1000 electronics can result. Effective humidity control is the responsibility of the user.

Internal CR1000 module moisture is controlled at the factory by sealing the module with a packet of silica gel inside. The desiccant is replaced whenever the CR1000 is repaired at Campbell Scientific. The module should not be opened by the user except to replace the lithium coin cell providing back up power to the clock and SRAM. Repeated disassembly of the CR1000 will degrade the seal, leading to potential moisture problems.

Adequate desiccant should be placed in the instrumentation enclosure to prevent corrosion on the CR1000 wiring panel.

18.3 Enclosures

Illustrated in *FIGURE. Enclosure* (p. 410) is a typical use of an enclosure available from Campbell Scientific for housing a CR1000 and peripherals. This style of enclosures is classified as NEMA 4X (watertight, dust-tight, corrosion-resistant, indoor and outdoor use). Refer to *APPENDIX. Enclosures* (p. 497) for information concerning available enclosures.

FIGURE 127. Enclosure

18.4 Replacing the Internal Battery

Caution Fire, explosion, and severe burn hazard! Misuse or improper installation of the lithium battery can cause severe injury. Do not recharge, disassemble, heat above 100°C (212°F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent lithium batteries properly.

The CR1000 contains a lithium battery that operates the clock and SRAM when the CR1000 is not powered. The CR1000 does not draw power from the lithium battery while it is powered by a 12 Vdc supply. In a CR1000 stored at room temperature, the lithium battery should last approximately 3 years (less at temperature extremes). In installations where the CR1000 remains powered the lithium cell should last much longer.

While powered from an external source, the CR1000 measures the voltage of the lithium battery daily. This voltage is displayed in the status table (*APPENDIX. Status Table and Settings* (p. 457)). A new battery supplies approximately 3.6 volts. The CR1000 Status Table has a "Lithium Battery" field. This field shows lithium battery voltage. Replace the battery when voltage is approximately 2.7 V. If the lithium cell is removed or allowed to discharge below the safe level, the CR1000 will still operate correctly while powered. Without the lithium battery, the clock will reset and data are lost when power is removed.

- The CR1000 is partially disassembled to replace the lithium cell. See *FIGURE. Loosening Thumbscrews* (p. 411) through *FIGURE. Remove and Replace Battery* (p. 413). When the lithium battery is removed, the user program and most settings are maintained. Items not retained include
  - Run now and run on power-up settings.
  - Routing and communications logs (relearned without user intervention).
  - Time. Clock will need resetting when the battery is replaced.
  - Final storage data tables.

A replacement lithium battery (pn 13519) can be purchased from Campbell Scientific or another supplier. *TABLE. Internal Lithium Battery Specifications* (p. 411) lists battery specifications.

TABLE 88. Internal Lithium Battery Specifications

Manufacturer	*Tadiran*
Model	TL-5902S (3.6 V)
Capacity	1.2 Ah
Self-discharge rate	1%/year @ 20°C
Operating temperature range	-55°C to 85°C

When reassembling the module to the wiring panel, assure that the module is fully seated or connected to the wiring panel by firmly pressing them together by hand.

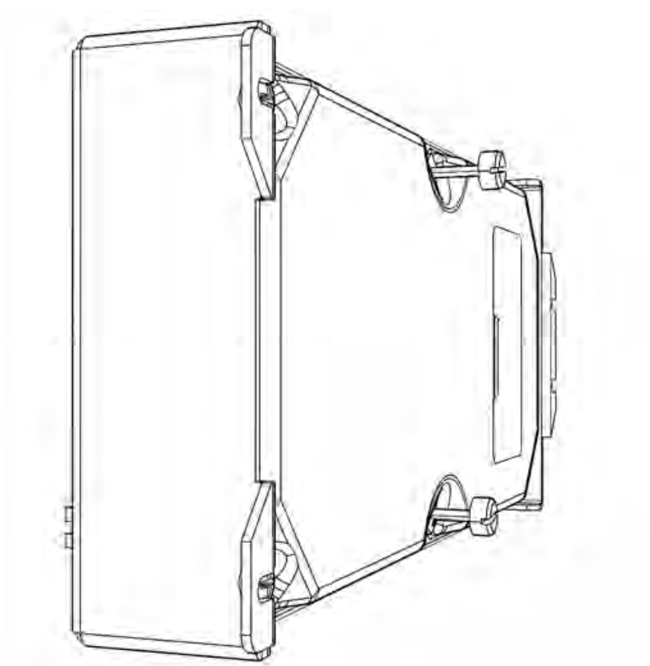

FIGURE 128. Loosening Thumbscrews

Fully loosen the two knurled thumbscrews. Only loosen the screws. They will remain attached to the module.

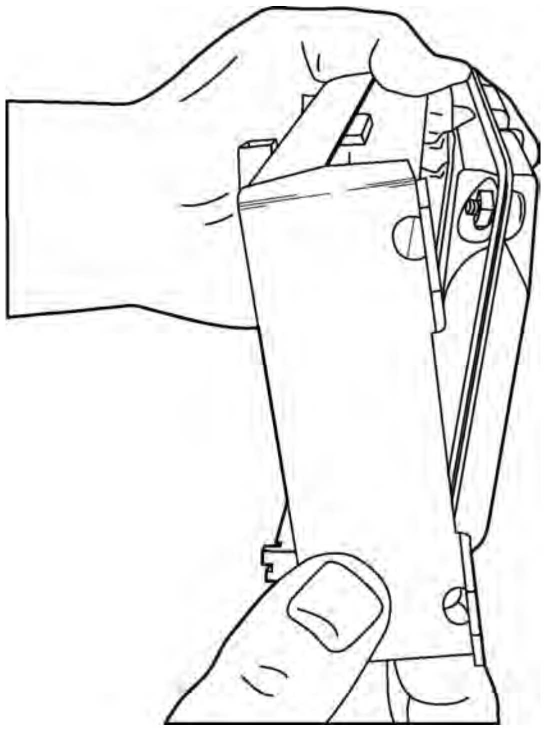

FIGURE 129. Pulling Edge Away from Panel

Pull one edge of the canister away from the wiring panel to loosen it from three connector seatings.

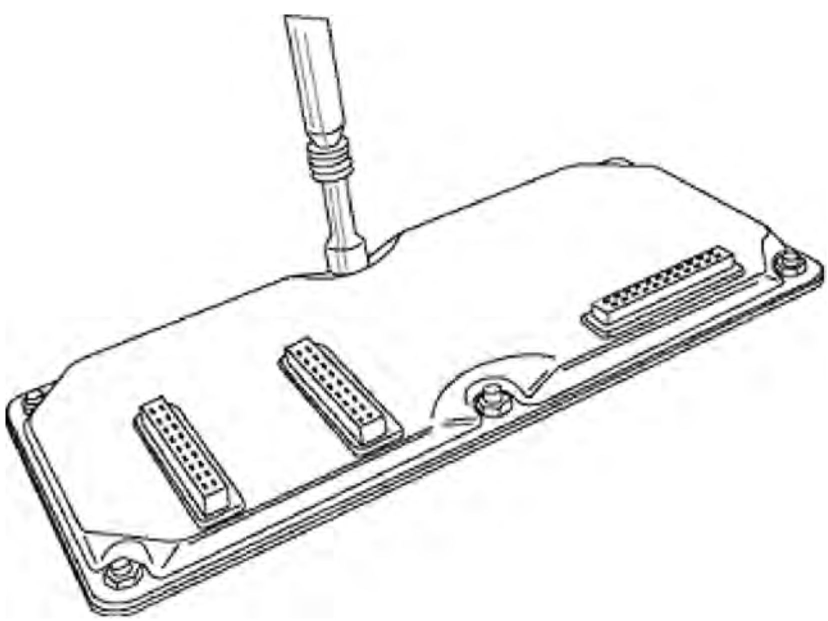

FIGURE 130. Removing Nuts to Disassemble Canister

Remove six nuts, then open the clam shell.

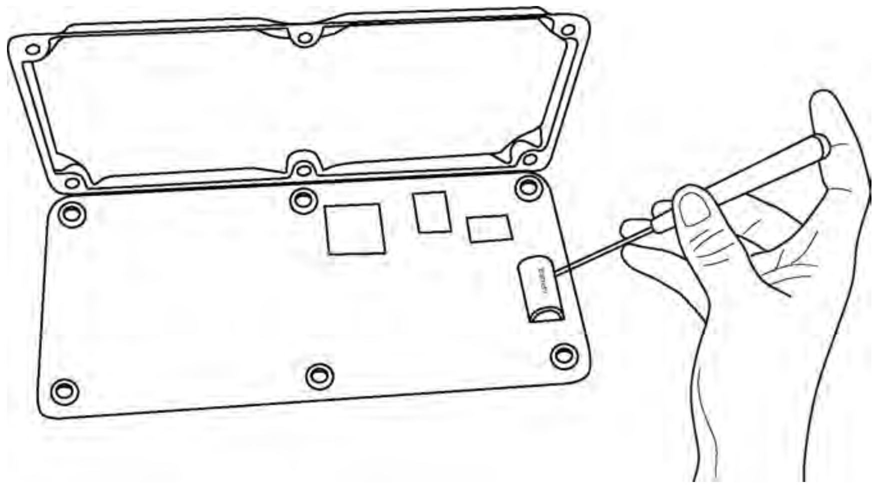

FIGURE 131. Remove and Replace Battery

Remove the lithium battery by gently prying it out with a small flat point screwdriver. Reverse the disassembly procedure to reassemble the CR1000. Take particular care to ensure the canister is reseated tightly into the three connectors.

18.5 Repair

Occasionally, a CR1000 requires repair. Consult with a Campbell Scientific applications engineer before sending any product for repair. Be prepared to perform some troubleshooting procedures while on the phone with the applications engineer. Many problems can be resolved with a telephone conversation. If a repair is warranted, the following procedures should be followed when sending the product.

Products may not be returned without prior authorization. The following contact information is for US and International customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit *www.campbellsci.com* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 753-2342. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a "Declaration of Hazardous Material and Decontamination" form and comply with the requirements specified in it. The form is available from our web site at *www.campbellsci.com/repair*. A completed form must be either emailed to *repair@campbellsci.com* or faxed to 435-750-9579. Campbell Scientific will not process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Appendix A2 - CFM100 CompactFlash Module

INSTRUCTION MANUAL

CFM100 CompactFlash® Module

Revision: 6/12

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twelve (12) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

CAMPBELL® SCIENTIFIC

Campbell Scientific (Canada) Corp.
11564 149 Street | Edmonton AB T5M 1W7
780.454.2505 | fax 780.454.2655 | campbellsci.ca

PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

CFM100 Table of Contents

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Appendix

Figure

Table

CFM100 CompactFlash® Module

1. Introduction

Campbell Scientific's CFM100 CompactFlash® Module stores the datalogger's data on a removable CompactFlash (CF) card. The CFM100 module connects to the datalogger via the 40-pin peripheral port. Currently, only our CR1000 and CR3000 dataloggers have the 40-pin peripheral port; the CFM100 is not compatible with the CR200-series, CR800, CR850, CR5000, and CR9000X dataloggers.

Before using the CFM100, please study:

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 4, *Quickstart*

The Quickstart explains how to quickly begin using a CFM100 for straightforward data storage operations. The remainder of the manual is a technical reference which describes in detail such operations as: file formats, datalogger programming and data retrieval.

2. Cautionary Statements

- The CFM100 is rugged, but it should be handled as a precision scientific instrument. There are no user-serviceable parts inside the module.

- The 28033 surge suppressor and/or a shielded 10baseT Ethernet cable should be used for locations susceptible to power surges and for cable length longer than 9 ft.

- Always power down the datalogger before installing or removing the CFM100 to/from the datalogger.

- Removing a CompactFlash card while it is active can cause garbled data and can actually damage the card. **Always** press the control button and wait for a green light before removing card.

- LoggerNet's File Control should not be used to retrieve data from a CompactFlash card. Using File Control to retrieve the data can result in a corrupted data file.

3. Initial Inspection

Upon receipt of the CFM100, inspect the packaging and contents for damage. File damage claims with the shipping company.

4 Quickstart

This section describes the basics of storing and retrieving datalogger data. These operations are discussed in detail in Section 7, *Operation* of this manual.

4.1 Preparation

CAUTION Always power down the datalogger before installing or removing the CFM100 to/from the datalogger.

After powering down the datalogger, plug the CFM100 into the datalogger peripheral port. Restore power to the datalogger. Insert formatted CF card. (For instructions on formatting a CF card, see Appendix A.)

4.2 Programming the Datalogger to Send Data to the CFM100

The **CardOut()** instruction is used in the datalogger program to send data to the CF card. The **CardOut()** instruction must be entered within each **DataTable()** declaration that is to store data to the CF card. The file is saved to the card with the name stationname.tablename and a .DAT extension.

The **CardOut()** instruction has the following parameters:

StopRing: A constant is entered for the *StopRing* parameter to specify whether the **DataTable()** created should be a Ring Mode table (0) or a Fill and Stop table (1).

Size: The *Size* parameter is the minimum number of records that will be included in the **DataTable()**. If –1000 is entered, the size of the file on the card will be the same as the size of the internal table on the datalogger. If any other negative number is entered, the memory that remains after creating any fixed-size tables on the card will be allocated to this table. If multiple DataTables are set to a negative number, the remaining memory will be divided among them. The datalogger attempts to size the tables so that all of them will be full at the same time

In the following example, the minimum batt_voltage and a sample of PTemp is written to the card each time the data table is called. The *StopRing* parameter is 0 for ring mode. This means that once the data table is full, new data will begin overwriting old data. The *size* parameter is –1, so all available space on the card will be allocated to the table.

```
DataTable(Table1,1,-1)
CardOut(0,-1)
    Minimum(1,batt_volt,FP2,0,False)
    Sample(1,PTemp,IEEE4)
EndTable
```

CAUTION To prevent losing data, collect data from the CF card before sending the datalogger a new or modified program. When a program is sent to the datalogger using the Send button in the Connect screen of LoggerNet or PC400, an attribute is sent along with the program that commands the datalogger to erase all data on the CF card from the currently running program.

4.3 Data Retrieval

Data stored on cards can be retrieved through a communication link to the datalogger or by removing the card and carrying it to a computer with a CF adapter. With large files, transferring the CF card to a computer may be faster than collecting the data over a communication link. Data retrieval is discussed in detail in Section 7.3, *Data Retrieval*.

CAUTION Removing a card while it is active can cause garbled data and can actually damage the card. **Always** press the control button and wait for a green light before removing card.

CAUTION LoggerNet's File Control should not be used to retrieve data from a CompactFlash card. Using File Control to retrieve the data can result in a corrupted data file.

5. Overview

The CFM100 connects to a datalogger's peripheral port and has a slot for a Type I or Type II CompactFlash (CF) card (3.3 V, 75 mA). The CFM100/CF card combination can be used to expand the datalogger's memory, transport data/programs from the field site(s) to the office, upload datalogger power up functions, and store JPEG images from the CC640 camera. Data stored on cards can be retrieved through a communication link to the datalogger or by removing the card and carrying it to a computer. The computer can read the CF card either with the CF1 adapter or 17752 Reader/Writer. The CF1 adapter allows the PC's PCMCIA card slot to read the CF card; the 17752 Reader/Writer allows the PC's USB port to read the CF card. User-supplied CF adapters may also be used.

CAUTION LoggerNet's File Control should not be used to retrieve data from a CompactFlash card. Using File Control to retrieve the data can result in a corrupted data file.

FIGURE 5-1. CompactFlash Module

5.1 LEDs/Buttons

There is one red-green-orange LED (light emitting diode) and two buttons: control and eject. The LED indicates the status of the module. The LED will flash red when the CF card is being accessed, solid green when it is OK to remove the card, solid orange to indicate an error, and flashing orange if the card has been removed and has been out long enough that CPU memory has wrapped and data is being overwritten without being stored to the card. The control button must be pressed before removing a card to allow the datalogger to store any buffered data to the card and then power it off.

NOTE The CFM100 will consume more current if a Status LED is continuously on. When a red or green LED is continuously on, add 1 mA to the power consumption. When an orange LED is continuously on, add 2 mA to the power consumption.

5.2 Power

5.2.1 Primary Power

The CompactFlash module is powered by 12 VDC received from the datalogger through the peripheral port.

5.2.2 Backup Power and Data Retention

The CompactFlash (CF) cards do not require power to retain data.

Typically, a CF card can be erased and rewritten a minimum of 100,000 times. Industrial CF cards, graded for 2,000,000 write cycles, are recommended for most applications.

6. Specifications

Storage Capacity:	Depends on card size (up to 2 GB supported)
Dimensions:	10.0 x 8.3 x 6.5 cm (4.0 in x 3.3 in x 2.6 in)
Weight:	132.5 g
Operating Temp. Range:	-35° to +65°C (-55° to +85°C optional)
Typical Access Speed:	200 to 400 kbits s^{-1}
Memory Configuration:	User selectable for either ring style (default) or fill and stop.

6.1 Power

The CFM100 receives 12 V power from the datalogger through the peripheral port. The following currents are for the CR1000 with the CFM100 attached and can vary with the card.

Writing to card with RS-232 port active:	30 mA (avg.)
Reading from card with RS-232 port active:	20 mA (avg.)
Writing to card with RS-232port not active:	20 mA (avg.)
Reading from card with RS-232 port not active:	15 mA (avg.)
Low Power Standby State:	700 to 800 µA
Red or green LED continuously on:	Add 1 mA to current drain
Orange LED continuously on:	Add 2 mA to current drain

7. Operation

7.1 File Formats

This section covers the different types of files stored on the CF card

7.1.1 Data Files

The datalogger stores data on the CF card in TOB3 Format. TOB3 is a binary format that incorporates features to improve reliability of the CF cards. TOB3 allows the accurate determination of each record's time without the space required for individual time stamps.

TOB3 format is different than the data file formats created when data are collected via a communications link. Data files read directly from the CF card generally need to be converted into another format to be used

When TOB3 files are converted to another format, the number of records may be slightly greater or less than the number requested in the data table declaration. There is always some additional memory allocated. When the file is converted this will result in additional records if no lapses occurred. If more lapses occur than were anticipated, there may be fewer records in the file than were allocated.

The CardConvert software included in LoggerNet, PC400, and PC200 will convert data files from one format to another.

7.1.2 Program Files

The CF card can be used to provide extra program storage space for the datalogger. Program files can be copied to the card while it is attached as a drive on the computer. They can also be sent to the card using LoggerNet's File Control. They may also be copied from CPU memory to the card (or from the card to CPU memory) using the keyboard display.

7.1.3 Power-up Files (powerup.ini)

Users can insert a properly-configured CF card into the CFM100, cycle through the datalogger power, and have power up functions automatically performed.

Power-up functions of CompactFlash® cards can include

a) Sending programs to the CR1000 or CR3000
b) Setting attributes of datalogger program files
c) Setting disposition of old CF files
d) Sending an OS to the CR1000 or CR3000
e) Formatting memory drives
f) Deleting data files

CAUTION Test the power-up functions in the office before going into the field to ensure the power-up file is configured correctly.

The key to the CF power-up function is the powerup.ini file, which contains a list of one or more command lines. At power-up, the powerup.ini command line is executed prior to compiling the program. Powerup.ini performs three operations:

1) Copies the specified program file to a specified memory drive.

2) Sets a file attribute on the program file

3) Optionally deletes CF data files from the overwritten (just previous) program.

Powerup.ini takes precedence during power-up. Though it sets file attributes for the programs it uploads, its presence on the CF does not allow those file attributes to control the power-up process. To avoid confusion, either remove the CF card or delete the powerup.ini file after the powerup.ini upload.

7.1.3.1 Creating and Editing Powerup.ini

Powerup.ini is created with a text editor, then saved as "powerup.ini".

NOTE Some text editors (such as WordPad) will attach header information to the powerup.ini file causing it to abort. Check the text of a powerup.ini file with the datalogger keyboard display to see what the datalogger actually sees.

Comments can be added to the file by preceding them with a single-quote character ('). All text after the comment mark on the same line is ignored.

Syntax
Syntax allows functionality comparable to File Control in LoggerNet. Powerup.ini is a text file that contains a list of commands and parameters. The syntax for the file is:

Command,File,Device

where

Command = one of the numeric commands in Table 7.1-1.
File = file on CF associated with the action. Name can be up to 22 characters.
Device = the device to which the associated file will be copied to. Options are CPU:, USR:, and CRD:. If left blank or with invalid option, will default to CPU:.

TABLE 7.1-1. Powerup.ini Commands

Command	Description
1	Run always, preserve CF data files
2	Run on power-up
5	Format
6	Run now, preserve CF data files
9	Load OS (File = .obj)
13	Run always, erase CF data files now
14	Run now, erase CF data files now

By using **PreserveVariables()** instruction in the datalogger CRBasic program, with options 1 and 6, data and variables can be preserved.

EXAMPLE 7.1-1. Powerup.ini code.

```
'Command = numeric power-up command
'File = file on CF associated with the action
'Device = the device to which File will be copied.  Defaults to CPU:

'Command,File,Device
13,Write2CRD_2.cr1,CPU:
```

7.1.3.2 Applications

- Commands 1, 2, 6, 13, and 14 (Run Now and / or Run On Power-up). If a device other than CRD: drive is specified, the file will be copied to that device.

- Command 1, 2, 13 (Run On Power-up). If the copy (first application, above) succeeds, the new Run On Power-up program is accepted. If the copy fails, no change will be made to the Run On Power-up program.

- Commands 1, 6, 13, and 14 (Run Now). The Run Now program is changed whether or not the copy (first application, above) occurs. If the copy does succeed, the Run Now program will be opened from the device specified.

- Commands 13 and 14 (Delete Associated Data). Since CRD:powerup.ini is only processed at power-up, there is not a compiled program to delete associated data for. The information from the last running program is still available for the datalogger to delete the files used by that program.

7.1.3.3 Program Execution

After File is processed, the following rules determine what datalogger program to run:

1) If the Run Now program is changed then it will be the program that runs.
2) If no change is made to Run Now program, but Run on Power-up program is changed, the new Run on Power-up program runs.
3) If neither Run on Power-up nor Run Now programs are changed, the previous Run on Power-up program runs.

7.1.3.4 Example Power-up.ini Files

Example 7.1-2 through Example 7.1-7 are example powerup.ini files.

EXAMPLE 7.1-2. Run Program on Power-up.

```
'Copy pwrup.cr1 to USR:, will run only when powered-up later
2,pwrup.cr1,usr:
```

EXAMPLE 7.1-3. Format the USR: drive.

```
'Format the USR: drive
5,,usr:
```

EXAMPLE 7.1-4. Send OS on Power-up.

```
'Load this file into FLASH as the new OS
9,CR1000.Std.04.obj
```

EXAMPLE 7.1-5. Run Program from CRD: drive.

```
'Leave program on CRD:, run always, erase CRD: data files
13,toobigforcpu.cr1,crd:
```

EXAMPLE 7.1-6. Run Program Always, Erase CF data.

```
'Run always, erase CRD: data files
13,pwrup_1.cr1,crd
```

EXAMPLE 7.1-7. Run Program Now, Erase CF data.

```
'Copy run.cr1 to CPU:, erase CF data, run CPU:run.cr1, but not if later powered-up
14,run.cr1,cpu:
```

7.1.4 Camera Files

JPEG images taken by a digital camera connected to the datalogger can be stored to the CF card rather than CPU memory. This is done by configuring the PakBus setting “Files Manager” for the datalogger. This can be done using the Device Configuration Utility or PakBus Graph.

7.2 Programming

7.2.1 The CardOut() Instruction

The **CardOut()** Instruction is used to send data to a CF card. The **CardOut()** Instruction must be entered within each **DataTable** declaration that is to store data to the CF card. Data is stored to the card when a call is made to the data table.

CardOut(*StopRing, Size***)**

Parameter *& Data Type*	**Enter**
StopRing *Constant*	A code to specify if the Data Table on the CF card is fill and stop or ring (newest data overwrites oldest). **Value** – **Result** 0 – Ring 1 – Fill and Stop
Size *Constant*	The size to make the data table. The number of data sets (records) for which to allocate memory in the CF card. Each time a variable or interval trigger occurs, a line (or row) of data is output with the number of values determined by the Output Instructions within the table. This data is called a record.
	Note Enter –1000 and the size of the table on the card will match the size of the internal table on the datalogger Enter any other negative number and all remaining memory (after creating any fixed size data tables) will be allocated to the table or partitioned among all tables with a negative value for size. The partitioning algorithm attempts to have the tables full at the same time.

7.2.2 Program Examples

7.2.2.1 Ring Mode

The following program outputs the maximum and minimum of the panel temperature to the card once a second. The first parameter of the **CardOut()** instruction is 0, which sets the table on the card to ring mode. The second parameter is negative, so all available memory on the card will be allocated to the data table. Once all available memory is used, new data will begin overwriting the oldest data.

PROGRAM

```
'CR1000

Public temp

DataTable (Table1,1,-1)
    CardOut (0, -1)
    Maximum (1,temp,FP2,False,False)
    Minimum (1,temp,FP2,False,False)
EndTable

BeginProg
    Scan(1,SEC,3,0)
        PanelTemp(temp,250)
        CallTable Table1
    NextScan
EndProg
```

7.2.2.2 Fill and Stop Mode

The following program outputs a sample of the panel temperature to the card once a second. The first parameter of the **CardOut()** instruction is 1, which sets the table on the card to fill and stop mode. The second parameter (1000) is the number of records which will be written before the table is full and data storage stops. Once 1000 records have been stored, data storage will stop.

PROGRAM

```
'CR1000

Public temp

DataTable (Table1,1,1000)
    CardOut (1,1000)
    Sample(1,temp,IEEE4)
EndTable

BeginProg
    Scan(1,SEC,3,0)
        PanelTemp(temp,250)
        CallTable Table1
    NextScan
EndProg
```

To reset a table after a fill and stop table has been filled and stopped, either use the reset button in LoggerNet (LN Connect | Datalogger | View Station Status | Table Fill Times, Reset Tables button) or use the CRBasic **ResetTable** instruction.

7.2.2.3 Mixed Modes

The following program stores four data tables to the card. The first two tables will output samples of the panel temperature and battery voltage to the card once a second. The first parameter of the **CardOut()** instructions is 1, which sets the tables on the card to fill and stop mode. The second parameter is 1000, so 1000 records will be written to each table before stopping.

Tables 3 and 4 will output the maximum and minimum of the panel temperature and battery voltage to the card once every five seconds. (The tables will be called once a second. The **DataInterval()** instruction causes data to only be stored every five seconds.) The first parameter of the **CardOut()** instructions is 0, which sets the tables on the card to ring mode. The second parameter is negative, so all available memory on the card will be allocated to these tables, once space for the fixed-size tables has been allocated. The datalogger will attempt to size the tables so that both of them will be full at the same time.

PROGRAM

```
'CR1000

Public temp
Public batt

DataTable (Table1,1,-1)
    CardOut (1,1000)
    Sample(1,temp,IEEE4)
EndTable

DataTable (Table2,1,-1)
    CardOut (1,1000)
    Sample(1,batt,IEEE4)
EndTable

DataTable (Table3,1,1000)
    DataInterval(0,5,sec,4)
    CardOut (0 ,-1)
    Maximum (1,temp,FP2,False,False)
    Minimum (1,temp,FP2,False,False)
EndTable

DataTable (Table4,1,1000)
    DataInterval(0,5,sec,4)
    CardOut (0 ,-1)
    Maximum (1batt,FP2,False,False)
    Minimum (1,batt,FP2,False,False)
EndTable
```

```
BeginProg
    Scan(1,SEC,3,0)
        PanelTemp(temp,250)
        Battery(Batt)
        CallTable Table1
        CallTable Table2
        CallTable Table3
        CallTable Table4
    NextScan
EndProg
```

7.2.3 Table Size and Mode

The size of each data table in CPU memory is set as part of the **DataTable()** instruction and the size of each data table on the CF card is set with the **CardOut()** instruction. Because they are set independently, they can be different. It is important to note that if the CPU memory is set to fill and stop mode, once a table is full, all data storage to the table will stop. No more records will be stored to the CPU memory or the card.

7.3 Data Retrieval

Data stored on CF cards can be retrieved through a communication link to the datalogger or by removing the card and carrying it to a computer.

7.3.1 Via a Communication Link

Data can be transferred to a computer via a communications link using one of Campbell Scientific's datalogger support software packages (e.g., PC200, PC400, LoggerNet). There is no need to distinguish whether the data is to be collected from the CPU memory or a CF card. The software package will look for data in the CPU memory and then the CF card.

The datalogger manages data on a CF card as final storage table data, accessing the card as needed to fill data collection requests initiated with the Collect button in datalogger support software. If desired, binary data can be collected using the File Control utility in datalogger support software. Before collecting data this way, stop the datalogger program to ensure data are not written to the CF card while data are retrieved. Otherwise, data corruption and confusion will result.

7.3.2 Transporting CF Card to Computer

With large files, transferring the CF card to a computer may be faster than collecting the data over a link.

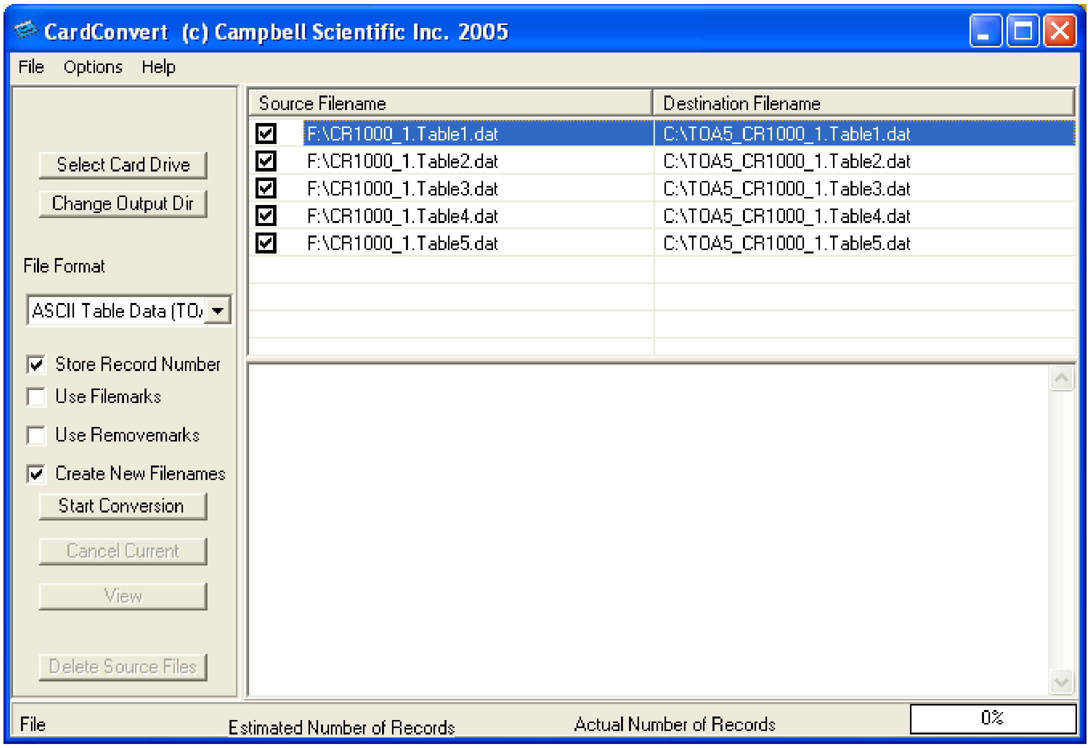
CAUTION Removing a card while it is active can cause garbled data and can actually damage the card. Do not switch off the CR1000 power if a card is present and active.

To remove a card, press the control button on the CFM100. The CR1000 or CR3000 will transfer any buffered data to the card and then power off. The Status LED will turn green when it is OK to remove the card. The card will be reactivated after 20 seconds if it is not removed.

When the CF card is inserted in a computer, the data files can be copied to another drive or used directly from the CF card just as one would from any other disk. In most cases, however, it will be necessary to convert the file format before using the data.

7.3.2.1 Converting File Formats

Files can be converted using LoggerNet's CardConvert. Begin by using "Select Output Drive" to indicate where the files to be converted are stored. Then use "Change Output Dir" to choose where you would like the converted files to be stored. Place check marks next to the files to be converted. A default destination filename is given. It can be changed by right-clicking with the filename highlighted. Use the drop-down to select what file format to convert to. Then press "Start Conversion" to begin converting files. Green checkmarks will appear next to each filename as conversion is complete.



7.3.2.2 Reinserting the Card

If the same card is inserted again into the CFM100, the datalogger will store all data to the card that has been generated since the card was removed that is still in the CPU memory. If the data tables have been left on the card, new data will be appended to the end of the old files. If the data tables have been deleted, new ones will be generated.

NOTE Check the status of the card before leaving the datalogger. If a CF card was not properly accepted, the CFM100 will flash orange. In that case, the user needs to reformat and erase all data contained on the CF card. Formatting or erasing a CF card might be done on a PC or datalogger. The procedure for formatting a CF card is explained in Section OV5 of the CR1000 and CR3000 manuals.

7.3.2.3 Card Swapping

When transporting a CF card to a computer to retrieve data, most users will want to use a second card to ensure that no data is lost. For this method of collection, use the following steps.

1. Insert formatted card ("CF-A") in CFM100 attached to datalogger.

2. Send program containing **CardOut()** instruction(s).

3. When ready to retrieve data, press CFM100 button to remove card. LED will show red while the most current data is stored to the card and then go green. Eject card, while LED is green.

4. Put in clean card ("CF-B").

5. Use CardConvert to copy data from CF-A to PC and convert. The default CardConvert filename will be TOA5_*stationname_tablename*.dat Once the data is copied, use Windows Explorer to delete all data files from the card. NOTE: Windows98 and WindowsME users need to shift-delete to completely delete files. Using standard delete may create an invisible recycle bin on the CF card.

6. At the next card swap, eject CF-B and insert the clean CF-A.

7. Running CardConvert on CF-B will result in separate data files containing records since CF-A was ejected. CardConvert can increment the filename to TOA5_*stationname_tablename*_0.dat.

8. The data files can be joined using a software utility such as WordPad or Excel.

CardConvert File	CF-A Record Numbers	CF-B Record Numbers
TOA5_*tablename*.dat	0-100	
TOA5_*tablename*.dat		101-1234
TOA5_*tablename*.dat	1235-….	

Appendix A. Formatting CF Card

The CF card can be formatted using 1) Windows Explorer, 2) the CR1000KD or 3) LoggerNet File Control.

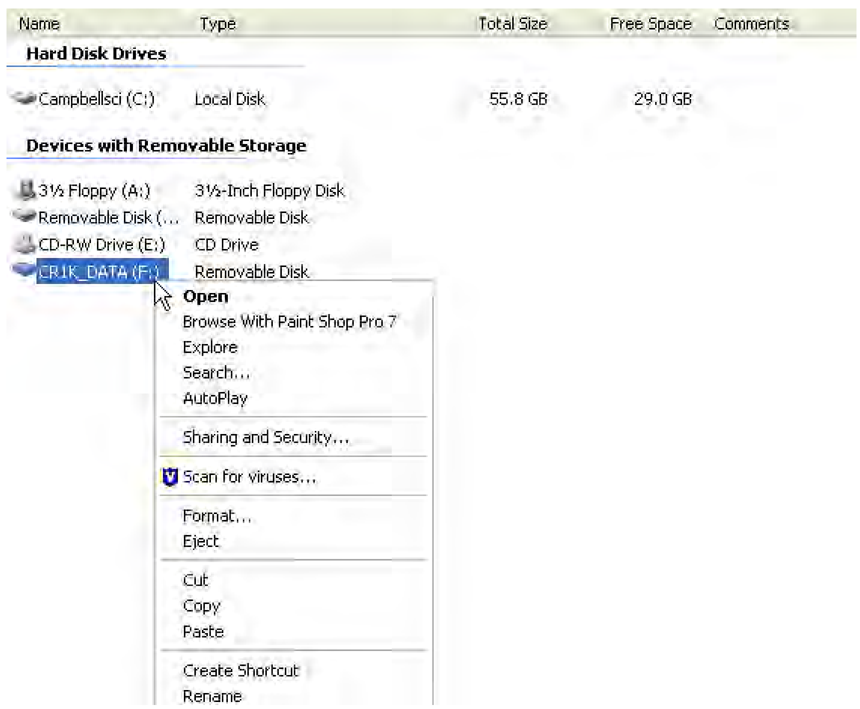
A.1 Windows Explorer

To format card using Windows Explorer:

1) Insert CF card into CF adapter or CF reader.

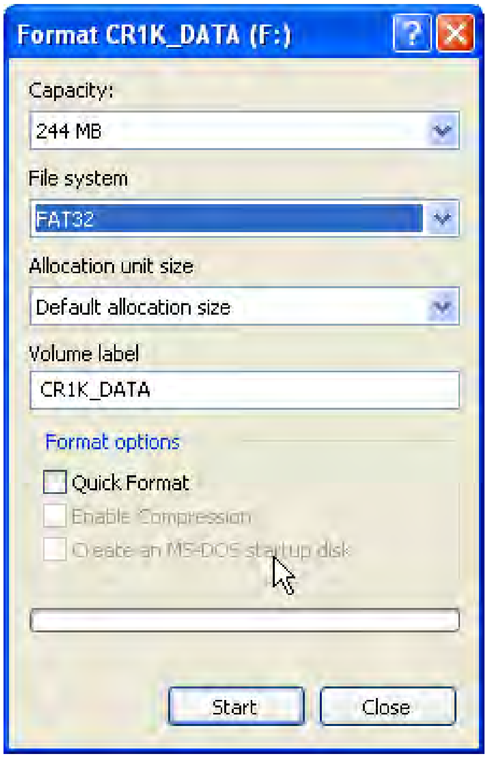
2) Windows Explorer should identify a drive as a removable disk (F:\).

3) Select that drive and right click.



4) Choose Format.

5) Choose FAT32 under file system, give the card a label, then Start. (The CR1000 will work with either FAT or FAT 32.)



A.2 CR1000KD

To format card using the CR1000KD:

1) Insert CF card into CFM100.

2) From Main Menu of CR1000KD, choose PCCard.

3) Choose Format Card..

4) Choose Yes to proceed.

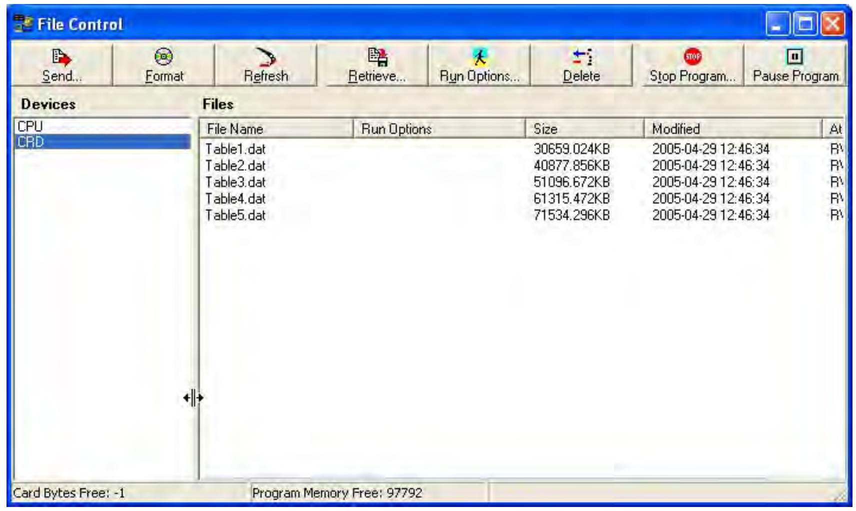
A.3 LoggerNet File Control

To format card using LoggerNet File Control:

1) Insert CF card into CFM100.

2) Use LoggerNet to connect to datalogger

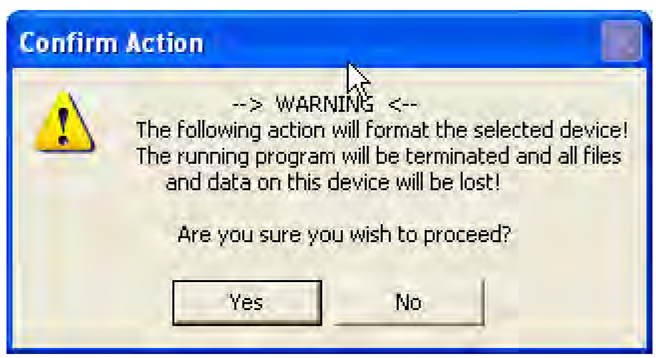
3) Choose FileControl under the Tools menu of the Connect screen.



4) Highlight CRD.

5) Press Format.

6) Press Yes to confirm.



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Appendix A3 - Digital Inclinometer Probe

Digitilt Inclinometer Probe

Applications

Digitilt® inclinometers are used to monitor subsurface movements of earth in landslide areas and deep excavations. They are also used to monitor deformations in structures such as dams and embankments.

Operation

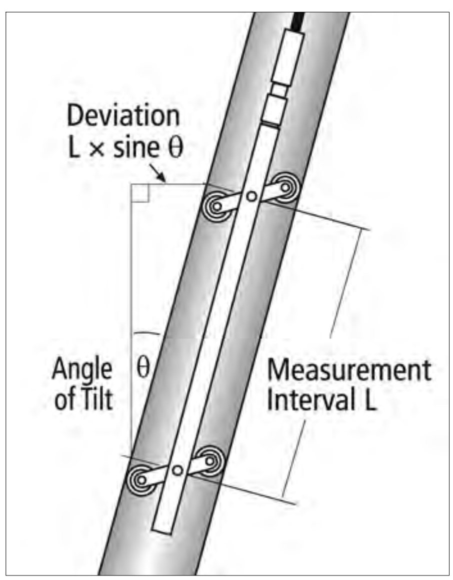
Inclinometer casing is typically installed in a vertical borehole that passes through suspected zones of movement into stable ground. The Digitilt inclinometer probe, control cable, pulley assembly, and readout are used to survey the casing. The first survey establishes the initial profile of the casing. Subsequent surveys reveal changes in the profile if ground movement occurs.

During a survey, the probe is drawn upwards from the bottom of the casing to the top, halted in its travel at 0.5 m or 2' intervals for tilt readings.

The inclination of the probe body is measured by two force-balanced, servo-accelerometers. One accelerometer measures tilt in the plane of the inclinometer wheels, which track the longitudinal grooves of the casing. The other accelerometer measures tilt in the plane perpendicular to the wheels.

Inclination measurements are converted to lateral deviations, as shown in the drawing below. Changes in deviation, determined by comparing current and initial surveys, indicate ground movement.

Plotting changes in deviation yields a high resolution displacement profile. Displacement profiles are useful for determining the magnitude, depth, direction, and rate of ground movement.



Advantages

Proven Performance: Digitilt inclinometer probes have earned a world-wide reputation for durability, high precision, and rapid response.

Repeatable Tracking: To ensure consistent tracking in all types of casing, the probe is equipped with robust wheel carriages, sealed wheel bearings, and specially designed wheels.

Extended Installation Life: The compact size of the Digitilt probe allows it to pass through small radius curves, extending the useful life of the installation beyond that provided by other inclinometer probes.

Computerized Testing: Each probe undergoes thorough testing on a computerized calibration table.

Reliable Control Cable: Digitilt control cable is durable and easy to handle, stays flexible in cold weather, resists chemicals and abrasion, and provides excellent dimensional stability. Flexible rubber depth marks are permanently vulcanized to the cable jacket. The marks cannot loosen and have no rigid edges that can damage the cable jacket and conductors.

Consistent Depth Control: The pulley assembly, a recommended accessory, helps the operator achieve uniform depth control. The one-way action of its cable clamp ensures consistent positioning of the probe.

Complete Solutions: Slope Indicator's inclinometer system includes high-quality casing, vertical and horizontal traversing probes, vertical and horizontal in-place sensors, recording readouts, graphing software, and specialized accessories.

DIGITILT INCLINOMETER PROBE

Metric-Unit Probe 50302510
English-Unit Probe 50302500

Digitilt inclinometer probe includes a carrying case and instruction manual. Control cable, pulley, and readout are not included.

METRIC PROBE SPECIFICATIONS

Wheel base: 500 mm.
Range: ±53° from vertical.
Resolution: 0.02 mm per 500 mm.
Repeatability: ±0.01% FS.
Calibration: 14 point calibration with NIST traceable calibration device.
Temperature Rating: -20 to +50 °C.
Dimensions: 25.4 x 653 mm. Control cable connector adds 92 mm to length of probe.
Weight: 1.8 kg.
Material: Stainless steel.

ENGLISH PROBE SPECIFICATIONS

Wheel base: 24".
Range: ±35° from vertical.
Resolution: 0.0012 inch per 24 inches.
Repeatability: ±0.01%FS.
Calibration: 14 point calibration with NIST traceable calibration device.
Temperature Rating: -4 to +122 °F.
Dimensions: 1 x 30". Control cable connector adds 3.75"to length of probe.
Weight: 4 lb.
Material: Stainless steel.

ACCURACY SPECIFICATIONS

Metric Systems: ±0.25 mm per reading and ±6 mm per 50 readings.

English Systems: ±0.01 inch per reading and ±0.3 inch per 50 readings.

These system accuracy specifications were derived empirically from the analysis of a large number of surveys and include both random and systematic errors introduced by casing, probe, cable, readout, and operator. Casing was installed within 3 degrees of vertical, and operators followed recommended reading practices.

When corrections for systematic error are made, the remaining error is random. It accumulates with the square root of the number of readings. Thus the best precision obtainable with a metric system is approximately ±1.4 mm per fifty readings, and the best precision of an English unit system is approximately ±0.05 inch per fifty readings.

CONTROL CABLE

30m Control Cable, Complete . . . 50601030
50m Control Cable, Complete . . . 50601050
100m Control Cable, Complete . . 50601100

100 ft Control Cable, Complete . . 50601002
150 ft Control Cable, Complete . . 50601003
300 ft Control Cable, Complete . . 50601004

Metric Cable, Custom Length. . . . 50601010
English Cable, Custom Length . . . 50601000
Connector for Readout 50301800
Connector for Probe. 50303100

Control cables listed as complete are standard lengths of cable and include connectors. If you order a custom length cable, you must also order connectors.

Control cable is supplied with no splices or surface defects and has a rated strength of 480 lb and a working strength of 120 lb.

Metric cable is graduated with yellow 0.5-meter marks and red 1-meter marks. English cable is graduated with yellow 2-foot marks and red 10-foot marks.

Cable has a steel core wire to control stretching, a dacron torsion braid to counter cable torque and eliminate slipping of cable jacket relative to the steel core, and depth marks that are molded onto the cable jacket. The Santoprene cable jacket resists chemicals and abrasions and stays flexible in cold temperatures.

PULLEY ASSEMBLY

Small Pulley 51104604
Large Pulley 51104606

Pulley assembly clamps onto top of casing to help operator control depth of probe. Cable clamp serves as reference for depth marks. Clamp is made of carbon-fiber and does not freeze in cold weather. Removable pulley wheel facilitates insertion of probe into casing.

Use small pulley with 48 or 70 mm (1.9 or 2.75") casing. Use large pulley with 70 or 85mm (2.75 or 3.34") casing.

READOUTS

Digitilt DataMate II. 50310900

The Digitilt DataMate II is a recording readout. The Digitilt 09 is a manual readout. See separate data sheets for details.

DUMMY PROBE

Metric Wheel Base 50304810
English Wheel Base. 50304800
Reel & Line for Dummy Probe 50304900

Dummy probe is used to test for casing continuity, groove continuity, and obstructions or severe distortions of casing that could hinder retrieval of Digitilt probe and control cable. Dummy probe is stainless steel and has dimensions and wheels identical to those of Digitilt probe.

Reel with 60 m (200') of nylon line is used to lower and retrieve dummy probe.

SLIP-RING REEL

200 m (650') capacity 50503100
300 m (1150') capacity 50503300

Slip-ring cable reel allows the readout to remain connected while the reel is operated. Includes jumper cable to connect reel to readout.

STORAGE REEL

30m (100') capacity. 50502030
70 m (230') capacity 50502050
100 m (360') capacity 50502110

Sturdy storage reel with large diameter hub keeps cable neat when not in use.

Note: The use of reels is optional. Cable can also be stored in a figure-8 or using the over-under method of coiling cable, as presented in the manual. If you choose to use a reel, be sure that the hub of the reel has a diameter of eight inches or larger (as do the reels above). Power reels should be sixteen inches or larger.

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Digitilt Inclinometer Probe 50302599

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NOVA METRIX

Contents

Introduction

Inclinometer System

An inclinometer system includes inclinometer casing, an inclinometer probe and control cable, and an inclinometer readout unit.

Inclinometer casing is typically installed in a near-vertical borehole that passes through a zone of suspected movement. The bottom of the casing is anchored in stable ground.

The inclinometer probe is used to survey the casing and establish its initial position. Ground movement causes the casing to move away from its initial position. The rate, depth, and magnitude of this movement is calculated by comparing data from the initial survey to data from subsequent surveys.

This Manual

This manual addresses the use and maintenance of the inclinometer probe and control cable. It also provides an overview of taking readings and reducing data.

Other manuals cover casing installation, inclinometer readouts, and software for reducing data.

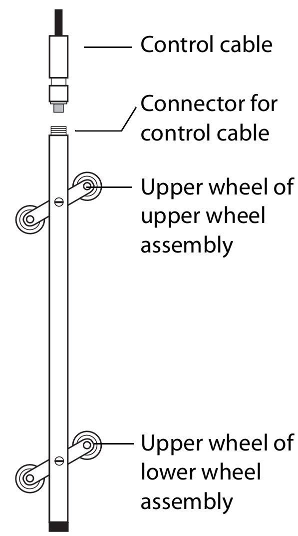
The Inclinometer Probe

Parts of the Probe

The inclinometer probe consists of a stainless steel body, a connector for control cable, and two pivoting wheel assemblies.

When properly connected to the control cable, the probe is waterproof and has been used deeper than 1000 feet.

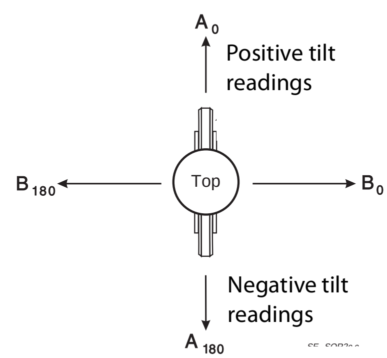
The wheel assemblies consists of a yoke and two wheels. One of the wheels in each assembly is higher than the other. This wheel is called the "upper wheel" and has special significance, as explained below.



Measurement Planes

The inclinometer probe employs two force-balanced servo-accelerometers to measure tilt. One accelerometer measures tilt in the plane of the inclinometer wheels. This is the "A"axis. The other accelerometer measures tilt in the plane that is perpendicular to the wheels. This is the "B" axis.

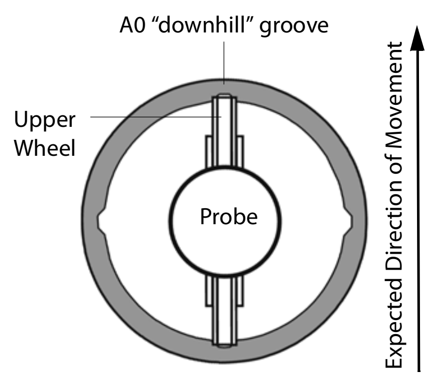
The drawing at right shows the probe from the top. When the probe is tilted toward the A0 or B0 direction, readings are positive. When the probe is tilted in the A180 or B180 directions, readings are negative.



Orientation of the Probe

Inclinometer casing is installed so that one set of grooves is aligned with the expected direction of movement. One groove, typically the "downhill" groove should be marked A0.

In a standard inclinometer survey, the probe is drawn from the bottom to the top of the casing two times. In the first pass, the upper wheels of the probe should be inserted into the A0 groove. This ensures that movements are positive values.



Always start surveys with upper wheel in A0 groove.

Handling the Probe

The inclinometer probe is a sensitive measuring instrument. Handle it with care.

- Transport the probe in its carrying case. If you drive to the site, carry the casing in the passenger compartment, preferrably on a passenger seat.
- When you connect control cable to the probe, avoid overtightening the nut, since this will flatten the O-ring and reduce its effectiveness.
- Before you lower the probe into the casing, turn the power on.
- When you insert the probe into the casing, cup the wheels with your hands to compress the springs and allow smooth insertion.
- When you lower the probe into the borehole, do not allow it to strike the bottom.
- When you withdraw the probe from the casing, again cup the wheels with your hands to prevent them from snapping out.
- When you rotate the probe, keep it upright and perform the rotation smoothly.
- The probe is rated for temperatures from -20 to 50 °C (-4 to 122 °F). Avoid using the probe in temperatures outside this range.

Caring for the Probe

This is an overview. See the last chapter, Inspection and Maintenance, for additional information.

Cleaning the Probe: When you finish a survey, wipe moisture off the probe and replace the protective cap. If necessary, rinse the probe in clean water or wash it with a laboratory grade detergent when you return to the office.

Cleaning the Connectors: Do not clean connectors with spray lubricants or electrical contact cleaners. Solvents in these products will attack the neoprene inside the connector. When it is necessary to clean the connectors, use a cotton swab slightly moistened with alcohol. Be careful to use only a small amount of alcohol.

Drying the Probe: When you return to the office, remove protective caps from the control cable, probe, and readout unit. Allow connectors to air-dry thoroughly for a number of hours. Afterwards, replace the caps.

Storing the Probe: The probe, control cable, and readout unit should be stored in a dry place. For extended storage, keep the probe in a vertical position.

Lubricating the Wheels: Lubricate the wheels regularly. Spray a small amount of lubricant or place a drop of oil on both sides of the wheel bearings. Check that the wheels turn smoothly.

O-Ring Care: Periodically clean and lubricate the O-ring on the connector end of the inclinometer probe. Use O-ring lubricant.

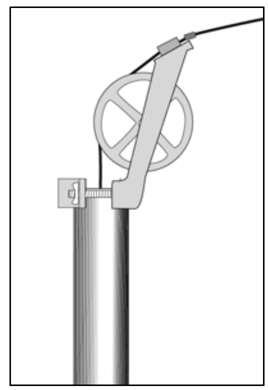
Control Cable

Introduction

Control cable is used to control the depth of the inclinometer probe. It also conducts power to the probe and returns signals to the readout.

- Metric control cables are graduated with yellow marks at 0.5 meter intervals and red marks at 1-meter intervals. There are numeric marks at 5-meter intervals.
- English control cables are graduated with yellow markers at 2-foot intervals and red marks at 5-foot intervals. There are numeric marks at 50-foot intervals. In addition, there are yellow bands of tape at 10 foot intervals. Each band represents 10 feet from the last numeric mark. For example, 4 bands represent 40 feet from the last numeric depth mark.

Depth Control



Accurate inclinometer measurements depend on consistent placement of the inclinometer probe. Always align the depth marks on the control cable with the same reference. Aim for placement repeatability of 6 mm (1/4 inch) or better.

We recommend using a pulley assembly to assist with depth control. The jam cleat on the pulley assembly holds the cable and the top edge of the chassis provides a convenient reference for cable depth marks.

The small pulley assembly is used with 48 mm and 70 mm casing (1.9 and 2.75 inch). The large pulley assembly is used with 70 mm and 85 mm casing (2.75 and 3.34 inch).

Using the Pulley Assembly

1. Remove the pulley from the chassis.
2. Clamp the chassis to the top of the casing.
3. Insert the inclinometer probe and control cable.
4. Replace the pulley.

Note: The distance between the top edge of the pulley chassis and the top of the casing is one foot. Your data reduction software can automatically adjust for this, so keep your survey procedure simple: use the marks on the cable and the top edge of the pulley chassis for reference. Let the software do any extra work required.

Check that operators consistently use the pulley assembly. If the pulley is used for one survey and not for the next, the resulting data sets will not be directly comparable. Sometimes a monument case or a protective pipe makes it impossible to attach the pulley assembly to the casing. In this case, you can make a removable adapter for the pulley assembly. If you use an adapter, be sure to use it consistently.

Cable Tips

Connecting Cable: When you connect control cable to the probe, avoid overtightening the nut, since this will flatten the O-ring and reduce its effectiveness.

Calibrate your Cable: If you have time, "calibrate" your cable, recording the exact position of cable marks. This can be important for long term monitoring projects.

Caring for Cable

Cleaning the cable: If necessary, rinse the cable in clean water or wash the cable in a laboratory-grade detergent, such as Liquinox.® Do not use solvents to clean the cable. Be sure the protective cap is in place before immersing the end of the cable in water. Do not immerse the Lemo connector.

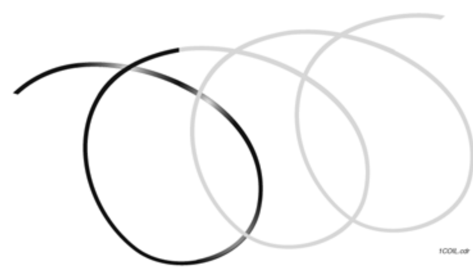
Cleaning Connectors: If it is necessary to clean the connector, use a cotton swab moistened with a small amount of alcohol. Do not use spray lubricants or electric contact cleaners. Solvents contained in such products will attack the neoprene inserts in the connectors.

Drying Connectors: When you return to the office, remove protective caps from the control cable, probe, and readout unit. Allow connectors to air-dry well for a number of hours.

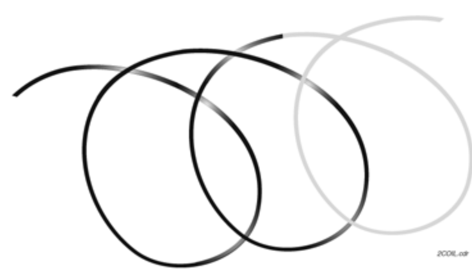
Storage: Store cable on a cable reel when possible. The reel should have a minimum hub diameter of 300 mm (12 inches). If a reel is not available, use the technique below to coil the cable.

Coiling Cable

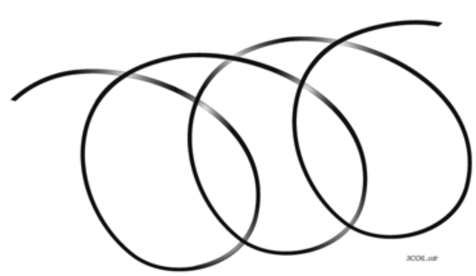
1. Loop cable forward as shown in drawing.



2. Twist cable backwards to make a second loop as shown in drawing.



3. Continue coiling cable, alternating loops as in steps 1 and 2.



Taking Readings

Good Practices

- Use the same probe and control cable for each survey, if possible.
- Use a pulley assembly, if possible. It protects the control cable and provides a good reference.
- Use a consistent top reference. The goal is placement repeatability within 5 mm or 1/4 inch. If one technician uses a pulley and another technician does not, probe positioning will be inconsistent, and data will have to be manipulated before it is useful.
- Always draw the probe upward to the reading depth. If you accidentally draw the probe above the intended depth, lower the probe down to the previous depth, then draw it back up to the intended depth. This technique ensures the probe will be positioned consistently.
- Wait 10 minutes for the probe to adjust to the temperature of the borehole.
- Wait for displayed readings to stabilize as much as possible. If the readings do not stabilize, try to record an average reading.

Setting Up

1. When you arrive at the site, lay out a plastic sheet or tarp to set the equipment on. You should have the inclinometer probe, the indicator, the control cable, and the pulley assembly. Some people find it is useful to bring a basket or box to hold the control cable and a rag to wipe off the probe and cable after readings have been taken.
2. Unlock and remove the protective cap from the casing. Attach the pulley assembly.
3. Remove protective caps from probe and control cable.
4. Align the connector key with the keyway in the probe. Then insert the connector and tighten the nut to secure the connection. Do not over-tighten the nut, since this will flatten the O-ring and reduce its effectiveness.

Position the Probe

1. Turn on the indicator. This energizes the accelerometers, making them less susceptible to shock.
2. Insert the probe into the casing with the upper wheels of both wheel assemblies in the A0 groove. (Cup the wheels with your hands to compress the springs for a smooth insertion). If you are using the pulley assembly, take out the pulley wheel, insert the probe, and then replace the wheel.
3. Lower the probe slowly to the bottom. Do not allow it to strike the bottom. Allow the probe to adjust to the temperature inside the casing. Five or ten minutes is usually sufficient.

Record Data

1. Raise the probe to the starting depth. Wait for the numbers on the readout to stabilize. If you are using the DataMate, press the button to record both the A and B axis readings. If you are using a manual indicator, write down the A-axis reading, then switch to the B-axis and record that reading.
2. Raise the probe to the next depth. Wait for a stable reading, and then record it. Repeat this process until the probe is at the top of the casing.
3. Remove the probe and rotate it 180 degrees, so that the lower wheels of both wheel assemblies are inserted into the A0 groove. When you remove the probe, cup the wheels with your hands to prevent them from snapping outwards. Also, hold the probe upright when rotating it.
4. Lower the probe to the bottom, raise it to the starting depth, and continue the survey. Take readings at each depth until you have reached the top. Remove the probe. At this point, you may want to validate the data set and make any corrections necessary.

Leaving the Site

Wipe off the probe and cable. Replace end-caps on cable and probe and return the probe to its protective case. Replace the indicator's protective plugs. Coil the cable. Remove the pulley assembly and replace and lock the protective cap.

At the Office

Wipe off the indicator and recharge its batteries. Transfer the data set to a PC. Oil the probe wheels. If the storage place is dry, remove protective caps from probe, indicator, and control cable to allow all connectors to dry.

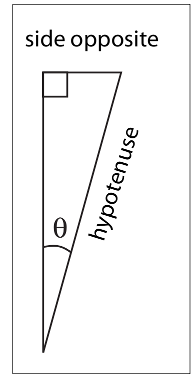
Data Reduction

Inclinometer Measurements

The inclinometer probe measures tilt, rather than lateral movement. How does tilt provide information about lateral movement? The basic principle involves the sine function, an angle, and the hypotenuse of a right triangle. We are interested in the length of the side opposite the angle θ.

$$\sin\theta = \frac{\text{side opposite}}{\text{hypotenuse}}$$

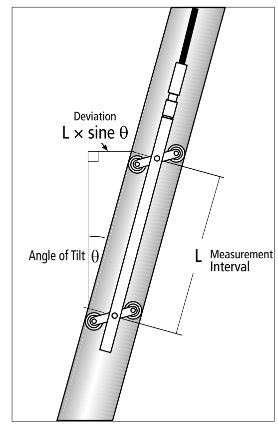
$$\text{side opposite} = \text{hypotenuse} \times \sin\theta$$



Deviation

In the drawing at right, the hypotenuse of the right triangle is the measurement interval. The measurement interval is typically 0.5 m with metric-unit inclinometers or 2 feet with English-unit inclinometers.

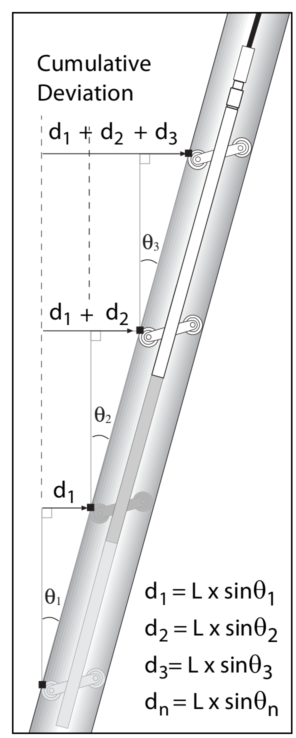
The side opposite the angle of tilt is deviation. It is calculated by multiplying the sine of the angle of tilt by the measurement interval. This calculation translates the angular measurement into a lateral distance and is the first step to calculating lateral movement.



Cumulative Deviation

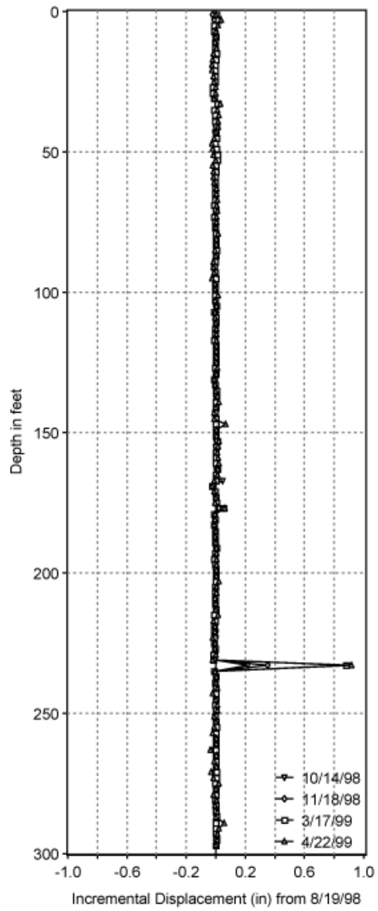
By summing and plotting the deviation values obtained at each measurement interval, we can see the profile of the casing.

The black squares at each measurement interval represent cumulative deviation values that would be plotted to show the profile of the casing.

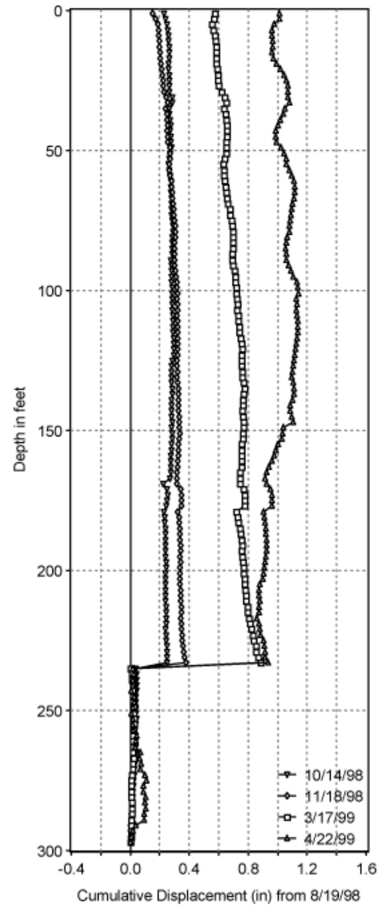


Displacements

Changes in deviation are called displacements, since the change indicates that the casing has moved away from its original position. When displacements are summed and plotted, the result is a high resolution representation of movement.



Incremental displacement plot shows movement at each measurement interval. The growing "spike indicates a shear movement.



Cumulative displacement plot shows a displacement profile. Displacements are summed from bottom to top.

Reducing Data Manually

Normally, computer software is used to reduce inclinometer data. Here, we show only a simple overview.

Displayed Readings

Slope Indicator's readouts display "reading units" rather than angles or deviation. Reading units are defined below:

$$\text{Displayed Reading} = \sin\theta \times \text{Instrument Constant}$$

$$\text{Reading}_{\text{English}} = \sin\theta \times 20{,}000$$

$$\text{Reading}_{\text{Metric}} = \sin\theta \times 25{,}000$$

Combining Readings

The standard two-pass survey provides two readings per axis for each interval. The probe is oriented in the "0" direction for the first reading and in the "180" direction for the second reading. During data reduction, we find the algebraic difference of the two readings, and then we divide by 2, since there were two readings. Use of the algebraic difference lets us preserve the direction of the tilt, as indicated with a positive or negative sign.

$$\text{A0 Reading} = 359 \qquad \text{A180 Reading} = -339$$

$$\frac{\text{Algebraic Difference}}{2} = \frac{359 - (-339)}{2} = 349$$

Calculating Deviation

To calculate lateral deviation, we find the algebraic difference of the two readings, divide by 2, divide by the instrument constant, and multiply by the measurement interval. In the example below, the English-unit measurement interval is 24 inches and the English-unit instrument constant is 20,000.

$$\text{Lateral Deviation} = \text{Measurement Interval x} \sin\theta$$

$$= 24 \text{ inches} \times \frac{359 - (-339)}{2 \times 20,000}$$

$$= 0.4188 \text{ inches}$$

Find the algebraic difference of the A0 & 180 readings and divide by 2.

Divide reading unit by instrument constant to obtain sine of angle.

Calculating Displacement

Displacement, the change in lateral deviation, indicates movement of the casing. To calculate displacement, we need two surveys. We subtract the algebraic difference of the initial reading from the algebraic difference of the current reading, divide by 2 x the instrument constant, and multiply by the length of the measurement interval.

$$\text{Algebraic Difference}_{\text{current}} = 700 \qquad \text{Algebraic Difference}_{\text{initial}} = 698$$

$$\text{Displacement} = \text{Measurement Interval} \times \Delta\sin\theta$$

$$= 24 \text{ inches} \times \frac{700 - 698}{2 \times 20,000}$$

$$= 0.0012 \text{ inches}$$

Calculating Checksums

A checksum is the sum of a "0" reading and a "180" reading at the same depth.

A0 reading = 359   A180 reading = -339

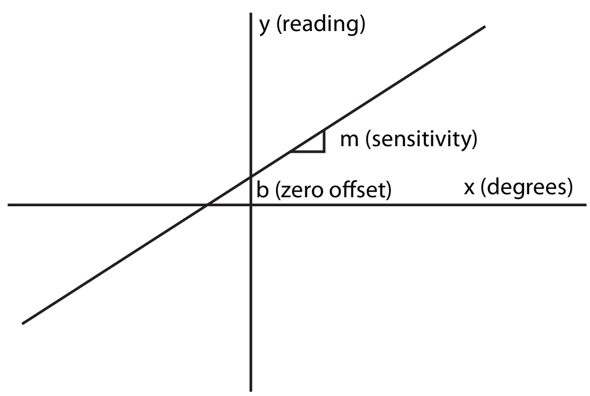
Checksum = 359 + (-339)

= 20

Bias (zero offset)

If you hold your inclinometer probe absolutely vertical and check the reading, you will typically see a non-zero value for each axis. The non-zero value is the result of a slight bias in the output of the accelerometers. The bias (or zero offset) may be negative or positive and will change over the life of the probe. This is not normally a matter for concern, because the zero offset is effectively eliminated by the standard two-pass survey and the data reduction procedure.

Below, we show an readings that have a zero offset of 10. During the first pass the probe measures a tilt of 1 degree. During the second pass the probe measures a tilt of -1 degree, because it has been rotated 180 degrees. See how the offset increases the positive reading and decreases the negative reading, even though the measured angle has not changed. However, when the two readings are combined, as discussed in "Combining Readings" above, the offset is eliminated and the correct value emerges.



Tilt angle = 1 degree.   Theoretical reading unit = 349   (20,000 x sin (1))

Offset = 10

Displayed A0 reading = 359   (349 + 10)

Displayed A180 reading = -339   (-349 + 10)

Algebraic Difference = 698   (359 - (-339))

$$\frac{\text{Algebraic Difference}}{2} = 349$$

Inspection & Maintenance

Probe Inspection

Part	What to check for	Remedy
Wheel yoke	Side to side movement	Check pivot pin, which looks like screw. If pivot pin has been turned too far, it may spread the wheel yoke. Turn the pivot pin counter-clockwise to see if movement disappears. If movement persists, replace the nylon spacers or the entire wheel assembly. The wheel assembly can be replaced by the user: kit number 50302555.
Wheel yoke	Yoke does not return to fully extended position.	If yoke is dirty, clean it. If problem persists, spring may be broken or weak. Replace spring and roll pins or replace wheel assembly using kit 50302555.
Wheel	Side to side movement	Bad bearing. Replace wheel assembly.
Wheel	Does not turn freely	Lubricate. If movement is still bad, replace wheel assembly.
Body screws	Loose screws, wobble in body, loose bumper	Tighten screws. (Do not tighten pivot pin).
Connector keyways	Wear, corrosion	Worn keyway may degrade O-ring seal. Learn how to connect cable without "hunting." Remove corrosion and change practice - allow connector to dry after use.
Connector O-ring	Flattened, split	Replace if flattened or split.
Connector pins	Bent pins	Bent pins are easily broken when straightened. Replacement of connector requires recuperation of probe (expensive). Change connection practice - no hunting.

Probe Maintenance

Moisture Management	Wipe off the control cable and probe when you finish the day's final survey, then wipe off the probe. Do not store wet cloth with the probe. Allow the connector to dry thoroughly: remove connector cap and allow connector to air-dry for a number of hours. Lubricate the wheels. This helps displace moisture.
Wheels	Lubricate the wheels by spraying a small amount of lubricant or placing drops of oil on both sides of the wheel bearings.
O-Ring	Lubricate regularly with O-ring lube or silicone based grease. Do *not* use WD-40 or any other lubricant spray that contains chlorinated solvents.
Connectors	Clean connectors as necessary. Use a slim cotton swab moistened with alcohol. Be careful not to bend pins. Do not use electrical contact cleaners, especially sprays. Solvents in these products will attack the neoprene inside the connectors. When attacked, the neoprene swells and reduces the effectiveness of the O-ring seal.
Storage	Store probe in dry place. Be sure that the box is dry, the wheels are oiled, the connector is dry. If probe is to be stored for an extended period, stand it vertically.

Control Cable Inspection

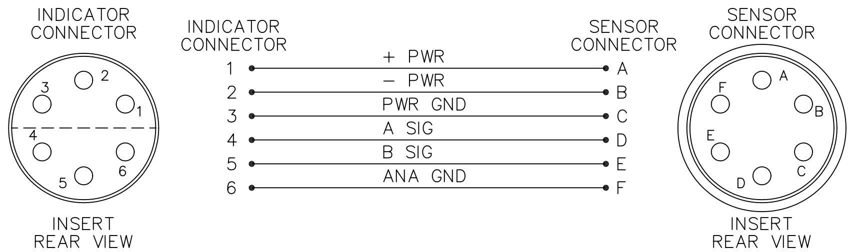
Part	What to check for	Remedy
Cable	Continuity	If you have intermittent failures, perform continuity tests. If a wire fails continuity test, you can check the Lemo connector or return cable for servicing or replacement.
Cable	Twists, worn markings, kinks, gouges	Twists indicate poor coiling technique. Change practice: use cable reel, figure-8 coils, or over-under coils. Worn markings: user is dragging cable over the edge of the casing. Change practice - but must keep consistent depths. Kinks: if kinks do not straighten, there is probably internal damage and likelihood of intermittent reading failures. If any deep gouges, water can enter cable. In both cases, bad section of cable must be removed, either by shortening the cable or replacing the cable.
Connector key	Wear, corrosion	Change connection practice - no hunting. Remove corrosion and change practice - allow connector to dry after use.
Connector rubber insert	Swelling, poor seal	Rubber swells when attacked by WD-40 or contact cleaners. Swelling may prevent good seal and allow water to enter connector. Return for service if sealing is compromised.
Connector for Indicator (Lemo)	Corrosion, bad connection.	Perform continuity check first. Then check this connector to eliminate as possible source of intermittent failures. Unscrew bottom nut, being careful not to twist cable. Slide shell off the end of the cable. Slide strain relief collet out of the way and inspect connections. Twist and pull wires gently. Good connections will not break. Repair as necessary.
Connector for Probe	Check O-ring	Do *not* disassemble this connector. Requires about two hours and a pressure test to reassemble.

Control Cable Maintenance

Moisture Management	Wipe off the control cable as you draw the probe up on the last run of the day. When you return to the office, remove connector caps and allow connectors to air-dry for a number of hours.
Cable	When necessary, rinse cable (but not connectors) in clean water or wash the cable in a laboratory-grade detergent, such as Liquinox. Do not use solvents to clean the cable.
Connectors	If it is necessary to clean the connector, use a cotton swab moistened with alcohol. Sockets can be cleaned with a brush. Do not use spray lubricants or electric contact cleaners. Solvents contained in such products will attack the neoprene inserts in the connectors.
Storing Control Cable	Improper coiling of any electrical cable twists conductors and can cause reliability problems. There are several ways to control twisting: • Use cable reel with hub diameter of at least 200mm or 8". • Coil cable in a figure-8. • Coil cable using over-under loops (2-foot diameter loops).

Control Cable Connectors

Below is the wiring diagram for the connectors on the control cable.



Testing

Connectors are made to mate with each other but not with any other objects. Never insert the probe of your multimeter into a socket. In making the measurements below, simply touch the probe to the top of the socket.

Continuity Test: Pin 1 to Pin A, Pin 2 to Pin B, etc, should measure a little less than 1 ohm per 30 m (100 feet).

Isolation Test: Pin to pin should measure infinity. Also any pin to the body of the connector should measure infinity.

Servicing

Use caution when attempting to service either connector.

The Lemo connector on the indicator end of the cable is easier to service. When you disassemble the connector, be sure that you do not twist the cables.

The heavy connector on the sensor (probe) end of the cable is more difficult to service. We recommend that you send it to the factory unless you are experienced and are willing to spend some time working with it.

Appendix A4 - Digitilt DataMate II

Digitilt DataMate II

Simple to operate, the compact Digitilt DataMate runs 16 hours on one charge, stores up to 320 surveys, and transfers data to a PC for processing.

The Digitilt DataMate II

The DataMate records data from inclinometer probes, tiltmeters, and spiral sensors. It stores up to 320 complete inclinometer surveys and can power a Digitilt inclinometer probe for 16 hours.

The DataMate II is compatible with the original DataMate but features updated electronics for faster operation, increased memory capacity, and a USB port for data transfers

The DataMate is designed for hard use in difficult environments. It has a bright, backlit display that is visible under all lighting conditions. The box is splashproof and sealed against humidity. In addition, all connectors are located on the top of the box, away from contact with mud, water, or snow.

Recording Surveys

The Digitilt DataMate stores a list of inclinometer installations in memory, so to begin a survey, the operator selects an installation from the list.

The DataMate then displays the starting depth for that installation, and the operator positions the probe at that depth.

The display shows the depth, the A-axis reading, and the B-axis reading. When both readings are stable, the DataMate displays a “ready” signal. The operator then records the reading, using the hand switch or the keypad. The DataMate beeps confirmation and then displays the next depth. The operator raises the probe to this depth, waits for the ready signal, and then records the readings, repeating these steps until the probe reaches the top of the casing. The DataMate then prompts the operator to rotate the probe 180 degrees and begin the second pass through the casing.

The operator can correct a mistake at any time by simply scrolling through the data to any depth, repositioning the probe, and continuing the survey from that point.

Validating Surveys

The DataMate provides checksum statistics to help the operator validate the survey. By comparing the mean and standard deviation of checksums for the current survey with those of previous surveys, the operator can be confident that the data are good.

The DataMate provides routines to help the operator identify questionable readings, which can then be corrected by repositioning the probe. The DataMate displays “live” and recorded readings side by side for comparison, and the operator can overwrite the recorded reading with the live reading, if appropriate.

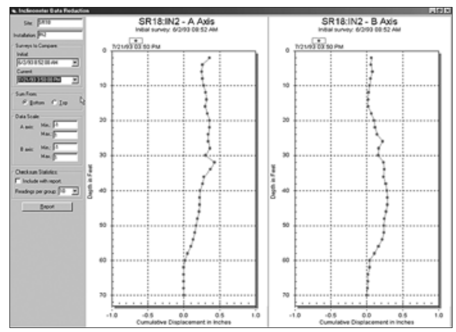
Convenient hand switch reduces fatigue and lets you keep the DataMate clear of the work area.

Retrieving Surveys

Returning to the office, the operator connects the DataMate to a PC, and then runs the DataMate Manager program. The manager program retrieves the recorded surveys and stores them in a database for easy access.

Processing Surveys

Slope Indicator inclinometer software eliminates repetitive work, ensures that calculations are performed accurately, and dramatically reduces the time required to process data.



DMM for Windows software lets you retrieve surveys and produce reports containing readings and graphics.

The DataMate Manager program is included with the DataMate. It can can print reports containing inclinometer readings, checksum statistics, and simple graphs. It also provides routines for settlement correction, spiral data set expansion, and bias shift analysis.

DigiPro for Windows is an optional graphing program that provides additional types of graphs, including some diagnostic plots, and a number of sophisticated correction routines. A trial version is available for download from the Slope Indicator web site.

DIGITILT DATAMATE II READOUT

Digitilt DataMate II 50310900

The Digitilt DataMate is a portable readout for Digitilt sensors. It provides depth prompts and stores readings in memory for transfer to a PC. Includes hand switch, battery charger, USB interface cable for PC, and CD with DMM for Windows and manual. Specify type of plug required for the charger. DigiPro software is not included.

Sensor Compatibility: English and metric versions of vertical and horizontal Digitilt inclinometer probes, tiltmeters, and spiral sensors.

Displayed Units: Metric indicator displays readings as 25000 x the sine of the angle of tilt. English indicator displays readings as 20000 x the sine of the angle of tilt.

Survey Types: 2-pass survey for inclinometer probes; 4-pass survey for spiral sensors.

Memory Capacity: Stores 160 installations and nominally 320 surveys of 100 depths each (a total of 32000 depths allocated to any number of surveys up to a maximum of 320).

Maximum Survey Depth: 500m or 2000 feet.

Reading Intervals: Fixed intervals. Minimum interval is 0.5 m with metric probe or 1 foot with English-unit probes.

Menu-Selected Functions

Record: Prompts operator with starting depth. Displays A and B axis readings. Displays ready signal when readings are stable. Displays next depth after readings are recorded.

Manual Read: Allows use of DataMate when memory is full or depth display is not required.

Validate: Calculates checksum statistics.

Correct: Allows user to correct mistakes.

Compare: Calculates a single value for cumulative deviation or cumulative displacement.

Comm: For communication with PC.

Print: Outputs ASCII data to a terminal program running on a non-DOS/Windows computer.

Operating Time: 16 hours @ 20°C (68°F) of continuous power to probe. Backup battery preserves data for six months.

Temperature Rating: -20 to 50°C (-4 to 122°F).

Display: 20 x 2 backlit LCD rated for extended temperatures.

Battery: 6 volt, 6 Ah, gelled electrolyte, lead-acid battery. Recharges to 80% capacity in 16 hours using the included charger.

Case: Splashproof, non-submersible, aluminum case with plastic shell. Connectors are waterproof when capped or in use.

Dimensions: 127 x 178 x 178 mm (5 x 7 x 7").

Weight: 3 kg (6.5 lb).

DMM FOR WINDOWS

DMM for Windows 50310970

The DataMate Manager program (DMM) transfers readings from Digitilt DataMate to a PC. DMM offers routines for checking surveys and maintaining the inclinometer database. DMM is supplied on a Resource CD with the purchase of the Digitilt DataMate. It can also also be downloaded free from www.slopeindicator.com. Note that DMM is not intended to replace DigiPro software. DigiPro software, available separately, is used to create presentation graphics and offers diagnostic and correction tools.

System Requirements: Windows computer with USB port.

Data Retrieval: DMM communicates with DataMate through a USB connection.

Data Storage: Surveys retrieved from DataMate are stored in an MDB database. DMM supports drag-and-drop operations between databases and provides easy functions for editing, renaming, moving, and archiving installations and surveys. Surveys retrieved from the DataMate can also be saved as ASCII files.

Data Manipulation: DMM provides a settlement correction routine and a spiral set expansion routine. Both routines generate new surveys.

Import Capabilities: DMM imports legacy data from Slope Indicator's previous formats and from GTILT®. The program also allows manual entry of data.

Report Capabilities: DMM prints inclinometer readings with checksums, compares two surveys (typically current vs initial) to generate A and B-axis graphs of cumulative displacement. The program generates graphs of cumulative deviation. Graphs are displayed on screen and can be printed in a report. Reports can also include checksum statistics, bias-shift analysis tables, and tabular data in digi units (differences and changes).

DIGIPRO SOFTWARE

DigiPro Trial . . . . Free Download
DigiPro, 1-User License 50310001
DigiPro, 3-User License 50310000
DigiPro, 12-User License 50310002

DigiPro software processes and plots inclinometer data recorded by the Digitilt DataMate readout. It creates high-resolution graphs and supports advanced routines for identifying and correcting systematic error. DigiPro is not included with the Digitilt DataMate. See separate datasheet for details.

DIGITILT 09 INDICATOR

Digitilt 09, Metric 50300910
Digitilt 09, English 50300900

The Digitilt 09 Indicator is a portable readout for Digitilt sensors. It displays readings, but does not record them. The user must keep track of depths and readings on a field data sheet. A battery charge is included. Please specify 100, 115, 220, or 240 volt and 50 or 60Hz.

Compatibility: Digitilt inclinometer probes, Digitilt tiltmeters, and spiral sensors.

Displayed Units: Metric indicator displays readings as 2.5 x the sine of the angle of tilt. English indicator displays readings as 2 x the sine of the angle of tilt.

Readings can be entered into the DMM for Windows database and graphed with DigiPro for Windows. If you chose to do this, write down readings without the displayed decimal point and enter the readings as integers.

Resolution: Metric indicator provides resolution of 1 in 25,000. English indicator provides resolution of 1 in 20,000.

Display: Large, backlit 4.5 digit LCD with heater for cold weather operation.

Battery: Rechargeable 6 volt, 6 Ah gelled electrolyte, lead-acid battery. Battery life is 12 hours with fully changed battery. LCD heater reduces operating time up to 50% when temperature is below 5° C (40° F).

Temperature Rating: -20 to 50°C (-4 to 122°F).

Dimensions: 127 x 178 x 178 mm (5 x 7 x 7").

Weight: 3.4 kg (7.5 lb).

Digitilt DataMate II

50310999

This equipment should be installed, maintained, and operated by technically qualified personnel. Any errors or omissions in data, or the interpretation of data, are not the responsibility of Durham Geo Slope Indicator. The information herein is subject to change without notification.

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Contents

Digitilt DataMate II

What is the DataMate II?

The Digitilt DataMate II is a recording readout used with the Digitilt inclinometer probes, the portable Digitilt tiltmeter, and the spiral sensor. It works with both metric and English-unit versions of these sensors.

The Digitilt DataMate records readings from inclinometer surveys. DMM software is used to transfer the recorded readings to a PC. The use of DMM software is covered by a separate manual: DMM for Windows.

DataMate Controls

Power Switch

The power switch locks into position. To switch on, pull the lever up, then move it to the On position. To switch off, pull the lever up, and then move it to the off position. The DataMate displays a copyright notice for ten seconds when you switch it on. The copyright date serves as the version number for the DataMate.

Connector Sockets

Probe: Socket for inclinometer control cable.

Charger: Socket for battery charger or external power.

USB: Socket for computer interface cable and remote hand switch.

Sockets are waterproof only when connectors are plugged in or when protective caps are in place.

KeyPad

Up: Moves cursor up. Also scrolls forward through the alphabet (a...z).

Down: Moves cursor down. Also scrolls backwards through the alphabet (z...a).

Left: Moves cursor to the left.

Right: Moves cursor to the right.

Esc: Cancels current process and returns to menu.

Enter: Chooses menu items. In record mode, records readings.

DataMate Menus

1. Use the arrow keys to select a menu item with the cursor.
2. Press Enter to choose the item or Esc to exit the item.

Main Menu

The Main menu appears when you turn on the DataMate. The Main menu shows the main functions of the DataMate.

Read	Surveys
Comm	Utilities

Read Menu

The Read menu lets you record inclinometer readings, edit inclinometer installation parameters, review and correct readings, and operate the readout in manual mode, which displays readings but does not record them.

Record	Installation
Correct	Manual Read

Surveys Menu

The Surveys menu lets you list the surveys that are stored in memory, validate a survey, check available memory, delete a survey, compare one survey to another, and print a survey to a terminal program.

Dir	Validate	Memory
Del	Compare	Print

Comm Menu

Comm puts the DataMate into communications mode for transferring data to and from a computer. Communications requires that the DataMate II is connected to the computer's USB port via the interface cable that is supplied with the DataMate.

Waiting for PC . . .

Utilities Menu

The Utilities menu lets you set defaults, and check battery voltage and memory.

Batt	Beep	Light
Temp	Date	Contrast

Setting Defaults

Go to the Utilities menu to set the defaults below:

Date and Time: Choose Date. The DataMate displays the current date and time. Press Enter to edit the date. Press Up or Down to change the year, then press Right to move the cursor to month, etc. Press Enter when done.

Beeper: Choose Beep. Press Enter to toggle the beeper on or off. The beeper produces a noise when you record a reading.

Backlight: Choose Light to toggle the backlight on and off. Backlight increases battery drain by about 12 percent.

LCD Contrast: Choose Contrast. Press Up or Down to adjust contrast for easy viewing. Press Esc when done.

Checking the Battery

Go to the Utilities menu. Choose Batt. A new, fully charged battery shows approximately 6.6 volts with a full charge. Recharge if below 6 volts.

Recharging the Battery

Recharge the battery after every use of the DataMate. It is best to charge overnight.

Plug the charger into an AC mains socket. Plug the Lemo connector into the DataMate's Charger socket. You can verify that charging is taking place by going to the Utilities menu and choosing Batt. You should see increasing voltage value.

Checking Memory

Go to the Surveys menu. Choose Memory. The DataMate displays how many depths and surveys are free (available to store data). The maximum numbers are 32000 depths and 320 surveys.

Moisture Management

When you return to the office, remove caps from the DataMate's connectors and allow connectors to air-dry for a number of hours.

Use desiccant to keep the inside dry. This is particularly important in hot humid weather. Warm moist air trapped in the readout can condense when the readout is brought into a cool air-conditioned office.

To check the moisture level in the DataMate, go to the Utilities menu and choose Temp. The DataMate displays humidity and temperature. Humidity levels from 20% to 60% are normal. If humidity exceeds 75%, replace the desiccant. See instructions in the chapter on inspection and maintenance.

Set Up

Overview

Setting up the DataMate involves entering a list of inclinometer installations into the DataMate's memory. You can do this with DMM software or with the DataMate's keypad.

Setting Up with DMM Software

This method is convenient when you are in the office:

1. Use DMM to create a setup database on your PC.
2. Connect the DataMate to your PC.
3. Use DMM to transfer the setup to the DataMate.

Setting Up with DataMate Keypad

This method is convenient when you are in the field.

1. Choose Read.
2. Choose Installation.
3. Press Down key to scroll past any previously entered installations. The cursor stops on the word, "Create." Press Enter.
4. Enter the required information into each field. The fields are explained on the next page. To make an entry:

   Press the Right key to enter edit mode.

   Press the Up or Down key to change the character under the cursor.

   Press the Right key to move to the next column.

   Press Enter when you are done. The DataMate exits edit mode and moves the cursor to the next line.
5. To correct a mistake, press the Up or Down key to display the line that you want to correct. Then press the Right key to enter edit mode.

Installation Fields

Site & Installation: Every installation has a two-part identifier consisting of a "site" and an "installation." Enter a 6 character identifier for each.

A0 dir: (Optional) Enter up to 3 characters to identify the compass heading of the A grooves. Not used for any calculation.

Operator: Optional) Enter up to 3 characters to identify the operator. Optional.

Sensor#: Enter the serial number of the probe. Optional, but recommended.

Sens Type: Choose Digitilt for inclinometer probes or Spiral for spiral sensors.

Units: Choose Metric or English. If you don't know, check the distance between the upper and lower wheels of the probe: 0.5 m for metric systems; 2 feet for English-unit systems.

Ins Constant: Use 25000 for metric-unit systems or 20000 for English-unit systems.

Start: Enter the starting depth for the survey. Surveys typically start at the bottom of the casing. With English-systems, it is best to use an even number so that 2-foot intervals coincide with cable markings.

End: Enter the ending depth for the survey, typically 0.5 for metric-unit systems or 2 for English-unit systems.

Interval: Interval is typically 0.5 for metric-unit systems and 2 for English unit systems. For a Spiral Sensor, set the interval to 1.5 meters or 5 feet.

Check the Installations

Verify that the DataMate now holds your installation list:

1. Choose Read from the main menu.
2. Choose Installation.
3. Scroll through the list of installations.

Recording Surveys

Good Practices

1. Use the same probe and control cable for each survey, if possible.
2. Use a pulley assembly, if possible. It prevents damage to the control cable.
3. Use a consistent top reference. The goal is repeatable placement of the probe within 5 mm or 1/4 inch. If one technician uses a pulley and another technician does not, probe positioning will be inconsistent, and data will be unusable.
4. Connect the probe to the DataMate and switch the power on before you insert the probe into the casing. Powered-up sensors resist shock better than unpowered sensors.
5. Wait 10 minutes for the probe to adjust to the temperature of the borehole. This helps prevent bias-shift (offset) errors.
6. Always pull the probe upward to the reading depth. If you accidentally pull the probe past the intended depth, lower it to the previous depth, then pull it back up to the intended depth. This ensures consistent placement.
7. Wait for displayed readings to stabilize. The DataMate displays 3 diamonds when readings have stabilized within two units. If the reading does not stabilize, watch the display and try to record an average reading.
8. When you remove the probe from the casing, use your hand to compress the wheels so that they don't spring free or force the body of the probe to strike the side of the casing. This helps prevent bias-shift errors.
9. Check your readings using the DataMate's Validate command. If necessary, reposition the probe at the required depth and use the Correct command to obtain a new reading for that depth. The Correct command is explained later.
10. If you accidently turn off the DataMate during a survey, turn it back on, and then use the Correct command resume the survey. There is no need to start a new survey.

Recording a Survey

1. Connect the control cable to the probe. Do not over-tighten. Plug the other end of the control cable into the Probe socket on the DataMate. Plug the handswitch into the USB socket.

2. Insert the probe into the casing with upper wheels in the A0 direction. Lower the probe to slightly below the start depth.

3. Switch on the DataMate and wait for the main menu. Choose Read.

Read	Surveys
Comm	Utilities

4. Choose Record.

Record	Installation
Correct	Manual Read

5. Choose an installation from the list.

Select Installation
SR18 IN1

6. Press Enter to step past the installation parameters without making changes. Normally, no editing is required.

Edit Installation	
Site	:SR18 IN1

Press Enter or Down to step past each parameters

7. Finally, the DataMate displays the Start depth (bottom depth).

Start depth

50.0♦	204	48
Depth	A0	B0

8. Wait ten minutes for the probe to adjust to the temperature at the bottom. This step is important for consistent readings.

9. Begin the survey. Raise the probe to the start depth, then watch for a stable reading. You will see three diamonds, as shown below. Press Enter to record the reading.

50.0♦	206♦	52♦
Depth	A0	B0

Three diamonds ♦ ♦ ♦
indicate stable reading.
Press Enter to record.

Recording a Survey continued

10. The DataMate beeps and scrolls to the next depth. The reading just recorded is now on the bottom line. Raise the probe to the next depth (shown in the top line of the display) and wait for the numbers to stabilize. Press Enter to record the reading.

After you record the reading, pull the probe up to the next depth.

48.0♦	210	55
50.0*	206*	52*

Recorded readings are marked with a *

11. Repeat this process until you have recorded the reading for the top depth. The DataMate displays a menu. Choose Continue.

Continue	0
Done	Del

12. The DataMate now displays the starting depth for the second pass. Remove the probe from the casing and rotate it 180 degrees so that the upper wheels point to the A180 direction. Insert the probe and lower to the bottom of the casing, or slightly below the start depth.

50.0♦	-210	-60
Depth	A180	B180

13. Pull the probe up to the start depth. Wait for the numbers to stabilize. Press Enter to record.

48.0♦	-215	-75
50.0π	-210π	-60π

Recorded readings for the second pass are marked with the Pi symbol.

14. Repeat these steps until you have recorded the reading for the top depth. A menu appears. This time, choose Done. Then remove the probe from the casing.

Continue	0
Done	Del

15. You may want to validate the survey using the DataMate's validate command. See Appendix 1 for instructions.

Making Corrections

If you make a mistake during the survey, you can easily correct it.

1. Use the Down key to return to the depth where the mistake was made. Stop scrolling when the depth appears in the top line of the display.
2. Now position the probe to that depth: lower it below the depth and then pull it upwards to the exact depth.
3. Press Enter to activate the top line of the display. A diamond appears next to the depth.
4. Wait for the readings to stabilize, then press Enter to record.
5. Continue recording just as you would in a normal survey. Or if you are finished, scroll to the top depth and complete the survey as you normally would.

Cancelling a Survey

1. Press Esc. If you press Esc by mistake, press Continue.
2. Choose Del to delete the survey that you cancelled. Cancelled surveys remain in memory until deleted.
3. The DataMate prompts for confirmation. Press Up to confirm.

Deleting a Survey

If you want to record a survey, but the DataMate prompts "no room in memory" or "too many surveys," you must free some memory by deleting a survey.

1. Choose Surveys from the main menu.
2. Choose Del.
3. Select a survey to delete and press Enter. (Surveys marked with the ^ symbol have been retrieved by a PC, so it might be safe to delete one of them.)
4. Press Up to confirm the deletion or Esc to cancel. The DataMate deletes the survey. To avoid possible loss of data, do not switch the DataMate off during this process.

Deleting an Installation

The DataMate itself provides no way to delete installations. DMM is required for deleting installations.

Retrieving Surveys

Overview

To retrieve surveys, connect your DataMate to your PC and run the DMM program. This is the normal and most efficient way to retrieve data.

Using DMM

Detailed instructions are provided in the DMM manual. The basic steps are:

1. Connect the DataMate to your PC. Choose Comm on the DataMate.
2. Start DMM, go to Datamate in the menu, and choose either Retrieve New or Retrieve all.
3. Drag and drop the retrieved surveys into your project database (or export surveys to a text file).

Using a Terminal Program

You can “print” surveys, one by one, to a PC that is running a terminal program on your PC to receive it. This is mainly for troubleshooting. The DMM program can import print files.

1. Connect the DataMate to the PC.
2. Start your terminal program. Set it for 8-bit, no parity at 9600 bps.
3. Set the terminal program to “capture” or “log” the data sent from the DataMate. Specify a file name for the captured data.
4. Choose Print from the DataMate survey menu. Set the baud rate for 9600 and press Enter. Then select the survey and press Enter to “print” it.
5. Your terminal program will usually display the readings as they are sent from the DataMate.
6. Close the file with your terminal program.

Validating Surveys

About Checksums

A checksum is the sum of 0 and 180 degree readings at the same depth. Ideally, the sum should be zero since the readings have opposite signs. In practice, checksums are rarely zero.

In general, you should look for consistency in checksums. A checksum that is significantly different from checksums above and below it may indicate that the probe wasn't positioned correctly or the reading was not stable when recorded. A large checksum may also be caused by debris in the groove, an out-of-round casing section, a separated casing section, or a wheel falling in the joint of a telescoping casing section.

A graph of checksums shows very clearly whether checksums are consistent or not. Alternatively, scanning through a column of checksums gives you an idea of consistency. Unfortunately, the DataMate provides neither graphs nor columns of checksums. However, the DataMate does provide the standard deviation of checksums, which can be used as a measure of reading quality, as explained below.

Standard Deviation of Checksums

The standard deviation of checksums can be used as a way to confirm that the current survey is comparable to other surveys for the same borehole.

You must first establish a "typical SD" for each axis. This is obtained from your initial survey. (It is good practice to take several surveys initially, then compare them and select one to be the "official" initial.) Since the initial survey represents good set of readings, the standard deviation of checksums for that survey can be used as a "typical SD" for that installation. Note that the "typical" is likely to be different for every installation.

When you obtain a new survey, run the DataMate's validation routine. Compare its SD to those of the initial survey. If the typical standard deviation of the A-axis is 3 to 5 units, the data is probably good. For example, if the typical standard deviation is 4, then acceptable standard deviations for subsequent surveys could range as high as 7 or 9 (typical for B-axis).

Narrower limits may be appropriate for deeper installations and critical measurements. Wider limits may be appropriate for shallower installations or for poorly-installed casing.

Validating a survey

Here is a typical validation procedure:

1. Check the standard deviation of checksums. Is it typical for this casing? If so, the survey is probably good and needs no further validation. You can quit the validation routine.
2. If the standard deviation is not typical, check the standard deviation for the different zones. If any group shows an obvious problem, examine the individual checksums in that group. Also look for drifting mean checksums. A drifting mean may indicate a problem with the electronics inside the probe.
3. If you find a checksum that is too large, examine the readings at that depth to determine whether the bad reading was recorded in the 0 or the 180 orientation. Afterwards, you can correct the data by taking another reading for that depth.
4. The steps below explain this in detail.

Check the Standard Deviation

1. Choose Validate from the Surveys menu.
2. Choose a survey to validate.
3. After a short delay, you will see a display that shows both the mean (MN) checksum and the standard deviation (SD) of checksums:

```
MN  A=51.337     B=45.674
SD  A=4.1781     B=5.7170
```

4. Compare the standard deviation with the "typical" SD that you have established for the installation. If the standard deviation is acceptable, press Esc to quit. Otherwise, look at the SD for each zone.

Check Zone Statistics

1. Press Enter to view the zone with the largest SD. You will see a display that looks something like this:

```
25.  -  20.     S.D.
A=3.2264       B=10.3388
```

Zone statistics include 10 readings. In this case, there are 10 half-meter readings in the zone from 25m to 20m.

2. To view the mean checksum for this zone, press the Left arrow. Press Right to redisplay the SD.
3. Press Up or Down to display other zones. Again, the Left and Right keys toggle between mean and standard deviation.
4. If you decide the survey is acceptable, press Esc to quit. Otherwise, note the zones (depths) that you want to inspect and continue.

View Individual Checksums

Follow the steps below to find depths with large checksums:

1. After viewing the checksum statistics, press Enter to view checksums. The DataMate first displays the largest checksum in the survey. In this case, the 89 in the B axis is largest.

Depths	A	B
25.	20	89
25.5	25	34

2. Use the Up and Down keys to view checksums at other depths. When you are finished viewing checksums, press Esc.

Isolating the Bad Reading

A large checksum may indicate a bad reading, but does not indicate which reading was bad (Was it the 0 or the 180 reading?). To isolate the bad reading, you must view readings above and below the suspect reading.

1. Choose Read from the main menu.
2. Choose Correct, then choose a survey (If necessary, press Right to see dates).
3. Press the Enter key to skip through parameters.
4. Choose 0 (orientation). Scroll through readings to the suspect depth. Check readings above and below the depth. A bad reading does not fit with the readings above and below it.
5. To view 180 readings at the same depth, press the Right arrow. Press again to display the 0 readings.
6. Note the depth and orientation of the bad reading. Then press Esc.

Correcting a Reading

1. Choose Correct from the Read menu.
2. Choose 0 or 180, and scroll the DataMate to the required depth. The depth should be displayed on the top line.
3. Lower the probe to the required depth. Wait for the probe to adjust to the temperature in the borehole (5 to 10 minutes if the probe has been in open air)
4. Press Enter to activate the reading. Press Enter again to record the reading.

Comparing Surveys

Overview

The DataMate can calculate a single value for cumulative deviation or for cumulative displacement.

Cumulative Deviation

1. At the Main Menu, select "Surveys." Then select "Compare."
2. The DataMate prompts for the current survey. Press Enter to select the suggested survey or scroll to find a different survey.
3. The DataMate prompts for a "previous" survey. Press Esc since you do not want to calculate displacement.
4. The DataMate asks you to confirm a conversion value of 1. Press Enter. This will display metric data in meters and English data in feet.
5. The DataMate then calculates the cumulative deviation for the survey and displays it.
6. Press Esc to return to the Surveys menu.

Note The DataMate calculates cumulative deviation by summing incremental deviations from the bottom of the casing to the top.

If you are interested in borehole drift, you probably want the top of the borehole to be used as reference. The DataMate does not offer this as a choice, but when summing from the top, the deviation at the bottom of the borehole will be the same value except in the opposite direction.

Cumulative Displacement

To calculate displacement, the DataMate must contain two surveys for the same installation.

1. Choose Surveys from the main menu, then choose Compare.
2. The DataMate prompts for the current survey. Press Enter to select the suggested survey or scroll to find a different survey. Then the DataMate prompts for a "previous" survey. Scroll to find the initial set, then press Enter.
3. The DataMate prompts for a conversion value. Enter 1000 for a displacement in millimeters (with metric data). Enter 12 for a displacement in inches (with English unit data).
4. The DataMate then calculates the cumulative displacement for the survey and displays it. Press Esc when done.

Inspection and Maintenance

Inspection

Part	What to check for	Remedy
Desiccant	Check humidity under utilities menu.	If humidity exceeds 75%, replace or recharge desiccant.
Batteries	Check main battery and Memory keep alive power under utilities menu.	Main battery can be recharged. If battery does not hold charge, battery can be replaced. Lithium backup battery is good for 7 to 10 years if main battery keeps charge. Return for servicing if memory power is bad.
Connectors	Dirt, bent pins, o-ring	Clean with alcohol moistened swab. Note that connectors are "water proof" only when capped or when connector is plugged in.
Self Test	Error A input Error B input	Bad signal input. Return for servicing. A value is displayed, but is not useful.
	Error +12volt Error -12volt	±12V sensor power. Disconnect control cable and probe. Try again. If error goes away, problem could be in probe or cable. Connect cable only. If no error, then probe is the problem. This error could also be caused by discharged battery. Try recharging battery first. If error persists, some component must be returned for servicing.
	Error battery	Main battery is low. Try recharging. If error persists, replace battery.
	Error +3v pwr	Memory keep alive power is bad. Retrieve any data before switching off, then return for service.
	Error temp	Operating temperature range exceeded. Either below -20 or above 60C.
	Error humidity	Humidity above 80%. Replace desiccant.

Maintenance

Battery	Recharge battery after every use. Charge at least two hours for every hour of use. Charging overnight is common practice. Do not charge longer than 72 hours. Longer charge time may damage the battery. A new, recharged battery will show 6.6V or higher. The DataMate displays a low battery warning when voltage drops to 5.5 volts. Turn off the DataMate when the warning appears and then recharge as soon as possible. Deep discharge of the main battery can reduce its performance and shorten its life.
Desiccant	Check humidity under utilities menu. If humidity exceeds 75%, replace desiccant.
Connector sockets	If it is necessary to clean the connector, use a small brush or a slim cotton swab. Do not use spray lubricants or electric contact cleaners. Solvents contained in such products will attack the neoprene inserts in the connectors.

Replacing Desiccant

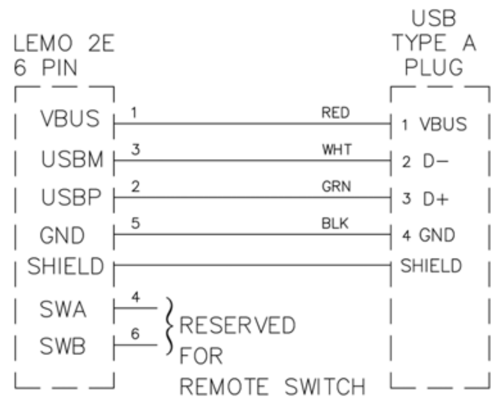
You must open the DataMate to change the desiccant. You should ground yourself to prevent a static discharge that could damage the DataMate's electronics.

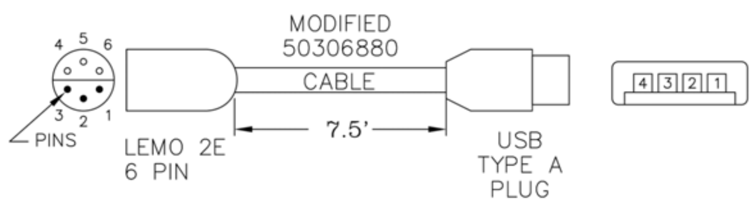
Remove the two screws from the bottom of the case. Hold the top panel and pull off the case. Look for the desiccant pack between the battery and the panel connectors. Replace the desiccant pack with a new one. You may be able to renew the desiccant in an oven at 250 °F (121 °C) for 16 hours. Do not use a microwave oven to renew the desiccant. You may damage your microwave oven.

Before you replace the case, apply a light coat of silicone grease to the gasket. Also lubricate the O-rings on the screws. Then slip the DataMate back into its case, checking that the gasket is seated properly. Replace the screws and tighten to draw the top panel squarely against the case. Do not over-tighten the screws

Wiring Diagram for USB Interface Cable

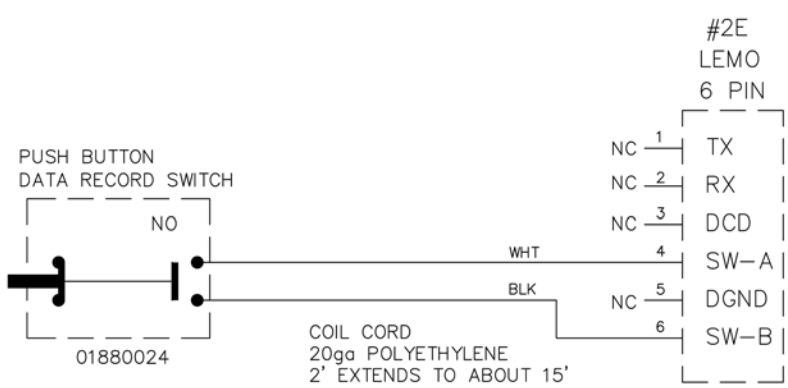
Below is the wiring diagram for the connectors on the USB interface.





Wiring Diagram for Hand Switch

Below is the wiring diagram for the hand switch.



Trouble-Shooting

Tech Notes on slopeIndicator.com

Many questions can be answered by a visit to the Tech Notes section of www.slopeindicator.com. Go to Support - TechNotes. Then scroll down the page to find the inclinometer tech notes. Take a look at the Digitilt DataMate Q & A page.

Readings Not Stable

The DataMate's ready signal is displayed when readings in both axes are stable within 2 digits. If this happens occasionally, but readings vary within 3 or 4 digits, you can record the readings with no significant loss of accuracy.

- If this problem always occurs at a single installation and at a just a few depths, it is possible that the backfill around the casing has washed away or was simply incomplete.
- In some situations, such as when there is no water in the inclinometer casing, control cable can go into a slow oscillation, shaking the probe, and preventing full stabilization of readings. The same may occur at sites where heavy construction machines are active. In this case, look for the average reading.
- Reading instability can also be caused by a low battery, so always check battery voltage before you leave the office.
- If readings always take a long time to stabilize, and this happens at all installations, contact Slope Indicator.

Strange Readings

A & B readings are midrange or higher (e.g. +6000 or -6000): Mid-range readings like this point to a cable problem. It is likely that one of the power wires is bad. The problem may be in a broken or corroded wire in the connector.

Readings are very high, for example 12,000: If your DataMate shows a full scale reading, such as 10,000 or 12,500, when the probe is near vertical, there is probably water in the connector or in the cable.

Reading of +1786 (English) or 3125 (Metric): This is the same number that the DataMate displays when the probe is not connected, so there is most likely a problem in the cable or a connector.

Reading of 60 or some other low number: If you see a low number that stays constant in one axis, the problem is mostly likely in the probe. The accelerometer for that axis is not working and the op amp is trying to compensate, resulting in a constant value.

Appendix A5 - DMM for Windows

DMM for Windows

50310970

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Contents

Introduction

Read This

- If you hate manuals, at least read the Quick-Tour pages.
- If you can't find a way to do something, read the "How To" pages.
- If you have the DataMate II, be sure to install the latest version of DMM.

What is DMM?

DMM (DataMate Manager) is software supplied for the Digitilt DataMate inclinometer readout. DMM is used to:

- Retrieve readings stored by the DataMate.
- Send setup data to the DataMate.
- Retrieve readings from the DataMate.
- Store readings on disk, either in a database or in an ASCII file.
- Edit and maintain the database.
- Print data, and statistics. DMM also has a simple graphing function to compare two surveys.

Installation

Obtaining DMM

We recommend that you download the DMM setup file from the the Slope Indicator web site: www.slopeindicator.com. The web site always offers the most recent version.

You can also install DMM from a Resource CD, but be sure to check the date on the Resource CD. If it is more than four months old, you may have better results by downloading DMM from the website.

Instructions for both methods follow.

Downloading DMM

1. Start your browser and navigate to www.slopeindicator.com.
2. Choose Downloads.
3. Choose Software.
4. Choose DMM for Windows.
5. Follow on screen instructions to download and install the software. You may want to print the instructions.

Installing DMM from a Resource CD

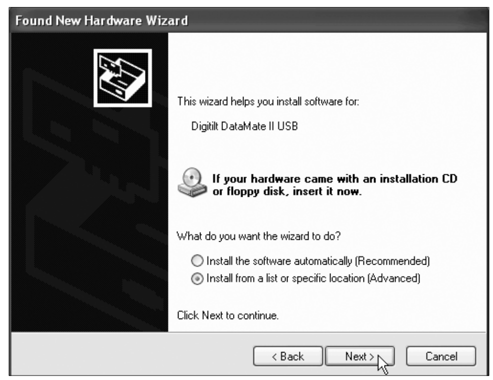
1. Insert the Resource CD in your CD-ROM drive.
2. Wait for your browser to start. If necessary, eject and reinsert the CD, or start your browser, navigate to the CD, and open the file called cdmenu.html.
3. Choose software from the menu.
4. Choose DMM for Windows.
5. Follow on screen instructions. It may be useful to print the instructions.

Installing USB Drivers (DataMate II Only)

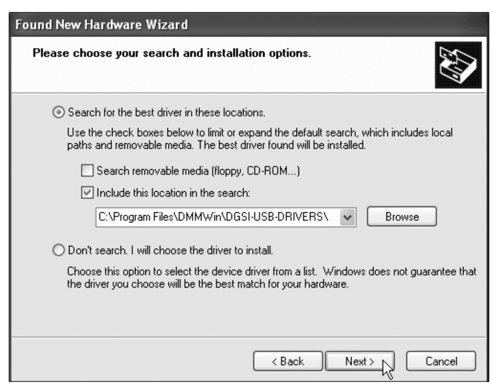
The DataMate II connects to the PC via a USB cable. Follow the steps below to install the USB software. There are two drivers, so you go through two installation procedures.

1. Start your PC.
2. Connect the DataMate to the PC.
3. Switch the DataMate on.
4. The hardware wizard appears and asks to search for software.
5. Choose “No, not this time.”
6. Click Next.

1. Windows wants to install software for the Digitilt DataMate II USB.
2. Choose “Install from a list or specific location.”
3. Click Next.



1. Windows asks for the location of the driver.
2. Click “Include this location in the search.”
3. Enter the following path. You can also browse to the path:



C: \program files\dmmwin\DGSI-USB-Drivers\Win2k-XP

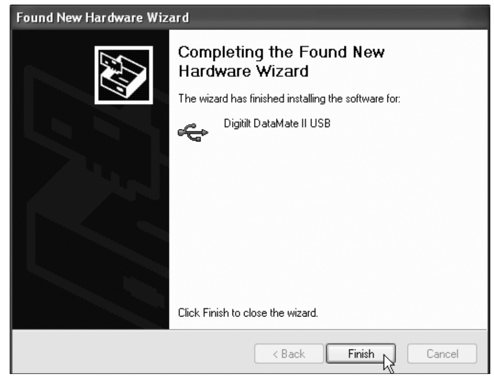
This folder contains 32-bit drivers. In the future, there will also be a folder with 64-bit drivers, which you would choose if you have a 64 bit operating system.

4. Click Next.

Installing USB Drivers Continued

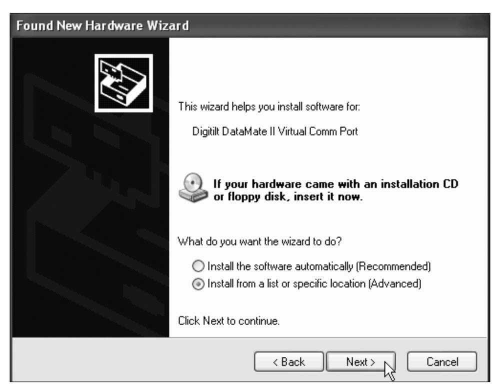
1. Windows starts the installation process.
2. If you see this warning message, choose "Continue Anyway."

1. Windows completes the installation and displays this screen.
2. Click Finish.



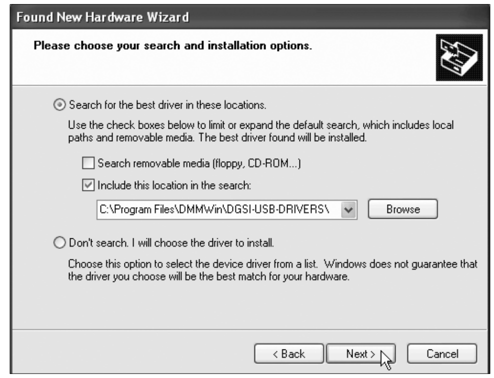
1. Windows immediately detects new hardware.
2. Another wizard appears and asks to search for software. Choose "No, not this time."
3. Click Next.

1. Windows wants to install software for the Digitilt DataMate II Virtual Comm Port.
2. Choose "Install from a list or specific location."
3. Click Next.



Installing USB Drivers Continued

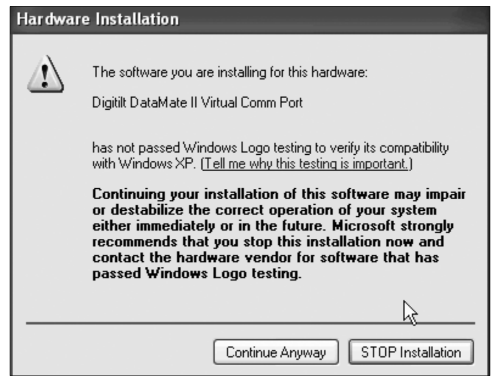
1. Windows asks for the location of the driver.
2. Click "Include this location in the search."
3. The path you recently entered should appear. If not, enter or browse to the following path:



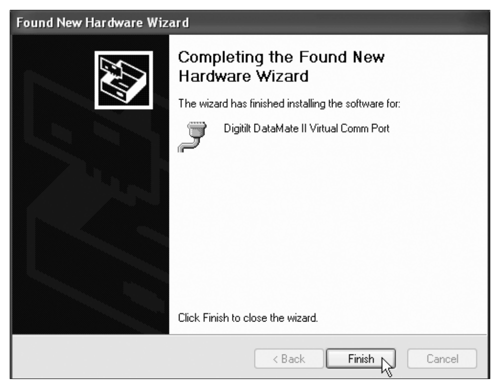
C: \program files\dmmwin\DGSI-USB-Drivers\Win2k-XP

(or the 64-bit folder name, if you have a 64-bit OS.)

1. Windows starts the installation process.
2. If you see this warning message, choose "Continue Anyway."



1. Windows completes the installation and displays this screen.
2. Click finish.



Note: You must tell DMM which com port to use for the USB device:

1. Start DMM.
2. Choose DataMate - Options. DMM displays the available com ports.

This USB device is likely to use the Com port with the highest number. For example, if DMM lists Com1, Com4, and Com7, try Com7 first.

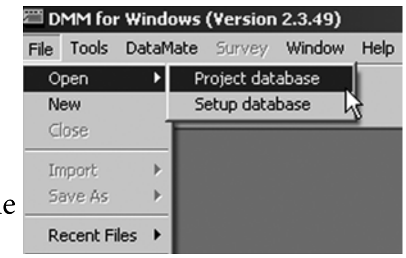
Quick Tour of DMM

Start DMM

1. Click the Start button.
2. Choose Programs.
3. Choose DMM for Windows.
4. Click on DMMWin.exe from the slide-out menu.

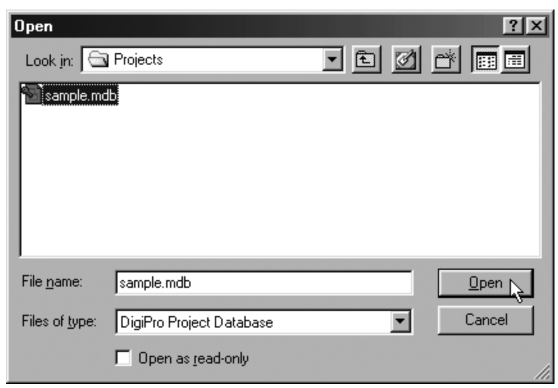
Open the Sample Database

1. Choose File.
2. Choose Open - Project Database.
3. DMM displays a folder of project databases. The default folder is called Projects and is located in the DMM folder.



   You can use different folders for your projects. DMM remembers the last folder used. DMM keeps a recent file list, so you can also select your database from File-Recent Files.

4. For now, select "sample.mdb" and click the Open button.

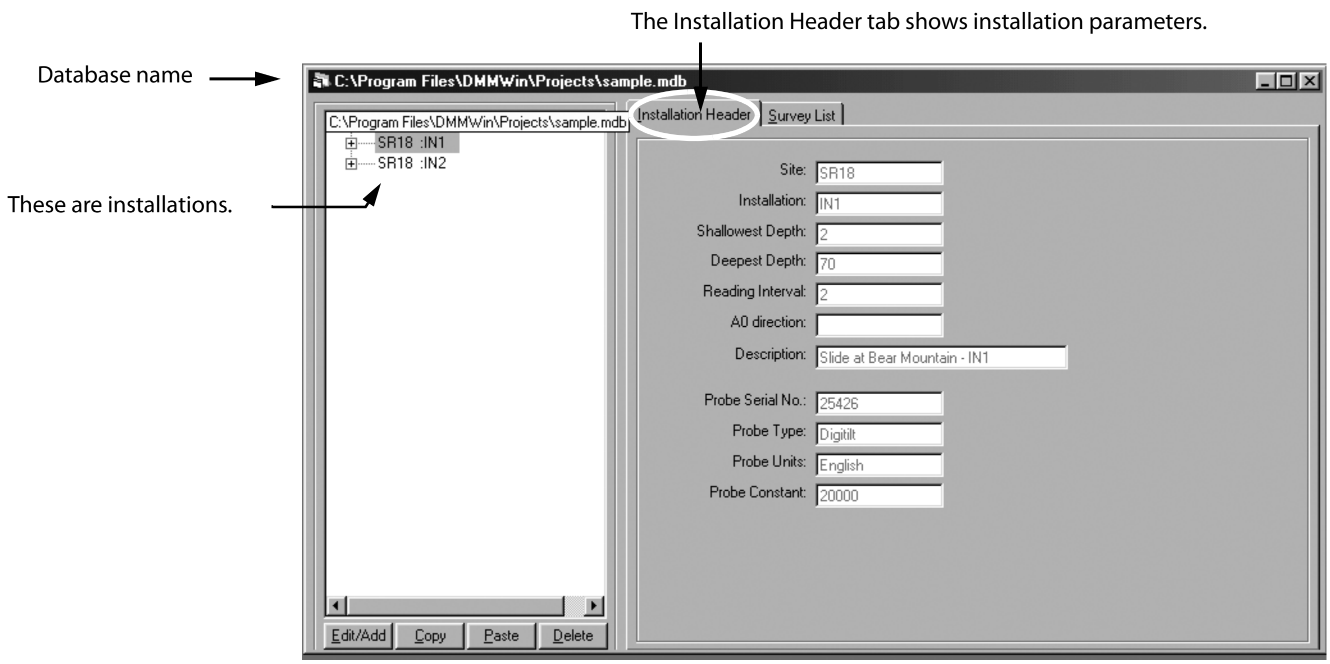


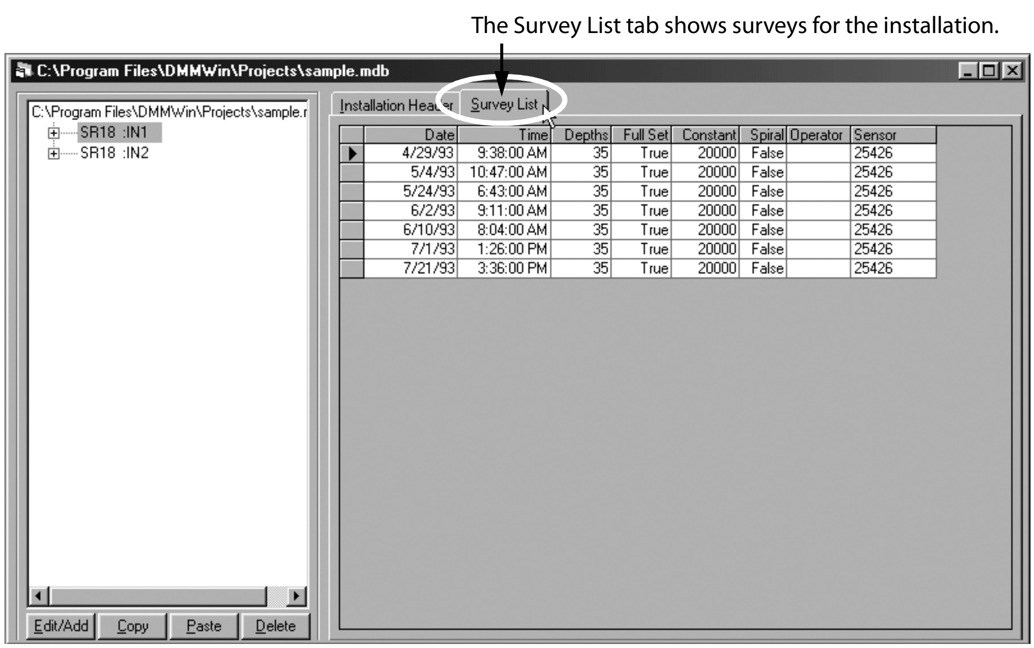
The Database Window

DMM opens a window to show the database. You can open other databases, too. Every database appears in its own window.

Viewing Installations

The first view of a database shows inclinometer installations. An installation, sometimes called a “borehole” or “hole” is the installed inclinometer casing.





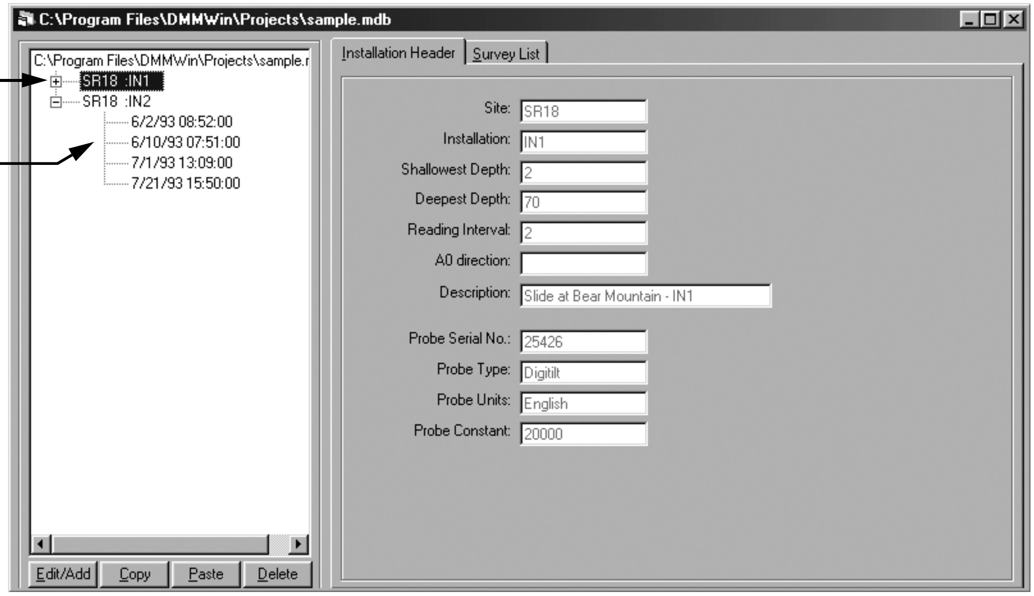
The fields in this view are mainly for trouble-shooting. It lets you check that the number of depths is the same for each survey, etc.

Viewing Surveys

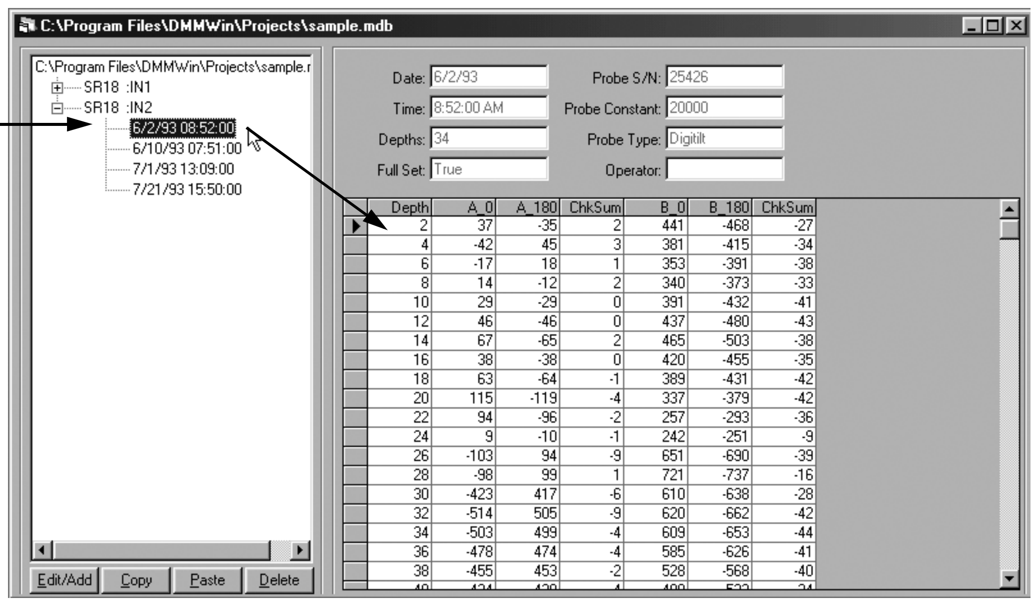
Click the + next to an installation to see surveys sorted by date. Surveys, sometimes called datasets, are the readings from the inclinometer probe.

Click + to see surveys.

Surveys are listed by date and time.

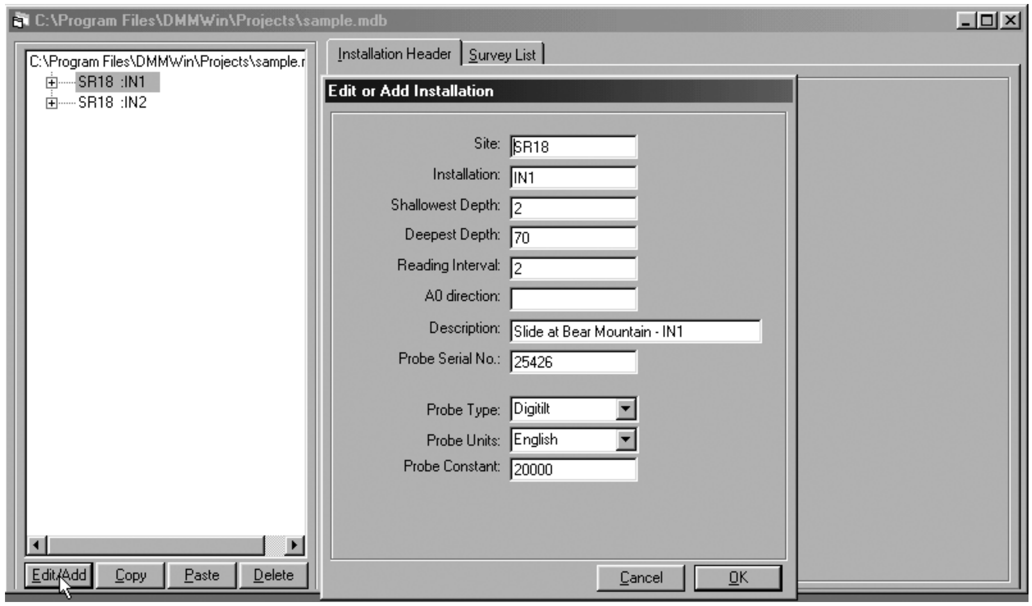


When you select a survey, readings appear at right



Editing Installations

Select an installation, then click the Edit/Add button.



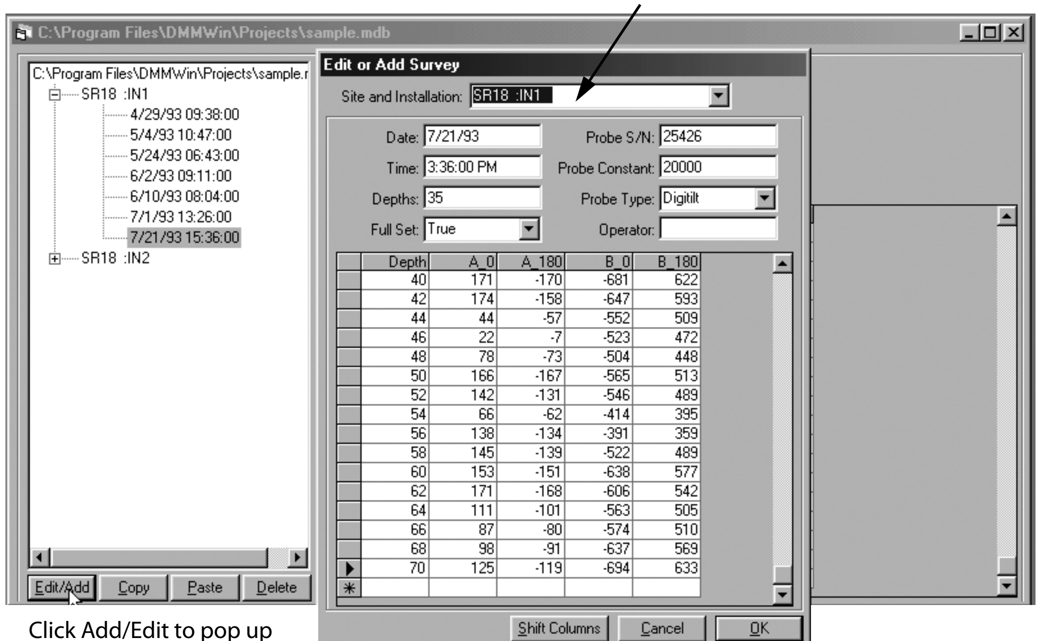
Click Add/Edit to pop up an edit window.

The edit window shows the selected installation and allows you to make changes.

Editing Surveys

Select a survey, then click the Edit/Add button.

Use this field to move a survey to a different installation.



Depth	A_0	A_180	B_0	B_180
40	171	-170	-681	622
42	174	-158	-647	593
44	44	-57	-552	509
46	22	-7	-523	472
48	78	-73	-504	448
50	166	-167	-565	513
52	142	-131	-546	489
54	66	-62	-414	395
56	138	-134	-391	359
58	145	-139	-522	489
60	153	-151	-638	577
62	171	-168	-606	542
64	111	-101	-563	505
66	87	-80	-574	510
68	98	-91	-637	569
70	125	-119	-694	633

Click Add/Edit to pop up an edit window

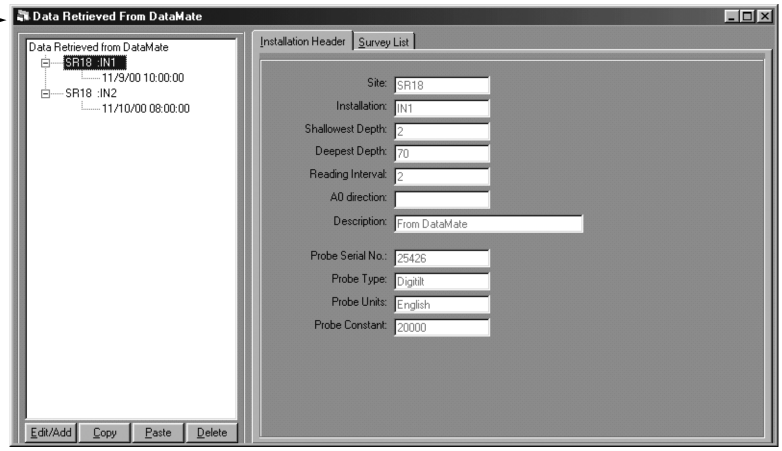
The edit window shows the selected survey and allows you to make changes.

Retrieving Data from the DataMate

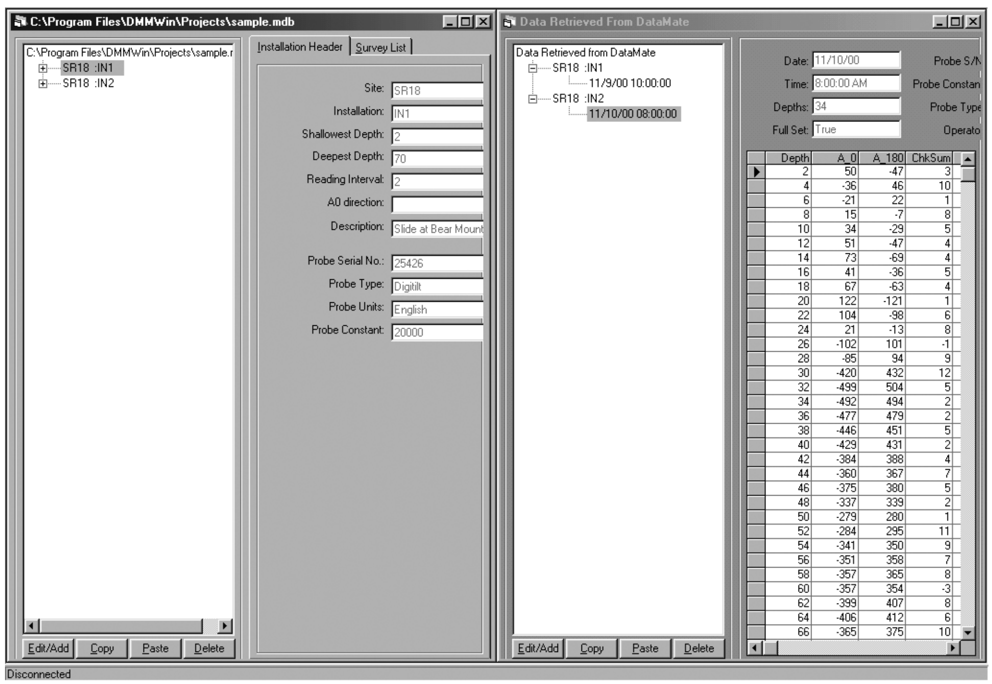
1. Connect the DataMate to your PC.
2. Run DMM and choose DataMate-Retrieve All or Retrieve New from the menu. DMM displays the retrieved data in a window.

This window is called: "Data retrieved from DataMate".

You will drag and drop surveys from this window into your project database.



3. Open a project database to receive the data. Place the two windows side by side using the Windows-Tile command.

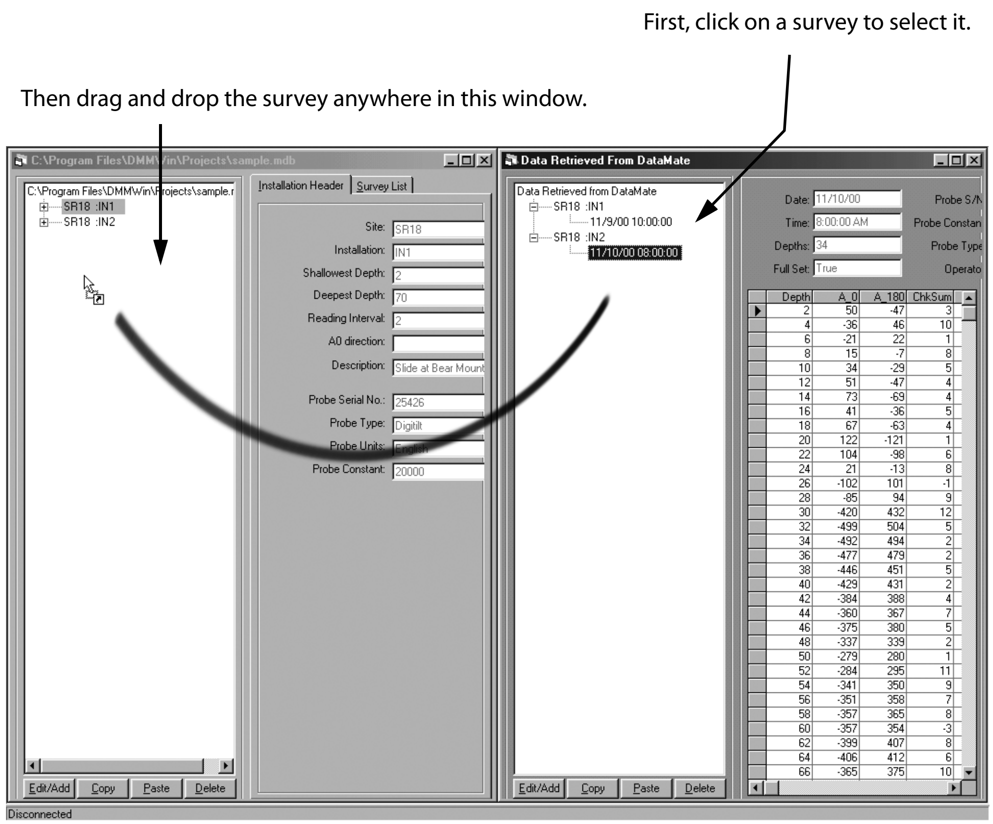


Project Database

Data Retrieved from DataMate Window

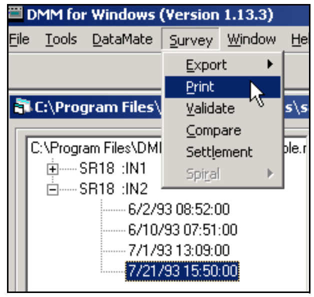
Retrieving Data continued

4. Click, drag, and drop surveys one by one. Click on the survey to select it. Then drag and drop it into the project database. It is not necessary to drop the survey on the installation. You can also use the copy and paste buttons: copy from the temporary database, and paste into the project database.



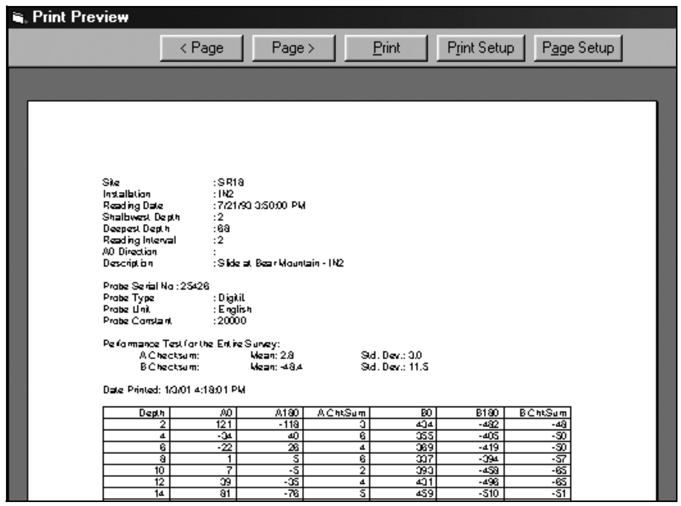
Printing a Survey

1. Choose Survey-Print from the menu bar.

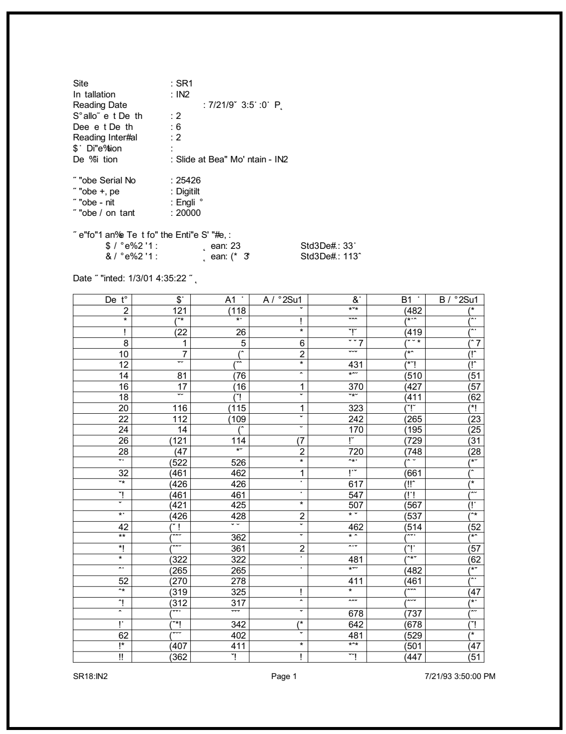


2. The print preview screen appears.

Zooming To zoom in, double-click the left mouse button. To zoom out, double-click the right mouse button.



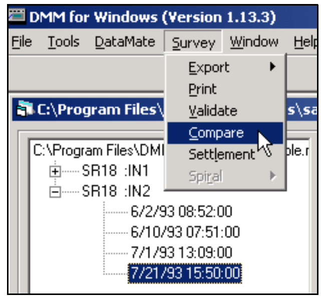
3. The printed page looks like this:



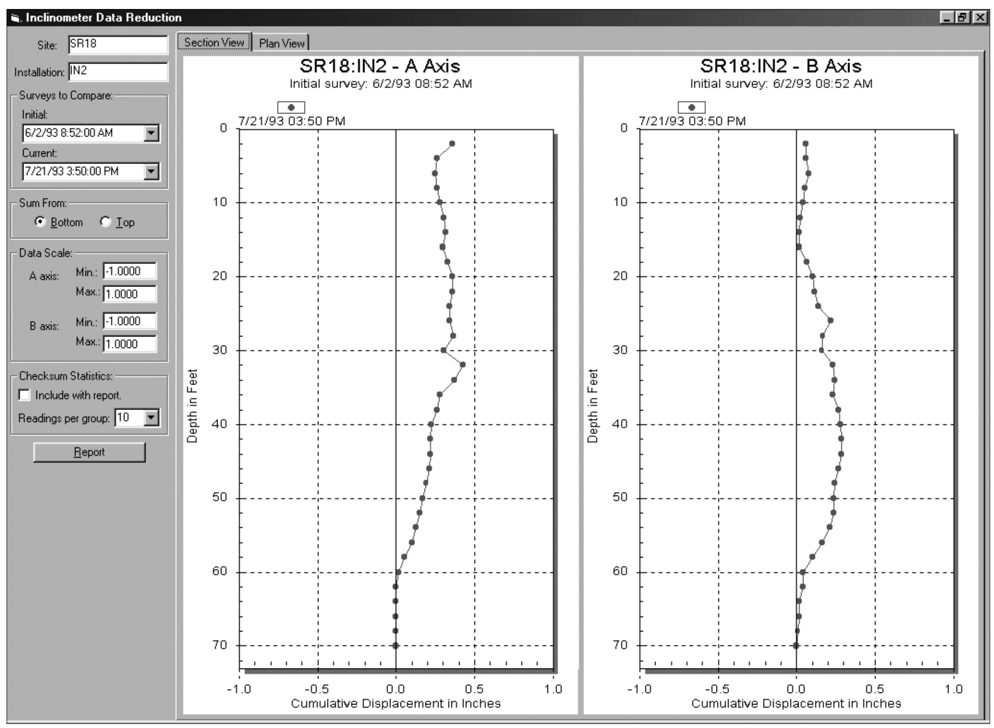
Plotting Survey Data

DMM has a convenient plotting routine that lets you compare two surveys.

1. Click on a survey, then choose Survey - Compare from the menu bar.



2. DMM displays a graph of cumulative displacement.



3. Now that you've seen DMM's main features, please take a look at the rest of the manual.

Menu Summary

File

Use this menu to create, save, open, and close databases.

Open: Offers a choice of project database or setup database. A project database contains your inclinometer surveys. A setup database contains a list of installations that you send to the DataMate.

New: Creates a new project database in its own window.

Close: Closes the database in the active window. All changes are saved. There is no explicit "Save" command.

Import: Imports surveys from RPP, PCSLIN, and GTILT. See Appendix 5, Importing Data.

Save As: Offers a choice of a project database or a setup database. Used to copy a database or create a setup database.

Recent Files: Shows the path and name of the most recently opened databases. Click on a database to open it.

Exit: Closes the DMM program.

Tools

Compact Database: Removes empty spaces left in the database after heavy editing.

Convert HDR to MDB: Starts the HDR2MDB utility to convert a DOS database to a Windows database. See Appendix 3.

DataMate

Use this menu to communicate with the DataMate.

Retrieve New: Retrieves only *new* surveys and displays them in a special window called "Data Retrieved from DataMate." In DataMate terms, "New" means a survey that is not stamped with a ^. The ^ stamp indicates that the survey has been retrieved at least once. If there are no new surveys, this command retrieves only a list of installations.

Retrieve All: Retrieves *all* surveys and displays data in a special window called "Data Retrieved from DataMate." This command always retrieve surveys, new and old, if there are any in the DataMate.

Send Setup: Used to transfer a setup database to the DataMate. Erases the DataMate's memory, then transfers the contents of the active database to the DataMate. This command is normally used to send a setup database to the DataMate, but it can be used to send a project database to the DataMate (within limits of memory).

DataMate Menu, Continued

Erase Memory: Erases installations and surveys from the DataMate and leaves the memory blank.

Options: Used to set the communications port. Also used to change the background color of the DataMate Window.

Survey

This menu becomes active when you have selected a survey. The same commands appear on a right-click menu, as well.

Export: Offers choice of exporting to RPP, Tab-Delimited ASCII, or PCSLIN. See Appendix 7.

Print: Prints the current survey along with checksum statistics.

Validate: Prints checksum statistics for the current survey.

Compare: Reduces data and displays a displacement graph of the A-axis and B-axis. Provides a "report" function that prints printing of the graphs along with data and statistics. See the chapter on data reduction and graphing for details.

Settlement: Generates a survey that is adjusted for settlement. See Appendix 10.

Spiral: Generates an interpolated spiral survey used for spiral corrections in DigiPro. This command becomes active only if there is a spiral survey found in the database. See Appendix 9.

Right-Click Survey Menu

The menu items above also appear on a right click menu. To display the menu, select a survey, then click the right button of your mouse.

Window

Use the Window menu to arrange windows on your screen. This is useful when you retrieve data from the DataMate.

Cascade: Stacks windows on top of each other, leaving only title bars visible, except for the window in front.

Tile Vertical: Arranges windows side by side. Useful for dragging surveys from the DataMate window to the project database window.

Tile Horizontal: Arranges windows side by side, using the full width of each window.

Help: Displays the version number of the program. The version number is also visible on the title bar.

Creating a Project Database

What's a Project Database?

The project database stores a list of inclinometer installations and the inclinometer surveys recorded for each installation.

Installation: This is a term used by Slope Indicator to refer to installed inclinometer casing. Other commonly used names are "inclinometer," "well," or "borehole." The project database holds the name of the installation, its depth, and measurement intervals.

Survey: This is a term used by Slope Indicator to refer to readings that are recorded for an installation. Other commonly used terms are "reading set" or "data set."

Creating a New Project Database

1. Start DMM.
2. Choose File-New.
3. Enter a name for the project, choose a folder, and click Save.
4. The new database is empty. The next steps explain how to add installations.

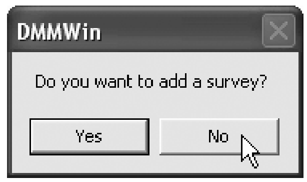
Overview of Adding Installations

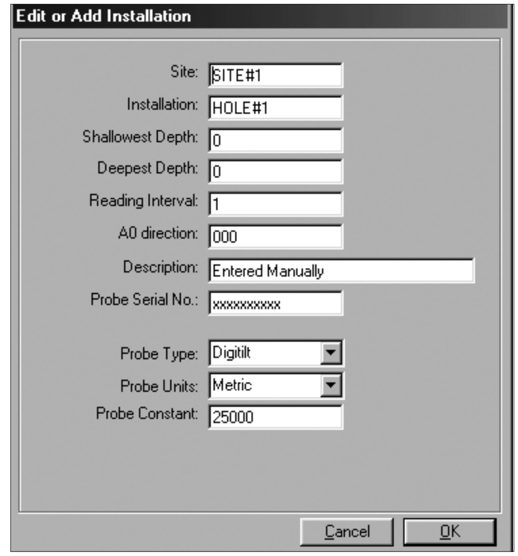
There are several ways to add installations to the new database.

- You can add installations manually, as discussed next.
- You can retrieve data from the DataMate. This adds both installations and surveys. See "Retrieving Surveys."
- You can drag and drop installations from other DMM databases into the new database. This brings surveys as well. See "How To - Make a Composite Database."
- You can import data from legacy formats. This brings in both installations and surveys. See Appendix 1.

Adding Installations Manually

1. Click Edit/Add.
2. Enter the required information. Each field is explained below.
3. Click OK.
4. Click No to the prompt asking if you want to add a survey.





Installation Fields

Site & Installation: Every installation has a two-part identifier: "site" and "installation." Enter up to 6 characters for each part.

Shallowest Depth: Typically, 0.5 for metric-unit systems or 2 for English-unit systems. Unit labels are not used.

Deepest Depth: Enter the appropriate value. With English-systems, it is best to use an even number so that 2-foot intervals coincide with cable markings. Unit labels are not used.

Reading Interval: Typically, 0.5 for metric-unit systems and 2 for English unit systems. Unit labels are not used.

A0 direction: Optional field of 3 characters for entering the compass heading of the A grooves. Not used for any calculation.

Description: Optional field up to 35 characters long.

Probe Serial No: Enter the serial number of the probe assigned to this installation.

Probe Type: Choose Digitilt for inclinometers.

Probe Units: Choose Metric or English. If you don't know, check the distance between the upper and lower wheels of the probe: 0.5 m for metric systems; 2 feet for English-unit systems.

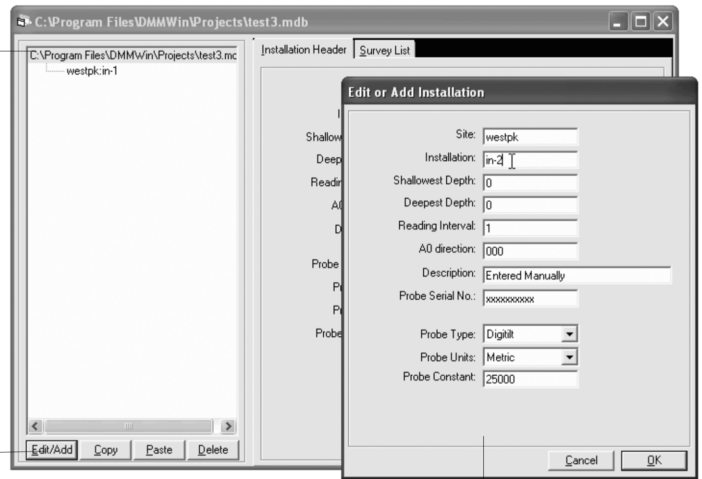
Probe Constant: Enter 25000 for metric-unit systems and 20000 for English-unit systems.

Add Another Installation

1. Click on the name of the database at the top of the column.
2. Click Edit/Add.
3. Enter the required information and click OK.

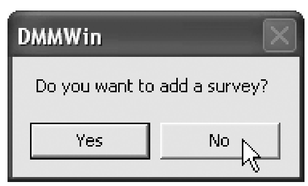
1. Click the database name

2. Click Edit/Add



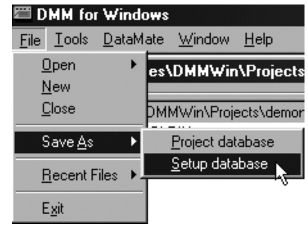
3. Enter the information and click OK

4. Answer No to the “Add Surveys” prompt.



Setting Up the DataMate

Create a Setup Database



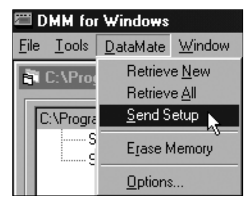
1. Open your project database.
2. Choose File-Save As Setup Database.

   DMM copies installations from the project database into a setup database. No surveys are copied.

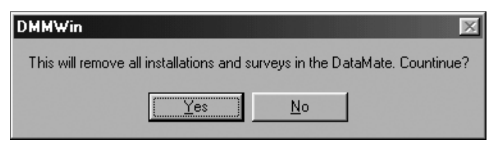
   The default name for the setup database is “setup for [name of your project database].” The default folder is “Setups” and is located in the DMM folder. You can use a different name and folder for your setups.

Send the Setup to the DataMate

1. Connect the DataMate to your serial port. Switch on the DataMate and select Comm. The DataMate displays: Waiting for PC.
2. Choose File-Open-Setup Database, if necessary. The setup database must be displayed.
3. Choose DataMate-Send Setup.



4. Sending a new setup removes any data that is in the DataMate. This is normally what you want, so click Yes.



   If you are not sure, click No. Then retrieve all surveys that are in the DataMate. You can store the retrieved surveys in a temporary project database, if necessary, and sort it out later.

5. DMM then sends the setup database to the DataMate. If you see an error message, try the troubleshooting steps listed on the next page.
6. When the database has been sent, check that the DataMate contains the required installations, then switch the DataMate off.

Note You can also send a project database to the DataMate, using the Send Setup command. Sending a project database sends the surveys as well, so check that you have not completely filled the memory.

Trouble-Shooting Communications

- If you see this error message, DMM may be using the wrong comm port. Choose DataMate-Options. DMM then scans for available comm ports and displays a list. Choose a different comm port and try again. Use this method even if you have a DataMate II, which uses USB communications.

- If DMM does not display a comm port that you think should be available, check if an “Active Sync” or “Hot Link” program is running and disable it. Such programs, supplied with Palm or Windows CE palmtop computers take control of the serial port and do not allow other devices to operate through it.
- All DataMates manufactured before the DataMate II use RS-232 serial communications. Most new notebook computers and many desktop computers no longer offer a serial port, so you can’t connect the interface cable to the PC. (Note that serial port has 9 pins. Do not confuse it with a monitor port, which has 15 pins).

  You can solve this problem by purchasing a Serial to USB adaptor at your local computer store. One end connects to the USB port on your PC. The other end connects to the serial interface cable supplied with the DataMate. You must also install the USB drivers supplied with the adaptor. It is always a good idea to check the manufacturer’s web site to download the most recent drivers.

More about Setup Databases

- The “File-Save As-Setup Database” command makes a copy of your project database, but removes survey data, so that only installation information remains.
- You can add installations from other project databases or other setup databases to your setup database. See the “How To” section for suggestions.
- When you send a setup database to the DataMate, it clears the entire data memory of the DataMate. If you share your DataMate, you may not want to erase installations and data that belong to someone else. In this case, add new installations using the DataMate’s keypad.
- The original DataMate holds up to 40 installations. The DataMate II can hold 160. Your setup database must not have more installations than these maximums.
- The project database and the setup database are not linked. Thus, if you make changes to installation information in the project database, you should update your setup database or overwrite it with the Save-As Setup command.

Retrieving Surveys

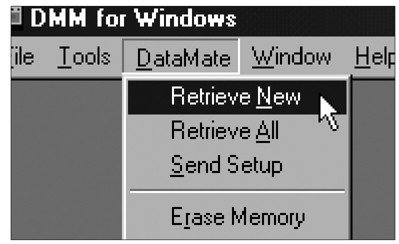
Overview

Retrieving surveys is a two step process.

1. Retrieve the surveys.
2. Copy the surveys into your project database.

Retrieve the Surveys

1. Connect the DataMate to your PC. Select Comm.
   The DataMate displays: Waiting for PC.
2. Run DMM. Choose DataMate - Retrieve All (or Retrieve New).



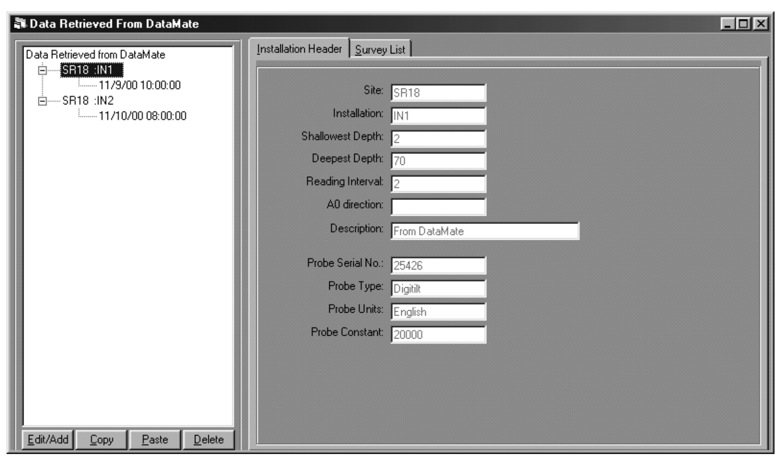
   If you choose Retrieve All, DMM displays all surveys. If you choose Retrieve New, DMM displays only new surveys (that have not been retrieved before).

   DMM retrieves the surveys from the DataMate. You can see its progress at the bottom left of the screen. If you have communications problems, see the troubleshooting steps in the previous chapter.

3. DMM displays the retrieved surveys in a temporary database window. This window is titled "Data Retrieved from DataMate" and is a slightly darker color. You can change the color of the window to make it easier to identify: Choose DataMate-Options. The color-change takes effect the next time that you retrieve surveys.

Data retrieved from DataMate is displayed in a temporary database.

You can change the color of this window to make it easy to identify.

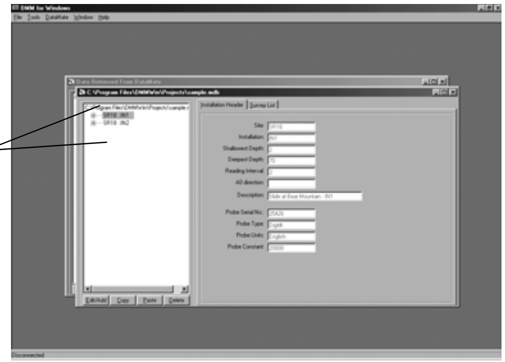


Copy Surveys to your Project Database

1. Open a project database to receive the data. If your DataMate holds surveys from different projects, you can open other project databases at the same time.

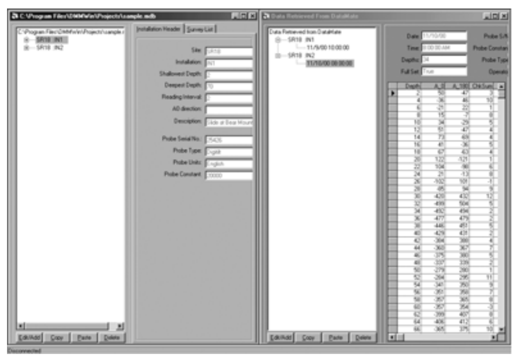
The project database window opens in front of the DataMate window.

To transfer surveys, you must see both windows, as shown below.



2. To position the windows side by side for easy drag and drop, Choose Windows - Tile Vertical.

Use the Windows Tile command or press Ctrl-T to place the windows side by side.



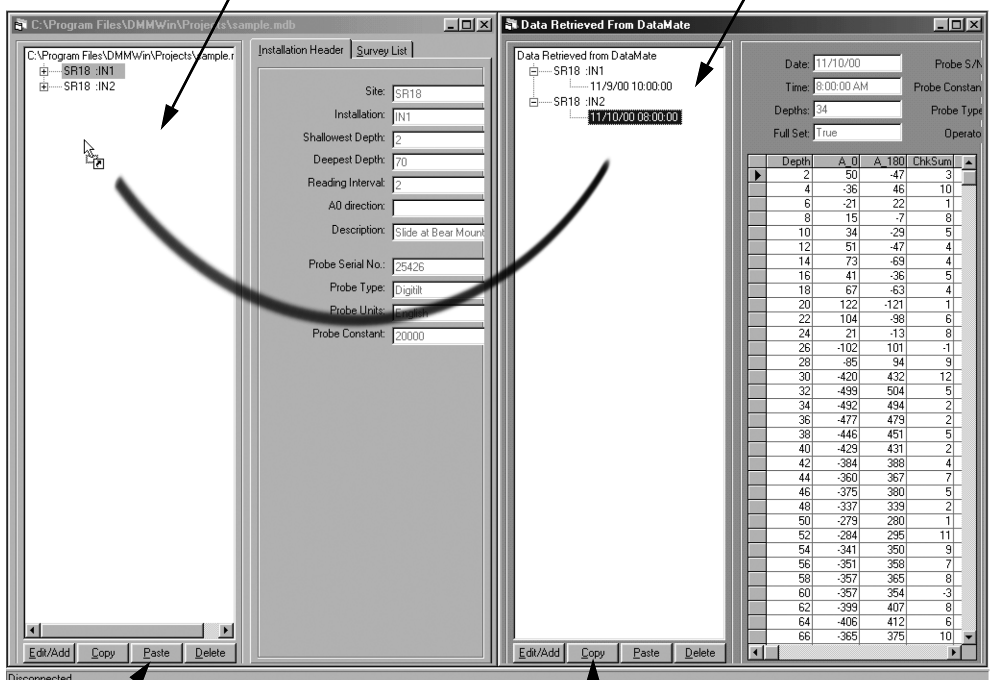
Project Database — Data Retrieved from DataMate

Retrieve Data continued

3. Click, drag, and drop surveys one by one from the DataMate window to the project window. It is not necessary to drop the survey on the installation. If you have difficulty copying surveys, you are probably trying to drag the survey before you select it. Instead of drag and drop, think: “Click, Drag, and Drop.

   You can also use the copy and paste buttons to copy from the temporary database and paste into the project database.

Click, drag, and drop: Click on a survey to select it, then drag the survey to the project window and drop it.



Using Copy and Paste: Click on a survey, click on the Copy button, and then click on the Paste button in the project window.

Data Reduction and Graphing

Introduction

Slope Indicator offers two programs for reducing inclinometer data: DMM for Windows and DigiPro for Windows.

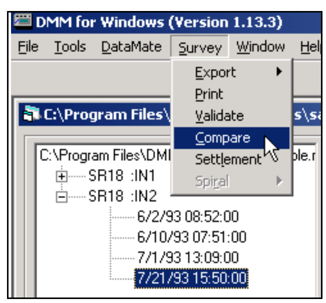
DMM for Windows can calculate checksum statistics, deviations, and displacements, and it can also create a graph of cumulative deviation or cumulative displacement (two surveys only).

DigiPro for Windows offers full graphing capabilities, more graph types, the ability to add titles, and a error correction routines. You can download a run-limited, full working version of DigiPro and the DigiPro manual from www.slopeindicator.com.

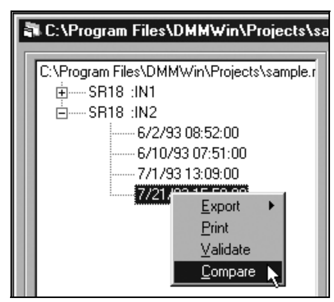
Data Reduction in DMM

DMM's data reduction functions are on the Survey menu or a right click menu. You must select a survey to activate the menus.

1. In the navigation window, click on the + next to an installation. Now you can see a list of surveys.
2. Select a survey.
3. Now click Surveys on the menu bar or click the right button on your mouse.



Select a survey, then click Survey on the menu bar.



The Right-Click Survey Menu

Print: DMM prints readings and checksums for the selected survey.

Validate: DMM displays the mean and standard deviation of checksums for the selected survey.

Compare: DMM compares the selected survey against an initial survey and displays graphs for the A and B axes. You can print a report that includes readings, graphs, and optionally, checksum statistics.

Printing Data

1. Select the survey that you want to print.
2. Click "Survey" on the menu bar.
3. Choose Print. DMM displays a print preview. It provides the following functions:

   Page: Page forward or backward through the preview.

   Print Setup: Choose a printer.

   Page Setup: Choose paper size and margins.

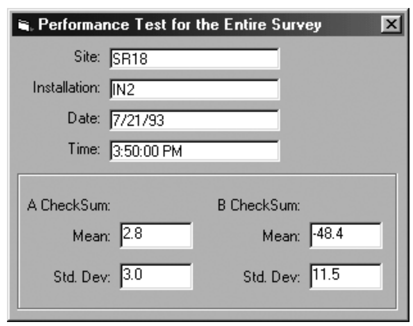
   Print: Print the data. You can print pages selectively.

   Left-Click: Double-click the left mouse button to zoom in. Drag the mouse to move the image.

   Right-click: Double-click the right mouse button to zoom out.

Validating Data

1. Select the survey that you want to validate.
2. Click "Survey" on the menu bar.
3. Choose Validate. DMM displays a table of checksum statistics. Click the X to close the table.



About Checksums

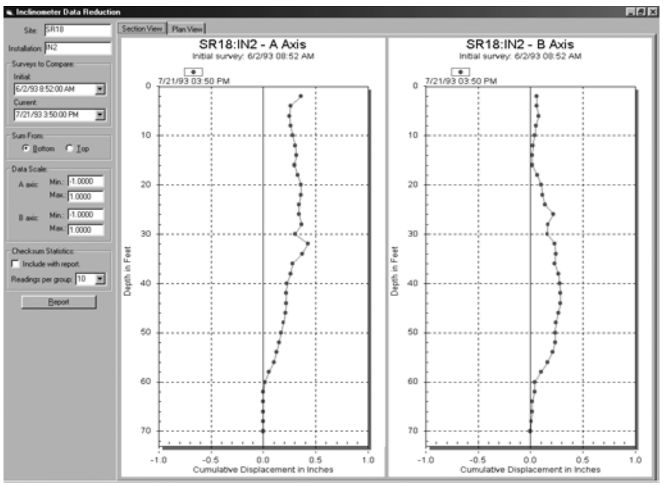
Checksums are one way to measure of the quality of your readings, but don't place too much importance on them. The consistency of checksums from survey to survey is more important than the actual value of the checksums. The standard deviation value is useful for comparing surveys.

Look at the checksums in DMM's display of survey data, especially if you have imported data or entered data manually. Very high checksums often reveal an omitted + or - sign.

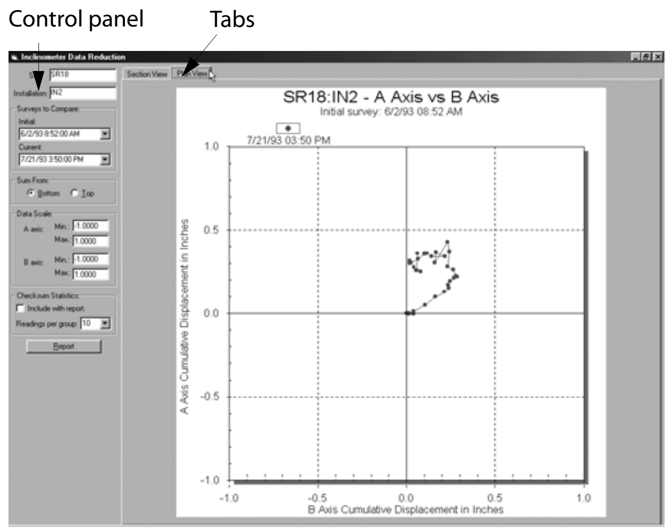
Look for a trend of checksums within a survey. A trend of decreasing checksums from bottom to top can be caused by omitting a warm up period for the probe. Trends of increasing or decreasing checksums within a survey may also indicate a problem with the probe.

Graphing

1. Select the survey that you want to compare.
2. Click “Survey” on the menu bar.
3. Choose Compare.
4. DMM displays a graph of cumulative displacement (movement). Note that DMM compares only two surveys.
5. Click on the tabs to show different views. Use the control panel to change options for the graphs and the printed report.

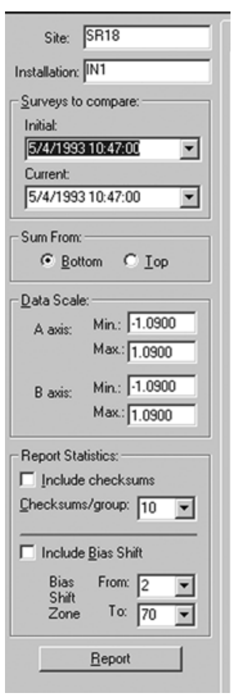


Section View: This view shows standard displacement graphs. A and B data are plotted against depth and shown in separate graphs.



Plan View: This view combines A and B-axis data by plotting the A value vs the B value at each depth.

Control Panel



Use the fields and buttons panel on the left side of the screen to control the graph.

Initial: Select a different initial survey. By default, DMM selects the earliest survey. You can also select “none” to force DMM to display a graph of cumulative deviation (the borehole profile).

Current: Select a different survey for comparison.

Sum From: Select top or bottom. Vertical inclinometers normally use sum from bottom since the bottom of casing is installed in stable ground.

Data Scale: We recommend that you use the scales set by DMM. You can enter other values, if necessary.

Printing a Report

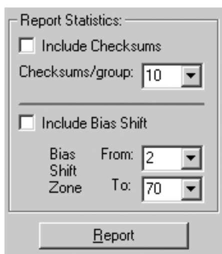
Report Button: When you click the Report button, DMM produces a report consisting of readings, graphs, and optional data. The report is displayed on screen as a print preview. You can page through the print preview and print all pages, the current page, or a range of pages. Some additional pages are added when you include checksum statistics and bias shift analysis.

Plain Report

With no checksum or bias shift information, the report contains:

- A-Axis readings, deviations & displacements in table form.
- B-Axis readings, deviations & displacements in table form.
- Graphs containing A-axis and B-axis displacement plots.
- Graphs of A-axis vs B-axis.

Include Checksums



To include checksum information with your report, click in the checkbox. (A check shows that checksum information will be included). Checksum statistics include a mean checksum and standard deviation of checksums for all readings in the survey. If the installation is deep, you may want to see statistics for smaller number of readings. To do this, enter a value from 1 to 10 in the groups field. Checksum information adds these pages to the report.

- A-axis readings, checksums, and change in checksums.
- A-axis checksum statistics.
- B-axis readings, checksums, and change in checksums.
- B-axis checksum statistics.
- A-axis readings, differences, and changes in digi units.
- B-axis readings, differences, and changes in digi units.

Include Bias Shift

The bias shift report, explained in Appendix 8, adds one page to the report:

- Differences and shifts for A and B axes.

How To . . .

Move a survey

This is useful if your survey is stored in the wrong place. For example, you chose the wrong installation when you started the survey and now you want to move the data to the correct installation.

1. Select the misplaced survey.
2. Click Edit Add to pop up the edit window.
3. Choose the correct installation from the drop down list at the top of the edit window, and click OK. This makes a copy of the survey and places it under the correct installation.
4. Finally, clean up the database. The original survey - the one you copied - is still there. Select it and click the delete button to remove it from the database.

Rename an Installation

1. Select the installation that you want to rename.
2. Click on Edit/Add to open the edit window.
3. Change the name of the installation and click OK. DMM adds a new installation to your database. There are no surveys under the installation.
4. Copy surveys one by one from the old installation to the new installation using the "misplaced survey" technique above.
5. After the surveys are copied, delete the old installation.

Enter Data Manually

Detailed instructions appear in Appendix 6, but here's an overview.

- Click on an installation, then click Edit/Add. If there are no surveys, DMM asks if you want to add a survey. Answer yes.
- If there are already surveys for that installation, you click on an existing survey and click Edit/Add to modify the existing survey. This saves you the time of entering header information and depths. Modify the survey as required, changing the date and time first, then entering the appropriate readings. When you click OK, the new survey is added.

Copy a Database

This is useful for making backup-copies of your database.

1. Open a project database.
2. Choose File - Save As.
3. Enter a name and location for the database, and click OK.

Split a Database

1. Open a project database.
2. Choose File - New to create a new project database.
3. Drag and drop installations from the original database to the new database. Surveys are dragged along with the installations.
4. Delete installations from the original database.

Send New Readings to the Head Office

Sometimes there are two project databases, one at the field office and one at the home office. The field office must maintain its own database and send new readings to the head office.

1. When you retrieve surveys from the DataMate, choose "DataMate - Retrieve New." DMM retrieves new readings and displays the temporary DataMate database.
2. Copy the new readings into your field database as usual.
3. Now, while the temporary DataMate database is still open,
4. Choose File - Save As. Enter a name and location for a database that will contain the new readings, and click OK. This saves the new readings in a database that you can send. Close the new database and update your local project database as usual.
5. Then, copy the new database onto disk or email it as an attachment. It will be fairly small because it contains only the new readings. You can use Winzip to make the file even smaller.
6. The DMM user at the head office then copies readings from the database that you sent to the permanent project database.

Delete a line of Data

1. Select the survey and click Edit/Add.
2. Click in the gray box to the left of the line of data. This selects the line.
3. Press the Delete key.

Make a Composite Setup Database

Suppose you have several projects and want the DataMate to hold inclinometers from each of those projects. You may also want the DataMate to hold a previous survey for each of those inclinometers.

To send installations and datasets (surveys) to the DataMate, you make a "setup" database. To make a setup database, simply save your project database as a setup database. DMM makes a copy of the database and then strips out any data, so all that remains is installation information.

To add a previous survey to the setup database, view your project database and setup database side by side (Use the Ctrl-T Tile command) and click-drag-and-drop the needed surveys from the project database to the setup database. Just drop the survey anywhere in the white window. It will find its own way home. Now you can close the project database, but keep your setup database open.

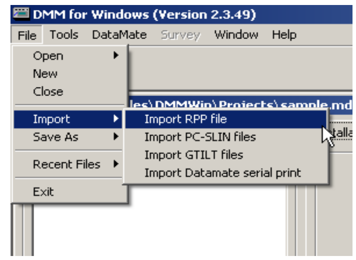
Now, open another project database and tile it side by side with your setup database. You'll be doing click-drag-and-drop operations again. Click-drag-and-drop surveys that you want in the DataMate. The surveys will bring installation information automatically. (Watch out: if you drag an installation, the installation will bring along all of its surveys. So drag a survey, not an installation).

Repeat this for any other installations that you need. Keep in mind that the DataMate has a 40 installation limit and the Datamate II has a 160 installation limit. If more than the maximum is installed, they will be arbitrarily truncated when sent to the DataMate. An alternative to this is to download the contents, save them, modify them (add new setups) and send them back to the DataMate

When the setup database holds the installations and surveys that you need, send the setup to the DataMate. This will cause the DataMate to delete everything that is in its memory and replace it with the contents of the setup database. So be sure that you have retrieved anything that you want from the DataMate before you send the setup.

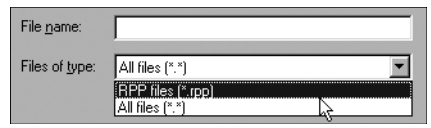
Appendix 1: Importing Data

Importing Data



1. Create a project database.
2. Choose File - Import.
3. Choose the type of import. These are explained below. To import data from a spreadsheet, see page 35.
4. Specify the file to import.
5. Click OK.

RPP Import Notes



- The import routine looks for an extension of RPP. If your RPP file has a different extension, click in the Files of Type field to show All Files.
- The first line of the RPP file must be a date. If DMM gives you an error message, open your RPP file with an ASCII editor such as notepad, and delete any lines above the date line
- If you have trouble importing, check that the date and time formats in the file match the date and time formats of your Windows computer.

The first line of the file must be time and date in this format.

Project and Hole # become Site and Installation. Check that these names are consistent in all surveys for this installation.

Check for missing equals (=).

```
TIME = 09:38:00   29 APR 1993
DIGITILT/SPIRAL = D
ENGLISH/METRIC = E
HOLE # = IN1
PROJECT = SR18
JOB DESC = Slide at Bear Mountain - IN1
DIR CODE =
PROBE SER # = 1
OPERATOR =
START DEPTH = +70.0
END DEPTH = +2.0
INCREMENT = 2.0
INSTR CONST = 20000
ROTATIONAL CORR A = 0.0000
ROTATIONAL CORR B = 0.0000
CALIBRATION CORR A = 0
CALIBRATION CORR B = 0


+2.00    A0    -472    B0     239
       A180     479  B180    -282
+4.00    A0    -265    B0     -17
       A180     273  B180     -13
```

PCSLIN Import Notes

- The import routine looks for an extension of PRN. If your PCSLIN file has a different extension, click in the Files of Type field to change to All Files.
- The first line of the file must start with the word “QUESTIONS.” If there is an error, open the PCSLIN file with an ASCII editor such as Notepad and delete any lines before the word “QUESTIONS.”

“QUESTIONS” must appear on the first line of the file.

Project No and Hole No become Site and Installation.

The import routine ignores reading set numbers.

Check that the equals (=) are always lined up. If necessary, shorten entries.

```
QUESTIONS
PCSLIN          = DATA FILE NAME
SR18            = PROJECT NO
Slide at Bear Mountain - IN1
IN1             = HOLE NO.
    1           = READING SET NO.
04/29/1993      = DATE
09:38           = TIME
       20.,     = STATISTICS INTERVAL
12345           = INSTRUMENT NO.
         0,     = HALF OR COMPLETE SET OF DATA
      .000,     = A-ROTATION ERROR CORRECTION
      .000,     = B-ROTATION ERROR CORRECTION
    20000.,     = INSTRUMENT CONSTANT
                = A+ COMPASS DIRECTION
                = A- COMPASS DIRECTION
                = B+ COMPASS DIRECTION
                = B- COMPASS DIRECTION
         0,     = SHIFT ANALYSIS PRINT
         0,     = A COMPONENT SHIFT
         0,     = B COMPONENT SHIFT
      400.,     = CHANGE IN READING SCALE
        2.,     = DEFLECTION SCALE
READINGS  ,   35
     2.000,      -472,       479,       239,      -282
     4.000,      -265,       273,       -17,       -13
```

GTilt Import Notes

The Gtilt import routine looks for an extension of GTL. If your file has a different extension, click in the Files of Type field to change to All Files.

Metric files are assigned an instrument constant of 25000 and a reading interval of 0.5 m. English files are assigned an instrument constant of 20000 and a reading interval of 2 feet.

This is truncated to 6 characters and becomes Installation. (→ SAMPLE1)

This is truncated to 6 characters and becomes Site. (→ NORTH PORTAL SLOPE)

```
SAMPLE1
NORTH PORTAL SLOPE
Urban Transit Authority
North Slope Investigation
E
4
2.25
37
M
637.0
45
10000
 5
*
07061998
1327
1400
Top of cable clamp
31.2
EDM
EDM
EDM
6.45
6.21
TAJ
TAJ


-150  131 -216  236
-54  36 -180  187
 69 -85 -204  218
```

DataMate Serial Print

This import function is included mostly for diagnostics. The DataMate can print a survey to a serial device. There are very few serial printers these days, so a terminal program, such as Hyperterm, is used to capture the output of the DataMate and save it as a text file. This import utility provides a way to import that text file.

```
Site     :SR18
Survey   :IN1
A0 dir   :
Operator :
Sensor # :25426
Axes     :DIGITILT
Units    :ENGLISH
Ins const:20000.0
Start    :70.0
End      :2.0
Interval :2.0
Time     :93/05/04

Depth     A0      A180     B0      B180
  2.0    -475     477      235     -286
  4.0    -270     274       -7      -14
  6.0     334    -329     -206      161
  8.0     393    -390     -129       78
 10.0     298    -293     -223      159
 12.0     246    -235     -258      210
 14.0     170    -167     -301      260
 16.0     123    -114     -363      321
 18.0      57     -56     -438      387
 20.0      -5      10     -421      374
 22.0      77     -72     -500      447
 24.0     174    -167     -418      376
 26.0     242    -238     -434      384
 28.0     173    -167     -406      352
 30.0      91     -88     -422      398
 32.0      85     -77     -615      586
 34.0     110    -103     -697      644
 36.0     193    -189     -669      615
 38.0     212    -208     -690      627
 40.0     172    -168     -683      622
 42.0     174    -155     -651      594
 44.0      47     -54     -559      510
 46.0      27     -11     -537      482
 48.0      86     -78     -511      462
 50.0     171    -167     -569      517
 52.0     152    -135     -566      511
 54.0      75     -72     -437      411
 56.0     146    -139     -389      369
 58.0     155    -147     -526      499
 60.0     155    -153     -645      590
 62.0     174    -167     -603      550
 64.0     115    -103     -557      510
 66.0      88     -81     -562      511
 68.0      99     -90     -629      569
```

Importing Data from a Spreadsheet

1. Export the data for a single survey to a text file (see sample below).
2. In DMM, select an installation then right-click and select "Add Survey".
3. Fill in the survey header information. Date, Time, Probe s/n, Probe Constant, Probe Type, Full Set, and Operator. Depths will be filled in during import.
4. Click "Import Data" at the bottom of the form.
5. Select the file to import.

Important:

- During the import, text lines will be ignored.
- Lines with at least 5 numeric values will be imported as data.
- When the import is complete, the data will be displayed and the number of depths will be set to the number of data lines read from the file.

Depth	A0	A180	B0	B180
2	289	263	194	208
4	6 0	-30	2 3	40
6	4 3	71	2	1 7
8	6 7	98	3 8	-21
10	-57	87	3	19
12	-62	91	-17	43
14	-49	78	9	21
16	-4	34	17	32
18	11	18	-62	82
2 0	29	1	8 8	107
22	63	27	104	127
24	66	39	-96	127
26	29	2	118	139
28	4	28	111	131
30	2	28	82	98
32	-12	48	-68	87
34	-63	89	-47	67
36	104	133	64	87
38	103	133	69	97
40	124	153	64	83
42	110	143	51	72
44	140	169	58	88
46	167	196	49	76
48	126	157	73	91
50	74	101	84	102
52	30	60	68	89

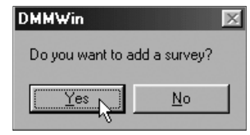
Appendix 2: Manual Entry of Data

Create a Database and Add Installations

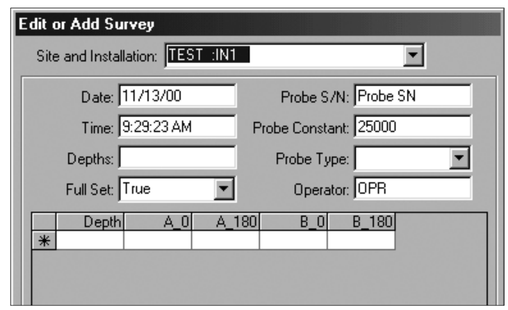
1. Create or open a project database.
2. Enter installation information. Both of these tasks are described in “Creating a Project Database.”

Enter the First Survey

1. .Click on the installation, then click on the Edit/Add button. DMM asks if you want to enter survey data. Click Yes.



2. The edit window appears. Enter the survey header information as explained below.



Site and Installation: Verify that the site and installation are correct. If not, choose a different installation from the drop-down menu.

Date and Time: Enter the date and time of the survey. DMM displays the current date and time so that you can see the proper format. The actual format will change according to your Windows' short-date setting.

Depths: Skip this field. It will be entered automatically after you have entered readings.

Full Set: Enter True if you have readings for both the 0 and the 180 directions. Enter False if you have only the 0 readings. The Full-Set value is used in calculations later.

Probe S/N: Enter the serial number of the inclinometer probe.

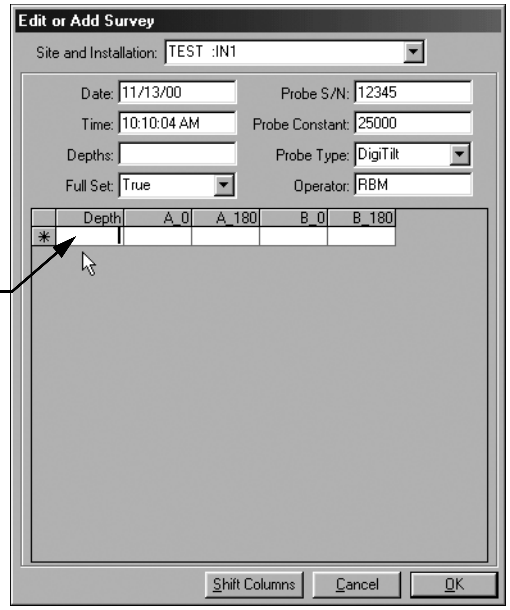
Probe Constant: Enter 25000 for metric-unit probes or 20000 for English-unit probes. This value is used in calculations

Probe Type: Enter Digitilt or Spiral. This value is used in calculations.

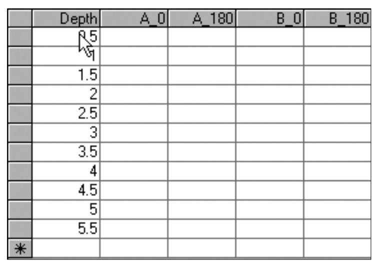
Operator: Enter initials of the operator (3 characters).

Enter the First Survey Continued

1. Enter depths, starting with the shallowest.
2. Enter the readings for each depth. When you are done, click OK.

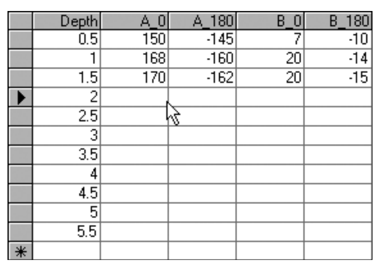


Click here to enter a depth. Start with the shallowest depth.



Depth	A_0	A_180	B_0	B_180
0.5				
1				
1.5				
2				
2.5				
3				
3.5				
4				
4.5				
5				
5.5				

Enter the depths first. Check that you have not missed any depths.



Depth	A_0	A_180	B_0	B_180
0.5	150	-145	7	-10
1	168	-160	20	-14
1.5	170	-162	20	-15
2				
2.5				
3				
3.5				
4				
4.5				
5				
5.5				

Enter readings for each depth. Press the arrow keys or tab to move from field to field.

Enter Subsequent Surveys

To enter other surveys for the same installation, you make a copy of the first survey (so that you do not have to enter depths again).

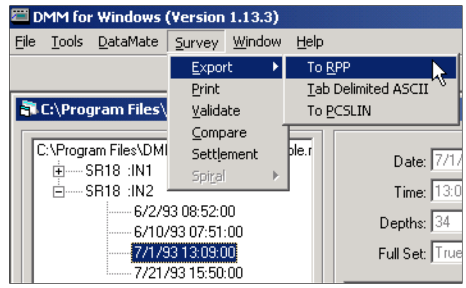
1. Select the first survey.
2. Click on Edit/Add. The edit window appears.
3. Correct the time and date for this survey.
4. Enter the readings and click OK.

Note: If there are many readings, you might want to save your work occasionally. To save your work simply click the OK button. To reopen the survey, select it (check the time and date), and click the Edit Add button.

Appendix 3: Exporting Data

Overview

1. Open a project database (or retrieve data from the DataMate).
2. Click on the + next to an installation. This makes surveys visible.
3. Select the survey that you want to export.
4. Click “Survey” on the menu bar and choose a format: RPP, Tab Delimited ASCII, or PCSLIN.
5. Specify a location and a name for the file and click OK.



RPP Format

This format includes header information, such as the installation ID and depth, the probe serial number, etc, followed by columns of data in fixed widths.

```
TIME = 10:00:00   09 Nov 2000
DIGITILT/SPIRAL = D
ENGLISH/METRIC = E
HOLE # = IN1
PROJECT = SR18
JOB DESC = From DataMate
DIR CODE =
PROBE SER # = 25426
OPERATOR =
START DEPTH = 70
END DEPTH = 2
INCREMENT = 2
INSTR CONST = 20000
ROTATIONAL CORR A = 0.0000
ROTATIONAL CORR B = 0.0000
SENSITIVITY FACTOR A = +0
SENSITIVITY FACTOR B = +0

+2.0     A0    -489    B0    209
       A180     494  B180   -293
+4.0     A0    -281    B0    -29
       A180     280  B180      9
+6.0     A0     337    B0   -220
       A180    -335  B180    185
+8.0     A0     411    B0   -139
       A180    -406  B180     90
+10.0    A0     323    B0   -207
       A180    -320  B180    169
+12.0    A0     267    B0   -263
       A180    -261  B180    219
+14.0    A0     192    B0   -305
       A180    -194  B180    264
+16.0    A0     142    B0   -373
```

Tab-delimited ASCII Format

This format includes column labels and tab-delimited values. It also includes checksums for both A and B readings.

Column labels can be excluded on import to the spreadsheet, as shown here.

2	(* ˘	*˘*	ˆ	209	-293	(*
*	-281	280	-1	-29	˘	-20
!	337	(˘˘ˆ	2	-220	185	(˘ˆ
	411	(*˙!	ˆ	-139	˘˙	(*˘
10	323	-320	ˇ	-207	169	(ˇ
12	267	-261	!	-263	219	(**
14	192	-194	-2	(˘˙ˆ	264	-41
16	142	-139	ˇ	-373	326	-47
18	81	-79	2	-451	˘˘ˇ	(ˆ
20	11	(˘	2	-413	ˇ!*	(*˘
22	91	-91	˙	(*˘ˇ	**ˆ	(*
24	178	-171	7	(*˙	ˇ!ˆ	(*ˇ
26	245	-242	ˇ	-431	377	(ˆ*
28	177	-170	7	-397	ˇ*˘	(*
ˇ˙	˘ˇ	(˘ˇ	˙	-414	˘˘ˇ	-21
32	˘	(ˆ	*	-619	ˆ ˆ	(ˇ*
ˇ*	112	-111	1	-700	!*!	(ˆ*
ˇ!	197	-193	*	-670	612	(ˆ
ˇ	213	-211	2	-691	631	(!˙
*˙	170	-168	2	(! ˆ	627	(ˆ
42	164	-159	ˆ	(!ˆ˙	ˆ˘˘	-51
**	*!	(ˆˆ	(˘	-557	515	-42
*!	22	(	14	(ˆˇ˙	481	(*˘
*	˙	-75	ˆ	(ˆ˙ˆ	*ˆˆ	(ˆ˙
ˆ˙	166	-166	˙	-571	515	(ˆ!
52	145	-133	12	(ˆˆ*	507	-47
ˆ*	70	(!!	*	-419	ˇ	-31
ˆ!	138	-137	1	-397	ˇ!ˆ	-32
ˆ	148	-143	ˆ	-529	ˆ˙˙	-29
!˙	152	-152	˙	-641	ˆ˘ˇ	(*
62	169	-169	˙	(!˙ˇ	547	(ˆ!
!*	110	-101	˘	(ˆˆ	511	-47

PCSLIN

This format includes a header followed by space delimited columns of data.

```
QUESTIONS
PCSLIN          = DATA FILE NAME
SR18            = PROJECT NO
Slide at Bear Mountain - IN1
IN1             = HOLE NO.
    1           = READING SET NO.
04/29/1993      = DATE
09:38           = TIME
       20.,     = STATISTICS INTERVAL
12345           = INSTRUMENT NO.
         0,     = HALF OR COMPLETE SET OF DATA
      .000,     = A-ROTATION ERROR CORRECTION
      .000,     = B-ROTATION ERROR CORRECTION
    20000.,     = INSTRUMENT CONSTANT
                = A+ COMPASS DIRECTION
                = A- COMPASS DIRECTION
                = B+ COMPASS DIRECTION
                = B- COMPASS DIRECTION
         0,     = SHIFT ANALYSIS PRINT
         0,     = A COMPONENT SHIFT
         0,     = B COMPONENT SHIFT
      400.,     = CHANGE IN READING SCALE
        2.,     = DEFLECTION SCALE
READINGS  ,   35
     2.000,      -472,       479,       239,      -282
     4.000,      -265,       273,       -17,       -13
```

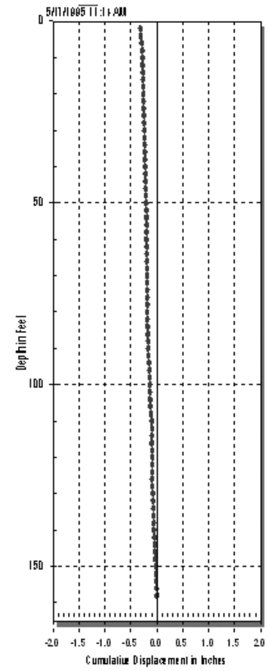
Appendix 4: Bias-Shift Analysis

What is Bias Shift

Bias: If you hold your inclinometer probe absolutely vertical and check the reading, you will typically see a non-zero value. This is the probe's bias. The bias value is normally eliminated in the data reduction process when the 0 readings are combined with the 180 readings.

Bias-Shift Error: If the bias value changes during a survey, the data reduction process cannot eliminate all of the bias. The remaining value is error that is embedded in the reduced data.

The straight, but leaning plot at right is the result of bias-shift error.



Identifying Bias Shift

Appearance: A straightened, but leaning cumulative displacement plot is a signature of bias shift error. The embedded error grows larger at each interval, so the plot leans to the left or right.

Unlikely Behavior: The graph above shows rotation of the entire 150 foot span of soil or rock. This unlikely behavior suggests error in the data.

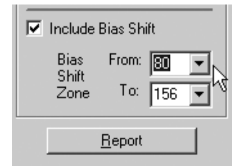
Site Knowledge: The plot shows movement where there should be no movement. Typically, the bottom 5 depths (or more) of the casing are anchored in stable ground. Any movement appearing there is generally error. In our example, we know that the casing entered rock below 80 feet, and that no movement has occurred from 80 feet downwards. This again suggests error in the data.

More information on bias-shift can be found in the training section of Slope Indicator's website: www.slopeindicator.com. Click on the link for Sample Chapters. Then click on "Bias Shift Error."

Quantifying Bias Shift Error

DMM provides a routine for quantifying bias shift error. The routine provides an average bias shift value that can be used as a correction value in DigiPro (but not in DMM).

1. Right click on the survey. Choose Compare.
2. Click the checkbox to include a bias shift analysis. Use the From and To drop boxes to limit the analysis to depths that you know are stable. This is important so choose the depths carefully. In our example, the casing is stable below 80 feet, so we enter 80 to exclude readings above 80 feet.



3. Click the report button. Then page through the report to find the bias-shift page.
4. The analysis routine finds the difference between current and initial A0 readings and the difference between current and initial A180 readings. This is reported in the Diff column. Since movement affects the A0 and A180 passes in the same way, the values in the A0 column should match the values in the A180 column.

   The Shift column shows the difference between the A0 column and the A180 column. If you have limited the analysis to depths where no movement is likely to occur, the value in the Shift column represents bias shift error (plus some possible random error).
5. An average error appears at the bottom of the column. This is the correction value that you can enter into DigiPro.

Bias Shift for Aand B Axes:

Depth (ft)	Diff. A0	Diff. A180	Shift A	Diff. B0	Diff. B180	Shift B
80	1.0	8.0	-7.0	27.0	-8.0	35.0
82	-1.0	6.0	-7.0	28.0	-19.0	47.0
84	-2.0	6.0	-8.0	25.0	-5.0	30.0
86	-1.0	7.0	-8.0	30.0	-14.0	44.0
88	4.0	8.0	-4.0	24.0	-13.0	37.0
90	-1.0	11.0	-12.0	28.0	-14.0	42.0
92	-6.0	11.0	-17.0	29.0	-21.0	50.0
94	-2.0	9.0	-11.0	25.0	-25.0	50.0
96	-3.0	6.0	-9.0	28.0	-12.0	40.0
98	-4.0	13.0	-17.0	14.0	17.0	-3.0
100	0.0	8.0	-8.0	24.0	-7.0	31.0
102	-1.0	11.0	-12.0	26.0	-5.0	31.0
104	-2.0	9.0	-11.0	20.0	-1.0	21.0
106	-6.0	11.0	-17.0	44.0	-10.0	54.0
108	-16.0	18.0	-34.0	20.0	4.0	16.0
110	4.0	9.0	-5.0	15.0	11.0	4.0
112	9.0	-1.0	10.0	32.0	5.0	27.0
114	7.0	0.0	7.0	20.0	-4.0	24.0
116	-8.0	13.0	-21.0	35.0	-15.0	50.0
118	1.0	2.0	-1.0	40.0	-35.0	75.0
120	5.0	5.0	0.0	23.0	-17.0	40.0
122	3.0	3.0	0.0	27.0	-20.0	47.0
124	0.0	4.0	-4.0	32.0	-21.0	53.0
126	-2.0	11.0	-13.0	28.0	-19.0	47.0
128	-5.0	11.0	-16.0	20.0	16.0	4.0
130	-2.0	11.0	-13.0	29.0	-13.0	42.0
132	0.0	8.0	-8.0	35.0	-1.0	36.0
134	-2.0	8.0	-10.0	30.0	-20.0	50.0
136	-3.0	9.0	-12.0	32.0	-29.0	61.0
138	-3.0	8.0	-11.0	32.0	-21.0	53.0
140	-4.0	5.0	-9.0	29.0	-6.0	35.0
142	-4.0	13.0	-17.0	21.0	14.0	7.0
144	-4.0	12.0	-16.0	31.0	-24.0	55.0
146	-6.0	12.0	-18.0	44.0	1.0	43.0
148	6.0	9.0	-3.0	20.0	-11.0	31.0
150	1.0	8.0	-7.0	26.0	-5.0	31.0
152	-2.0	10.0	-12.0	25.0	-5.0	30.0
154	-3.0	11.0	-14.0	13.0	2.0	11.0
156	-2.0	10.0	-12.0	-1.0	-1.0	0.0
Average			-9.9			35.4

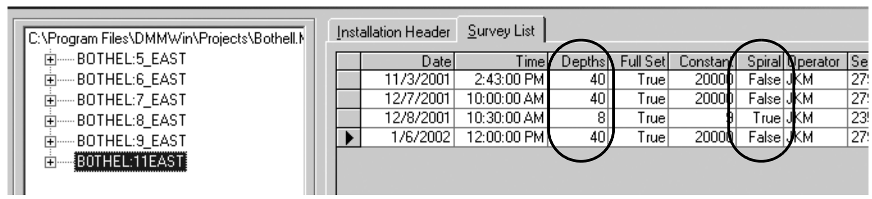
Averaged bias shift values

Appendix 5: Expanding Spiral Surveys

Spiral Surveys

Spiral surveys are obtained with a special-purpose spiral sensor. Please refer to the spiral sensor manual for instructions on conducting a spiral survey.

Spiral surveys are stored with inclinometer surveys in the project database. A typical spiral survey has depths and two or four columns of data, one column of data for each pass through the casing. The spiral survey can be identified as explained below:

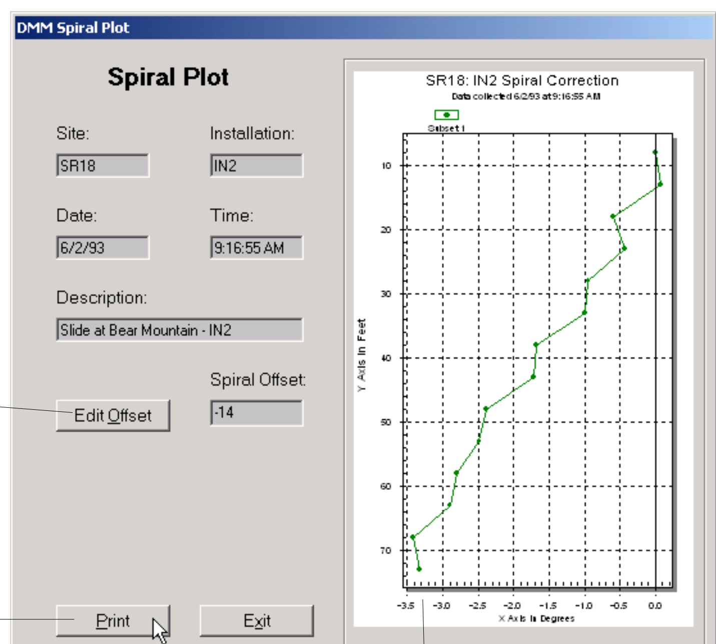


The spiral survey has fewer reading depths than an inclinometer survey. Also, it is marked True in the Spiral column.

Plotting Spiral Data

DMM can generate a plot from the spiral data. The spiral plot shows the magnitude of the spiral in the casing. If the accumulated spiral is small (<20 degrees), you may decide to ignore spiral.

1. Select the spiral survey.
2. Click Survey on the menu bar, then choose Spiral - Plot Spiral.



Click this button to enter an offset for the spiral sensor. See the spiral manual for detail.

You can print the spiral plot.

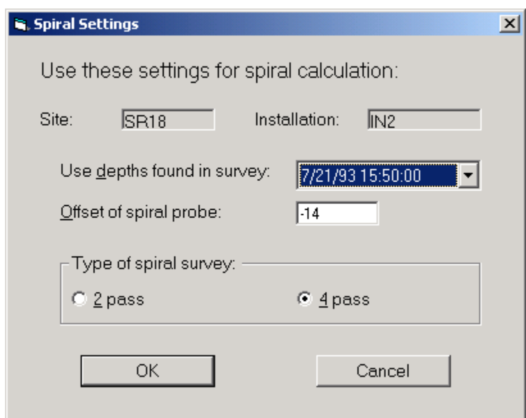
Spiral values are accumulated from top to bottom, so the maximum value appears at the bottom.

Expanding Spiral Data

To correct inclinometer surveys for Spiral, the DigiPro program requires a spiral value for each depth in the inclinometer survey.

DMM's spiral expansion routine reads the spiral survey and generates a new survey with values for each inclinometer depth. Later when you use DigiPro to graph inclinometer data, you simply switch on spiral correction and DigiPro automatically finds the expanded spiral survey and applies the data.

1. Select the unexpanded spiral set.
2. Click on Survey, and choose Spiral - Expand Spiral.
3. Specify which survey has the proper number of depths.
4. Enter the spiral sensor offset. (See the Spiral Manual).
5. Choose the number of data columns in the spiral survey (2 or 4).
6. Click OK. DMM then generates a new spiral survey. It has the same date as the original spiral survey, but the time is changed by one second. In addition, the operator field is marked EXP.

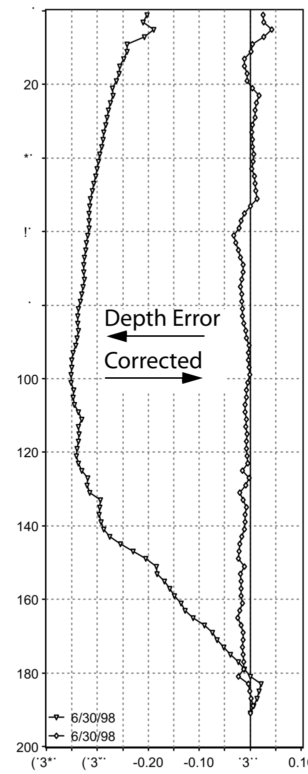


Appendix 6: Settlement Corrections

Depth Error

The accuracy of an inclinometer system depends on repeatable positioning of the inclinometer probe. When the probe is positioned consistently at each depth in the survey, readings can be compared reliably. If the reading changes, movement has occurred. If the reading stays the same, no movement has occurred.

However, if the probe is positioned above or below the proper depth, the reading will change, even if there is no movement. This changed reading is a depth error. In casing that is very straight, the change in reading is small, and can typically be ignored. But in casing that is "wavy," the change can result in obvious error, as shown in the DigiPro plot at right.



Sources of Depth Error

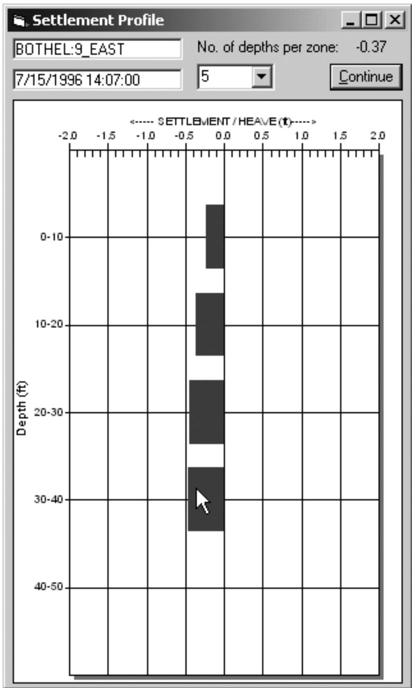
Changed reference: The operator positions the probe by aligning depth markers on the cable to a reference at the top of the casing. If the reference changes, every reading in the survey is affected. This can be corrected by DMM's settlement correction.

Change in casing length: If the casing is compressed by settlement, the probe will be positioned deeper in the casing. Readings are affected at and below the zone of settlement. This can be adjusted by DMM's settlement correction.

Change in cable length: Control cables may shrink or stretch over time. Cables may be interchanged with other cables that are not the same length. Repairs and splicing of cable may result in changed length. Readings are affected where differences in cable become active. This can be adjusted by DMM's settlement correction

Random positioning: A distracted operator accidently positions the probe at the wrong depth and take a reading. This cannot be adjusted by DMM's settlement correction. Edit the data instead.

Generating a Corrected Survey



1. Select the affected survey. Click on Survey. Choose Settlement.
2. Determine whether the depth error is settlement or heave (see explanation below).

Settlement	**Heave**
Reference is lower than before	Reference is higher than before
Casing is shorter than before	Casing is longer than before
Cable has stretched	Cable has shrunk

3. To enter a value, click on the zone line. A bar appears. You can see the numeric value of the bar in the upper right corner. Enter settlements on the left side and heave on the right side. Units are in feet or meters.

   If you reduce Sondex or Magnet extensometer readings as suggested in the manuals, your final calculations are changes for each ring or magnet. The values entered into DMM should be the complement of these changes (total settlement minus change).

   In the example below, the change for magnet 5 represents total settlement (the change in the distance between the datum magnet and the top magnet). You can see the required calculation. Although the values for DMM are positive, you should still enter them on the settlement side of the dialog.

Magnet	Change (feet)	Total Settlement - Change	Value for DMM
5	0.23	0.23 - 0.23	0
4	0.17	0.23- 0.17	.06
3	0.11	0.23 - 0.11	0.12
2	0.06	0.23 - 0.06	0.17
1	0.02	0.23 - 0.02	0.21

4. When you are done, click the Continue button. DMM generates a new survey, with the same date, but time changed to 23:59:59.

Appendix 7: Updating MDB Databases

Introduction

DigiPro for Windows version 1.26 and earlier had an automatic database conversion utility that copied data from a DOS "hdr" database into a Windows "mdb" database. The conversion was not perfect, so if you open these files with DMM for Windows, DMM will ask you to update the database.

To Update a MDB Database

1. Start DMM for Windows.
2. Navigate to your existing MDB database. They have the same name and are in the same location as your hdr databases, the ones created by the DOS version of DMM.
3. Open the mdb database.
4. Choose File-Save As and enter a new name for the database. After a short delay, DMM displays the new, updated database in its own window. From now on, you should use this new database. You may want to delete the old mdb database.

   Note: When you use the save-as command, DMM automatically assigns a file name using the words "copy of....." It also uses the default folder (Program Files\DMMWin\Project\). You will probably want to specify a different name. You may want to specify a different folder as well. If you save the program into the same folder, you must use a different name. DMM will not overwrite the existing database.
5. Check each installation record. If you use an English-unit system, check that you have English units and an instrument constant of 20,000 entered into the installation record.

   If you have metric-unit database, you must correct any decimal entry: shallowest depth, deepest depth, reading interval. You must also check that you have chosen metric units and have entered an instrument constant of 25,000.

   Note that these corrections affect only the installation information. Data is not affected and requires no corrections.

Appendix 8: Converting DOS DMM Databases

Introduction

- DMM for Windows uses an ".mdb" database. It replaces the old ".hdr" database used by the DOS version of DMM.
- If you use DigiPro for Windows, you already have an ".mdb" database, but you must update it with DMM. See the previous page.
- To convert "hdr" databases directly to mdb databases without going through DigiPro, use the utility program called HDR2MDB.EXE.

Using the Hdr2Mdb Utility

This program is installed in your DMM for Windows folder. It is used to convert DMM DOS databases to the DMM Windows format.

1. Start the Hdr2Mdb program.
2. Open an hdr database.
3. Specify a name and location for the mdb database, and click OK. After a short delay, the program announces a successful conversion.

   The program will prompt you if it cannot determine the serial number of your probe or whether it is a metric-unit or English-unit probe.

Work-Around for Double-Byte Windows

The Hdr2Mdb program does not work properly with double-byte Windows systems, such as Chinese, Japanese, and Korean Windows. We are sorry for this inconvenience. Here are two work-arounds:

- Install HDR2MDB on a computer that is running a US version of Windows. Do the conversion, then copy the new mdb database to your double-byte version of Windows.
- Use DMM DOS to export your surveys in RPP format, then import the surveys with DMM for Windows.

Appendix 9: Windows vs DOS DMM

Introduction

If you used the DOS version of DMM, you'll want to know what is different in the Windows version:

System Requirements

- DMM for Windows requires Windows 95/98/ME/NT4/2000.
- DMM for Windows does not run on DOS or Windows 3.1.

Project Database

- DMM for Windows uses an ".mdb" database. It replaces the old ".hdr" database used by the DOS version of DMM.
- You can convert your DOS hdr files to mdb files using DigiPro for Windows or the utility program called HDR2MDB.EXE.

DataMate Setup

- DMM for Windows creates a "setup database" to load installations (and surveys) into the DataMate. (There is no equivalent to the setup database in DMM for DOS.)
- The setup database lets you create an installation list from separate databases and is also used to manage the DataMate's memory.

Retrieving Data

- Datasets are called "surveys" in DMM for Windows.
- DMM lets you retrieve all surveys or new surveys. (In DMM DOS, you tagged each survey and then retrieved them).
- DMM holds retrieved surveys in a temporary database. You then drag and drop surveys into one or more project databases. (In DMM DOS, you retrieved surveys directly into the project database)

Managing DataMate Memory

- DMM provides two ways to clear the DataMate's memory. You can send a setup to the DataMate or you can use the erase memory command provided in DMM.
- To delete individual surveys, you must use the DataMate itself.

Managing the Database

- You can move misplaced datasets.
- You can shift columns of readings.
- You can easily copy installations and datasets between databases.
- You can easily create a database of new readings for emailing.

Appendix A6 - DigiPro for Windows

DigiPro for Windows

SLOPE INDICATOR
12123 Harbour Reach Drive
Mukilteo, Washington, USA, 98275
Tel: 425-493-6200 Fax: 425-493-6250
E-mail: solutions@slope.com
Website: www.slopeindicator.com

Contents

Introduction

Read This

- Even if you hate manuals, it is important that you read this introduction and the Quick Tour pages.
- If you have DigiPro version 1.26 or earlier on your computer, we suggest that you remove it before installing later versions. This will not affect your data files or your unlocking key.
- If you are working on an NTFS system (Windows NT 4, 2000, XP, or later), you may find that administrator rights are required to install DigiPro. See your IT person for help.

What is DigiPro?

DigiPro software is used to process and plot inclinometer data. It creates high-resolution graphs and provides advanced routines for identifying and correcting systematic errors.

DigiPro works with the project databases created by DMM for Windows. If your inclinometer readings are not in this format, see Appendix A.

DigiPro is not free software. It must be purchased. However, when you first install DigiPro, purchased or not, it will run 45 times, so you can get some work done without worrying about licensing. Read "About Unlocking Keys" on the next page.

Installing DigiPro from a Resource CD

1. Remove any earlier version of DigiPro first. Doing this will not affect your data or your unlocking key.
2. Insert the Resource CD in your CD-ROM drive. The CD will start automatically on some computers. On other computers, you have to open and close the CD-ROM drive a second time to make Autostart work.
3. The browser window appears: click on Software.
4. The software page appears: click on DigiPro for Windows.
5. The DigiPro page appears: click on "Download DigiPro."
6. The File-Download dialog appears: choose "Run this program from its current location" and click OK. You may see an security warning. Click Yes to continue the install.
7. Follow on-screen instructions. You may be asked to restart your computer more than once.

Installing DigiPro from a Setup File.

If you downloaded DigiPro from www.slopeindicator.com, you have a setup file named “setupdpwin.exe” on your hard disk.

1. Remove any earlier version of DigiPro first. Doing this will not affect your data or your unlocking key.
2. Click the Start button and choose Run.
3. The Run dialog appears: click the Browse button to navigate to the setup file that you downloaded.
4. Select the setup file (setupdpwin.exe) and click Open.
5. Click OK when the Run dialog reappears.
6. Follow on-screen instructions. You may be asked to restart your computer more than once.

About Unlocking Keys

After DigiPro is installed, it will run 45 times. After that, it will stop running. To remove the run-limitation, you must purchase DigiPro and request an unlocking key (a coded number). If you have already purchased DigiPro, we have your company and city in our database, but you must contact us for the key. Follow the steps below:

To obtain a key

1. Find your DigiPro serial number. Start DigiPro. When the start screen appears, click on the "License" button. A dialog appears with the serial number.
2. Use one of the methods below to contact us. We need your serial number, name, company, and city.

- Visit www.slopeindicator.com. Click on “Support,” then click on “Get a DigiPro Key” and fill out the form.
- Call Slope Indicator or your local distributor.
- Fax Slope Indicator or your local distributor.

3. We will generate a key to match your serial number and give it to you.

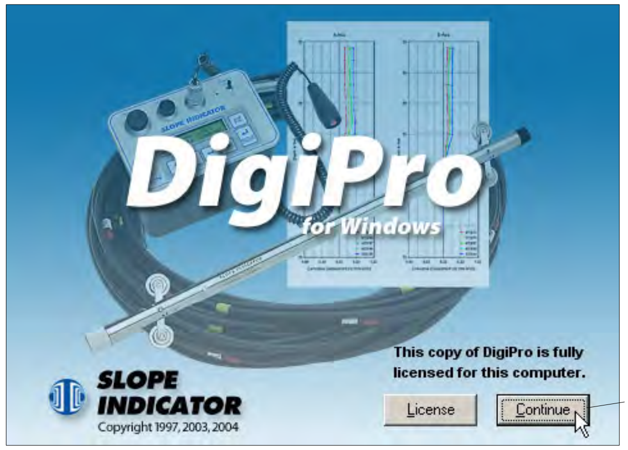
To enter the key

1. Start DigiPro. The start screen appears. Click on License.
2. Check that your serial number is the one that you sent us, then click on Modify.
3. Enter your the unlocking key, and click OK.
4. You should see the message: “This copy of DigiPro is fully licensed for this computer.”

Quick Tour

Start DigiPro

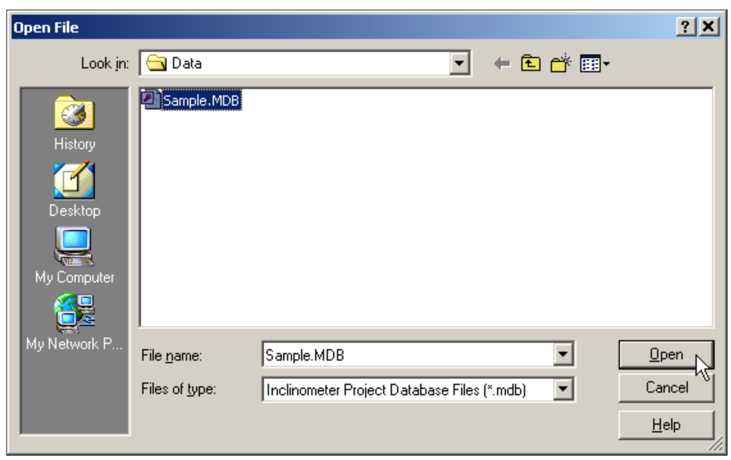
Click on the DigiPro shortcut, or go to:
Start > Programs > DigiPro > DigiPro.exe. Click Continue.



Click on the Continue button.

Open a Database

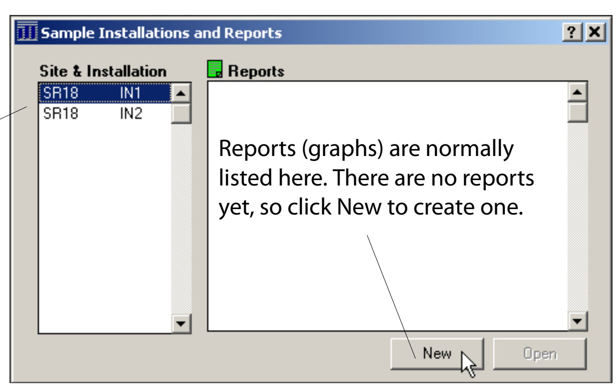
DigiPro displays the Open File dialog. Choose "Sample.MDB." If you don't see it, navigate to C:\Program Files\DigiPro\Data.



Choose an Installation and Create a Report

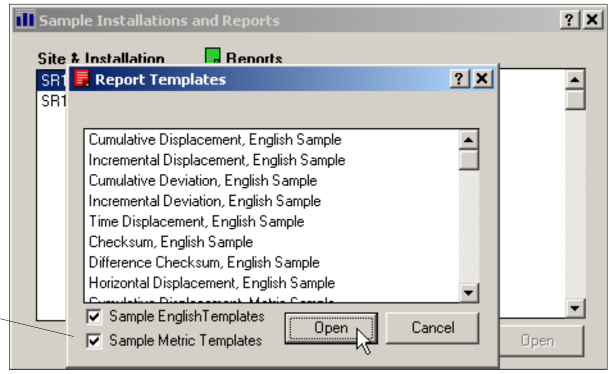
DigiPro displays a list of the installations in the database. Select the top one, SR18 IN1, and click New to create a report.

Installation List



Choose a Report Template

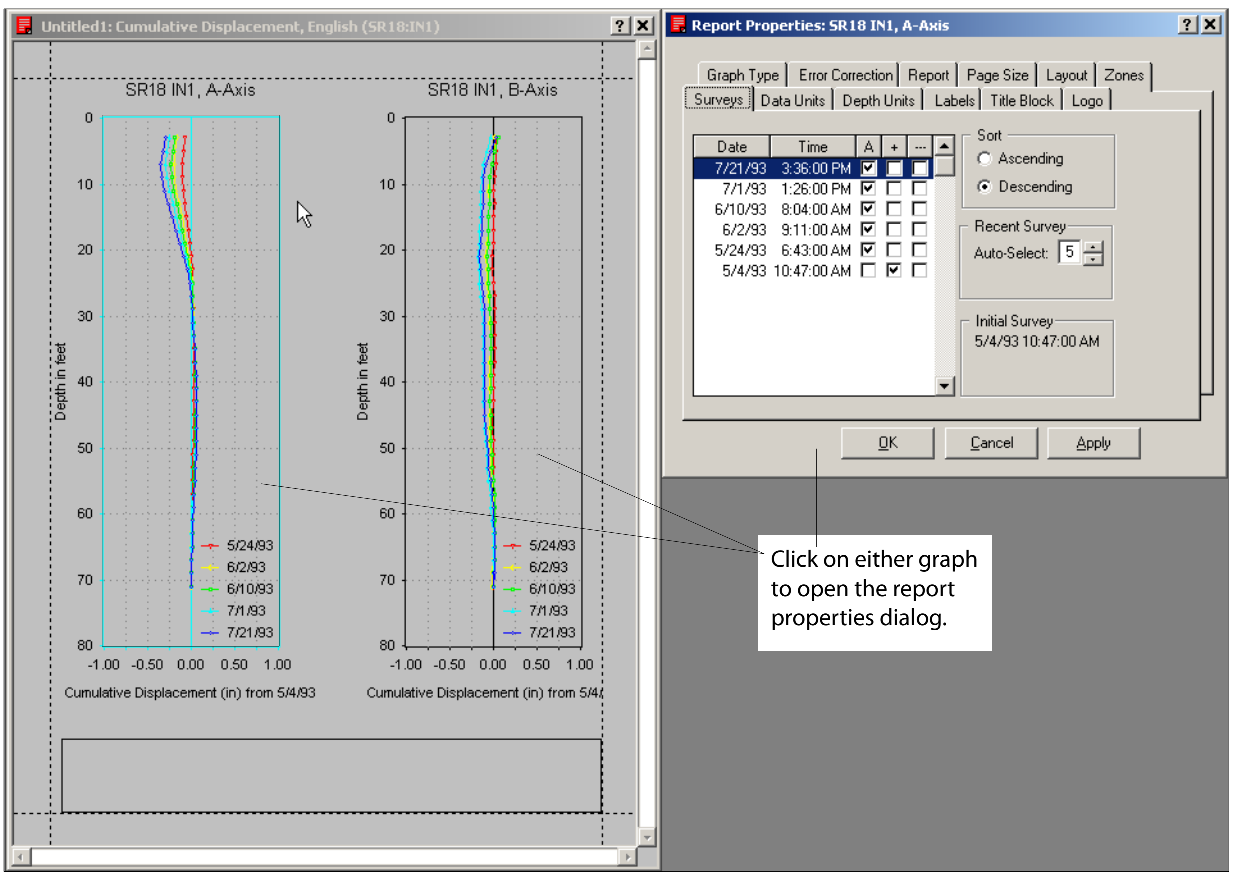
DigiPro displays a list of report templates. Each template offers a different type of graph. Choose "Cumulative Displacement, English Sample." Click Open.



If you use metric data, you can hide the english-unit templates, and vice versa. You can also make your own templates.

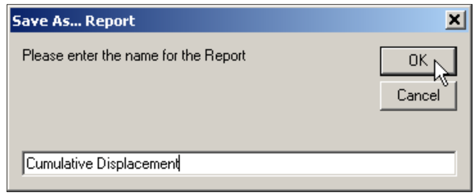
View and Modify the Report

The report appears with two graphs. Click on either graph to open the report properties dialog. Using the report properties dialog, you can select different surveys, modify scales and labels, add text to the title block, and make other changes.



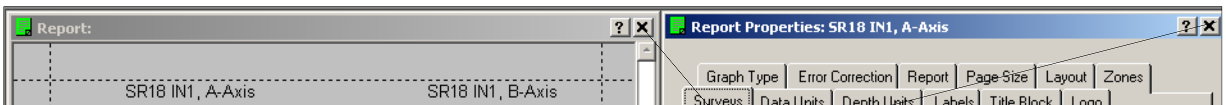
Save the Report

Click the disk icon or choose File > Save As >Report. Enter a name, and click OK. DigiPro stores the graph type and all the settings for the graphs.



Close the Report

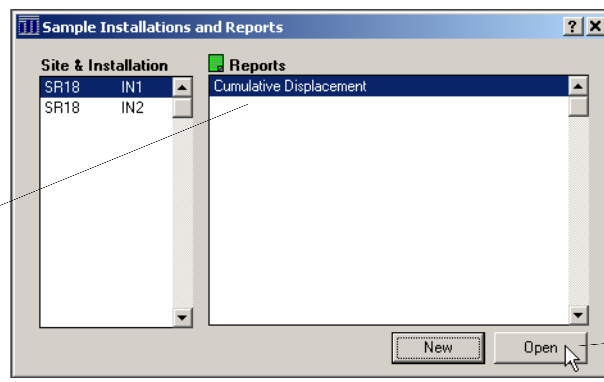
Click the X in the upper right corner of the graph. Close the report properties dialog too.



To close the dialog or graph, click the X box.

Open the Report to Recreate the Graphs

Select the report and click Open. DigiPro recreates your graphs. In addition, DigiPro automatically includes any new surveys that were added to the database, so the graphs are updated too.

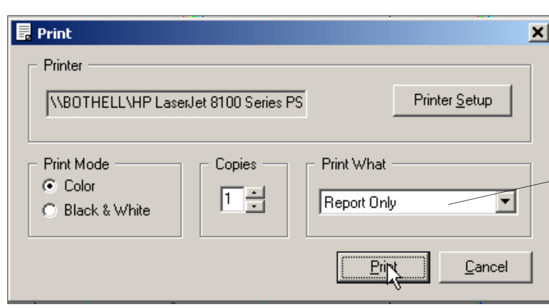


Reports are listed in the reports window. To recreate a graph, select a report and click Open.

Click Open to open a report.

Print the Report

When the graph appears on screen, click on the printer icon, or choose Print from the File menu.



This prints just the graph. You can also print a listing of the current survey.

Creating Reports

Overview of Reports

- It's easy to make reports: simply open a report template and save the resulting graph.
- Reports save time. You can reproduce or update a graph with just two mouse clicks.
- Reports can be customized. For example, you can specify two different types of graph for the report.
- You can create as many reports as you need.
- You can save the report as a template.

Creating a Report

These basic steps are explained in detail on the following pages.

1. Open a database.
2. Select an installation.
3. Choose a report template.
4. Save the report.

Open a Database

1. Start DigiPro, and click the Continue button.
2. The Open File dialog appears. DigiPro displays the most recently opened folder.
3. Select your database, and click Open.

How to find your database

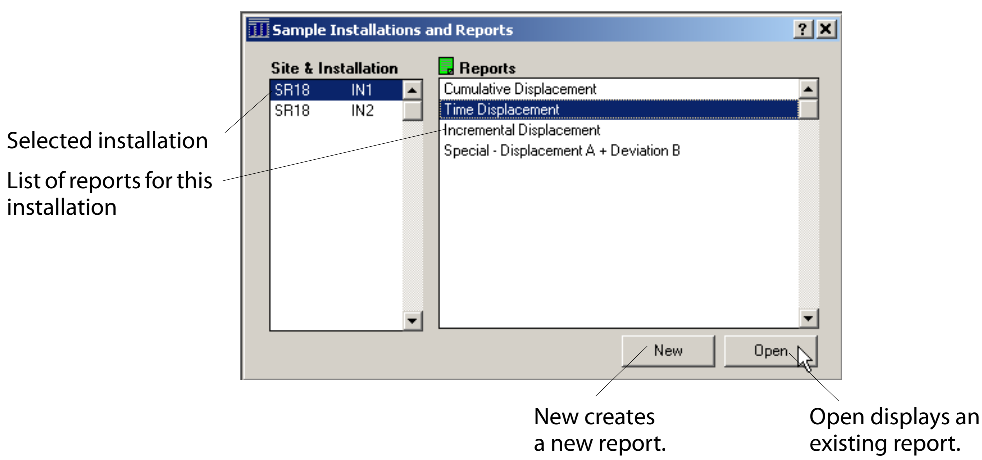
- If you can't see your database, click in the "Look-in" field to navigate to a different folder or drive.
- The default location used by DMM for Windows is: C:\Program Files\ DMMWin\Projects.
- DigiPro keeps a list of the last five databases that you opened. To see this list, click on the File menu (Close the Open File dialog first). The databases are listed at the bottom of the menu.

How to create a database

If you don't have a database, you must create one with DMM for Windows. DMM can also convert and import data. DMM is a free download from www.slopeindicator.com. See Appendix A for more information.

Select an Installation

After you open a project database, DigiPro displays the "Installations and Reports" dialog. The left side of this dialog shows a list of installations. Click on the installation of interest.



New vs Open

After you select an installation, you can choose to create a new report or open an existing report.

- To create a new report, click New.
- To open an existing report, select it and click Open.

Choose a Report Template

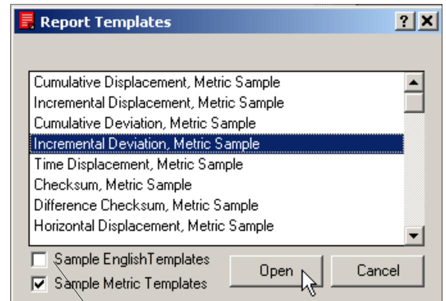
If you clicked New in the previous step, DigiPro displays a list of report templates. Each template offers a different type of graph. Graph types are explained on the following page.

English-Units or Metric-Units?

1. Select a template. Note that there are English-unit templates and metric-unit templates.

   It is important to choose correctly because this controls how readings are processed.

   - Choose English if you use an English-unit probe.
   - Choose metric if you use a metric-unit probe.



If your data is metric, you don't need English unit templates. Remove the checkmark to hide them.

2. Click Open.

Note: DigiPro allows you to change the displayed units later, if necessary, but at this point, you must choose according to your probe units.

Creating Templates

You may find it convenient to make your own templates. For example, you may want templates that have:

- A title block with your company's name and logo.
- Standard depths.
- Different types of graph in the same report.

To Create a Custom Template

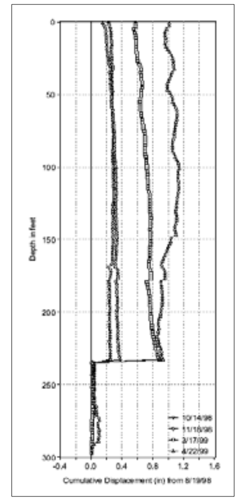
1. Open a report. Modify it as needed.
2. Choose File > Save As > Template.
3. The new template will appear in the Report Templates dialog.

Note: DigiPro's templates are stored in the "templates.mdb" file in the DigiPro\System folder. You can copy this file to other computers.

Graphs for Analyzing Movement

These graphs are the standard graphs used to analyze the behavior of the ground.

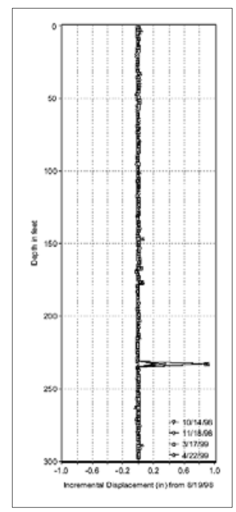
Cumulative Displacement



Displacements are changes in the position of the casing and are assumed to be equivalent to ground movement. A displacement graph requires at least two surveys: an initial survey and a current survey. The initial survey does not appear on the graph.

In a cumulative displacement graph, the plotted point at any depth is the sum of incremental displacements from the reference point (typically the bottom). The graph shows how subsurface movement relates to movement at the surface. Shear movements are easily seen.

Incremental Displacement

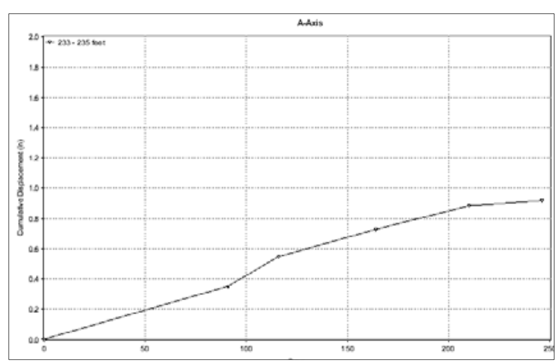


This graph shows displacements at discrete depths. A growing "spike" indicates movement. The graph at right uses the same data as the cumulative displacement plot above.

No summing is involved, so systematic error is minimized.

Time Displacement:

This graph shows the rate of movement at one or more zones. A steepening slope represents accelerating movements.

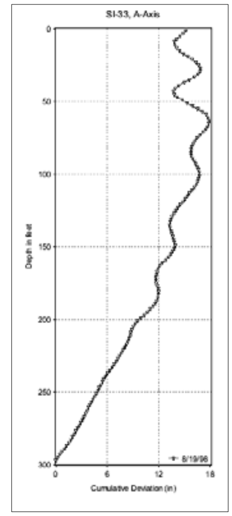


The plotted value for each zone is the difference between the displacement value at the top of the zone and the displacement value at the bottom of the zone. Zones are set in the "zone" tab of the report properties dialog.

Graphs for Diagnosing Systematic Error

These graphs are generally used for troubleshooting or verifying that graphs represent movements accurately.

Cumulative Deviation

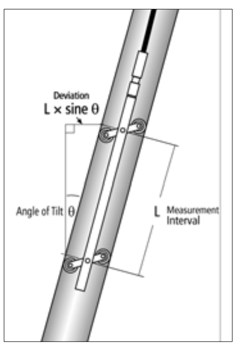


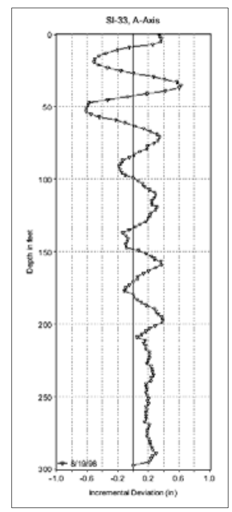
This graph shows the profile of the casing relative to vertical. Drillers can use this graph to see borehole drift.

The plotted point at any depth is the sum of incremental deviations up to and including that depth. (Deviations are defined below).

In error analysis, this graph is used to show the potential for systematic error due to cross-axis tilt and a rotation of the sensitive axis of the inclinometer probe.

Incremental Deviation

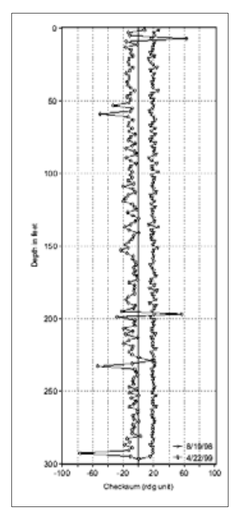




This graph shows the deviation at each depth. This represents the curvature of the casing. The drawing at left shows deviation. The angle of tilt is measured by the inclinometer, the hypotenuse is the measurement interval (typically the distance between the wheels) and the side opposite the angle is the deviation.

In error analysis, this graph is used to show the potential for systematic error due to casing curvature and settlements or inaccurate depth control.

Checksum and Difference Checksum



Checksums are the sum of the “0” and “180” readings at each depth.

In error analysis, this graph provides an indication of the potential for systematic error due to bias shift. A tilted plot may indicate problems with the electronics of the sensor.

The difference-checksum graph shows changes in checksum, and removes variations that are due solely to characteristics of the installed casing.

Save the Report

After you have selected a template and clicked Open, DigiPro displays the new report.

1. Choose File>Save from the menu or click the disk icon.
2. The Save As dialog appears. Enter a name for the report and click OK.

Naming a Report

- A simple name, such as “Cumulative Displacement” is sufficient, since it indicates the kind of graph that the report will produce.
- There is no need to make unique names for reports. Each installation has its own list of reports. For example, you can have a report named “cumulative displacement” for each of your installations. In fact, this is recommended.
- To rename a report, right-click on the report name and choose “Rename” from the pop-up menu.

Modifying Reports

Overview

The basic steps required to modify a report are:

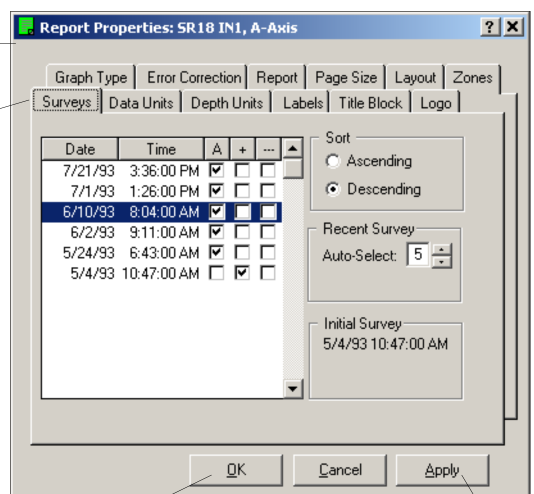
1. Open the report.
2. Open the Report Properties dialog.
3. Modify the properties for each graph.
4. The settings that you have changed are saved with the report and are automatically retrieved the next time you open the report.

Open a Report

1. Start DigiPro.
2. Open a project database.
3. Choose an installation.
4. Click on the report that you want to modify.
5. Click on the Open button.

Open the Report Properties Dialog

1. Click on either graph. The report properties dialog appears.
2. The title bar shows which graph is active. To make the other graph active, just click on it.



The title bar shows which graph is active and can be modified.

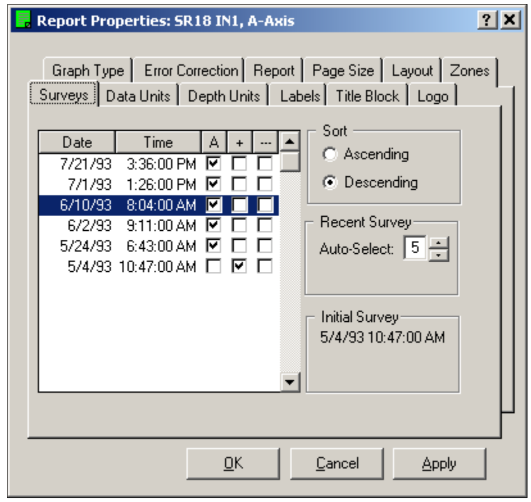
Report properties are organized by tabs. Click on a tab to display its properties.

When you change a property, click Apply to see the effect.

Click OK to close the dialog. OK applies any remaining changes.

Click Apply to see the effect of your changes. The dialog stays open so that you can make more changes.

Surveys



What is a Survey?

A survey is the data from one inclinometer survey. Each survey is identified by date and time.

Survey Selection

DigiPro graphs only surveys that have been selected. Check boxes for each survey indicate its selection status.

- A check mark in the A column indicates that the survey is auto-selected. New surveys are auto-selected so that DigiPro can update graphs automatically. The Recent Surveys field controls the number of auto-selected surveys.
- A check mark in the + column indicates that the survey is selected permanently. It will be used every time you run a report. Click the box to check or uncheck.
- A check mark in the – column indicates that the survey is excluded permanently. Click the box to check or uncheck.
- Surveys with no checkmark are not selected. When you have many surveys, most of them will have this status.

Sort

Sorts the order of the surveys in the Selection window.

- Ascending displays oldest survey first.
- Descending displays newest survey first.

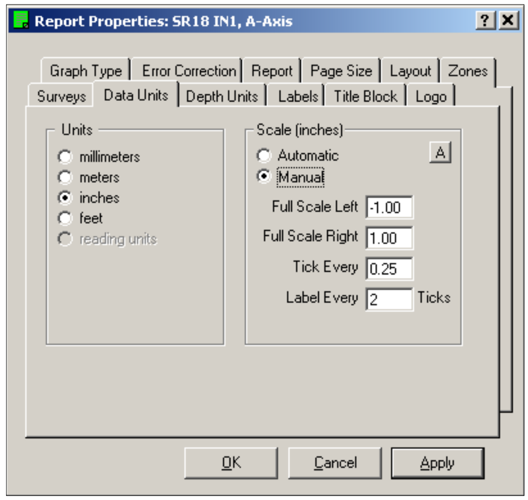
Recent Survey Auto-Select

Specifies the number of new surveys to be automatically selected for the report. To change the number, click the up and down arrows next to the number. Then click apply.

Initial Survey

Shows which survey is used as the initial. DigiPro automatically selects the oldest survey as the initial and puts a check mark in the + column. To choose a different initial survey, scroll the window until you can see it. Then right click on the + box and choose “Mark as Initial Survey” from the pop-up menu. Note that earlier surveys are ignored.

Data Units



Unit Conversion

The Unit conversion setting is provided for US users who need metric-unit reports from their English-unit inclinometer systems. These users should use the standard English-unit templates and make the conversion here by clicking the radio button for mm.

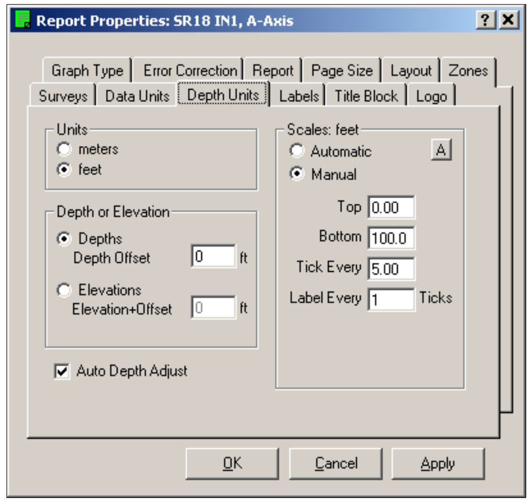
Other users will probably not need this setting because templates provide appropriate units automatically. Be sure to choose metric templates for metric inclinometer systems and English templates for English-unit inclinometer systems.

Troubleshooting Note: If you have used the correct templates but your units and values appear strange, don't try to correct the problem with the units conversion setting. Instead, go back to the Installation and Reports dialog, right-click on the installation, and choose "properties" from the pop up menu. Check that Units is properly set to English or Metric (the same units as your inclinometer system).

Scales

- Automatic: Sets full scale left and right to accommodate the maximum values found in the surveys.
- Manual: Allows manual control over the settings. Click on the Manual button to show the fields below:
- Full Scale Left: Enter a value to be used for full scale left.
- Full Scale Right: Enter the value to be used for full scale right.
- Tick every: Ticks are graduations on the data scale. For example, if you want a graduation every 10 mm, enter 10.
- Label every nth tick: DigiPro will label every nth tick. For example, enter a 2 to label every second tick. For example, if ticks are 10 mm apart, labels will appear every 20 mm.

Depth Units



Unit Conversion

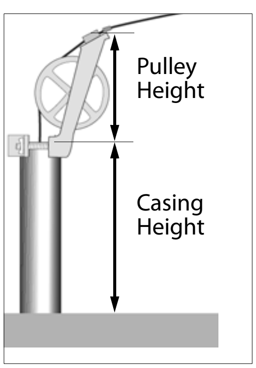
The Unit conversion setting is provided for US users who need metric-unit reports from their English-unit inclinometer systems. These users should use the standard English-unit templates and make the conversion here by clicking the radio button for m.

Other users will probably not need this setting because templates provide appropriate units automatically. Be sure to choose metric templates for metric inclinometer systems and English templates for English-unit inclinometer systems.

Depth or Elevation

You can show depth-axis labels as depths or elevations. Click the appropriate radio button. If you choose elevations, you must also enter the elevation at the top of the casing. See depth offset and elevation offset below.

Depth Offset



During a survey, depths are read from the control cable, which is referenced to the top of the casing or (preferably) to the top of the pulley assembly. If you want the depth-axis labels referenced to ground level, enter an offset:

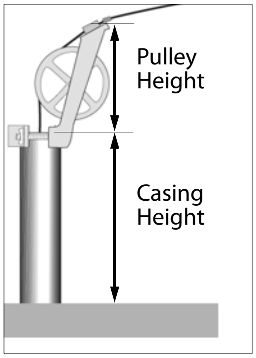
Depth Offset = casing height + pulley height

Casing height is the height of the casing above ground level. Pulley height is 1 foot or 0.3 meters.

Metric Example: The top of the casing is 0.5 meters above ground level. The pulley assembly adds 0.3 meters. Enter 0.8 meters for the depth offset. Now the depth-axis label scale will be referenced to ground level.

English Example: The top of the casing is 14 inches (1.17 ft.) above ground level. The pulley assembly adds 1 foot. Enter 2.17 feet for the depth offset.

Elevation + Offset



If you want the depth-axis label referenced to elevations, first click the radio button for elevations, then enter an offset:

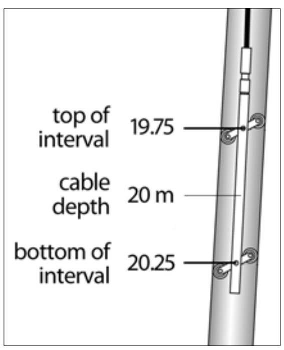
Elevation Offset = ground elevation + casing height + pulley height

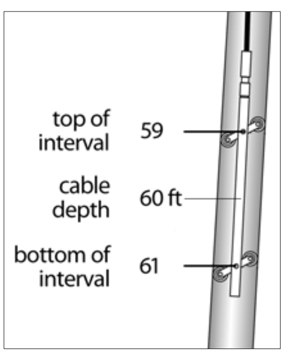
Casing height is the height of the casing above ground level. The pulley assembly adds 0.3 meters (1 foot).

Metric Example: Ground elevation is 200 meters above sea level. The top of the casing is 0.4 meters above ground level. The pulley assembly adds 0.3 meters. Enter 200.7 meters for the elevation offset. Labels will be referenced to ground elevation.

English Example: Ground elevation is 1200 feet above sea level. The top of the casing is 1.5 feet above ground level. The pulley assembly adds 1 foot. Enter 1202.5 feet for the elevation offset.

Auto Depth Adjustment





With auto-depth adjustment turned on, DigiPro correctly plot data points at the top (or bottom) of the measurement interval. Auto-depth is turned on by default.

Why is an adjustment provided? Depth marks on Digitilt control cable are measured from the middle of the inclinometer probe, but deviations and displacements are calculated for the top (or bottom) of an interval.

Metric example: The depth stored with the inclinometer reading is the cable depth of 20 meters, but the top of the interval is actually at 19.75 meters. With auto-depth adjust turned on, the plotted point will be placed correctly on the graph at 19.75 meters, not at the cable depth of 20 meters.

English example: The depth stored with the inclinometer reading is the cable depth of 60 feet, but the top of the interval is actually at 59 feet. With auto-depth adjust turned on, the plotted point will be placed on the graph at 59 feet, not at the cable depth of 60 feet.

On the graph, these adjustments are visually quite small, but if you print out the data, you will see the adjusted depths.

Scales

DigiPro sets the depth axis scales automatically, or lets you specify values for the top and bottom of the depth-axis scale.

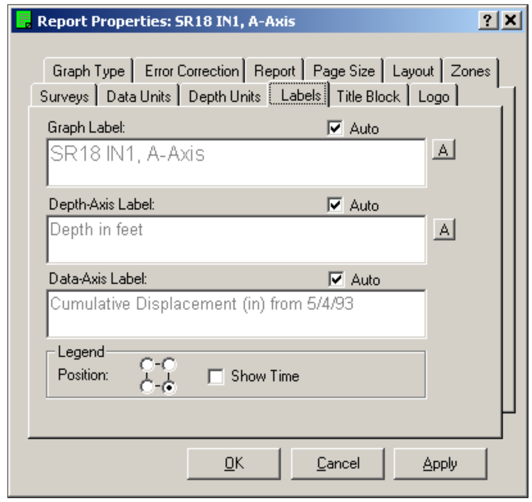
Automatic: Automatically displays the entire depth-axis and applies labels and ticks at multiples of 10.

Manual: Allows manual control of scales. Click on the Manual button and enter the desired values in each field. If your report shows elevations rather than depths, be sure to enter elevations for top and bottom. Click Apply when finished.

- Top: Enter a value for the top of the depth-axis scale.
- Bottom: Enter a value for the bottom of the depth-axis scale.
- Tick every: Ticks are graduations on the depth-axis scale. If you want a graduation every 5 meters, enter 5.
- Label every nth tick: DigiPro will label every nth tick. For example, enter 2 to label every second tick. For example, if ticks are 5 meters apart, labels will appear every 10 meters.

Tip: If you frequently zoom in to inspect a particular zone, you might find it useful to make a report that shows only that zone. Use manual scales to specify the top and bottom of the zone, then save the result as a new report.

Labels Tab



Editing a Label

DigiPro creates graph labels and legends automatically. This dialog lets you change the automatic labels. If you want these labels changed for all subsequent reports, save the report as a template (See page 8).

1. Click to remove the check mark from the Auto box above the Label field. When the check is removed, you can edit the text.
2. Enter text in the Label field. The Graph Label field accepts up two lines of text. The Depth-Axis and Data-Axis fields accept one line of text. The A button lets you choose a font.
3. Click Apply to see your changes.

Note: If your Windows display is set for Large Fonts, text appears larger on-screen than it prints on paper. Print the report to see the true effect, then modify as needed.

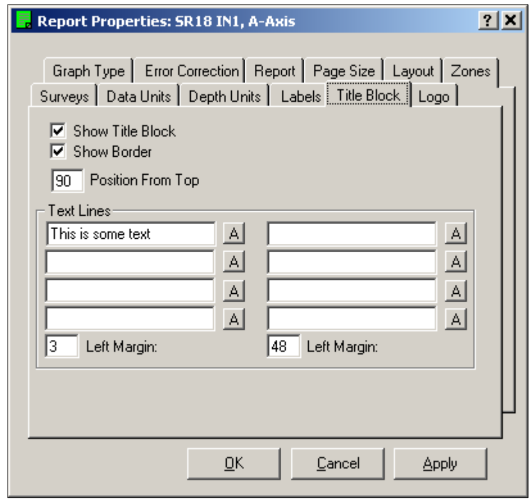
Legend Position

DigiPro can place the legend in one of the four corners of the graph. For example, if you click the upper right button in the square, the legend will appear in the upper right corner of the graph when you click Apply.

Show Time

DigiPro can append time to the date in the legend. Normally time is not required, but if you need it, click in the checkbox.

Title Block



Function

The title block provides a place to enter information about the graph. You can also include a company name, address, and company logo in the title block. If you want to add a logo to the title block, use the Logo tab before setting the title block text.

Text Lines

DigiPro provides eight cells for text arranged into two columns. Click in one of the eight fields to enter text. When finished, tab to the next field. Click Apply to see the result on screen.

Note: The screen display of text is not accurate, especially if your display is set for Large Fonts. Print the report to see the true appearance of the text.

Tip: Save the report as a template so you can base future reports on the same style with very little additional work. (See page 8).

Left Margin

There are two left margin fields, one for each column of text. Enter a percentage value, estimated from the left side of the page. Then click Apply.

Show Title Block

When the box is unchecked, DigiPro shows the title block. If you hide the title block, you can enlarge your graphs using the Layout tab.

Show Border

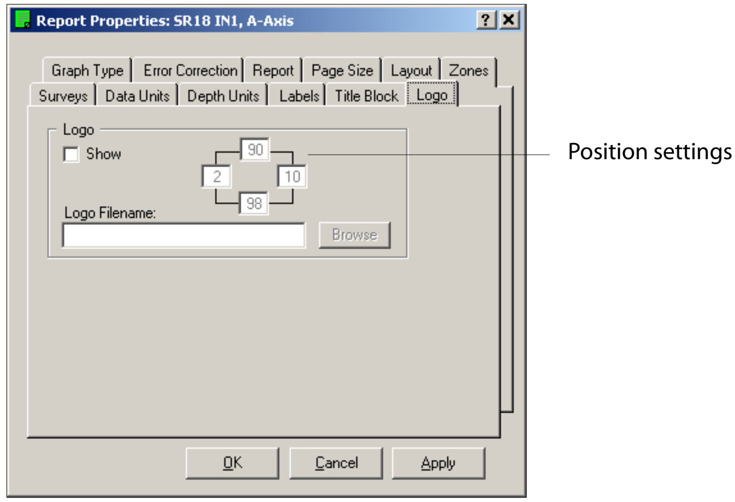
When the box is checked, DigiPro draws a line around the title block. You may find that hiding the rule provides a neater result.

Position from Top

Enter an estimated percentage value. By default, the title block appears at the bottom of the page. However, if you set the value to zero, it will print at the top of the page.

Note: If you change the position of the title block, you must move the graphs down using the Layout tab.

Logo



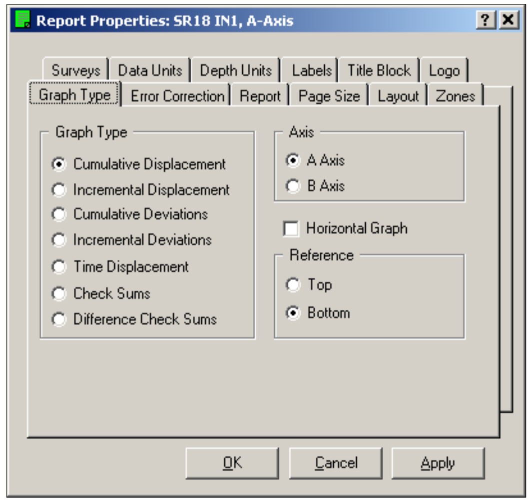
Displaying a Logo

DigiPro has a simple facility to print a bitmap (.bmp) image of your logo on the report.

1. Click (check) the Show check box.
2. Enter the path and file name of your logo. You can use the browse button to do this for you.
3. The position settings are percentages. They change the boundaries of the logo box and also the position of the logo box. You will probably need to make several adjustments to find the right setting.

Note: We recommend that you place the logo file in DigiPro's BMP folder so that it will not be accidentally lost during routine disk cleanups. The path will appear like this: C:\Program Files\DigiPro\BMP\myLogo.bmp.

Graph Type



Overview This useful feature lets you change the type of graphs shown in the report. For example, you could place a graph of time displacement next to a graph of cumulative displacement. You could also show two versions of the same graph, one with error correction turned on and one with error correction turned off.

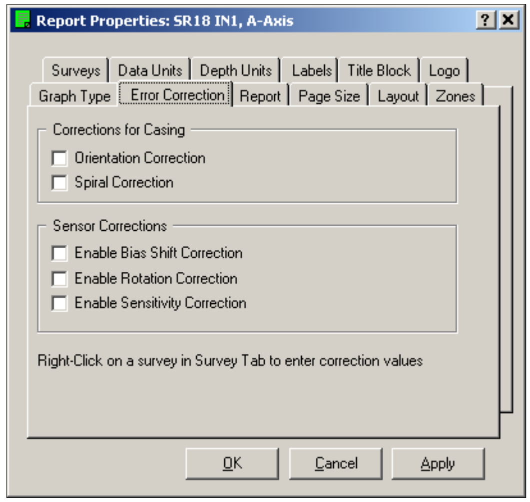
Graph Type Graph types are explained in "Creating a Report." The radio button shows the type of graph currently displayed. To change, click a different radio button. When you click Apply, the graph is redrawn.

Axis The sample templates use A-axis data for the left graph and B-axis data for the right graph, but you are not limited by this. You can show two A axis graphs or two B axis graphs, etc.

Horizontal It is easier to use the Horizontal template to create a horizontal graph, but this checkbox is here for completeness.

Reference Select top or bottom of the casing as the starting point for calculations of cumulative displacement and cumulative deviation. Bottom reference is the default.

Error Correction

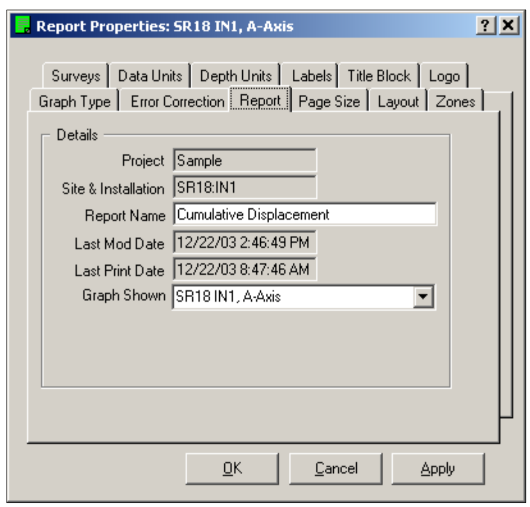


Overview

This dialog lets you enable and disable correction routines. Except for the orientation correction, values used by the routines are entered elsewhere. For information on corrections, see the chapter on error correction.

- To enable a correction routine, put a check in its checkbox.
- To disable a correction routine, remove the checkmark.

Report



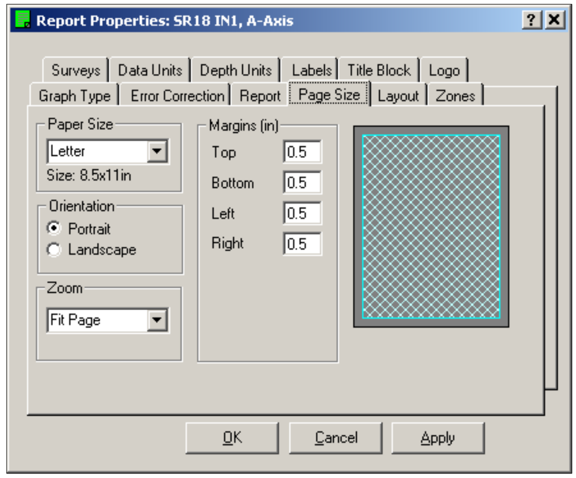
Overview

This dialog is generally not used. Only two fields can be manipulated: report name and graph shown.

Report Name: You can rename a report here. Note that you can also rename a report by right clicking on the report in the installations and reports dialog.

Graph Shown: This can be used to show a graph that was previously hidden.

Page Size



Overview Page size and orientation are generally set by report templates. Global defaults are controlled by settings in the File > Options and Defaults dialog. The settings here affect only the current report.

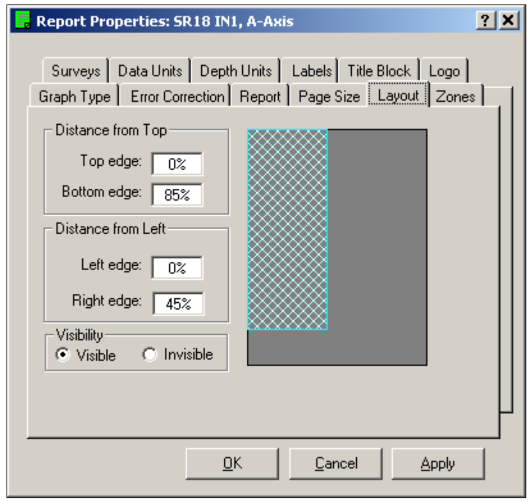
Paper Size Controls paper size.

Orientation Controls the page orientation for the report. Choices are portrait (long side is vertical) or landscape (long side is horizontal).

Margins Controls the page margins for the report. The default margin values are in inches. If you select the A4 or B4 paper sizes, the margin values automatically convert to centimeters.

Zoom Controls the screen size of the report. The default is “Fit Page,” which allows the report and report properties to be displayed on-screen simultaneously (with no overlap) on a monitor set to a resolution of 800x600 or better.

Layout



Overview

Layout settings determine the placement and size of each graph.

Distance from Top

This controls the vertical size and placement of a graph.

1. Click on a graph. An image of the graph appears in the dialog box.
2. Enter values for the top and bottom edges of the graph in percent from top of page.

Distance from Left

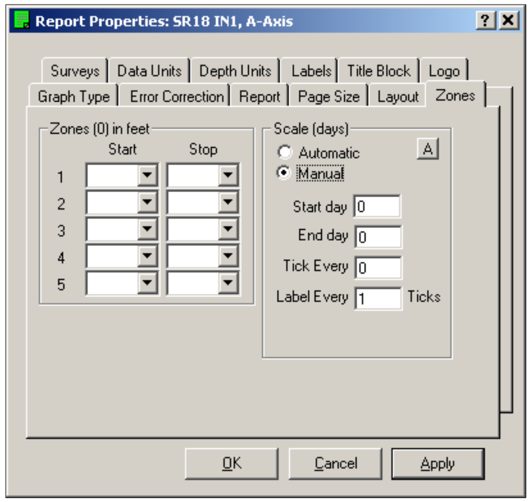
This controls the horizontal size and placement of the graph.

1. Click on a graph. An image of the graph appears in the dialog box.
2. Enter values for the left and right edges of the graph in percent from left side of page.

Visibility

This controls whether a graph is visible or not. For example, if you want only one graph on the page, you can hide the other graph and then adjust size and placement of the visible graph as needed.

Zones



Overview

The zone tab is used to select zones for time-displacement graphs.

Zones

You can graph up to five zones by specifying a start and stop depth for each zone. Click the drop list to choose a valid depth or elevation. The stop depth must be deeper than the start depth.

The value that DigiPro plots is the difference between cumulative displacement at the start depth and cumulative displacement value at the stop depth.

Scales

The automatic setting shows the number of days from the initial survey. The manual setting lets you choose a start and an end day to show only a portion of the available time span. You can also set the frequency of tick marks (in days) and labels (numbers). The current version of DigiPro does not allow display of dates.

Printing a Report

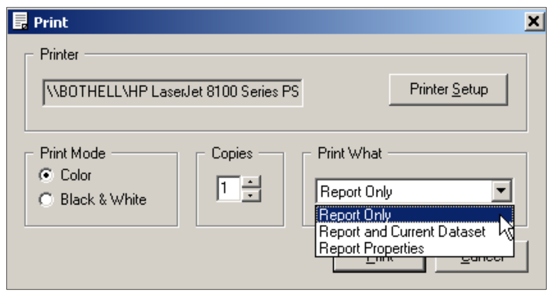
Overview

DigiPro offers the following options

- Print report only or report with current survey data.
- Print plotted data
- Write plotted data to a file

Printing a Report

1. Open a report.
2. Choose File>Print from the file menu, or click on the printer icon located on the tool bar. The Print dialog appears.



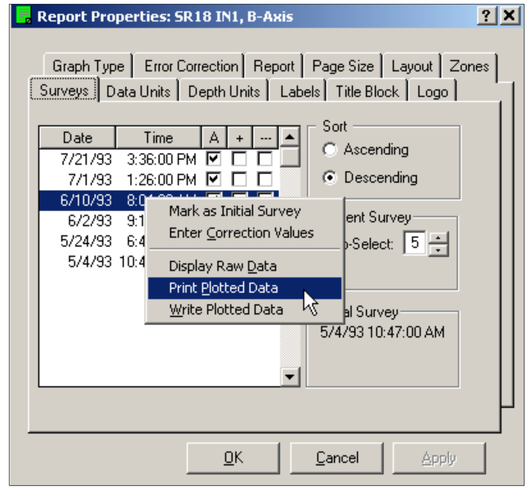
3. Click in the "Print What" field. Choose Report Only or Report with Current Survey.
4. Check the Printer window to be sure it displays the printer you want. To change printers or adjust the printer setup, click on the Printer Setup button.

   Note: If you change the printer in DigiPro's Print dialog, the new printer becomes the Windows default printer.
5. Click in the Copies field and enter the number of copies you want.
6. Select a print mode: color or black and white. (If you are using a black and white printer but choose the color print mode, the report will print in grayscale.)
7. Click Print to print the report.

Note: You can change the colors that DigiPro uses, if some plots are hard to see. Choose File>Options and Defaults>Preferences. You will see a band of eight colors. click on the color that you want to change and choose a different color from the pop up menu.

Printing Plotted Data

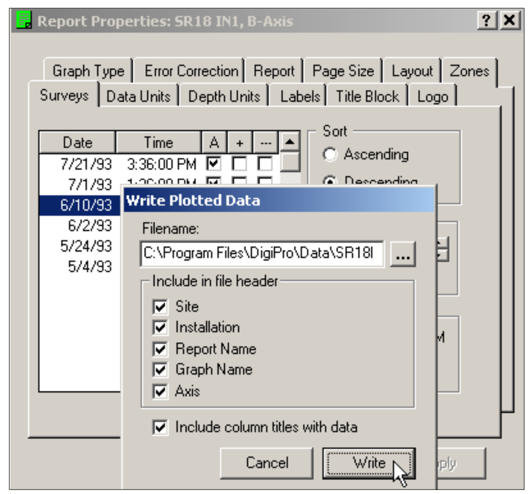
Plotted data are the data points plotted on the graph. DigiPro can print a maximum of 8 columns of data.



1. Open a report and click to open the report properties dialog.
2. Place the pointer in the Survey window and right click.
3. Choose Print Plotted Data from the pop-up menu.

Writing Plotted Data

You can write plotted data to a file for use in a spreadsheet. You can write a maximum of 8 columns of data



1. Open a report and click to open the report properties dialog
2. When the Report Properties dialog appears, click in the survey window.
3. A menu appears. Choose Write Plotted Data.
4. A submenu appears. Choose the items that you want to appear in the file header. You can also specify a filename and location if the default filename is not suitable.
5. Click Write to write the data to the file. The file is placed in the same folder as your project database. It has a .txt extension.

Error Correction

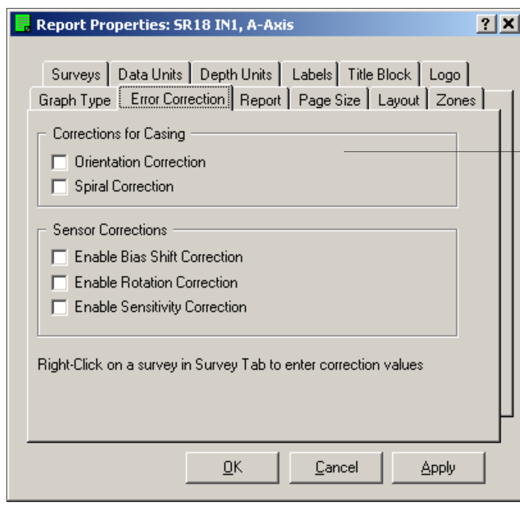
Introduction

The error correction routines that are built into DigiPro were requested by expert users. Error correction is not a simple subject, and applying corrections appropriately requires knowledge and experience.

In this chapter, we provide an brief introduction to some aspects of error correction. Those who need to know more should consider attending Slope Indicator's short course on Data Reduction and Error Correction. The course schedule is listed in the Training section at www.slopeindicator.com.

Enable or Disable Corrections

Correction values are stored separately from readings and are applied on-the-fly when the graphs are generated. Thus corrections can be enabled and disabled at any time



Use the report properties dialog to enable or disable corrections.

- Correction routines are disabled by default.
- If you want to use correction routines, use the report properties dialog to enable them.
- Correction routines apply at the graph level. Thus a report can show one graph with corrections turned on and another graph with corrections turned off.
- Corrections values for casing are entered once for each installation and are applied to any survey selected for the graph.
- Corrections values for sensors (inclinometer probes) are entered for each survey that requires them. A special dialog is used for this.

Corrections for Casing

Corrections for casing are accessed with the report properties dialog.

Orientation Correction

If casing grooves are not oriented to the direction of movement, you can use DigiPro to mathematically rotate the orientation of the measurement axes into the direction of interest.

1. Enable the Orientation Correction. An entry field appears.
2. Enter an orientation correction in degrees. For example, enter 10 to rotate the orientation 10 degrees clockwise.
   Enter -10 to rotate orientation 10 degrees counterclockwise.

Spiral Correction

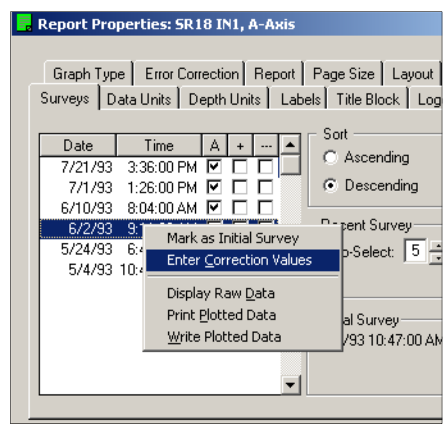
A spiral survey, obtained with a spiral sensor, provides measurements that can be used to correct for spiraled (twisted) casing. The spiral survey is processed and placed in the database by DMM for Windows. DigiPro has no entry fields for spiral data.

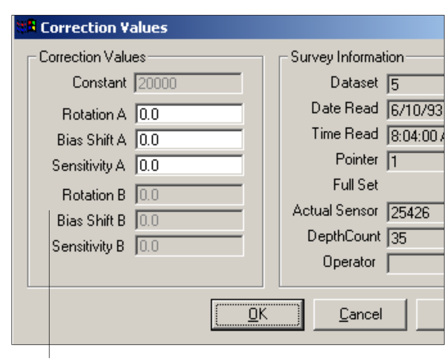
DigiPro automatically recognizes the spiral survey if it is present. If DigiPro cannot find a spiral survey, the checkbox is grayed out and cannot be enabled.

Corrections for Sensors

These corrections must be entered for each survey.

1. Enable the correction.
2. Click on the Surveys tab.
3. Right click on the survey that requires correction. A dialog appears.
4. Choose Enter Correction Values. The Correction Values dialog appears.
5. Enter a value in the appropriate field.
6. Click Apply to see the effect on the graph.
7. Repeat steps 5 and 6 until the correction value is correct.





To enter values for the B axis, you must click on the B-axis graph.

Bias-Shift Error

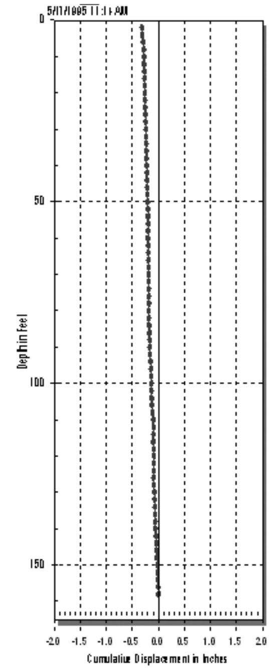
Bias shift values are entered in reading units. Here is a simple introduction to bias shift error. More information can be found in the "Training" section of www.slopeindicator.com.

What is Bias Shift

Bias: If you hold your inclinometer probe absolutely vertical and check the reading, you will typically see a non-zero value. This is the probe's bias. The bias value is normally eliminated in the data reduction process when the 0 readings are combined with the 180 readings.

Bias-Shift Error: If the bias value changes during a survey, the data reduction process cannot eliminate all of the bias. The remaining value is error that is embedded in the reduced data.

The straight, but leaning plot at right is the result of bias-shift error.



Identifying Bias Shift Error

Appearance: A straightened, but leaning cumulative displacement plot is a signature of bias shift error. The embedded error grows larger at each interval, so the plot leans to the left or right.

Unlikely Behavior: The graph above shows rotation of the entire 150 foot span of soil or rock. This unlikely behavior suggests error in the data.

Site Knowledge: The plot shows movement where there should be no movement. Typically, the bottom 5 depths (or more) of the casing are anchored in stable ground. Any movement appearing there is generally error. In our example, we know that the casing entered rock below 80 feet, and that no movement has occurred from 80 feet downwards. This again suggests error in the data.

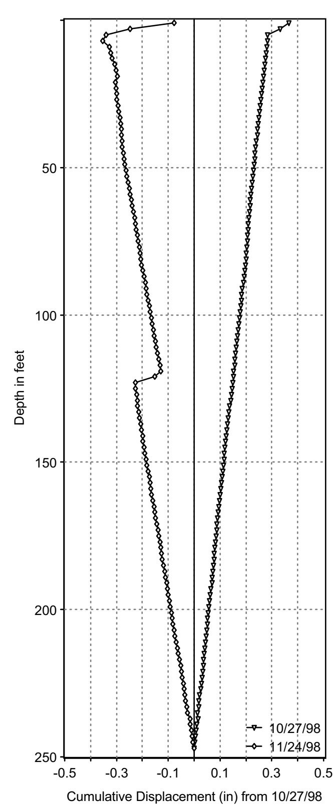
Quantifying Bias Shift Error

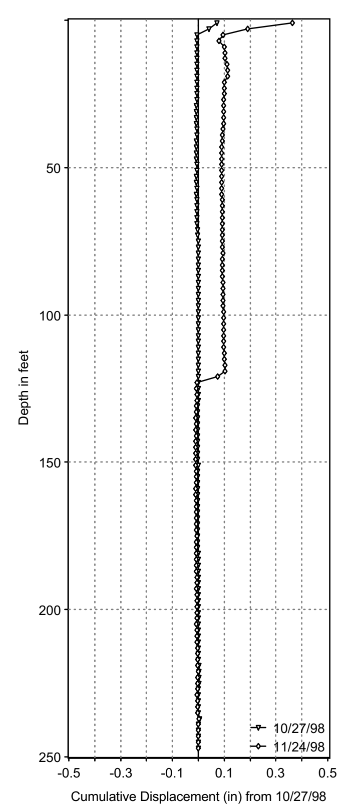
DMM for Windows has a routine for quantifying bias shift error. It suggests an value that you can enter in DigiPro's correction routine. Refer to the DMM manual for details.

Visual Correction

You can also arrive at an correction value visually.

1. Display a cumulative displacement graph.
2. Identify displacements that are produced by bias-shift error. For example, if you know that the bottom 20 feet of the casing are installed in rock, then any displacement seen there is probably error. If the error appears as a straight line tilted away from vertical, then it is probably due to bias-shift.
3. Enable bias-shift corrections. Then right click on one of the surveys, and choose Enter Correction Values.
4. In the Corrections Value dialog, enter a value, typically less than 20. If the tilt is to the right, enter a positive value. If the tilt is to the left, enter a negative value.
5. Click Apply and observe the graph. The tilted line should be vertical when the error has been corrected. Experiment with different values until you have found the correct one.





This example shows uncorrected and corrected graphs. You can see the typical linear pattern of bias-shift error. The second survey was obtained on the same day as the initial survey, so any movement is certainly false. The second survey was taken a month later and apparent displacement is in the wrong direction. When corrected, both surveys make sense and we can see that some real movement has occurred at about 125 feet.

Rotation

Rotation corrections are entered in radians. Here is a simple introduction to "rotation" error. More information can be found in the "Training" section of www.slopeindicator.com.

What is Rotation Error?

Rotation is a small change in the alignment of the measurement axis of the inclinometer probe. The change is usually less than one degree.

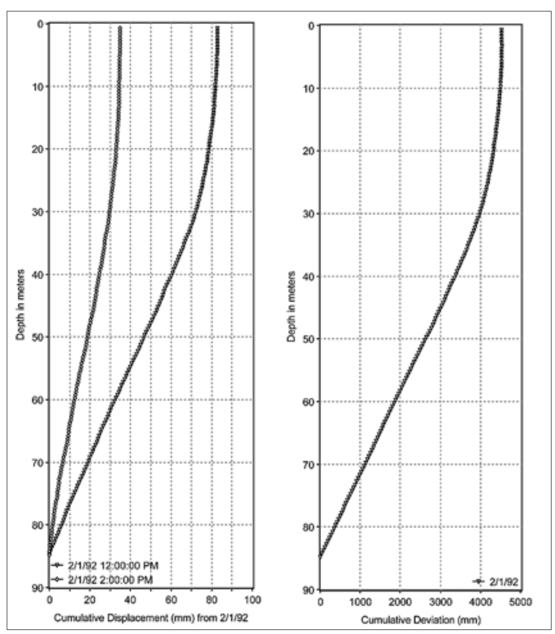
Ideally, the mechanicals of the probe are aligned so that the A-axis accelerometer measures tilt only in the A-plane. If the mechanicals of the probe are rotated slightly towards the B-plane, the A-axis accelerometer becomes slightly sensitive to tilts in the B-plane, too.

Rotation error is the cross-axis component in a reading, for example, the B-axis tilt in the A-axis reading. Rotation error becomes noticeable when two conditions combine:

- There is significant inclination in the cross axis.
- The change in the alignment of the probe occurs after the initial set was taken.

Identifying Rotation Error

- The cumulative displacement plot shows a curved line, when the line should really be straight.
- The cumulative deviation plot shows significant tilt in the cross axis.
- The two plots have a similar shape, as shown below.

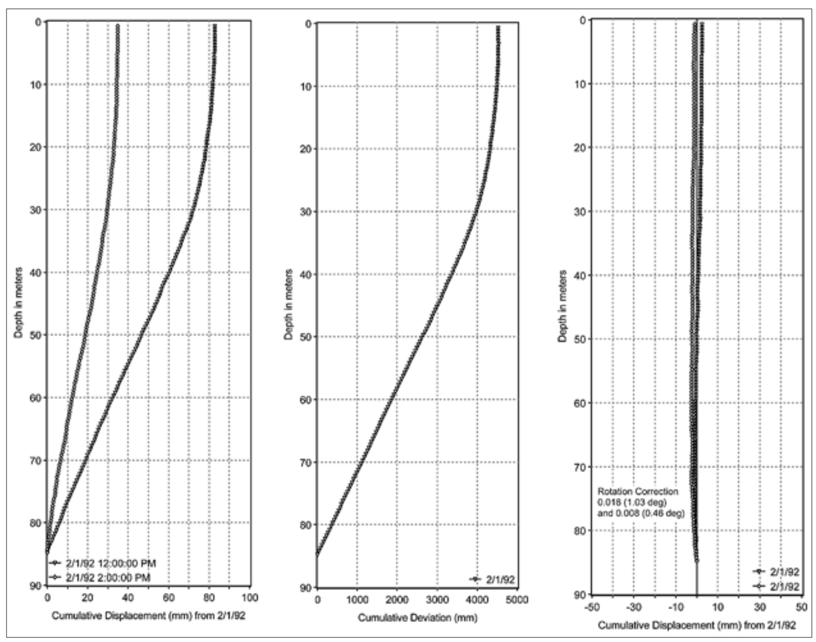


Cumulative Displacement A-Axis

Cumulative Deviation B-Axis

Correcting Rotation Error

1. Display a cumulative displacement graph. Use surveys that contain the error.
2. Identify displacements that are produced by rotation error. Find the depth of the maximum error.
3. Display a cumulative deviation plot of the cross axis. Find the deviation value at the same depth noted above.
4. Divide the displacement value by the deviation value. The result is a starting value for correcting rotation.
5. In DigiPro, enable rotation corrections and enter the rotation value.
6. Apply the correction and inspect the redrawn plot. The curve in the line should straighten..



Cumulative Displacement A-Axis

Cumulative Deviation B-Axis

Cumulative Displacement Corrected

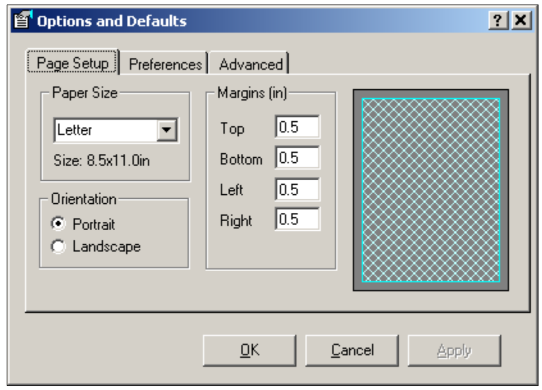
This example was a comparison test of three inclinometer probes. Readings from two probes are plotted against the third probe. All readings were taken on the same day. The casing was tilted about 4 degrees in the B-axis. The similarity between the A displacements and the B profile signals rotation error. The corrected displacement are shown at right.

Options and Defaults

Overview

Some of DigiPro's default settings can be changed by using options and defaults dialog: File > Options and Defaults.

Page Setup

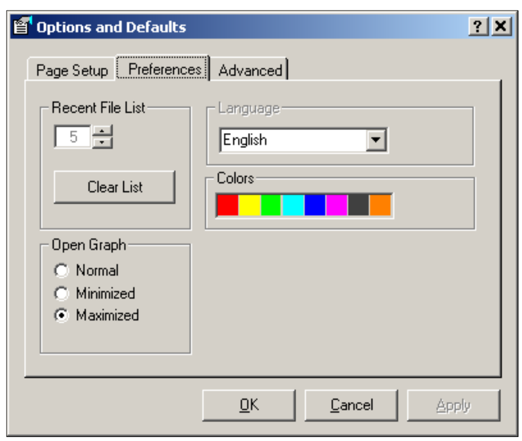


Paper Size Set the default paper size for all new reports.

Orientation Normally, you will allow report templates to take care of this.

Margins Set page margins. Choose paper size first.

Preferences



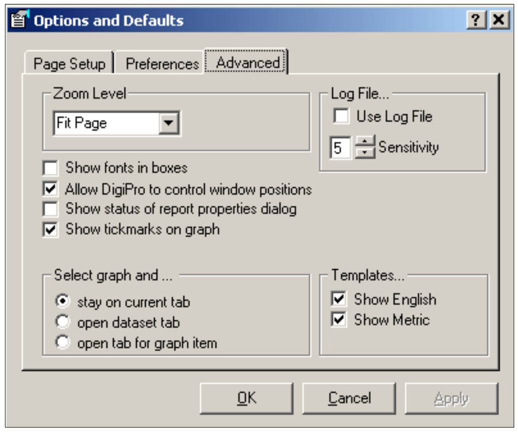
Recent File List Sets the number of recent files displayed on the File menu.

Language Currently, the only choice is English. Sorry.

Colors Set colors for DigiPro graphs by clicking on a color patch and choosing a different color from the pop-up pallet.

Open Graph Sets DigiPro's window: normal is resizable, minimized is a task on the task bar, maximized is full screen.

Advanced Tab



Zoom Level

Sets the initial size of all displayed reports. We recommend using the default “Fit Page.”

Show Fonts in Boxes

If unchecked, the text fields in the Title Block and Labels tabs will display text in DigiPro’s default display font (Arial 10). If the box is checked, the text fields will display text in the font you select using the A button.

Allow DigiPro to Control Window Positions

Starts the report window in the upper left corner of the screen and the Report Properties dialog to the top edge of the screen.

If the box is not checked, the Windows system controls placement. This may be the preferred setting if you open multiple windows.

Show Status of Report Properties

If this box is checked, a grid appears at the bottom of the Report Properties dialog. The grid lists the tabs in which changes have been made. When you click Apply, the grid resets.

Show Tickmarks on Graph

When this box is checked, DigiPro displays tick marks on the borders of the graphs. When the box is unchecked, the tick marks do not appear. You can set the tick mark positions in the Data Units and Depth Units tabs of the Report Properties dialog.

Select Graph and...

Sets what happens when report properties dialog is closed and then reopened.

- Stay on Current Tab: This is the default. Report Properties displays the same tab as you switch back and forth between graphs.
- Open Survey Tab: Report Properties shows the Survey tab each time you switch between graphs.

Open Tab for Graph Item: Report Properties opens to the tab that corresponds to the part of the graph that you clicked on.

Appendix A: Project Databases

What is a Project Database?

Slope Indicator's project databases contain:

- Information about inclinometer installations, such as their ID and depth. The database can contain any number of installations.
- Surveys of the installations above. The database can contain any number of surveys.
- Reports created by DigiPro. A report is a collection of parameters that tell DigiPro how to create a graph. The database can contain any number of reports.

Use DMM to Create the Database

Project databases are created by DMM for Windows. DMM also imports or converts older data formats. DigiPro simply uses the data in the database.

If you don't have DMM for Windows, you can download it from Slope Indicator's website: www.slopeindicator.com or install it from Slope Indicator's Resource CD. DMM for Windows is free.

Use DMM to Convert or Import Data

Project databases created by DMM for Windows have a ".mdb" extension. If you have been using the Windows version of DMM, your data are already in this format, so no conversion is necessary.

Converting .hdr Databases

Project databases created by DMM for DOS consisted of a number of files. The main file had an ".hdr" extension. DMM for Windows provides a utility to quickly convert any of your old .hdr files to the .mdb Windows format. See Appendix 3 of the DMM manual: "Converting DOS DMM databases."

Importing GTilt, RPP, and PCSLIN Files

DMM for Windows can import RPP, PCSLIN, or GTilt files. It will also accept manually-entered data. See Appendix 5 and 6, "Importing Data" and "Manual Entry of Data."

If you are switching from some other inclinometer system to Slope Indicator's system, you can usually export your data in one of these formats.

Note: DMM does not import spreadsheet files.

Appendix A7 - DigiPro2 for Windows

DigiPro2

User Manual

50310199

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Contents

Introduction

About DigiPro

DigiPro2 creates databases, manages inclinometer data, and generates plots and reports. It also provides advanced routines for identifying and correcting systematic errors.

DigiPro2 works with both the Digitilt Classic system and the Digitilt AT system. It replaces the original DigiPro for Windows and it also replaces DMM, since it can retrieve surveys from the DataMate directly.

Compatibility

DigiPro2 runs on XP and later versions of Windows. It features a new database engine and a new database format. It can import surveys from the mdb databases created by DMM, so there is no loss of data when you switch to DigiPro2. However, plots and reports must be recreated because DigiPro2 uses a new graphics library with support for many more features.

DigiPro 2 can also import import surveys from GTILT and other formats and export processed data in several formats.

Installing DigiPro2

1. Direct your browser to www.slopeindicator.com.
2. Click Downloads > Software > DigiPro2.
3. Run the “digipro2setup.exe” program after it downloads.

About DigiPro2 Licenses

DigiPro2 starts with advanced features enabled for 45 days. After 45 days, it reverts to a basic version, unless a license is purchased. See Appendix 1 for information about purchasing and installing a license.

The basic version has no time limits and is free to use.

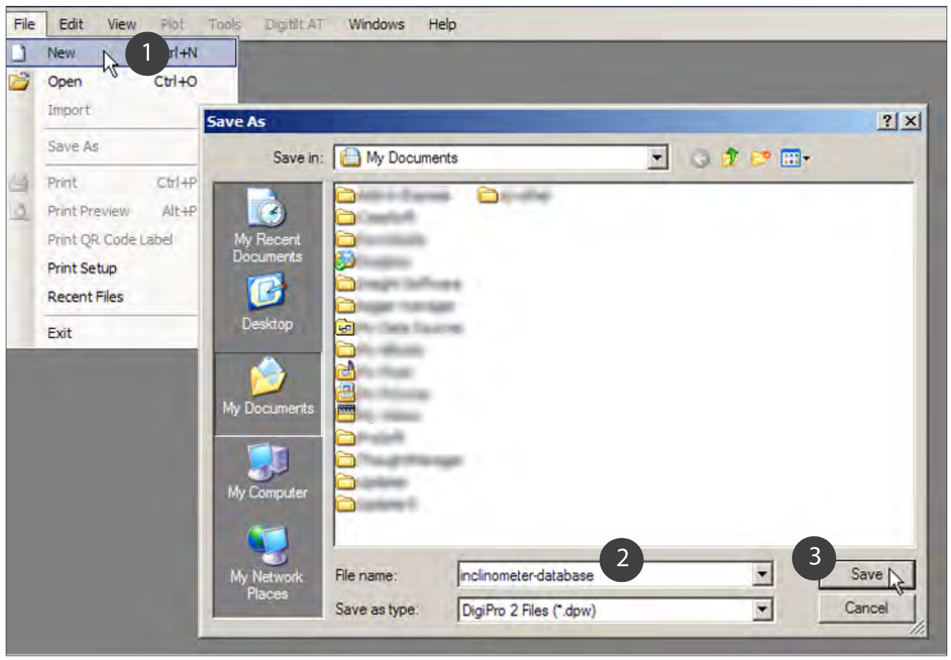
Creating a Database

Introduction

DigiPro2 creates a database to keep inclinometer surveys neatly indexed by name and date.

Creating a Database

1. Start DigiPro. The File menu appears.
2. Click New.
3. Enter a name for the database.
4. Click Save.



Notes

- The default folder is "My Documents" or "Documents."

  To set a different default folder, click Edit > Preferences > Database Folder. Be sure to create your new database in that folder.
- Choose your own filename for the database. All DigiPro2 databases have a .dpw extension.

Next Steps

The new database is empty. To fill it, you can:

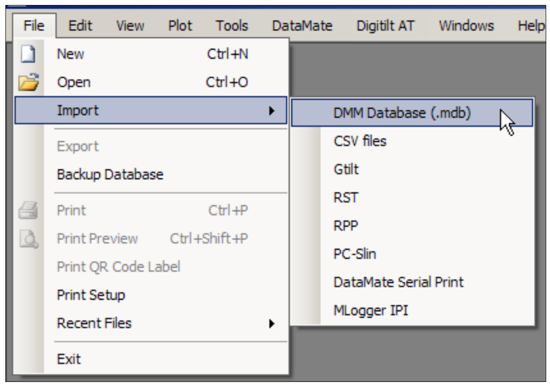
- Import DMM data.
- Retrieve surveys from a Digitilt DataMate readout.
- Import dux files from the Digitilt AT system.
- Import inclinometer data from other formats.

Importing DMM Data

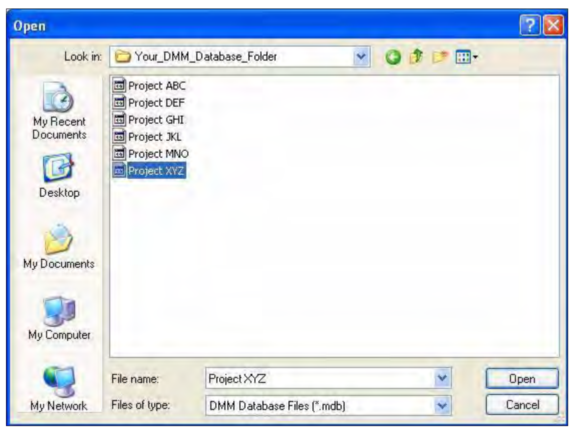
Importing DMM Data

DigiPro2 can import surveys from .mdb databases created by DMM. Note that plots and reports must be recreated.

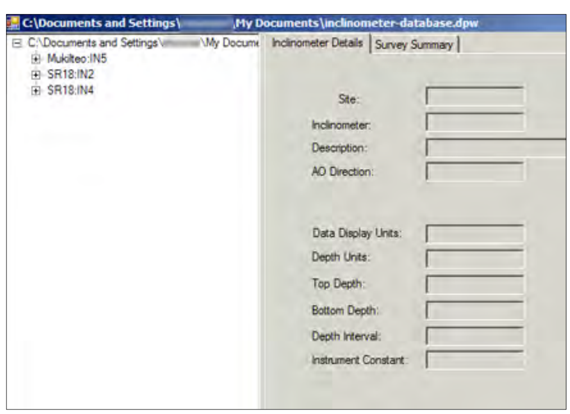
1. Create a database to hold the DMM data.
2. Click File > Import > DMM database (.mdb).



3. Navigate to the mdb file, select it, and click Open.



4. The screen refreshes to show the imported inclinometers and surveys



Inspecting a Database

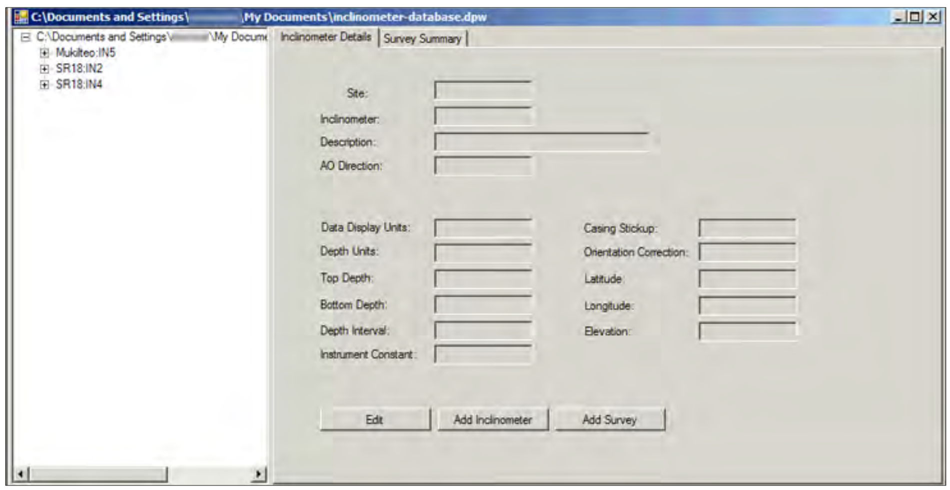
Opening a Database

Open the dpw database that you just created. Or, if you have no data yet, open the sample database, as explained below.

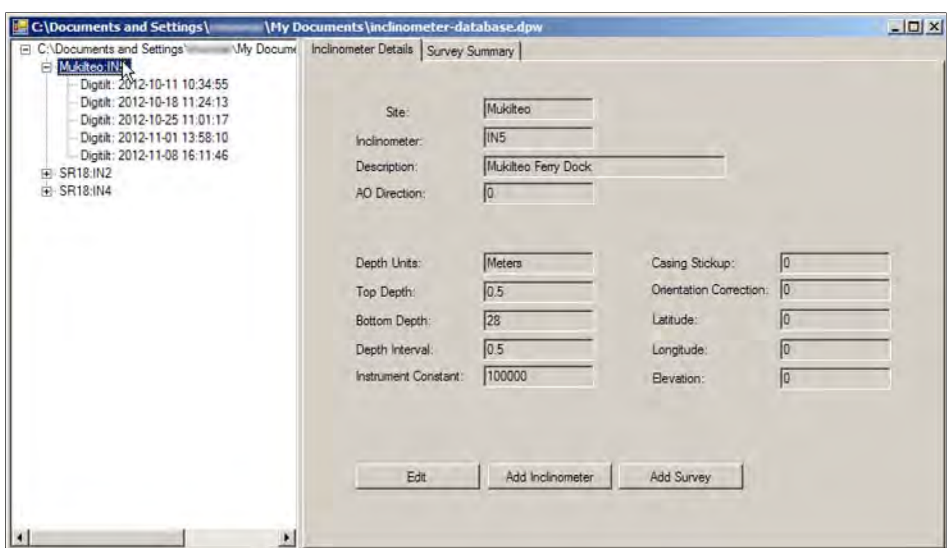
1. Start DigiPro2 from the desktop icon or the start menu.
2. The File menu appears. Choose Open.
3. Click My Documents (left side) or navigate to My Documents.
4. Double-click the folder named "Inclinometer-Data."
5. Choose "sample.dpw."

Inclinometer List

A list of inclinometers appears on the left.

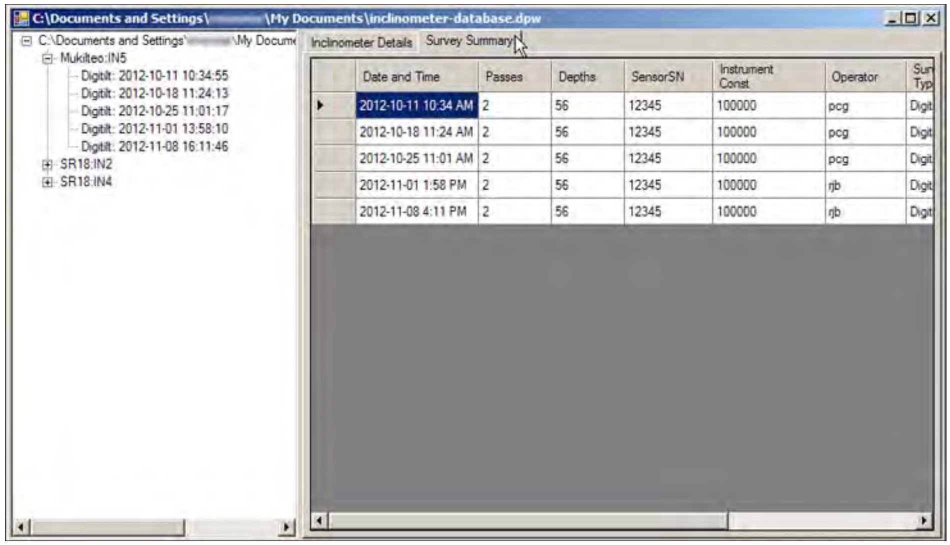


Double-click any inclinometer to see its details on the right. To modify any of the details, click the Edit button.



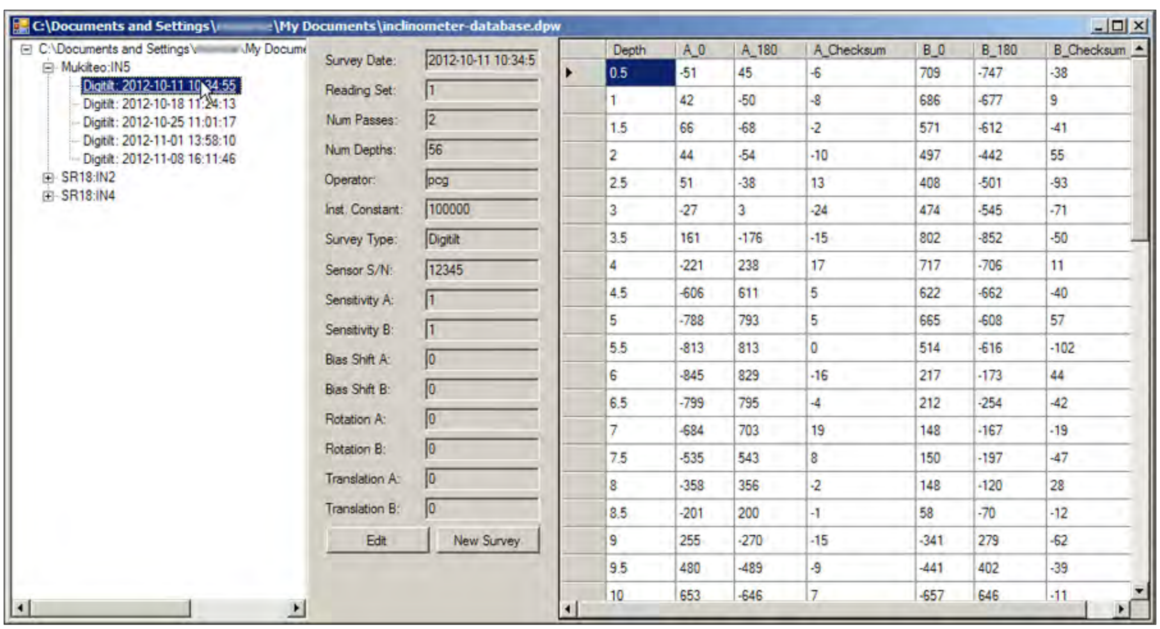
Survey Summary

Click the survey summary tab to see a summary of the surveys for this inclinometer. Double-click any date (left side or right side) to see data values, as shown in the next screen shot.



Survey Data

Double-click a survey (date) to see readings and checksums. Readings from the Classic system are shown in the traditional sine units. Readings from the AT system are shown in the units set by the AT Reader.



Working with the DataMate

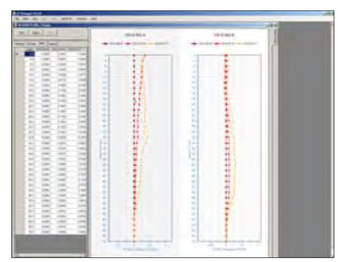
System Workflow

1. Survey the inclinometers with the Digitilt Classic system. The Digitilt DataMate readout stores the surveys in memory.

2. Connect the DataMate to a PC.

3. Open a database (.dpw only), establish a connection with the DataMate, and then retrieve surveys from the DataMate.

4. Use DigiPro2 to display and print inclinometer plots.

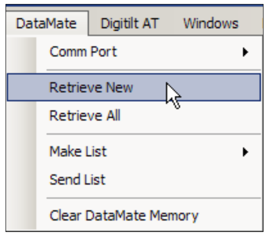


Terminology

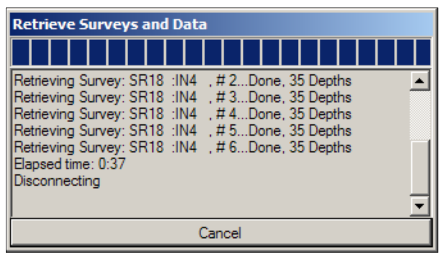
DigiPro2 uses "inclinometer" to refer to the installed portion of the inclinometer system. The DataMate, DMM, and the previous DigiPro use "installation" to refer to the same thing.

Retrieving Surveys

1. Connect the Datamate to the PC.
2. Switch on the DataMate.
3. Choose “Comm.” The DataMate displays “Waiting for PC.”
4. Start DigiPro2 and open the appropriate database.
5. Click DataMate > “Retrieve All” or “Retrieve New.”



6. DigiPro2 shows a progress bar as it imports data.



Communications Problems

1. If DigiPro reports a communications problem,
   click DataMate > Comm Port to choose a different comm port.
2. Additional help is available at www.slopeindicator.com. Go to:
   Support > Tech Notes > DataMate Communications FAQ.

Managing the DataMate

The DataMate holds a list of installations. It is convenient to create the list in DigiPro2 and send it to the DataMate. Please remember the following:

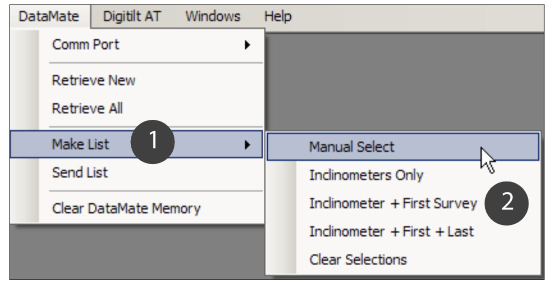
- DigiPro2 completely replaces the list held in the DataMate and also clears all surveys from the DataMate's memory.
- First you create the list. Then you send the list.

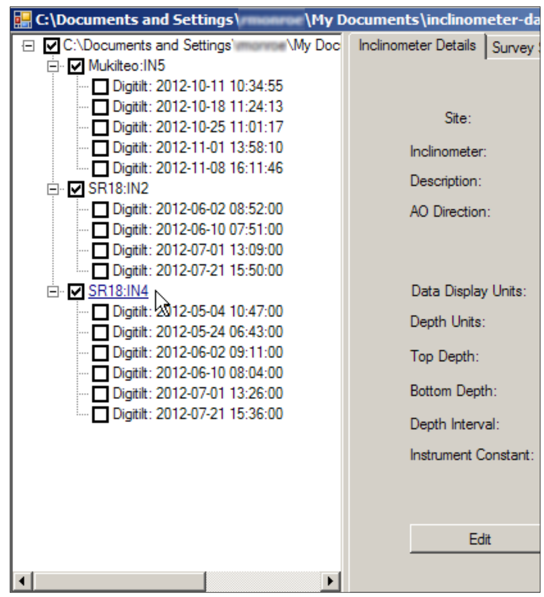
Create the List

1. Open a database and click DataMate > Make List.
2. Choose one of the options. DigiPro2 places checks next to the items selected for the list. In the example at right, only inclinometers were selected for the list.

   The original DataMate has room for 40 inclinometers. Keep as memory free for new surveys.

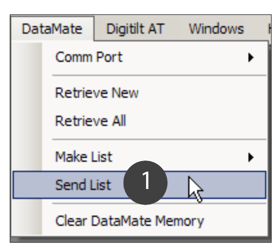
   The DataMate II has room for 160 installations and 320 surveys.

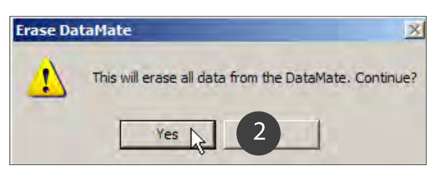




Send the List

1. Click DataMate > Send List.
2. DigiPro shows a warning. This is normal. Click Yes to continue.

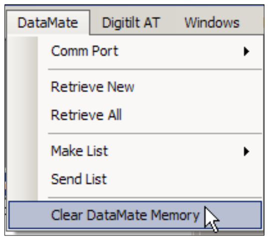




Clearing Memory

DigiPro2 offers an erase command that can clear the memory of the DataMate, if necessary. This erases all installations and surveys.

Click DataMate > Erase Memory.

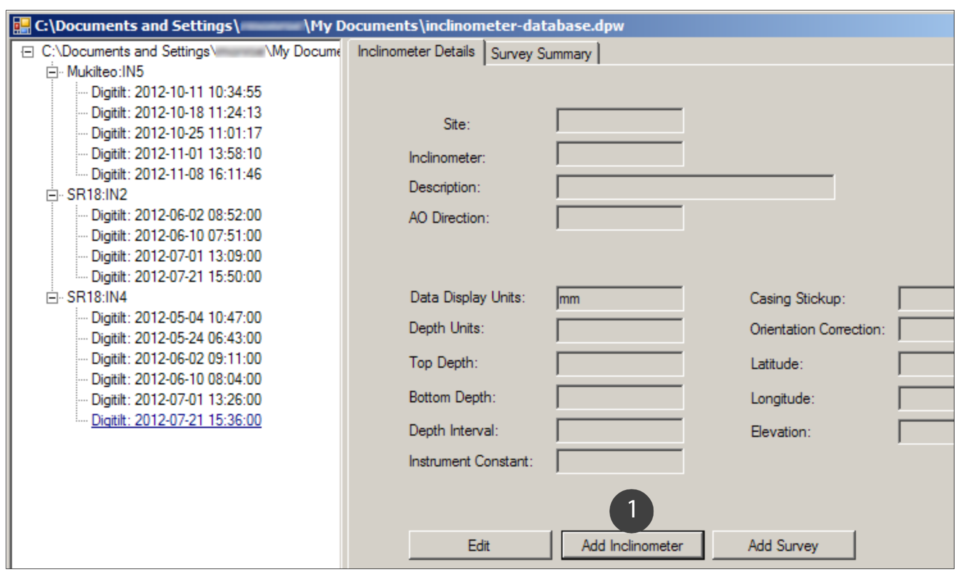


Adding Inclinometers to the Database

If you are in the field, you can create a new “installation” on the DataMate. Then, when you retrieve surveys with DigiPro2, the new installation will appear as an inclinometer in the database.

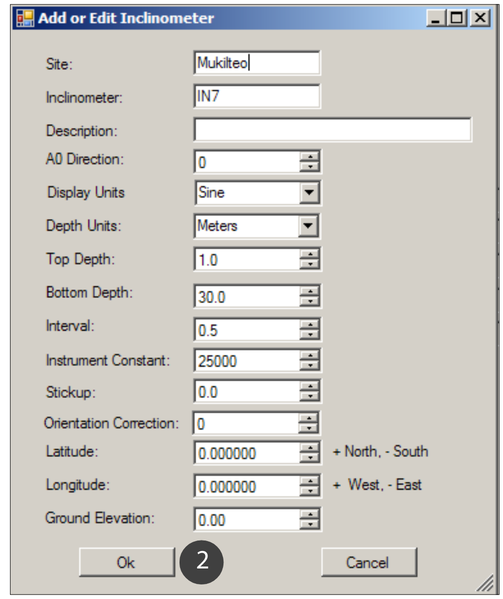
If you are in the office, you can use DigiPro2 to create new inclinometers. Afterwards, you make a list that includes the new inclinometers and send the list to the DataMate, as explained above. Here are instructions for creating an inclinometer in the database:

1. Open the database and click “Add Inclinometer.” DigiPro2 clears the fields and starts a new inclinometer



Adding Inclinometers continued

2. Enter the information. Starred fields are required.



***Site:** The Site and Inclinometer fields together make a unique ID for the inclinometer. DigiPro2 allows 12 characters for the Site ID but sends only 6 characters to the DataMate.

***Inclinometer:** Enter an ID for the inclinometer. Again DigiPro2 allows up to 12 characters (for the Digitilt AT system) but sends only 6 to the DataMate.

Description: Optional field that does not appear in the DataMate. Accepts up to 35 characters.

AO Direction Optional field for the compass heading (0-359) of the inclinometer "A" grooves. Not used in calculations.

Display Units: Choose sine, mm, or inches. Sine refers to the units displayed by the DataMate readout. Millimeters assumes a .5m gauge length. Inches assumes a 2-foot gauge length. Default is sine units.

***Depth units:** Choose feet or meters.

***Top Depth:** Typically 0.5 for metric-unit systems or 2 for English-unit systems.

***Bottom Depth:** Depth of deepest reading. With English-unit systems, use an even number to match the two-foot cable graduations.

***Depth Interval:** Typically 0.5 for metric-unit systems or 2 for English-unit systems.

***Instrument Constant:** Enter 25000 for metric-unit systems , 20000 for English unit systems, 100000 for AT system.

Reserved Fields

Casing Stickup: Distance from the top of the casing to ground level. Allowed values from -10 to + 10. Used by DigiPro.

Elevation: The elevation of the ground surface. Used by DigiPro.

Orientation Correction: Range is -180 to +360. Used by DigiPro.

Latitude, Longitude: Information field not used by DataMate.

Working with the Digitilt AT

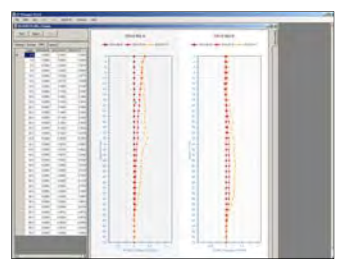
System Workflow

1. Use the Digitilt AT system to to survey the inclinometers. The Reader stores the surveys in inclinometer files.

2. Use the Reader to send the inclinometer files to the PC, where they are saved in an import folder for easy access by DigiPro2.

3. Use DigiPro2 to import the inclinometer surveys.

4. Use DigiPro2 to display and print inclinometer plots.

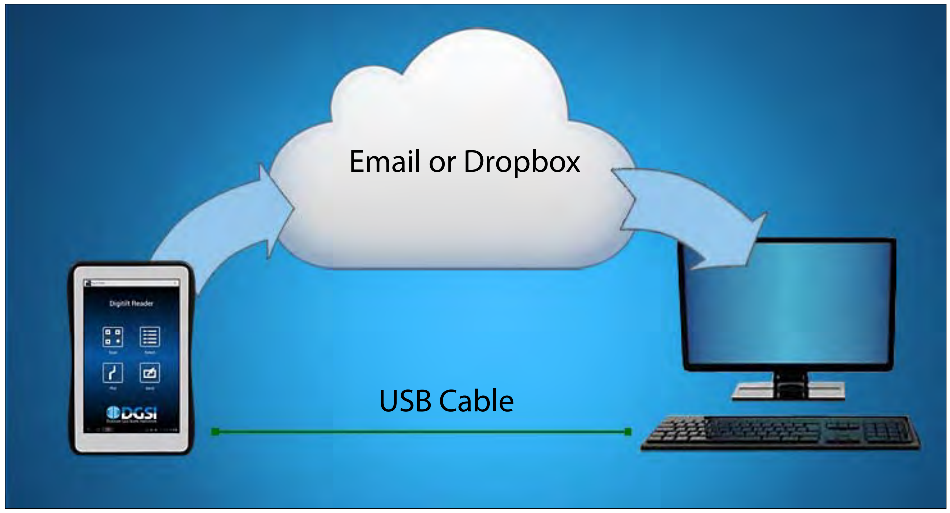


Transfer of Dux Files

The Reader stores surveys in inclinometer files. For convenience, we call these “dux” files because they have a .dux extension. (dux mean DigiPro Uniform eXchange).

Transfer Methods

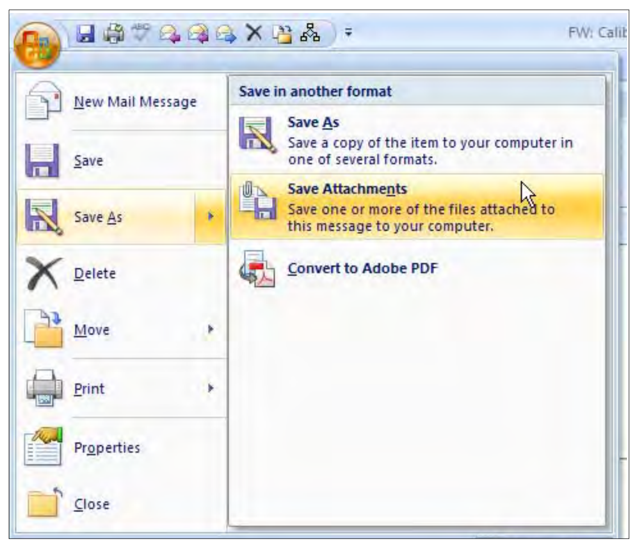
The Reader can send dux files to the PC by email or Dropbox. If the internet is not available, you can use a USB cable and the Windows file manager to copy files from the Reader to the PC.



Email Transfers

The Reader sends dux files as attachments to an email message.

1. Use Outlook, Gmail, or some other email program to open the email message.
2. Save the attached dux files into the import folder. (The import folder is explained in the next chapter.)



Dropbox Transfers

The Reader sends dux files to Dropbox. A few minutes (or seconds) later, the files appear in the Dropbox folder on the PC. No user actions are required.

The convenience of Dropbox is well worth the time that it takes to set up. Other cloud services such as Google Drive can be set up in a similar way.

1. Visit Dropbox.com using your web browser. Create a free Dropbox account. Enter an email address for the User ID, then create a Dropbox password. User ID and password are used again in the next steps

2. Download Dropbox for Windows. Run the setup program and then log in to Dropbox, using your User ID and password. Now your PC is linked to Dropbox in the cloud.

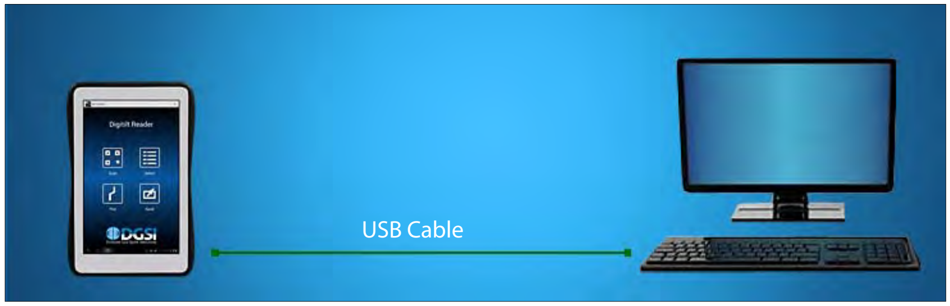
3. Start DigiPro2 and create a default import folder in Dropbox, as explained in the next chapter.

4. Visit the Google Play store using your Android device. Search for Dropbox and install it. You already have a Dropbox account, so login using your User ID and password. Now the Android device is linked to Dropbox, too.

5. The Dropbox listing on your Android device now shows the default import folder. That is where the Reader app will send dux files.

USB Transfers

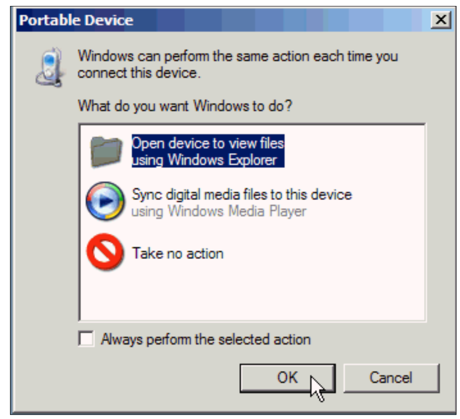
Use the Windows file manager and the USB cable supplied with your Android device. No USB drivers are required.



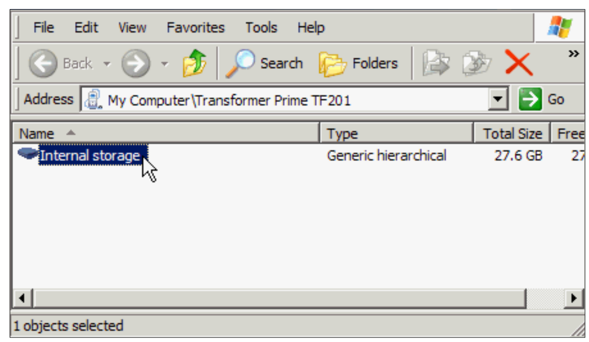
1. Connect the Reader to the PC using the USB cable.

   Switch on the Reader.

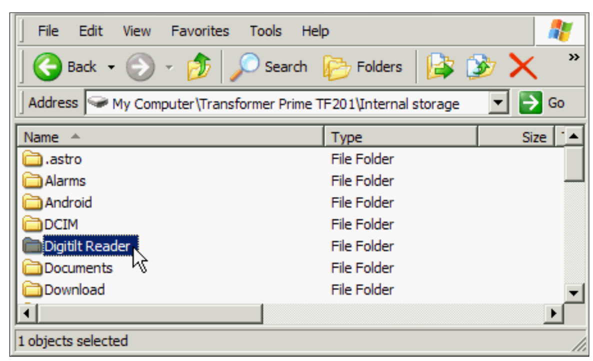
   A dialog appears on your PC. Choose "Open device ..."



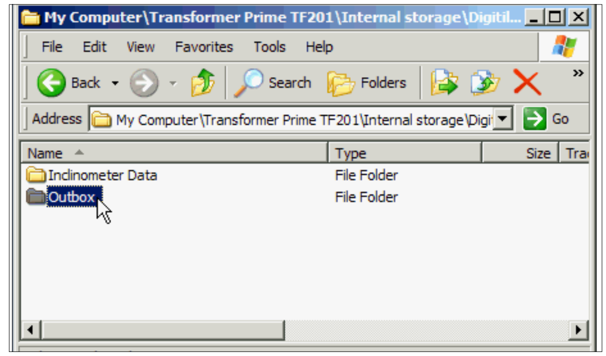
2. Windows opens the device. Click on "Internal storage."



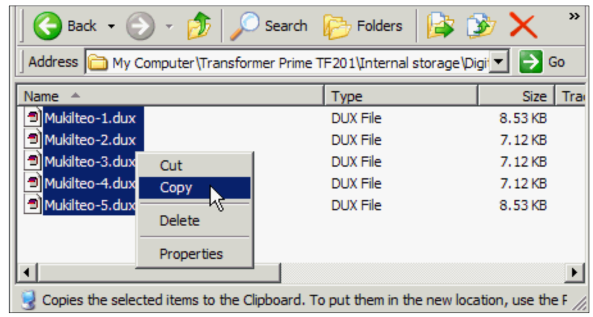
3. .Windows displays list of folders. Click on the "Digitilt Reader" folder.



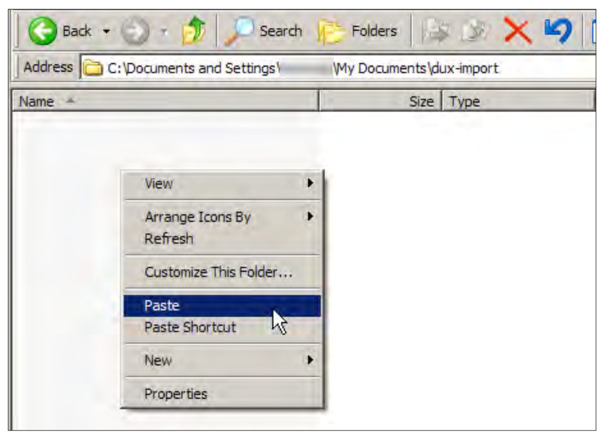
4. Click on the Outbox folder. This folder holds the dux files that should be transferred.



5. Select all the dux files in the Outbox, then right-click, and choose Copy.



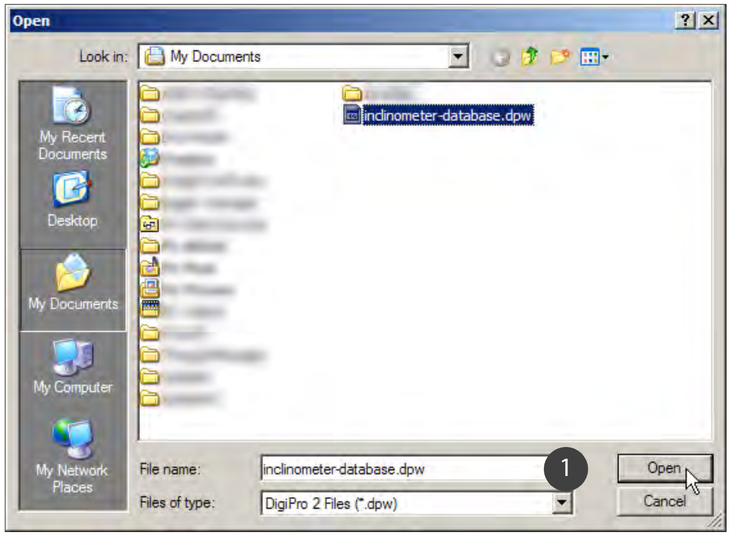
6. Now paste the dux files into the default import folder (which is explained in the next chapter).



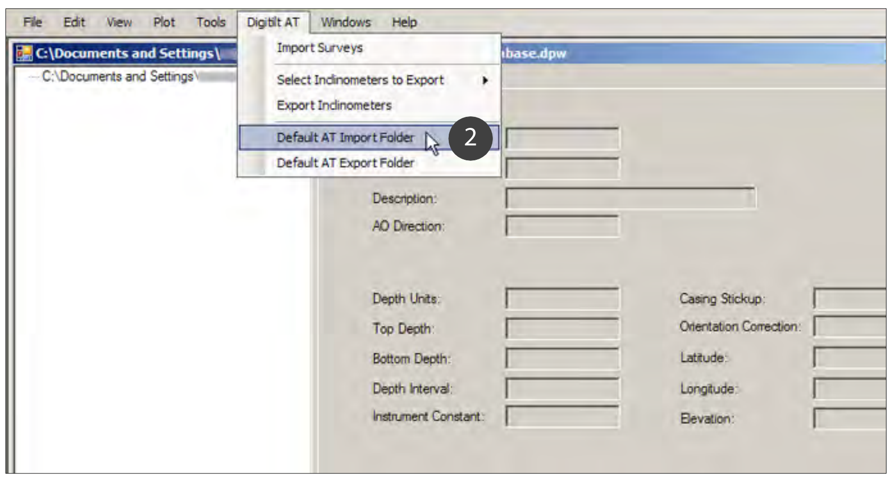
Create an Import Folder

Use DigiPro2 to create an import folder for dux files transferred from the Digitilt Reader. That will simplify importing the data into DigiPro.

1. Start DigiPro. Open the database that you just created.



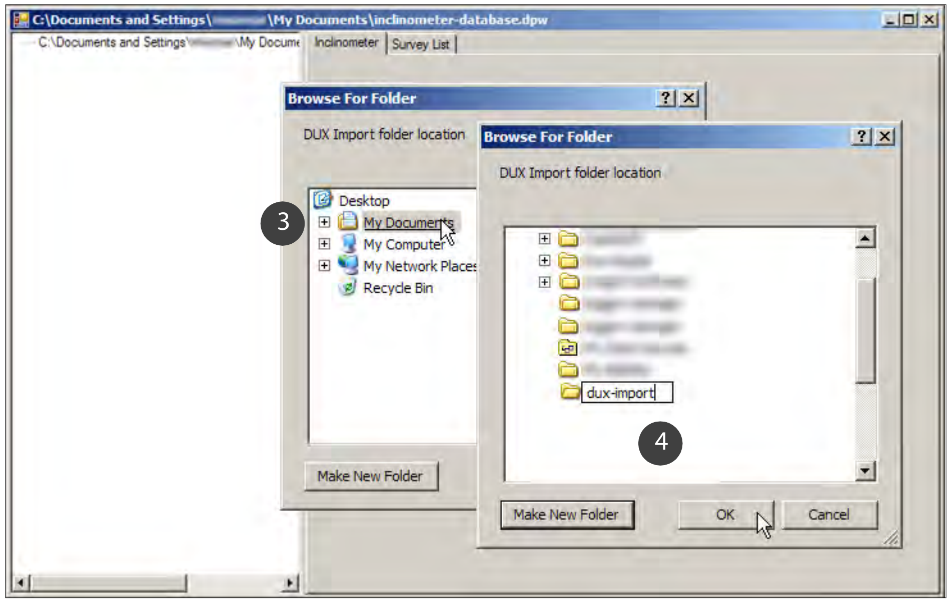
2. Click Digitilt AT > Default Import Folder.



...for Email or USB Transfers

3. Click “My Documents” (XP) or “Documents” (Win 7 & 8).

4. Click “Make New Folder,” enter a name for the folder, and click OK. In the example below, the folder is named “dux-import,” but you can choose your own name.



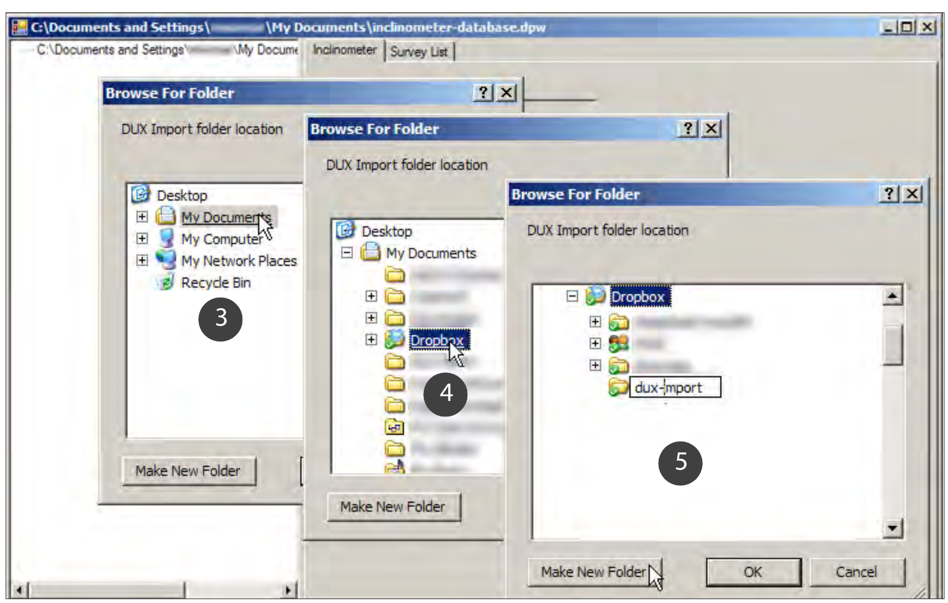
... or for Dropbox Transfers

After you install Dropbox, you can see a Dropbox folder in My Documents.

3. Click My Documents.

4. Click the Dropbox Folder.

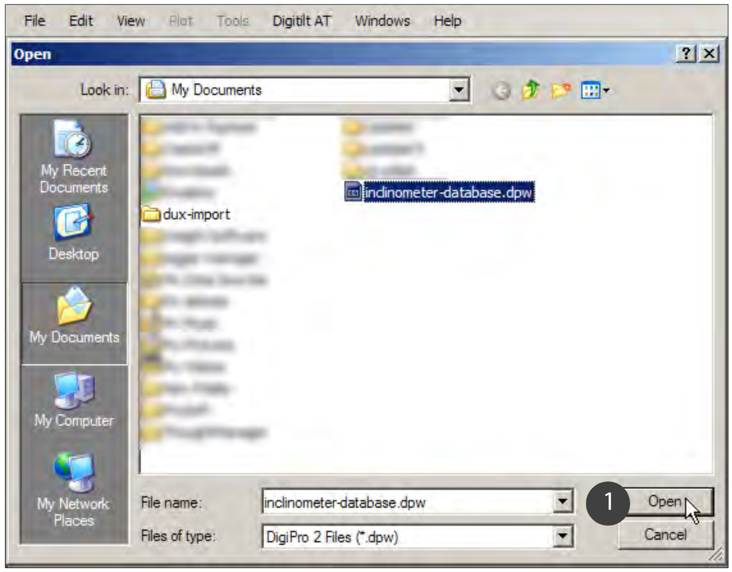
5. Click “Make New Folder,” enter a name for the folder, and click OK. In the example, the folder is named “dux-import,” but you can choose your own name.



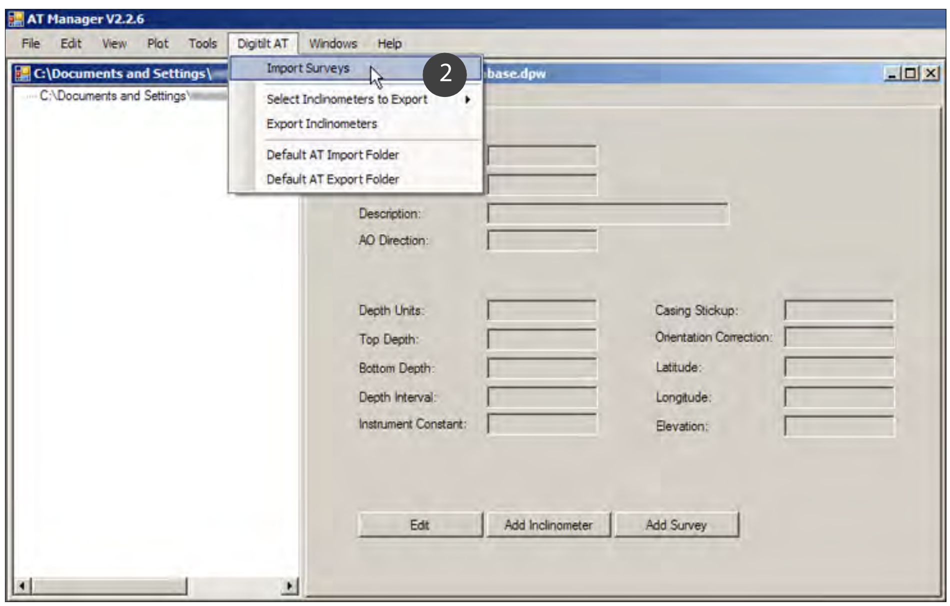
Import AT Surveys

Now it is time to import data from the dux files.

1. Open the .dpw database.



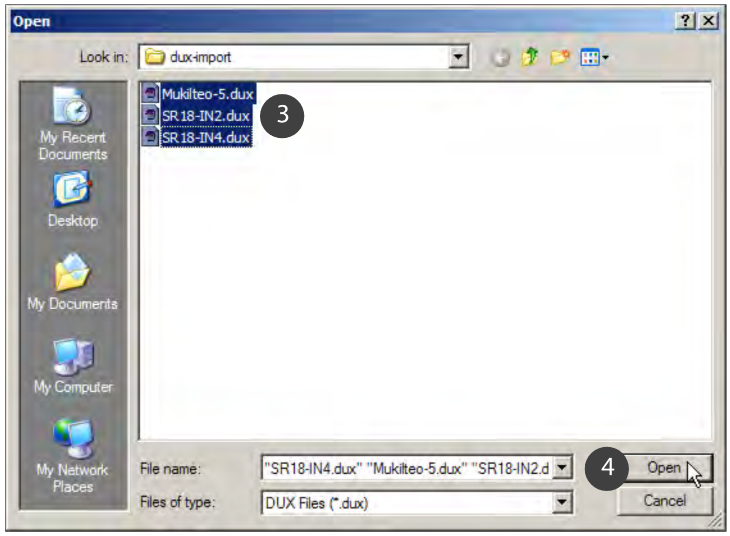
2. Click Digitilt AT > Import Surveys. DigiPro2 opens the default import folder.



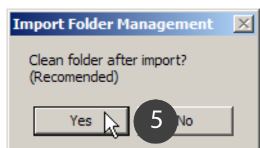
Import continued

3. Select the dux files that you want to import (Ctrl-A for All).

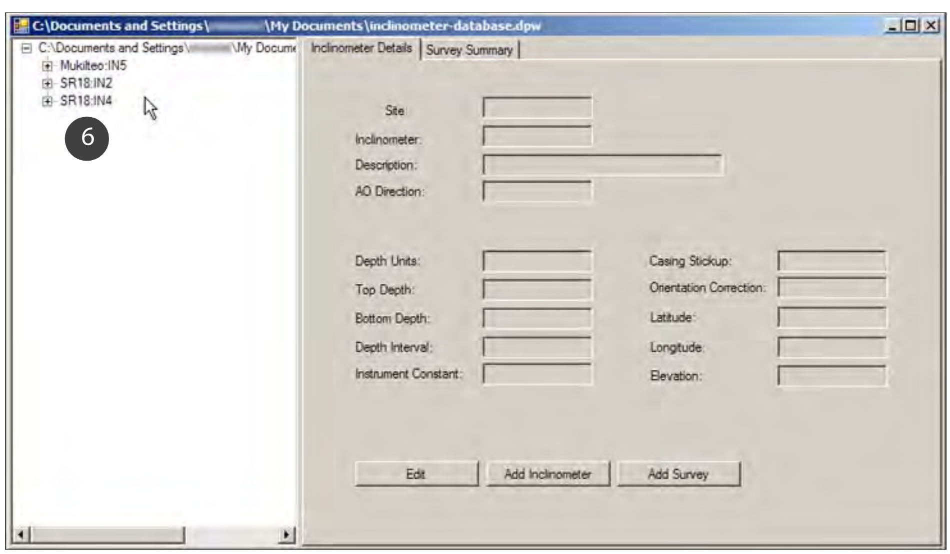
4. Click Open.



5. Click "Yes" to allow DigiPro2 to delete dux files that are imported successfully. These are no longer needed. The Reader keeps the original files and the database has the transferred readings.



6. DigiPro2 imports the surveys and clears the imported files from the folder.



Generating Plots

Overview

DigiPro2 can generate, print, and export a variety of plots. Plots can be saved as reports and reused with new surveys. DigiPro2 can also apply a variety of corrections to inclinometer data.

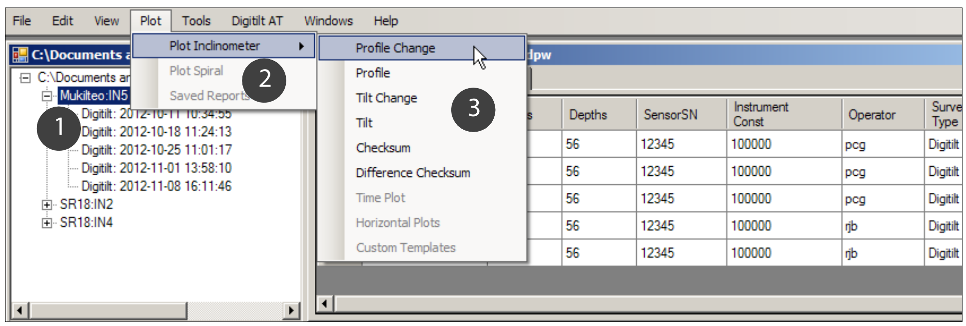
Some features explained below exist only in the Advanced version of DigiPro2, which requires purchase of a license key. The appendix presents a comparison of features available in the basic and advanced versions.

Plotting

1. Click on an inclinometer

2. Click Plots

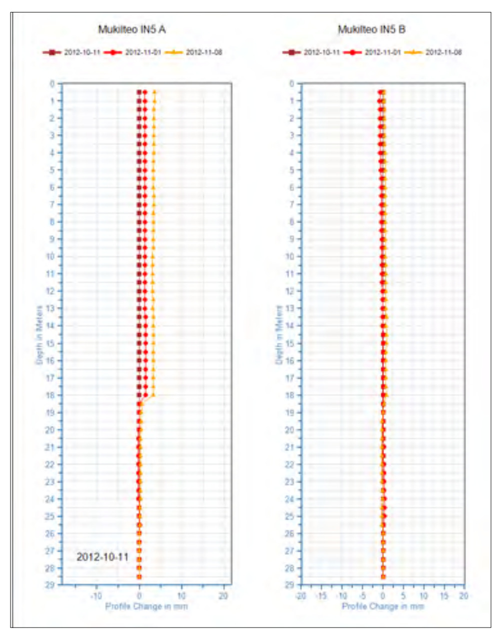
3. Choose a plot. Plot types are discussed below.



Profile Change Plot

This change plot is most common way to present inclinometer data. The plot compares compares the current profile to the initial profile. Changes are understood to be movement (displacement).

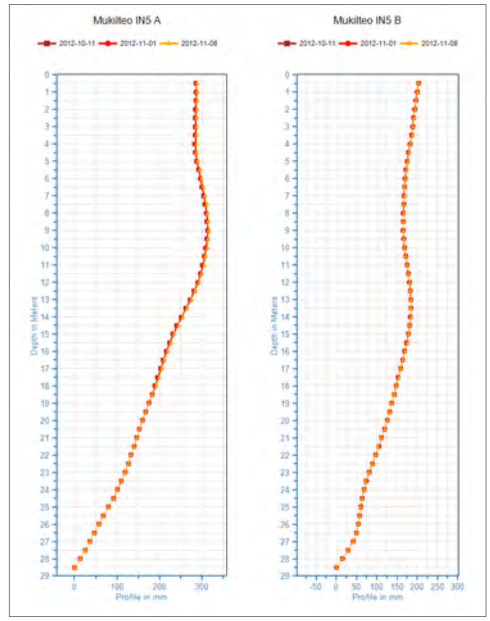
The previous name for this plot was “Cumulative Displacement.”



Profile Plot

This is a diagnostic plot. It accumulates tilt readings (in mm or inches) to show the profile of the installed casing. The plot is used to evaluate borehole verticality and is also used in diagnosing and correcting error.

The previous name for this plot was “Cumulative Deviation.” It is also known as an “absolute position” plot.

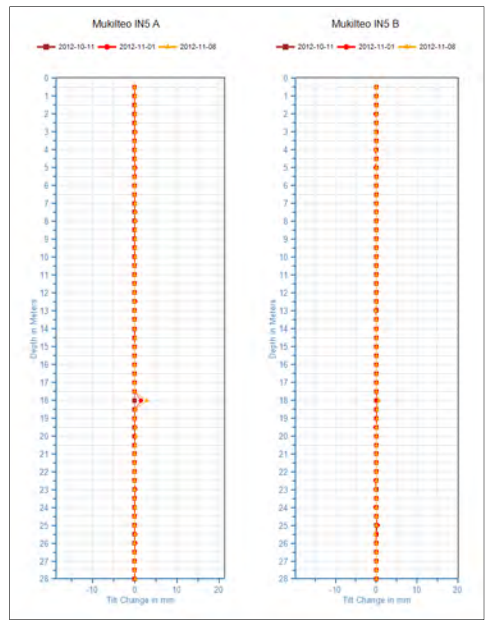


Tilt Change Plot

This change plot compares the current tilt reading at a given depth to the initial reading at the same depth. Changes are understood to be movements (displacement).

Tilt change plots do not accumulate values, so are immune to systematic error. Movement appears as a growing spike, typically centered on one or two depths.

The previous name for this plot was “incremental deviation.”

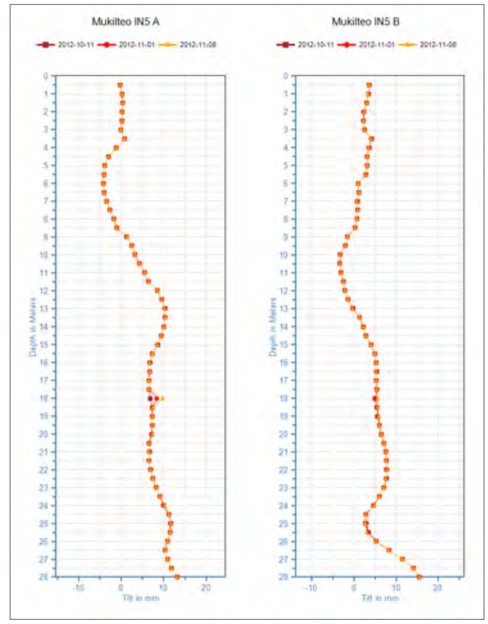


Tilt Plot

This is a diagnostic plot that shows tilt in mm or inches at each depth.

It can be used to evaluate the installed “straightness” of an inclinometer and the potential for depth control errors.

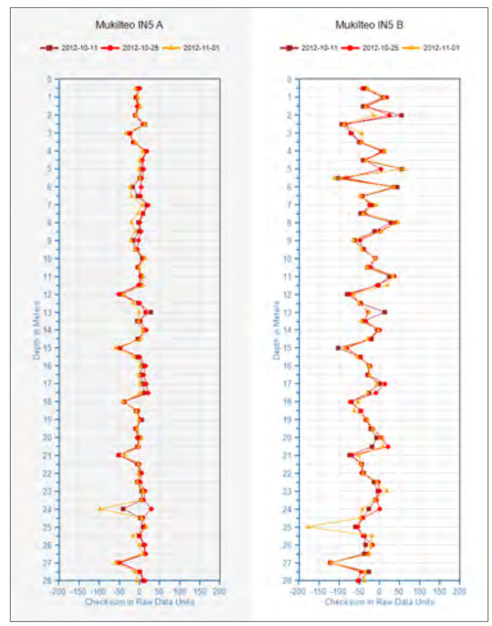
The previous name for this plot was “Incremental Deviation.”



Checksum Plot

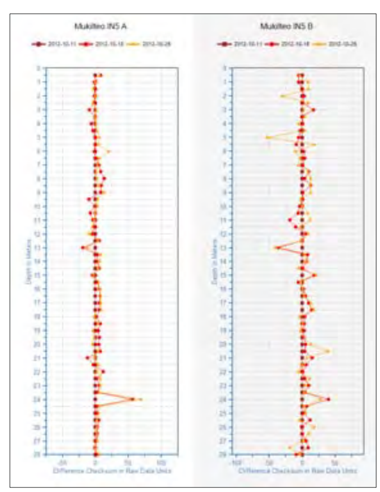
This is a diagnostic plot that shows the checksum at each depth. A checksum is the sum of the 0 and 180 readings.

Generally speaking, the magnitude of the checksums is less important than the uniformity of checksums within a survey. In that regard, you would hope to see plots that are straight and vertical rather than curved and off vertical.



Difference Checksum Plot

This is a diagnostic plot that attempts to remove casing irregularities from the analysis of checksums. The initial checksum is subtracted from the current checksum. This eliminates variations that are due to characteristics of the casing, such as telescoping couplings.

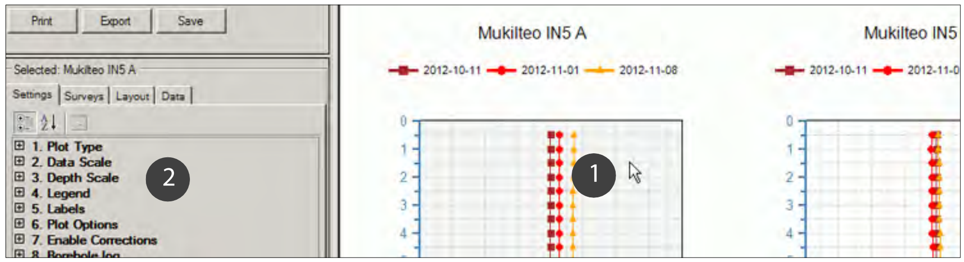


Modifying Plots

Overview

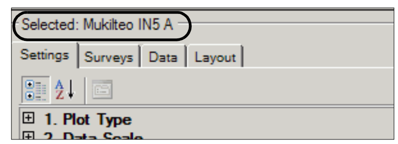
A tabbed control panel provides access to settings, surveys, and layout.

1. Click to select a plot. The plot background turns gray.
2. Double-click to open a settings.

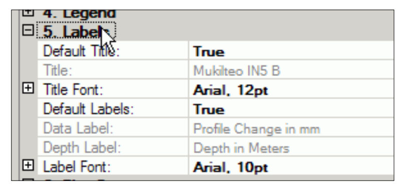


Helpful Hints

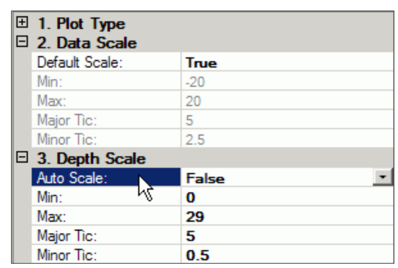
- The name of the selected plot appears above the settings tab.



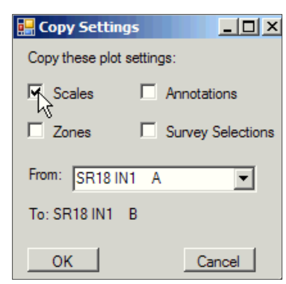
- To open a settings group, double-click on the name of the setting. You can also click the + mark.



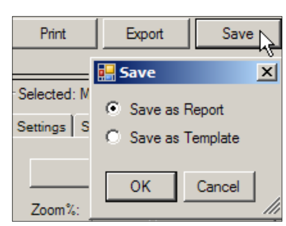
- To change default or automatic settings, first double-click the label to turn off the automation (false = off). Then you can edit the settings.



- To copy plot A settings to plot B, right-click on the B plot and choose "copy settings." Then choose which settings to copy.



- To save settings, click the "Save" button and choose Save as Report. When you have new surveys, choose "Saved Reports" to plot the new surveys with all the same settings

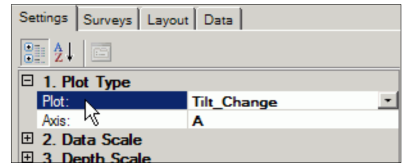


Settings Tab

Use the Settings tab to control the appearance of the plots.

Plot Type

DigiPro normally plots A and B using the same type of plot. Use this setting if you want a different type for one of the plots.



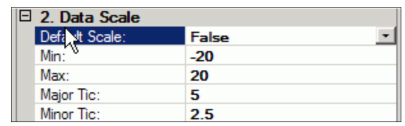
Plot: Double-click on “Plot” to iterate through the available plot types.

Axis: Double-click on “Axis” to iterate through the following choices:

- A shows tilt in the plane of the wheels.
- B shows tilt in the plane rotated 90 degrees to the wheels.
- Magnitude shows the magnitude of the tilt vector: sqrt(A^2 + B^2).
- Angle shows the direction of the tilt vector: arctan(B/A).

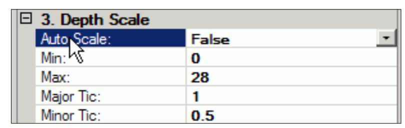
Data Scale

DigiPro2 sets default scale according to the depth of the inclinometer. To enter your own scales, turn off the default scale by double-clicking “Default Scale.”



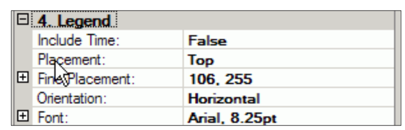
Depth Scale

DigiPro2 sets depth scales automatically. To enter your own depth scales, turn off the autoscaling by double-clicking “Auto Scale.”



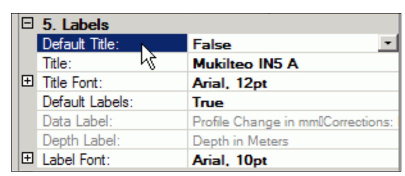
Legend

Legends usually show a date only. If time is important, double-click “Include Time.” Double-click “Placement” to view available locations for the legend. Fine Placement adjusts X Y placement of the plot starting from top left corner of the page. This adjustment is useful for printed plots. Double-click “Orientation” to place dates vertically or horizontally.

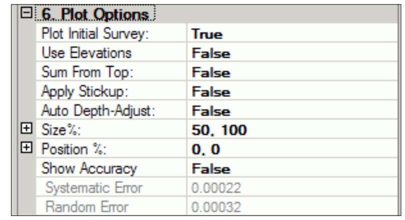


Labels

DigiPro2 automatically generates titles and labels.To turn off automation, double-click “Default Title” or “Default Labels,” and then enter your own text.

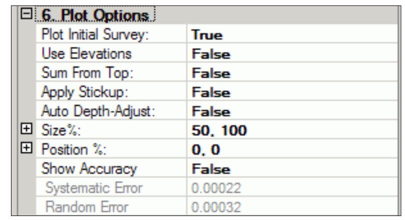


Plot Options



Plot Initial Survey: DigiPro2 automatically shows the initial survey in all plots. Double-click if you want to hide the initial survey.

Use Elevations: DigiPro2 shows depths by default. If you have entered elevation in the inclinometer header, double-click to show elevations.



Sum from Top: Profile plots are created by summing values. Summing from bottom is the default, since the bottom is normally assumed to be stable. To sum from top, double-click to change the value to "true."

Apply Stickup: Double-click to enable or disable. When enabled, and a stickup value has been entered in the inclinometer header, DigiPro2 plots values at their real depths (or elevations) rather than at cable depths.

We record readings at depths indicated by depth marks on the cable. We align depth marks to an index, such as the top of the casing or the top of a pulley assembly. Stickup is the distance from the index to the surface of the ground. If the index is 0.5m above the ground, the real depth of the probe is 0.5m shallower than the depth indicated by the cable. Applying a stickup of 0.5m will cause values to be plotted at their real depth (or elevation).

Auto Depth-Adjust: This adjustment is sometimes used with Classic systems, which have cabled marked from the middle of the probe. When turned on, readings are plotted at the depth of the top wheels rather than at cable depth. Auto depth-adjust should be off (false) for AT systems.

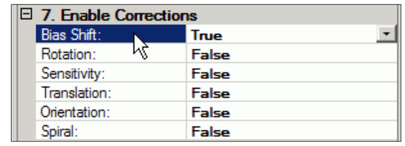
Size: This setting controls the width and height of the chart area (the area including the white space around the plot). It may be useful when you display only one plot. Double-click to make entries. Value are percent of page.

Position: This setting moves the chart area. It may be useful when you display only one plot. Double-click to make entries. Value are percent of page.

Show Accuracy: Field accuracy generates lines showing the approximate "Field Accuracy" of profile change plots, assuming systematic error increasing with the number of readings and random error increasing with the square-root of the number of readings. Double-click to toggle the accuracy lines on and off.

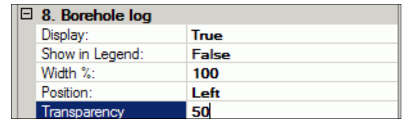
Enable Corrections

This settings group allows corrections to be double-clicked on and off. True is on, False if off. Corrections are discussed in a later chapter.



Boring Log

This settings group shows or hides a graphic representing a boring log. The graphic appears in the background of the plot.



Display: Double-click to show or hide the boring log graphic. Note that the details of the boring log are entered elsewhere: Edit>Add/Edit Boring Log.

Show in Legend: Double-click to show or hide boring log labels in the legend area.

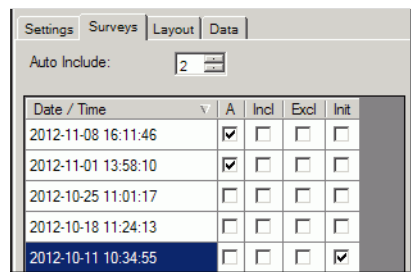
Width: Set width of the graphic. 100% is the full width of the plot. Try 10 for a narrow graphic.

Position: Move the graphic to the right side or left side of the plot.

Transparency: Make the graphic more transparent with a smaller number.

Survey Tab

Click the “Surveys” tab to select surveys to include in the plot.



Auto-Include: Automatically includes this number of recent surveys in the plot.

A: Shows which surveys are included by the Auto-Include setting.

Inc (Include): Check the box to always include this survey in the plot.

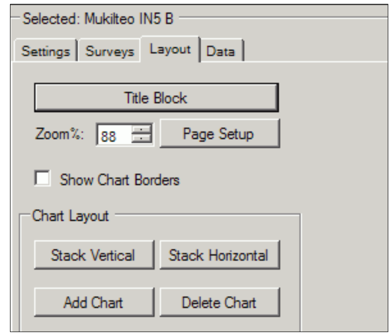
Exc (Exclude): Check the box to always exclude this survey.

Init (Initial): Check this box to choose the initial survey.

Note

DigiPro2 Basic is limited to three surveys: the initial plus two others.

Layout Tab



The layout tab provides mostly page-related settings.

Title Block: Click to add a title block. Details are explained below.

Zoom: This is a display setting. DigiPro2 sizes plots for your display automatically. Use zoom to adjust, if necessary.

Page Setup: DigiPro2 displays settings related to printing, such as paper size and margins. These are discussed in the next chapter.

Show Chart Borders: Check the box to draw borders around each chart. A chart includes the white space around each plot.

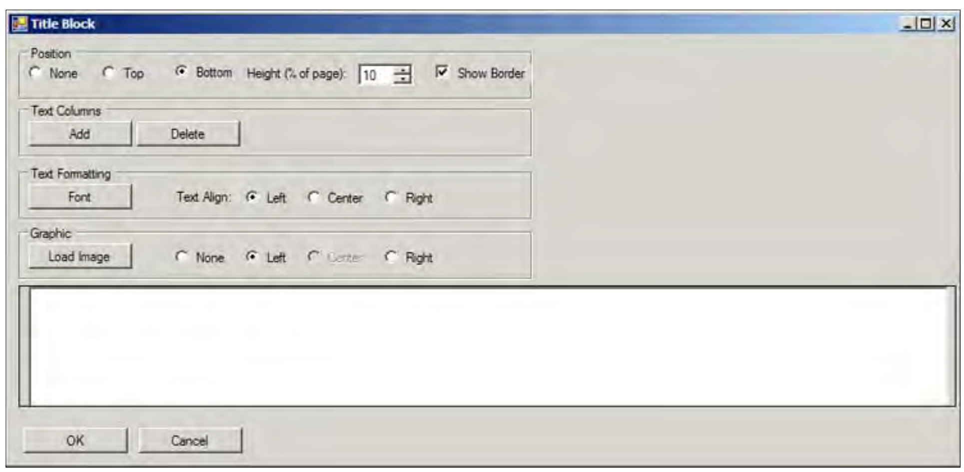
Stack Vertical / Stack Horizontal: Controls layout of charts. Click to see the effect. Horizontal is the default. Vertical may be useful for horizontal inclinometers.

Add Chart: Click to add an additional chart (and plot) to the page. It is not possible to add plots from other inclinometers.

Delete Chart: Removes a chart from the page.

Title Block Details

The title block dialog lets you add a logo and descriptive text to the plot.

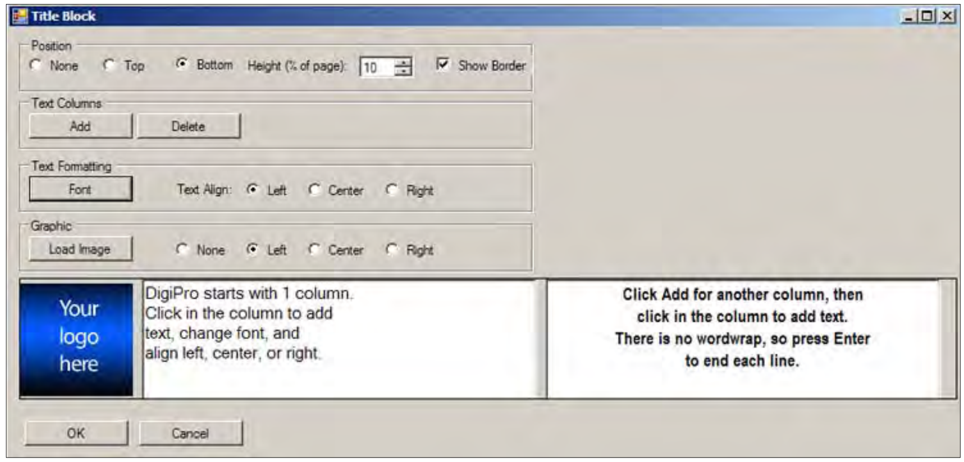


Position: Controls visibility, location, and size of the title block:

- None hides the title block but does not delete it. You can set the title block to none while inspect the plots and then set to top or bottom before you print.
- Top places the title block at the top of the page.
- Bottom places the title block at the bottom of the page.
- Height sets the vertical size of the title block.
- Show Border draws a line around the title block, if checked.

Title Block Details continued

Add columns, text, and a graphic:



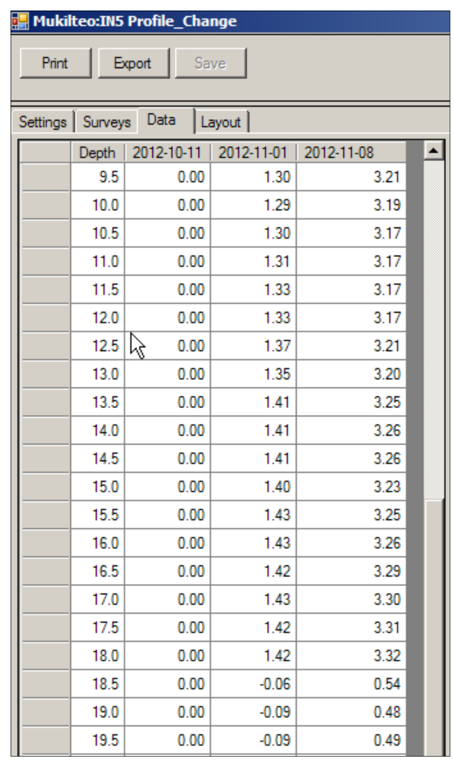
Text Columns: DigiPro starts with one column. Click in the column to enter text. Press Enter to end each line. There is no wordwrap. Click Add if you want more columns.

Text Formatting: Click in a column first, then adjust the font and alignment of the text. You cannot adjust individual lines within a column. The printed page is not the same as the displayed page, so you may need to experiment with line lengths and font sizes for a good appearance.

Graphic: Click the Load Image button to browse for a jpeg, gif, png, emf, or bmp graphic file. DigiPro resizes the graphic to fit the vertical space. You can choose left, center, or right alignment.

Data Tab

Click the "Data" tab to display values used in the plot. Survey dates appear at the top of each column. Use the scroll bar to see other depths.

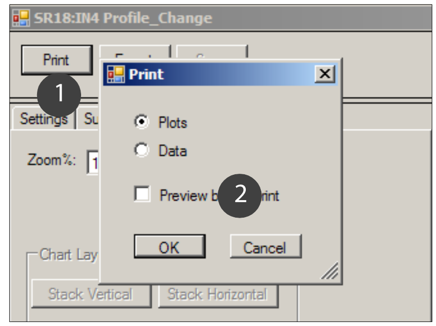


Depth	2012-10-11	2012-11-01	2012-11-08
9.5	0.00	1.30	3.21
10.0	0.00	1.29	3.19
10.5	0.00	1.30	3.17
11.0	0.00	1.31	3.17
11.5	0.00	1.33	3.17
12.0	0.00	1.33	3.17
12.5	0.00	1.37	3.21
13.0	0.00	1.35	3.20
13.5	0.00	1.41	3.25
14.0	0.00	1.41	3.26
14.5	0.00	1.41	3.26
15.0	0.00	1.40	3.23
15.5	0.00	1.43	3.25
16.0	0.00	1.43	3.26
16.5	0.00	1.42	3.29
17.0	0.00	1.43	3.30
17.5	0.00	1.42	3.31
18.0	0.00	1.42	3.32
18.5	0.00	-0.06	0.54
19.0	0.00	-0.09	0.48
19.5	0.00	-0.09	0.49

Printing & Exporting Plots

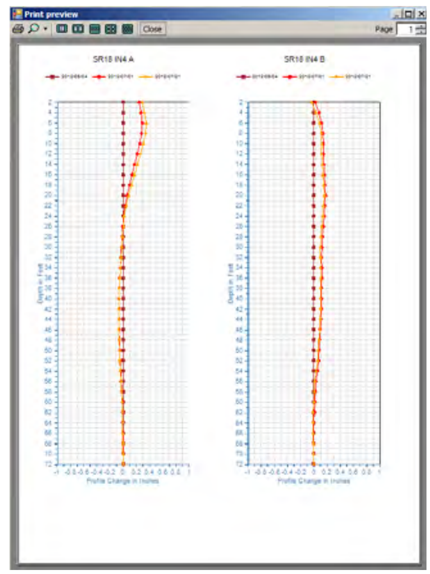
Printing Plots

1. Click the "Print" button.
2. Choose "Plots" or "Data." Click the checkbox for a print preview. Then click OK.



Preview

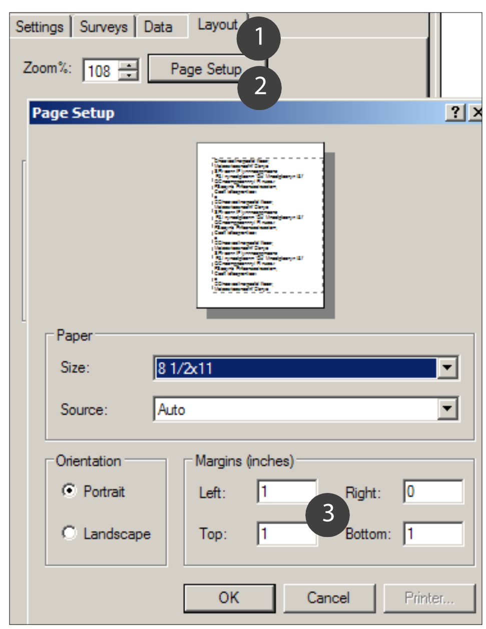
Print preview lets you inspect the page before you print it. Click the print button to print.



Page Layout

To adjust page margins:

1. Click the "Layout" tab.
2. Click the "Page Setup" button.
3. Adjust margins as required, then click OK.

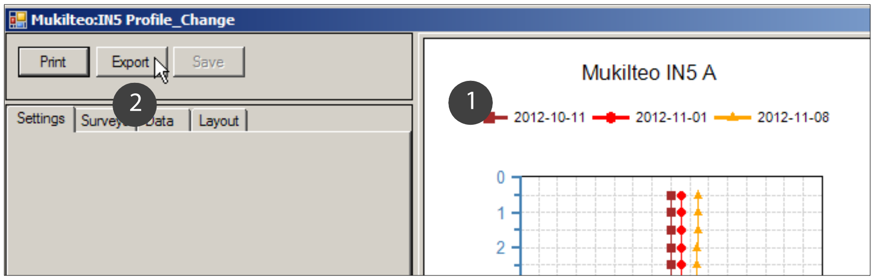


Exporting Plots

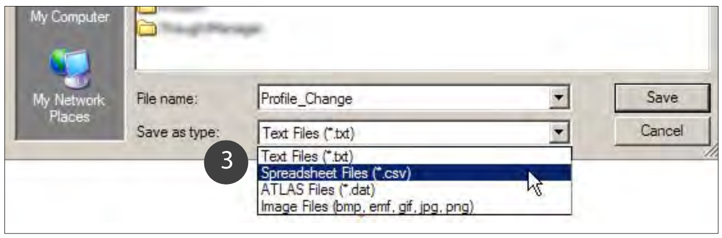
DigiPro2 can export plots as text files or graphic files.

1. Generate the plot.

2. Click the Export button.



3. The Save-As dialog appears. Choose a file type from the drop menu.

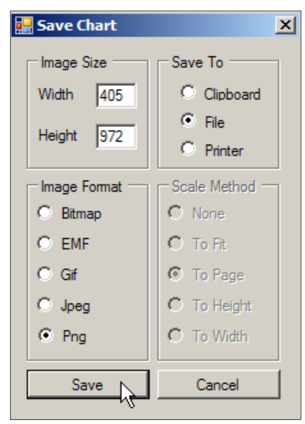


Text File: Printable file with tab separated values.

Spreadsheet File: Spreadsheet-ready file with regionalized field separators and decimals.

Atlas File: Data arrays formatted for Atlas. Each array has a date stamp followed by depth-value pairs. A values first, then B values.

Image File: First select the A or B plot, and then click Export. Choose an image format and click save. PNG and GIF provide the sharpest results.



Using Reports & Templates

What is a Report?

Reports are customized plots that are saved for reuse. You create a plot, modify scales, labels, title blocks, survey selections, etc. as needed, and then save it. Each inclinometer can have any number of reports.

When you have new surveys, you open the report rather than create a new plot. When the report is displayed, the new surveys are automatically included (according to the auto-select setting) and the plots are generated with all the saved settings.

Creating a Report

Modify the plot as needed, then click Save, enter a name, and click OK.

Using a Report

Open: Choose the inclinometer. Click Plot>Saved Reports. Select the report and click OK.

Modify: You can modify a report if necessary. Click Save when you are done.

Delete: The report dialog provides a delete button. Select the report that is no longer needed, then click "Delete."

What is a Template?

A template is similar to a report, in that it saves certain settings, but it is not dedicated to a particular installation.

- You may want all of your plots to include a standardized title block with the company logo.
- You may want a different combination of plots on the page.

Creating a Template

Generate a plot. Modify the plot as necessary and then click Save. Choose "Save as Template" and click OK.

Using a Template

1. Choose an inclinometer.
2. Click Plot > Plot Inclinometer >Custom Templates.
3. Choose a template and click OK.
4. After the template loads, make any extra modifications needed and save as a report.

Applying Corrections

Introduction

DigiPro2 provides correction routines that can improve the presentation and understanding of data. There are two categories of routines: those that apply to single surveys, and those that apply to all surveys of a particular inclinometer.

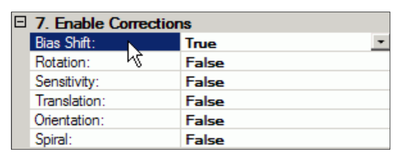
- Routines that affect single surveys are bias-shift, rotation, and sensitivity corrections, which are related to the inclinometer probe, and translation corrections, which are related to the inclinometer casing.
- Routines that affect all surveys are orientation correction and spiral correction. Orientation correction can help when casing grooves are not aligned with the real direction of movement. Spiral correction can help when casing was twisted during installation.

Most corrections routines involve a minimum of three steps:

1. Generate a plot.
2. Enable corrections in the plot settings panel.
3. Enter a correction value and check the result. This may be an interative process with different values entered until a satisfactory plot is generated.

Enabling Corrections

DigiPro2 stores correction values separately from readings. Correction routines apply these values on-the-fly when plots are graphs are generated. Thus corrections can be enabled and disabled at any time. To enable correction routines.



1. Generate a plot.
2. Double-click to open Enable Corrections.
3. Double-click on the particular correction that you want to enable. In the example, Bias-Shift correction has been enabled.
4. To disable a correction, double-click to toggle the value to false..

Bias-Shift Error

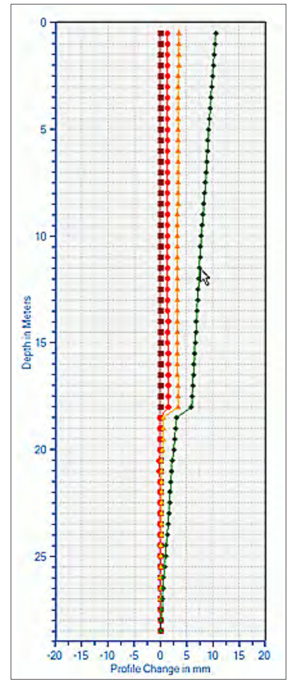
Here is a simple introduction to bias shift error. Refer to the support pages of www.slopeindicator.com for more information.

What is Bias Shift?

Bias: Bias is the value returned by the probe when it is held absolutely vertical. In theory, the value should be zero, but in practice, the value is non-zero. This non-zero value is embedded in every reading.

Bias Shift: It is normal for the bias of the probe to change from time to time. This is not a problem because the bias value is normally eliminated in the data reduction process, when 0 readings are combined with 180 readings.

Bias-Shift Error: If the bias shifts during a survey, the data reduction process cannot competely eliminate the bias. The remaining value is bias shift error. The error becomes visible when readings are accumulated, as in the profile change plot at right.



Identifying Bias-Shift Error

Appearance: The plot above shows the typical appearance of a bias-shift error: a straight-line that is tilted away from vertical. The tilt may be in either direction.

Unlikely Behavior: The plots above shows tilt over the entire span of the inclinometer. This unlikely behavior suggests error in the data.

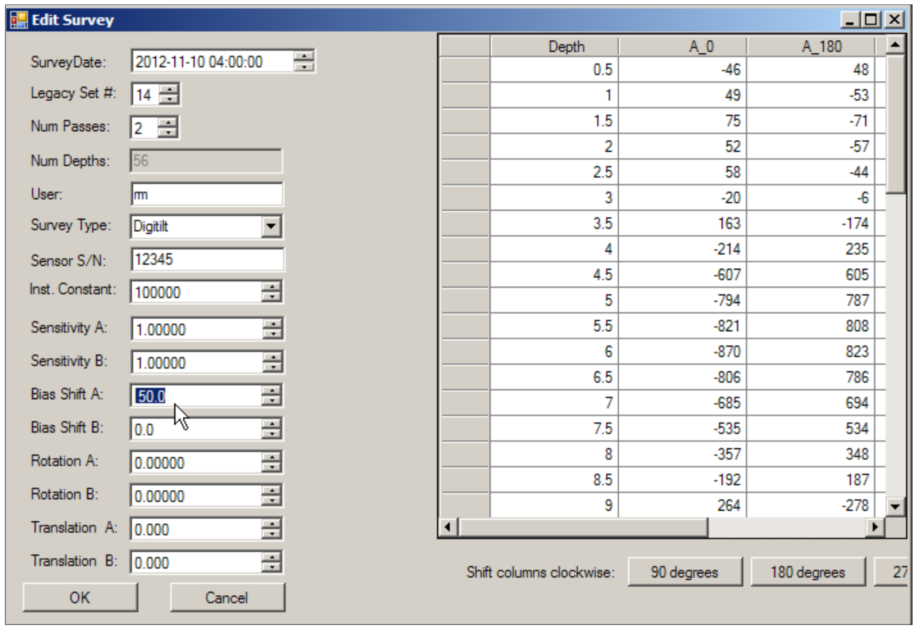
Site Knowledge: The plot shows movement where there should be no movement. Typically, the bottom 5 depths (or more) of the casing are anchored in stable ground. Any movement appearing there is generally error in the data.

Checksum Plots: Checksum plots show that a bias-shift has occurred.

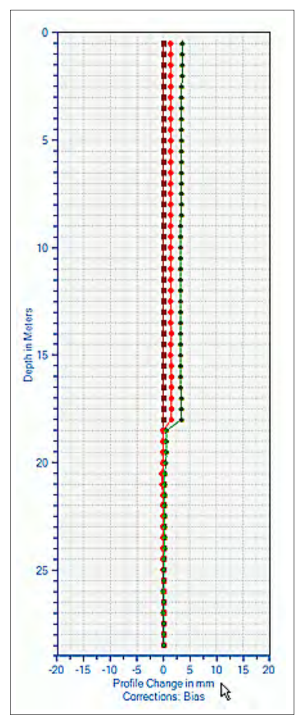
Correcting Bias-Shift Error

You identified bias-shift error in a profile change plot. Then you verified that a bias shift occured by plotting checksums. Now you want to correct for bias shift.

1. Generate the profile change plot again.
2. Enable bias-shift corrections in the settings panel.
3. Double-click the survey (the plot of the survey) that you want to correct.
4. DigiPro2 displays the Edit Survey dialog. Find the Bias-Shift field.



5. Enter a value. If the plotted survey was tilted to the right, try a positive value. If the tilt was to the left, try a negative value. The exact value doesn't matter yet. Click OK.



6. DigiPro2 redraws the plot. Inspect zones were no movement should have occurred (the bottom, for example). Have you eliminated the tilt in those zones?If necessary, double click the survey again and enter a different value. Continue until the tilt is eliminated.
7. The bias-shift error has been removed from the offending survey. The label for the data axis shows the type of correction that was applied.

Rotation

Here is a simple introduction to "rotation" error.

What is Rotation Error?

Rotation is a small change in the alignment of the measurement axis of the inclinometer probe. The change is usually less than one degree.

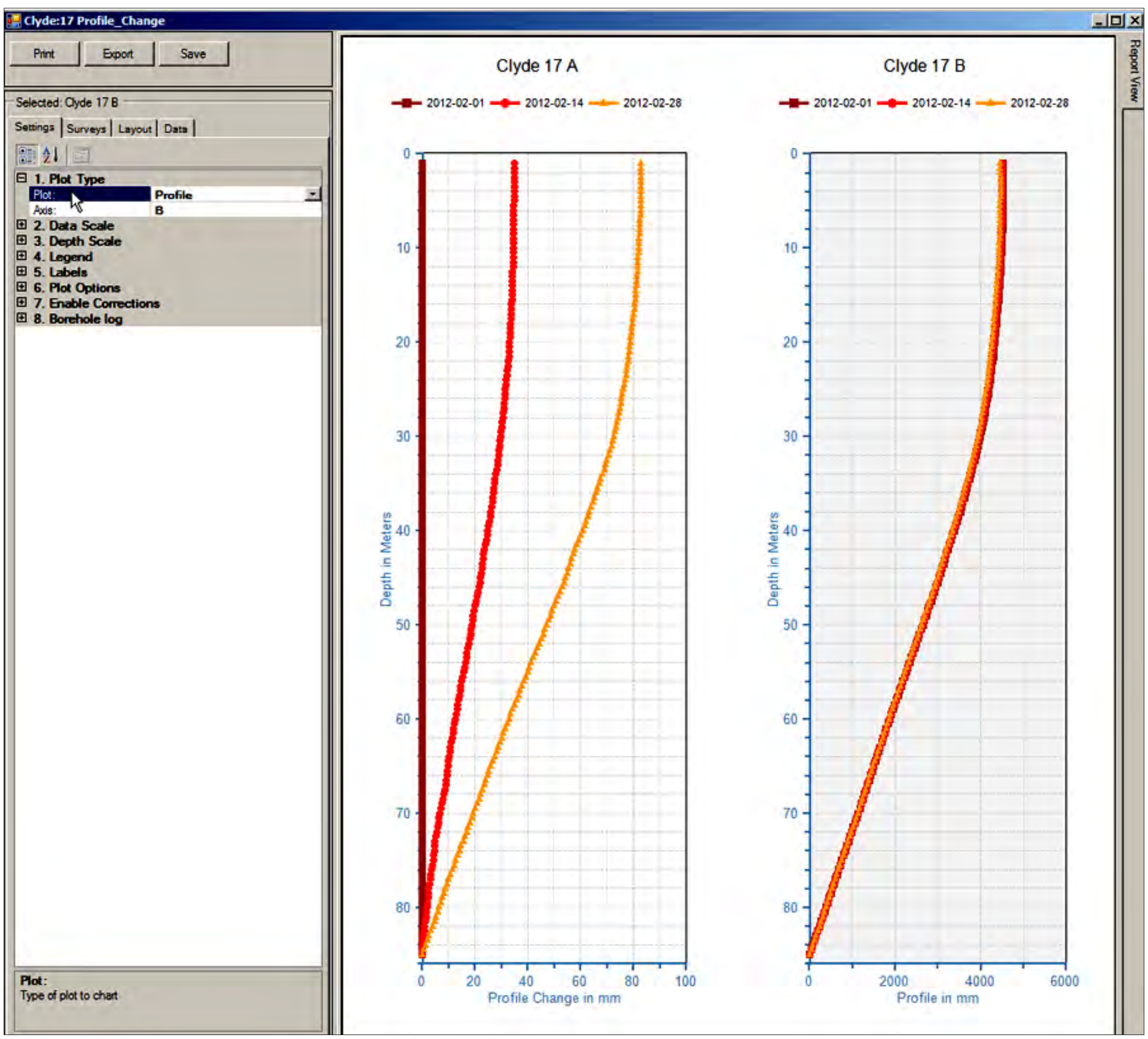
Ideally, each sensor is aligned to measure tilt in only one plane. If the mechanicals of the probe are rotated slightly towards the cross-axis plane, the A-axis sensor also measures some of the tilt in B and vice versa.

Rotation Error is the cross-axis component in a reading: for example, the B-axis tilt value that is embedded in the A-axis tilt reading. Rotation error becomes visibile when when two conditions combine:

- There is significant inclination in the cross axis.
- The change in the alignment of the probe occurs after the initial set was taken.

Identifying Rotation Error

- The profile-change plot is curved.
- The profile plot of the cross axis shows significant tilt.
- The two plots have a similar shape, as shown below.

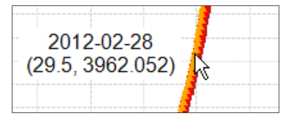


Correcting Rotation Error

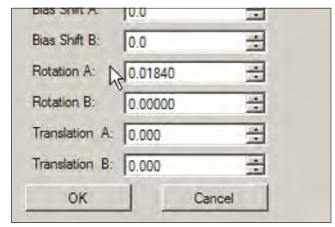
In the example on the previous page, a rotation error was identified in the profile change plot for A axis. To check, we selected the B plot and changed its plot type from profile change to profile. We saw that the A change plot looked similar to the B profile plot. Now we want to apply a correction.

1. Enable rotation correction in the settings panel.

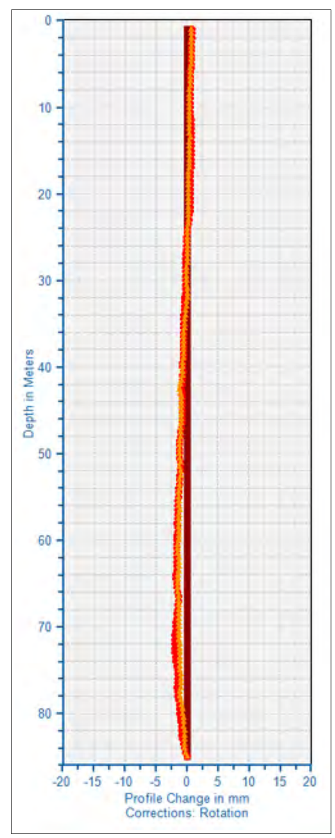
2. Move the cursor to the maximum profile change value in the A-axis plot. Note the depth and value that DigiPro displays: 29.5m and 73mm.



3. Move the cursor to the same depth on the B-axis plot. Note the profile value.
4. Find a starting correction value by dividing the the A profile-change value by the B profile value: 73 / 3962 = 0.0184. (Normally values are smaller than the sine of 1 degree: 0.01745).



5. Double-click the offending survey on the A plot. DigiPro2 displays the Edit Survey dialog. Enter the value into Rotation A field. Click OK.
6. Inspect the plot, and double-click to reopen the edit dialog as necessary.



7. Repeat these steps for any other surveys that show rotation error. The plots become useable, if not perfect.

Sensitivity Correction

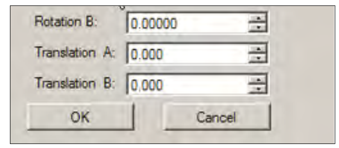
Sensitivity drift is not easy to recognize. It can easily be detected by the factory and is a reason for sending probes in for calibration at regular intervals. An example will appear in a future edition of this manual.

The error is directly proportional to reading magnitudes. Typical errors are 1 to 2 percent. Correction involves the same steps as others:

1. Generate a plot.
2. Click on a survey to call up the Edit Survey dialog.
3. Enter the sensitivity value and check the resulting plot.

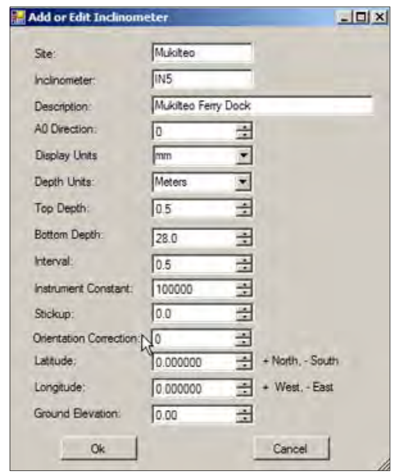
Translation Correction

This correction can be applied to shift all plotted values in the A or B direction. Values in inches or mm are determined by survey or other means and entered in the Edit Survey dialog.



Orientation Correction

Inclinometer casing is installed so that one set of grooves is aligned with the expected direction of movement. If the real direction of movement is some other direction, DigiPro2 can mathematically rotate the orientation of the measurement axes into the direction of interest.

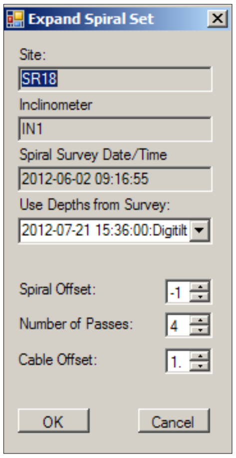


1. Select the inclinometer.
2. Click the Edit button to display the Edit Inclinometer dialog.
3. Enter a value in degrees into the Orientation Correction field. Enter a positive value to rotate orientation clockwise. Enter a negative value to rotate the orientation counter-clockwise.
4. When you plot the inclinometer, enable the Orientation Correction in the settings panel.

Spiral Correction

A spiral survey, obtained with a spiral sensor, provides measurements that can be used to correct for spiraled (twisted) casing. DigiPro2 retrieves the spiral survey from the DataMate.

Readings in the spiral survey are taken at 5 foot or 1.5m intervals. Readings in an inclinometer survey are taken at 2 foot or 0.5m intervals. DigiPro must “expand” the spiral survey to provide a correction value to be used with each inclinometer reading.



1. Select the inclinometer.
2. Select the spiral survey.
3. Click Tools > Expand Spiral Survey.
4. Enter the spiral offset, cable offset, and passes. The recommended number of passes is 4.

   The two offset values are important for calculations. This information must be obtained from the person who took the spiral survey.
5. DigiPro2 expands the spiral set.
6. Enable Spiral Correction in the settings panel. DigiPro will then automatically apply the spiral corrections to any surveys that you plot.

DigiPro2: Basic vs Advanced

DigiPro 2

DigiPro2 is distributed as a trial version with all the advanced features enabled. After 45 days, the advanced features are disabled and DigiPro reverts to a “basic” version unless you purchase and install a license key. The "basic" version is free to use and can be converted to the advanced version at any time. The table below provides a comparison between basic and advanced versions.

DigiPro2 Features	Basic	Advanced
Create dpw databases	●	●
Import dux files from Digitilt AT system	●	●
Retrieve surveys directly from Digitilt DataMate	●	●
Import mdb databases created by DMM	●	●
Import Gtilt and other file formats	●	●
Export surveys data to many formats	●	●
Export processed data to txt, csv, dat, and image file	●	●
Standard vertical plots	●	●
Surveys per plot	3	Unlimited
Spiral plot	●	●
Title block with multiple columns, graphic logo		●
Time displacement plot, Resultant plot		●
Horizontal plots		●
Copy settings from one plot to another		●
Mixed plot types, additional plots on page		●
Field Accuracy Indicator		●
Represent boring log on plot		●
Corrections for Inclinometer: Orientation, Spiral		●
Corrections for Surveys: bias shift, rotation, sensitivity, xy translation, settlement		●
Save plots for reuse on new surveys		●
Save plots as templates for use with other inclinometers		●

Licensing DigiPro2

Overview

DigiPro2 is distributed as a trial version with all the advanced features enabled. After 45 days, the advanced features are disabled unless you purchase and install a license key.

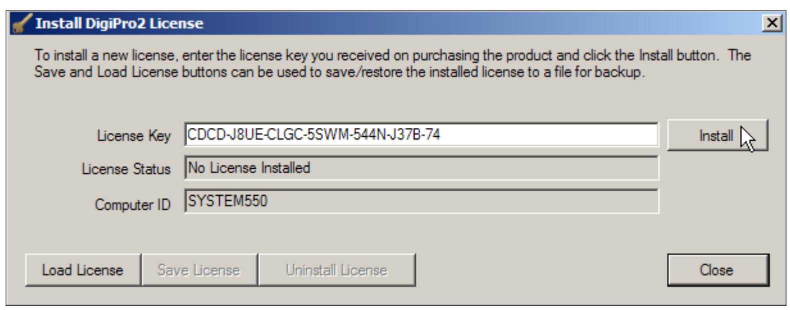
When you purchase DigiPro2, we make an entry in the license database and email the required number of keys to you. If you purchased DigiPro2 through a distributor, we typically email the keys to the distributor.

Installing a Key

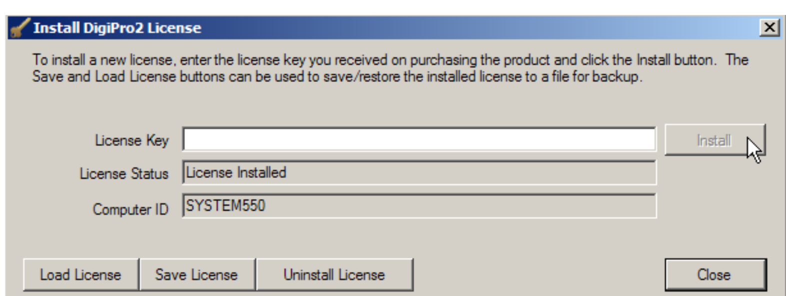
1. Start DigiPro2 and click “License.”

   In the example at right, DigiPro2 has reverted to the basic version.

2. DigiPro2 displays the license dialog. Cut and paste the key from your email into the License Key field. Then click “Install.

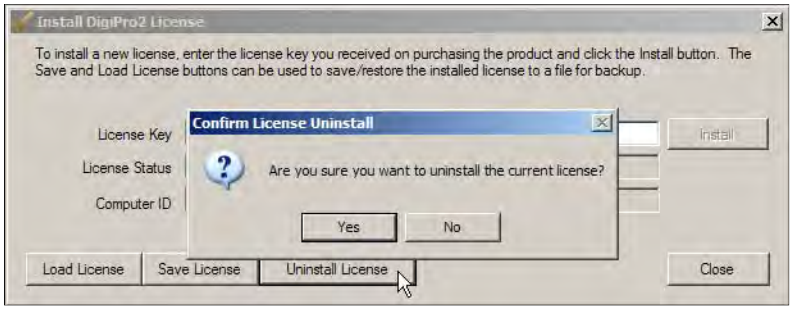


3. DigiPro2 activates the license via the internet. When the activation is successful, the License Key field goes blank, but the License Status field shows “License Installed.” Click “Close” to complete the process.



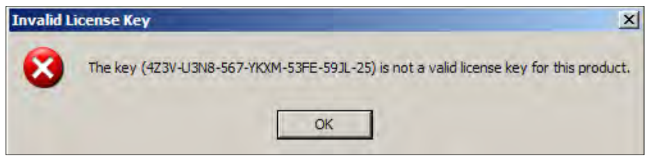
Uninstalling a Key

If you wish to move a key from one computer to another, you can uninstall a key and reinstall it on another computer. Click "Uninstall License" and then click "Yes." DigiPro2 then reverts to the basic version .



Invalid Key

If DigiPro2 cannot activate a key, it displays this message:.



Possible reasons for this message:

- The key has been used too many times. Perhaps the key was not uninstalled before it was reused on this PC.
- The internet connection was bad.

Contact DGSI or your distributor to correct the situation.

No Internet

If it is not possible to activate DigiPro via the internet, contact DGSI or your distributor. Other solutions are available.