



MEMS Digital Inclinometer System Instruction Manual

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RST INSTRUMENTS LTD.
11545 Kingston St.,
Maple Ridge, BC
CANADA V2X 0Z5

SALES + SERVICE + MANUFACTURING:
604 540 1100 | info@rstinstruments.com
TOLL FREE (USA & Canada) | 1-800-665-5599

www.rstinstruments.com

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1 INTRODUCTION

The RST MEMS Digital Inclinometer System represents a breakthrough in inclinometer system technology, providing unprecedented accuracy, efficiency and ease of use. The system is comprised of a Digital Inclinometer Probe, cable system, reel with battery power, and an Ultra-Rugged Handheld running Mobile Microsoft Windows™ that functions as a readout, analysis, and data storage device.

Wireless communication between the inclinometer control reel and the Ultra-Rugged Handheld ensures ease of use and reliability, by removing two weaknesses inherent in conventional analog inclinometer systems. By removing the physical connection between the inclinometer control cable and the readout instrument there is no concern with fragile connectors, cable related failure and related reliability problems. The Achilles heel of any inclinometer control cable reel is the slip ring required to maintain electrical contact as the reel revolves. As the RST system is wireless from the control cable to the readout, a slip ring is not required, and there are no associated electrical continuity problems.

The RST digital inclinometer probe incorporates cutting edge MEMS (Micro Electro-Mechanical Systems) technology providing high precision and durability. A highly accurate survey of the inclinometer casing is used to establish the initial position of the casing. Any subsequent deviations in the casing from this initial value (i.e. baseline reading) represent changes occurring in the subsurface. The RST MEMS Digital Inclinometer System can accurately measure the rate, depth, and magnitude of these deviations.

The information included in this manual outlines the use and care of the RST MEMS Digital Inclinometer System. It provides examples of how to take readings and interpret the data. For more information on the installation of inclinometer casing, and other related issues, please contact RST Instruments Ltd.

Note

Proper care and maintenance of the MEMS Digital Inclinometer System will greatly extend the life of the instrument and accuracy of the readings. Please take the time to read this manual thoroughly. If any questions arise, do not hesitate to contact RST Instruments Ltd. Proper maintenance of the probe **after each use** is outlined in Section 12.

Functions:

- Measure lateral movement of:
 - Earthworks or structures
 - Landslides
 - Embankment fills
- Stability adjacent to excavations or underground workings
- Deflection of piles, piers, abutments or retaining walls



Figure 1 – System Overview

2 DIGITAL PROBE

In general terms, the new Digital Probe resembles that of the traditional analog probes sold by RST. The RST Digital Incliner has the smallest package available for a given wheel spacing, with the best ability to track deformed casings. This means that the Digital Probe can handle greater bends in the casing without becoming stuck. The RST metric probe can negotiate a radius of 1.88m (74") in 70mm (2.75") OD inclinometer casing. The RST Digital Incliner will thus continue to provide readings past the limit for other probes on the market (see Figure 2).

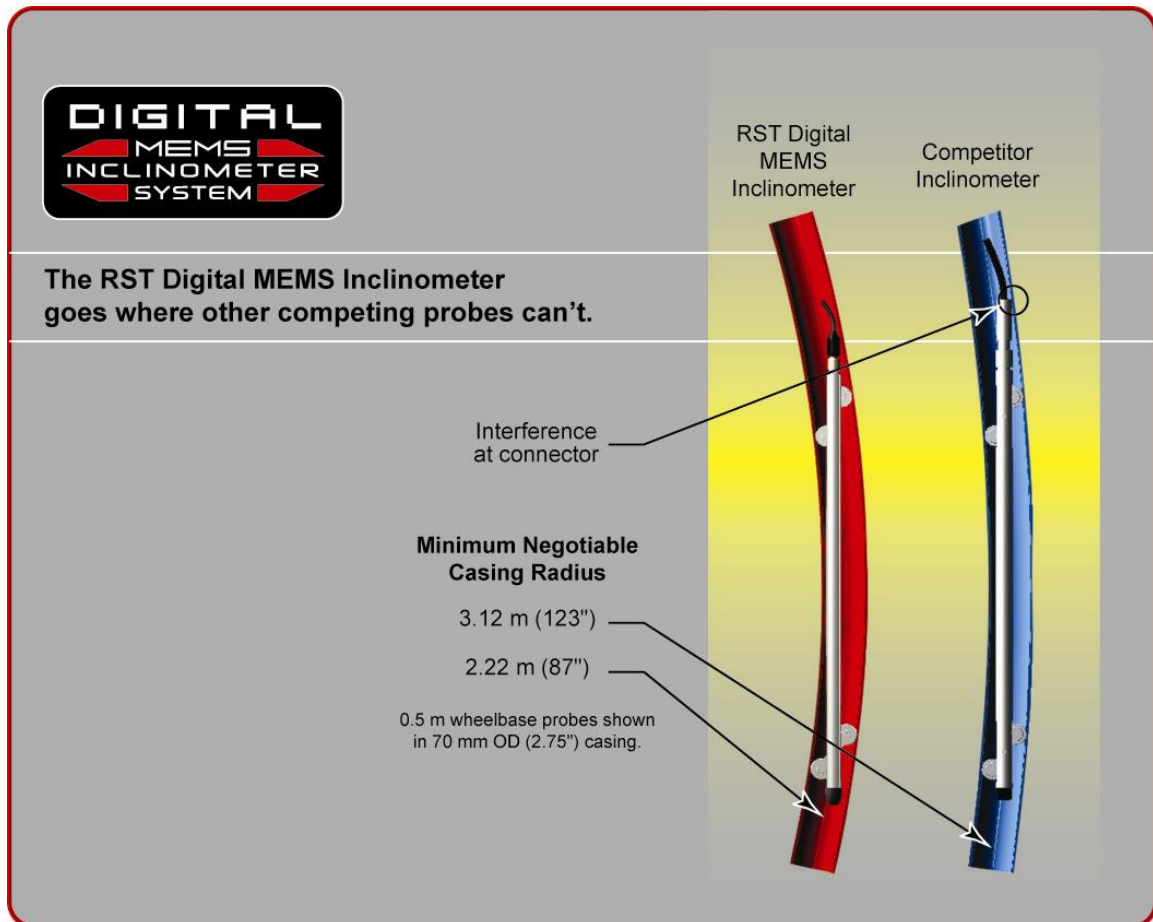


Figure 2 – Digital Probe Sizing

The connectors, wheels, and wheel carriages are the most precise and durable in the industry. The probe wheels are made of high grade hardened and heat-treated stainless steel. These are extremely durable and the most robust on the market.

The digital probe also incorporates shear pins on the wheel assemblies. In the event that the probe gets stuck in the inclinometer casing, a force of approximately 300 lbs is required to shear the shear pin. No damage to the probe or cable will result. **Please contact RST Instruments Ltd. for further instructions on retrieval of a probe that is stuck downhole, and the replacement of the probe shear pins.**

2.1 DUMMY PROBE

Dummy inclinometer probes are available for purchase from RST for testing purposes in a borehole. RST encourages customers to try the new digital dummy probe in existing holes where the competitor's probes do not work. If it is found that the dummy probe passes through all areas of the casing, the RST MEMS Digital Inclinator System will function. Therefore, the existing hole will still be viable, and a new hole will not need to be drilled.

The RST dummy probe has the exact same weight and dimensions as the standard probe. A ring is provided in place of the connector which allows the dummy probe to be lowered by a rope. For further information on purchasing a RST Dummy Probe, please contact RST Instruments Ltd.

2.2 SIGN CONVENTION AND MEASURED DEVIATION

The Digital Inclinator Probe houses two MEMS accelerometers, which measure tilt in two axes. Proper installation of the inclinometer casing attempts to align one set of grooves in line with the axis of expected movement. This is called the *A axis*. The perpendicular set of grooves is the *B axis*.

When an inclinometer casing is surveyed for the first time (i.e. baseline readings), it is necessary to select a fixed direction reference for the probe so that each time a survey is repeated, the probe will always have the same orientation in the casing.

For example, in an area suspected of landslide activity, the first set of readings would be taken by placing the upper wheels of the probe in the casing groove closest aligned to the downslope direction. Figure 3 illustrates an inclinometer casing installed with a groove orientation in the general downslope direction.

In practice, it is often difficult to achieve exact orientation of grooves relative to some predetermined direction. The groove closest to the anticipated movement direction is usually chosen as the main reference direction. It is recommended that this direction (A+) be marked on the casing itself to ensure surveys are performed in the same manner each time.

The azimuth of this groove direction can be measured in a clockwise direction from the main reference direction (A+). All subsequent measured inclinometer movements would be referred to this direction.

Readings taken from the inclinometer probe (see Section 4.2.7) are actually deviations from the vertical over the distance between the upper and lower wheels (see Figure 4), calculated as:

$$D = L \times \sin(\alpha)$$

Where: *D* = Deviation, e.g. lateral displacement in the direction of the axis of measurement
L = inclinometer probe length (typically 0.5 m for a metric probe or 2 ft for an imperial probe, as defined in Section 15).
 α = inclination angle of probe from vertical axis

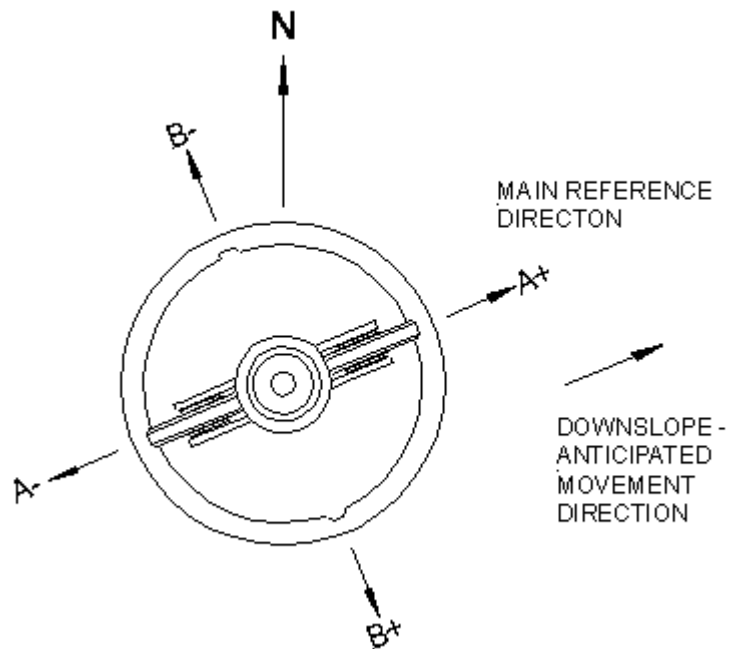


Figure 3 – Probe Orientation

The RST Digital Inclinometer System uses the industry standard sign convention, where tilt in the direction of the upper wheels results in a positive deviation and tilt in the direction of the lower wheels results in a negative deviation (Figure 4).

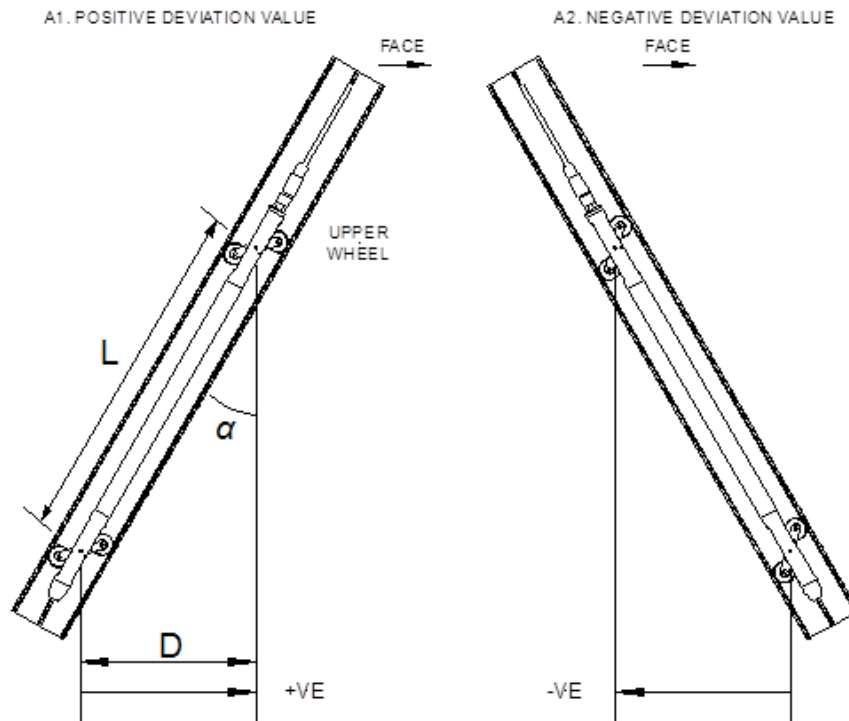


Figure 4 – Sign Convention in the A-axis and Deviation D measured by inclinometer probe

Figure 5 shows the sign convention for the A and B axis.

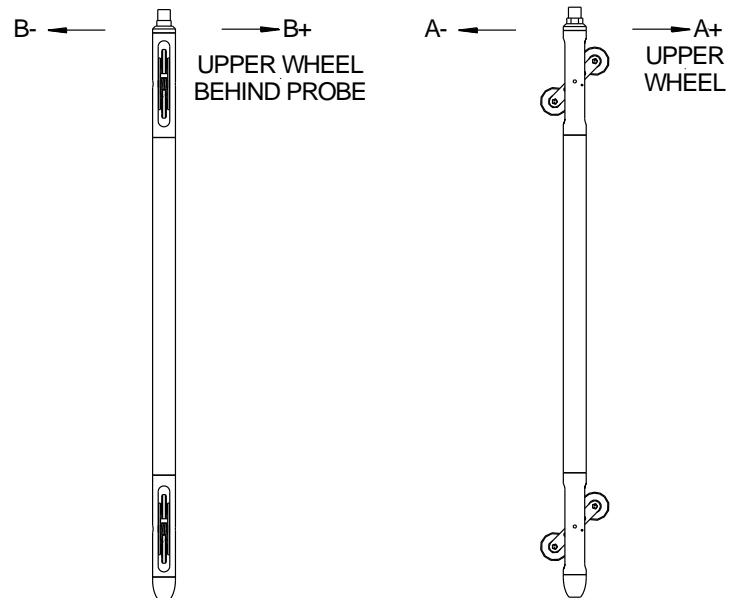


Figure 5 – Probe Axes

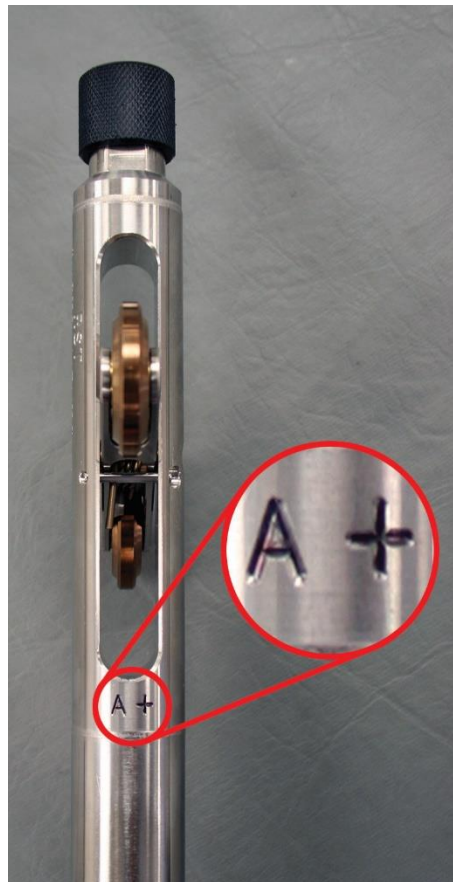


Figure 6 – A+ Marking on the Inclinometer Probe

2.3 TAKING READINGS

1. Upon arrival at the site, remove the protective caps from the casing, the probe, and the control cable. If possible, flush the borehole with clean water prior to taking measurements. **Groundwater with high salinity or suspended particulate content can damage the bearings in the probe wheels with repeated use.**
2. Attach the probe to the reel by aligning the keyways and threading the connector onto the probe. **Ensure the connector is lubricated, clean, and free of debris prior to making the connection.** Take care to turn only the threaded ring, not the cable itself. Do not over tighten the connector; a hand tight connection is sufficient.

Warning

Handle the inclinometer probe very carefully as the accelerometers are very susceptible to shock.

3. Once connected, turn on the power to the reel and Handheld. This energizes the MEMS accelerometers and makes them less susceptible to shock. Establish the Bluetooth connection between the reel and Handheld as described in Section 13.
4. Insert the probe into the borehole, aligning the upper wheel in the direction of the A+ axis (see Section 2.2).
5. Lower the probe to the desired depth *slowly* and as *smoothly* as possible. **Be extremely careful not to bounce the probe off the bottom of the hole. Any shock to the probe may damage the probe electronics and affect the its calibration.**
6. Once the probe is at the desired depth, place the cable grip on the top of the casing and hang the cable by the aluminum crimps. The objective is placement repeatability within 5mm (0.25 inch). This is extremely important to ensure accurate and repeatable results.

Warning

Do not drop the cable aluminum crimps onto the cable grip. The cable has very little stretch, especially near the top of hole, and the impact on the cable crimps may “hammer” them out of position or break the cable. This effect has been demonstrated for drops as little as 70 mm.

7. The probe will begin profiling the borehole from the bottom of the borehole. After each respective measurement has stabilized and a recording has been taken, pull the probe upwards to the next desired measurement depth. If you accidentally pull the probe too far, lower the probe back down to the previous measurement depth, and then pull it back to the next intended measurement depth. This procedure ensures that the readings will remain consistent. For maximum measurement repeatability, keep the cable as clean as possible during this process. If possible, a tarp or basket can be useful to avoid placing the cable directly on the ground.

Warning

Never tightly coil or sharply bend the cable during this process, as this can cause permanent coiling or twisting of the cable which can impact the spacing of the aluminum crimps and measurement repeatability. It is recommended to lay the cable in a "figure-8" or "spaghetti bowl" pattern as follows:

- a. "Figure-8" Cable Management: *As the probe is brought up-hole, lay the excess cable on a clean surface in alternating loops to form a figure-8 pattern. The loops of the figure-8 should be approximately the size of the cable reel diameter. Once the survey is complete, flip over the bundled figure-8 of cable for easy spooling back onto the reel.*
- b. "Spaghetti Bowl" Cable Management: *As the probe is brought up-hole, allow the cable to freely coil as it is laid on a clean surface. Do not attempt to twist or coil the cable, as this can deform the cable with repeated use.*

8. Allow the readings to stabilize at each location. Reading stability can be gauged by both the noise bar and the standard deviation, which are displayed on the Readings Screen (Section 4.2.7).
9. Once the readings have stabilized, press the *Accept* button and move the probe to the next interval as prompted by the software.
10. Repeat Steps 7-9 until the probe reaches the top of the borehole. The software will then prompt you to turn the probe 180 degrees and repeat the survey, this time in the A- direction (i.e. with the lower probe wheels in the A+ groove).

Warning

When the probe has reached the top of the casing, avoid allowing the wheel assemblies to snap out of the casing. As the wheels reach the top, grasp them with your hand and release the wheel assembly slowly until it reaches the stops. Failure to do so will damage the shear pin and subject the MEMS accelerometers to sudden shock, which can damage them and affect the calibration of the probe.

11. ***Prior to lowering the probe for the second pass, remove the cable grip*** to avoid accidentally catching the aluminum crimps on the cable grip (this will impact load the crimps, cable, and probe). Once the probe is at the bottom of the borehole, replace the cable grip and position the probe for the deepest reading.
12. Repeat Steps 7-9 to take a second pass of readings in the A- direction. During this second pass, checksum data will be displayed underneath each reading. Ensure that these remain small and consistent; however, checksums can vary due to different site conditions. Large checksums can indicate errors in probe positioning or fouling of the probe. Expect checksums to be slightly larger when the probe encounters an expansion coupling in the casing (if applicable). Refer to Section 7 for further detail on checksums.
13. The RST MEMS Digital Inclinator can perform data reduction in the field, please refer to Section 4.2.8 for information on viewing and validating the data.

14. Upon completion of the survey, close the inclinometer program, turn off the power to the reel, and disconnect the probe. Wipe off the probe and cable. If possible, rinse the probe and cable with fresh water. Replace end caps on the cable and probe. Replace the protective cap on the casing.
15. Upon returning to the office, clean the instrument and reel once more to remove any moisture from the instruments and the case. Recharge the batteries for the Reel and connect the power and USB communication cables to the Ultra-Rugged Handheld (Figure 10). ***Please refer to Section 12 for proper care and maintenance of the system.***
16. Transfer data to a desktop PC using Windows Mobile Device Center software, as detailed in Section 6. Alternatively, a flash memory stick can be used for data transfer.

3 INCLINOMETER CABLE AND REEL

The RST MEMS Digital Inclinometer System comes with a durable lightweight reel that is easy to handle. Since only a pair of conductors is needed in the cable, the weight and dimensions of the cable are drastically reduced as compared to a traditional analog cable. The reel is battery powered and houses the electronics used for wireless communication.

An important part to any inclinometer casing survey is the repeatability of the depth measurements. It is extremely important that measurements be consistently within 5mm (0.25in) of one another between subsequent surveys. To facilitate accurate repeatability, two aluminum cable grips are provided with the system, for 70mm (2.75") and 85mm (3.34") OD casing respectively. The cable grips provide a solid reference for the cable crimps to sit in. The result is that operator error is reduced, checksums will be smaller and surveys more accurate.

The thin, strong cable contains a Kevlar® strength member, allowing a long length of cable to fit on a small reel with no stretch. The aluminum sleeved measure marks are precision swaged to the cable and are not subject to tearing when handling. The measure marks are spaced at 0.5 metre or 2 feet intervals. The cable is marked with a red measure mark and a label every 5 metres or 10 feet depending on whether the metric or imperial system is being used. The urethane jacket is highly abrasion resistant and maintains flexibility at low temperatures. It is good practice to avoid running the cable over sharp edges and to periodically clean it with a soft, clean cloth. Be sure to keep the protective cap on the connector whenever the probe is not in use and avoid dropping or banging the cable end. Always keep the connectors and threads clean by rinsing them with water and be sure to lubricate frequently. Exercise care when connecting and removing the cable from the probe; make sure to only turn the connector ring, not the entire cable.

3.1 INCLINOMETER REEL BATTERY

If the serial number of the reel is 2500 or above, the battery is contained inside the inclinometer reel. The inside of the reel is not accessible to the user and the battery is not removable. **Do not attempt to remove the battery.**

The inclinometer reel has a green LED light that will flash to indicate battery status (Table 1). The LED light on the reel will flash when the power button is pressed.

Monitor the battery status. **Do not let the battery completely discharge.** A full charge will last around 30 hours.

Note

For reels with serial numbers **under 2500**, refer to Appendix A for instructions on how to remove and recharge the battery. Only batteries on reels with serial numbers under 2500 may be removed from the reel. Do not attempt to remove the battery from the reel if the serial number on the reel is 2500 or higher.

For reels with serial numbers of 2500 or higher, refer to Section 3.1 for battery status and Section 3.2 for instructions on how to recharge the battery. Only reels with a serial number of 2500 or higher may be recharged. Do not attempt to remove the battery from the reel if the serial number of the reel is 2500 or higher.

Table 1 Battery status LED

LED Flash	Battery Status
1 flash, reel does not power on	Battery completely discharged
2 flashes, reel does not power on	Battery discharged below level required to connect
1 flash, reel powers on	Battery discharged below 25%
2 flashes, reel powers on	Battery discharged below 50%
3 flashes, reel powers on	Battery discharged below 75%
4 flashes, reel powers on	Battery is at full charge.

3.2 CHARGING THE BATTERY (FOR REELS WITH SERIAL NUMBER OF 2500 OR HIGHER)

Note

Refer to Appendix A if the reel serial number is under 2500. Do not proceed with the following instructions if the reel serial number is under 2500.

3.2.1 REELS WITH SERIAL NUMBER OF 5000 OR HIGHER

The following instructions are for reels with serial numbers of 5000 or higher.

The battery will need to be recharged using standard USB charger. The battery port may be accessed by unscrewing the cap on the outside of the reel. Refer to Figure 8 for the location of the battery cap.

**Figure 7 – Unscrewing the Battery Cap**

Unscrew the battery cap by turning it counterclockwise. The charger will plug into the port and begin charging the battery. The charging red LED will be on until charging is complete. Replace and tighten the cap when the charger is not in use to ensure debris does not enter the battery port.

3.2.2 REELS WITH SERIAL NUMBER OF 2500 OR HIGHER

The following instructions are for reels with serial numbers of 2500 or higher.

The battery will need to be recharged using the provided charger. The battery port may be accessed by unscrewing the cap on the outside of the reel. Refer to Figure 8 for the location of the battery cap.



Figure 8 – Unscrewing the Battery Cap

Unscrew the battery cap by turning it counterclockwise. The charger will plug into the port and begin charging the battery. Replace and tighten the cap when the charger is not in use to ensure debris does not enter the battery port.

3.3 WIRELESS COMMUNICATION

Turn on the power to the reel by pressing the button located to the left of the battery housing on the Reel Hub. A solid green light indicates the reel has been powered on. After turning on the power to the reel, it automatically searches for a connection to the Ultra-Rugged Handheld. Once the Ultra-Rugged Handheld is powered up, and the RST Digital Inclinometer software is launched, it will automatically try and link to the reel. The light indicator will flash rapidly when the reel is communicating with the probe. During Ultra-Rugged Handheld wireless communication, the reel indicator light will blink with 1-second intervals. The status of the connection is also displayed on the status screen or on the bottom of the main menu screen (see Section 4.2.6).

Note

The reel incorporates power saving feature. After 5 minutes of inactivity and lack of Ultra-Rugged Handheld wireless communication, the reel will power down automatically to save battery charge.

4 ULTRA-RUGGED HANDHELD UNIT

The RST MEMS Digital Inclinometer System comes with an Ultra-Rugged Handheld running Microsoft Mobile Windows™, which is the heart of the system. This hand-held device functions as a readout and data storage device. Data reduction can be performed “at-the-borehole” as soon as the survey is complete. The program has the ability to create plots of the data instantly. This is important if on-site personnel require immediate results to verify that data is accurate. No time is wasted by having to take the readout back to the office to download and process the data.

An overview of the Ultra-Rugged Handheld is provided in the following sections. The Handheld consists of numerous features that may be omitted in this manual. A more thorough guide may be accessed on RST’s website:

https://software.rstinstruments.com/NautizX8/nautiz_x8_manual.pdf

4.1 OVERVIEW

The Ultra-Rugged Handheld is well suited for use in the often-demanding field conditions where the inclinometer system is utilized.



Figure 9 – Ultra-Rugged Handheld

4.2 USING THE ULTRA-RUGGED HANDHELD

Once the inclinometer probe is connected to the reel and the probe is ready to be placed in the borehole, turn on the power to the Ultra-Rugged Handheld by pressing the power button (Figure 10).

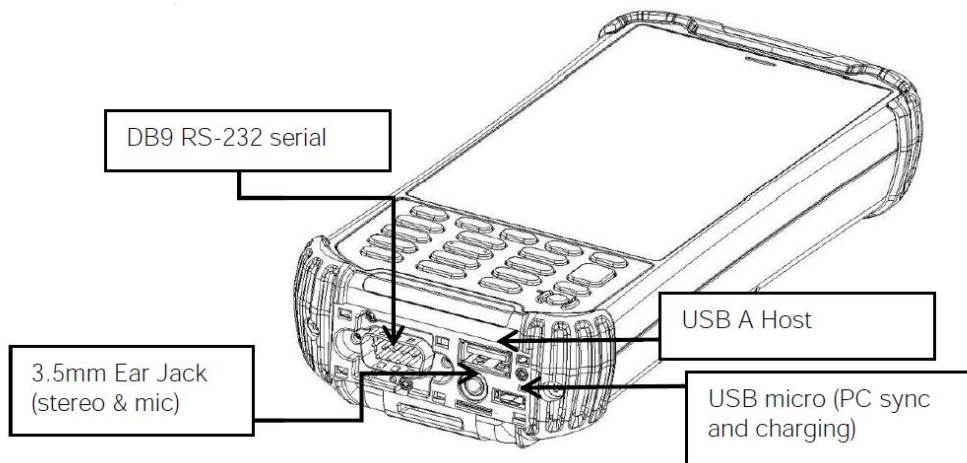


Figure 10 – Overview of Ultra-Rugged Handheld

USB A HOST: This connector supports High speed USB 2.0 communication (up to 480 Mbps).

USB MICRO: It also can be used to charge the Terminal with external power from the MicroUSB adapter as well as used for syncing to the PC.

EARJACK: 3.5mm Ear Jack supports stereo and microphone.

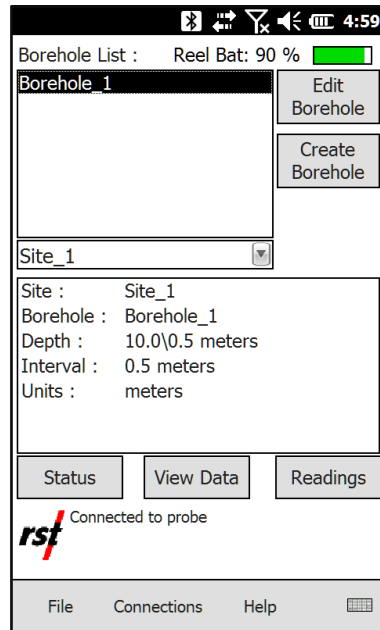


Figure 11 – RST Digital Inclinator Software Main Screen

Upon start-up, the inclinometer will automatically begin searching for the Reel and Inclinator Probe. This status is displayed at the bottom of the screen. The opening screen (Figure 11) displays the current set-up and status of the system. The top menu provides a list of the current boreholes (a default site/borehole will appear, if none have been created). Underneath the borehole list is a drop-down menu which is used to select the site.

4.2.1 BATTERY STATUS

The reel battery status is located at the top right of the main menu screen. It shows the real-time status of the battery

Should the battery charge drop below 25%, the battery status will turn red (Figure 12). This indicates that the battery will not last more than a few more hours. The device should be plugged into a power source to recharge the battery.

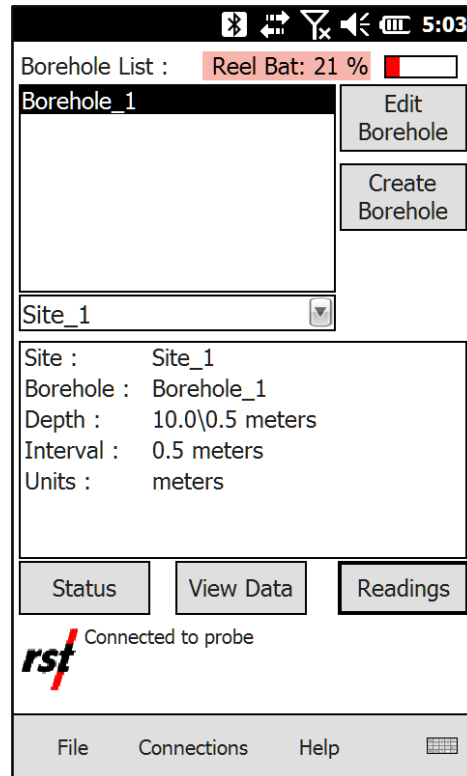


Figure 12 – RST Digital Inclinometer Battery Status

4.2.2 MENU ITEMS

The *File* menu allows the user to backup the current files to the Handheld's non-volatile memory location and exit the Digital Inclinometer program. For more information on the backup function please refer to Section 9.

The *Connections* menu allows the user to view the status of the Bluetooth (radio) connection and allows the user to disconnect and reconnect to the reel and probe manually. Should a new Reel be used (i.e. a replacement which was not supplied with the original system), the Ultra-Rugged Handheld needs to be made aware of this new instrument, and thus the Bluetooth Connections must be changed. For further information please refer to Section 13.

4.2.3 CREATING A SITE AND BOREHOLE

To create a new borehole and site, click on the “*Create Borehole*” button on the Main Menu and the following screen will appear:

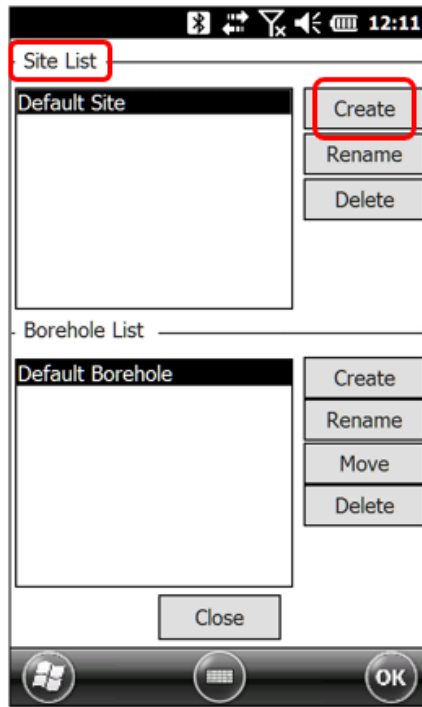


Figure 13 – Creating a Site and Borehole

First, create a new site by pressing the *Create* button under the *Site List* heading. This brings up the Create Site screen (Figure 14):

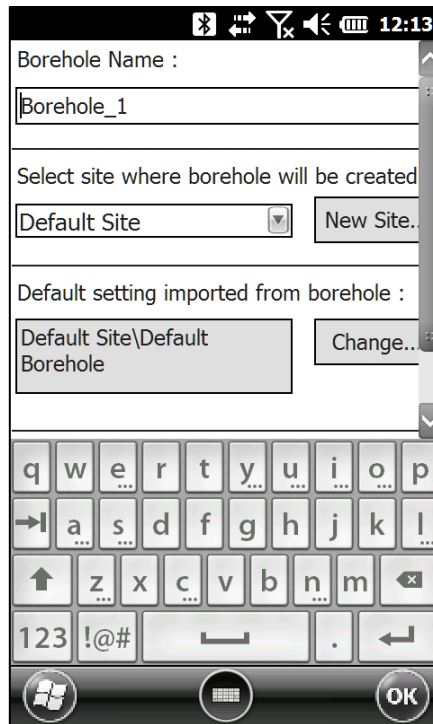


Figure 14 – Create Site

Please note that the remote keyboard automatically pops up when this screen is selected. Touching the keyboard icon in the bottom of the screen can hide the keyboard. Press *New Site...* and enter the new site name and borehole name in the appropriate dialog boxes. Once the new site and borehole is entered, press *OK*. Both site name and borehole names can be edited, deleted, re-named and moved by pressing the appropriate options on this screen. To return to the main menu, press the *Close* button at the bottom of the screen (after hiding the remote keyboard), or press *OK* at the top right of the screen.

4.2.4 EDITING A BOREHOLE

To edit a borehole, pressing the *Edit Borehole* button on the main menu screen. The Edit Borehole screen will appear (Figure 15):

The screenshot shows a mobile application interface for editing a borehole. At the top, there's a status bar with icons for Bluetooth, signal strength, and battery, along with the time 12:14. Below this, the title bar reads "Default Site : Default Borehole". The main form contains several input fields and buttons. The "Depth" field is set to 10, "Interval" is 0.5, and "Units" is meters. The "Reading Units" is also meters, and the "Operator" field has a "Select..." button. The "Borehole Type" is set to Vertical, and "Top Depth" is 0.5. There are buttons for "Comment...", "Data Filename...", "OK", and "Cancel". At the bottom of the screen, there are three circular icons: a Windows logo, a keyboard icon, and an "OK" button.

Figure 15 – Edit Borehole Screen

The site and borehole name appear at the top of the screen (in this case they are "default") followed by *depth*, *interval*, *units* and *reading units*. Set *depth* to the depth of the borehole of the lowest reading you wish to take (match this to the cable marking). Choose the *interval* and *units* based on whether you are using a metric or imperial probe. In most cases this will be either 0.5 metres or 2 feet, which is equal to both the length of the probe and the divisions marked on the inclinometer cable.

Ensure the correct borehole type has been selected.

Pressing the *Comment* button invokes a screen where comments can be made about the site, borehole information etc. Comments are entered using the remote keyboard.

Pressing the *Data Filename* button brings up the following screen:

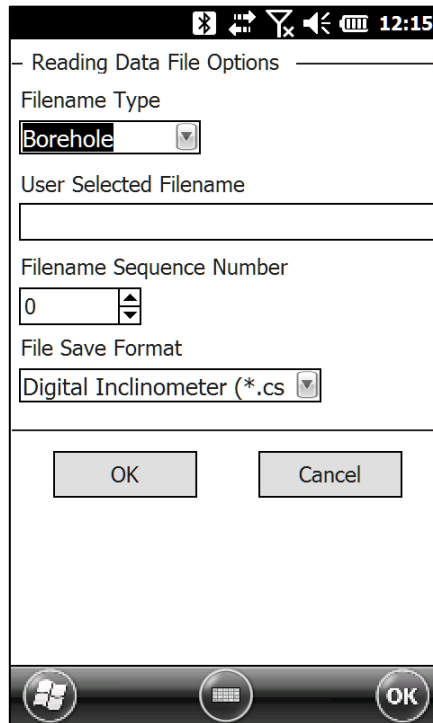


Figure 16 – Data Filename Screen

Filename Type can be chosen from the drop-down menu. Options under this menu include *User Selected*, *Borehole*, *Site* and *Site Borehole*. These options specify the name of the file to be written after the borehole is surveyed. If *User Selected* is chosen, enter the name in the dialog box under *User Selected Filename*. The *Filename Sequence Number* defines the numeric label of the file name. All subsequent files will be named in sequence. For instance, if you had a *User Selected File* named “Test”, subsequent files will be named Test(2), Test(3), etc. (incremented by 1).

Note

The default file name for an inclinometer survey is the *Borehole* name. If *User Selected* is chosen as the file format, and the *User Selected Filename* dialog box (Figure 16) is left blank, the software will default to the *Borehole* name. In most cases, it is recommended that the data files be managed using the *Borehole* name, as this will avoid confusion between multiple sets of data under a single *Site*.

4.2.5 FILE SAVE FORMATS

File Save Format enables the user to choose which format to save the inclinometer file as. To change the file save format, choose the appropriate option from the drop-down list as shown in Figure 16. These are outlined below:

1. **Digital Inclinometer (*.csv)** format: Files are saved in a format which includes the probe serial number in the header file.
2. **Standard RST (*.csv)** format: This is the default file setting and is compatible with RST Inclinalysis™ software. Files are saved as *.csv (comma separated value). This data format also has the ability to be imported into most popular spreadsheet software. Files of this type can also be imported into GTilt (Section 14.3).
3. **RPP Format (*.rpp)**: This type of file can be imported into Inclinalysis™ and is also compatible with Slope Indicator's software including DMM for Windows and DigiPro. GTilt and GTilt Plus software also has the ability to import *.rpp file formats. If directly comparing data between two inclinometer systems, please ensure that the depth placement of the probe is identical between the surveys with the two different systems. For further reference on importing *.rpp files into Slope Indicator's software, please see Section 14.1.

Once the correct data file options have been chosen, exit the *Reading Data File Options* screen by pressing *OK*. If you want to exit without saving the changes, press *Cancel*. You will be returned to the *Edit Borehole* screen. If all the parameters in the *Edit Borehole* screen are correct, press *OK*. Otherwise press *Cancel* and you will be returned to the *Main Menu*. The new borehole information will be displayed in the bottom half of the *Main Menu* screen. Verify that these settings are correct.

4.2.6 STATUS SCREEN

Navigate to the *Status Screen* by pressing the *Status* button on the main menu. The following screen will appear:

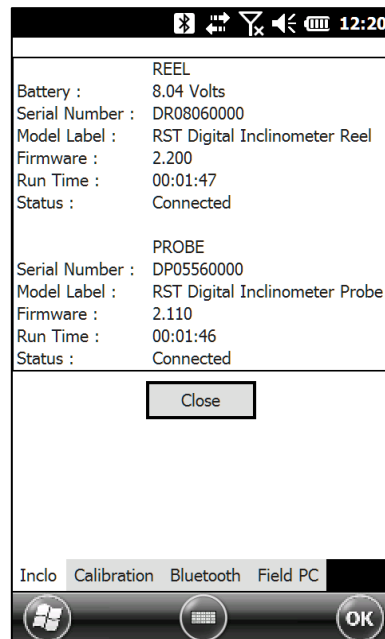


Figure 17 – Status Screen

If the Ultra-Rugged Handheld is connected to the Reel and the Probe, information will appear in the appropriate areas. If there is no connection, the information fields will be blank (and the status will read *not connected*). Vital information for both the Reel and the Probe is displayed which includes: Battery Voltage, Serial Number, Model Label, Firmware Version, Run Time, and Status.

Choosing the *Calibration* tab invokes the calibration screen (Figure 18):

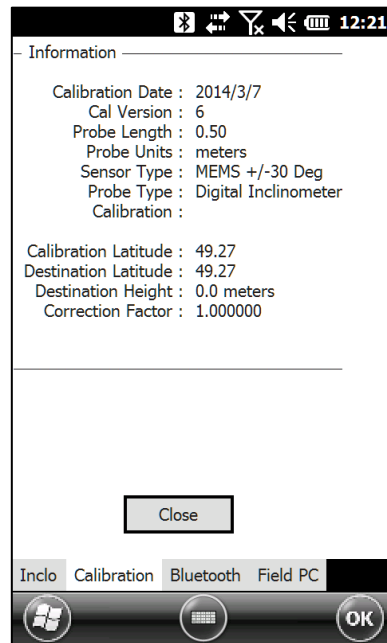


Figure 18 – Calibration Screen

The *Calibration Screen* provides information about the calibration date, calibration version, probe length and probe units (metric or imperial). Corrections can also be made to individual inclinometer probes to account for latitude and elevation changes.

Note

RST highly recommends that the inclinometer probe be calibrated on an annual basis. The probe should also be recalibrated if it has been exposed to any type of shock or shows high checksum values for no apparent reason.

A calibration overdue indicator will be displayed when the probe was calibrated more than a year ago.

Clicking on the *Bluetooth* tab brings up the Bluetooth Status screen (Figure 19):

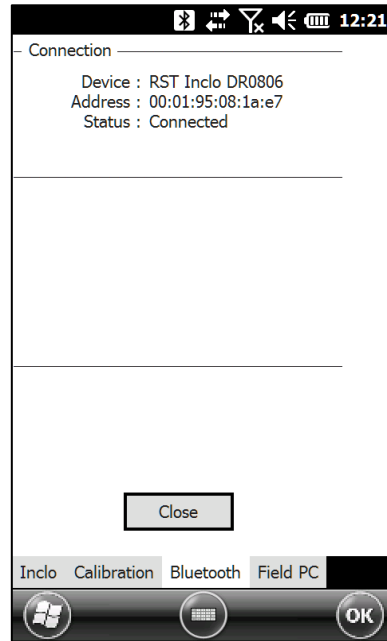


Figure 19 – Bluetooth Status Screen

The Bluetooth Status screen indicates which device is connected and the status of the connection. Please note that the range of the Bluetooth radio is approximately 10 metres and this distance may vary depending on objects and line of site.

The above two screens are used primarily to confirm that the Ultra-Rugged Handheld has established wireless communication with the Reel and Digital Probe and to display the hardware information. If communication has not been established, the hardware information will not display until a satisfactory connection has been made.

Pressing the *Field PC* tab brings up specific information about the Ultra-Rugged Handheld Serial # as shown in the following screen:

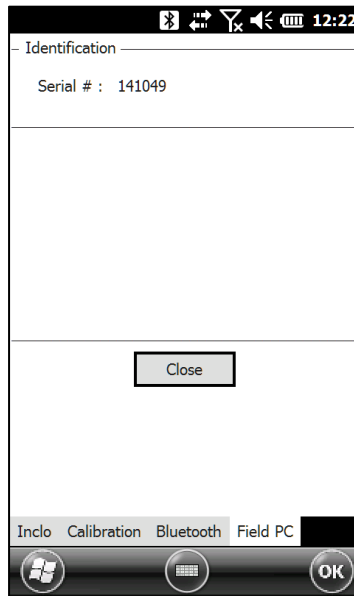


Figure 20 – Handheld Status Screen

4.2.7 READINGS

Once you have set up the Site Name, Borehole Name, and Filename and the Ultra-Rugged Handheld has successfully connected to the Reel and Digital Probe (see *Status* Screen), you are ready to begin logging the borehole. Follow the instructions outlined in Section 2.3. From the *Main Menu*, pressing the *Readings* button invokes the Readings Screen (Figure 21). This option is only accessible once the readout is connected to both the Reel and the Digital Probe.:

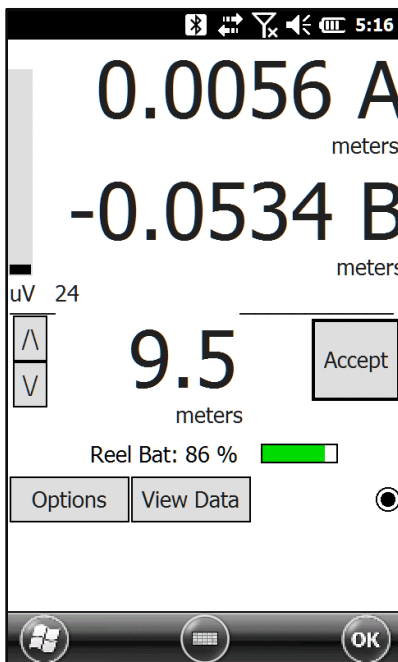


Figure 21 – Readings Screen

After a few seconds the real-time reading should appear as in Figure 21. This screen shows the real-time data in both the A and B axes. The units are displayed underneath both sets of readings. To the left of the readings is a dynamic bar which indicates the noise level (i.e. the difference, reported in microVolts, between subsequent readings). The user should wait until the noise level is at a minimum before taking a reading. This minimum can vary depending on the site conditions. In particularly noisy environments (i.e. heavy equipment is moving in the vicinity) the amount of averaging can be adjusted to help reduce the noise (for more information please refer to the *Averaging Data* section in this manual, Section 6.4 and Figure 22). The number displayed under the noise bar reports the microVolt change between successive readings. It should simply be used as a reference as to how noisy the readings are, this number does not correlate directly to the measurement units, it simply indicates the microVolt change between each subsequent measurement (1 measurement per 0.4 second).

The current depth of the instrument in this example is set to 10.0 metres. Pressing the *Accept* button will store the reading and the depth will move to whatever the next interval is set at (i.e. 9.5m). The arrow keys allow the user to scroll up and down the readings which permits re-taking readings if necessary.

Note

Be careful not to miss any data intervals when using the scroll feature as this can offset the data. The user can view the data at any time by pressing the *View Data* button to confirm that they have the probe in the correct location and the readings at that depth have been taken correctly.

The small black dot on the right-hand side of the screen appears whenever data is being sent from the probe.

Once the top of the hole has been reached, the software will prompt the user to turn the probe 180° and lower it back to the bottom of the hole (unless the user specifically sets the software to only take a single set of readings, please see the *Advanced Options Menu*, Figure 23). The readings will automatically start at 10.0 metres once again (in this example). Checksum data will appear in a smaller font underneath the current readings. The real-time checksums allow the user to monitor the second set of readings. If the checksum is large or inconsistent, either the probe has fouled, or the probe is not at the correct measurement depth. Continue logging until the top of the hole is reached. If the probe has been accidentally raised above the measurement point, lower the probe back down below the proper depth and then raise it slowly to the correct depth. This ensures consistent and accurate readings. Once the top is reached on the second pass, a dialog box will appear that says, "Readings Complete". The software will then save the data to the filename which was specified in the *Reading Data File Options* screen.

Pressing the *Options* button on the readings screen brings up the *Readings Options* screen:

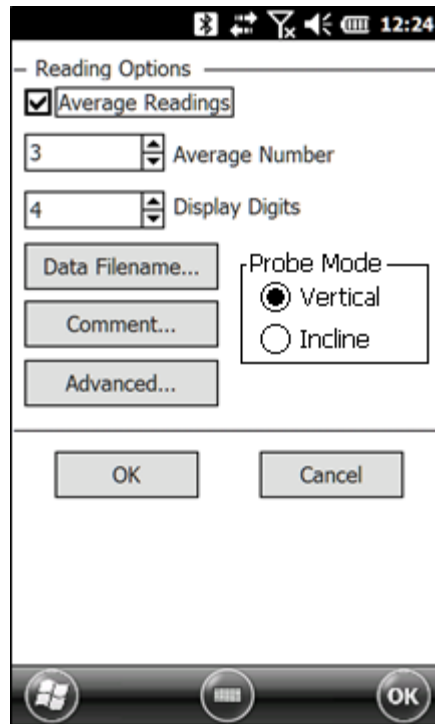


Figure 22 – Readings Options Screen

This option allows the user to specify whether or not the data from the probe is to be averaged. The number of readings to be averaged can be set in *Average Number* dialog box.

Note

Readings from the probe are taken once 0.4 second, therefore increasing the amount of averaging means that you increase the wait time between taking readings (i.e. if an averaging value of 5 is chosen, you must wait at least 2 seconds after moving the probe before taking a reading).

The number of decimals shown can be changed in the *Display Digits* dialog box. Pressing the *Comment* button permits the user to make any comments about the data set and the *Data Filename* allows the user to change the name of the data file where the information is written upon completion of logging the borehole (for additional information please see Section 4.2.3).

When an Incline Probe is connected, the Probe Mode settings allow switching between vertical mode and incline mode. The Probe Mode settings do not appear for single mode probes. For further info regarding Incline Probe, refer to Section 5.3.

Pressing the *Advanced* button brings up the following screen:

Figure 23 – Advanced Options Menu

The first check box allows the user to specify whether or not to take a single set of readings during a borehole survey. The inclinometer readout will save the data after a single pass of the borehole.

A sound option allows the user to turn on/off the sound upon acceptance of a reading. User specified sound files (*.wav) can be placed in the following directory:

My Device\My Documents\Digital Inclinometer\SoundFiles\

This allows the user the option to have a custom sound played each time a reading is taken. The default sound is a simple beep.

The Noise Bar can be turned on and off and the drop-down menu provides a choice for the limit of the range of the Noise Bar. The numbers represent microVolt reading from the inclinometer probe. The last pull-down menu allows the option to display the standard deviation of the incoming data. This range can also be adjusted, depending on how noisy the readings are in the field. Measurements should be taken at the point of least noise whenever possible to obtain the most accurate readings.

4.2.8 VIEW DATA

By pressing the *View Data* button from the main menu, the following screen appears:

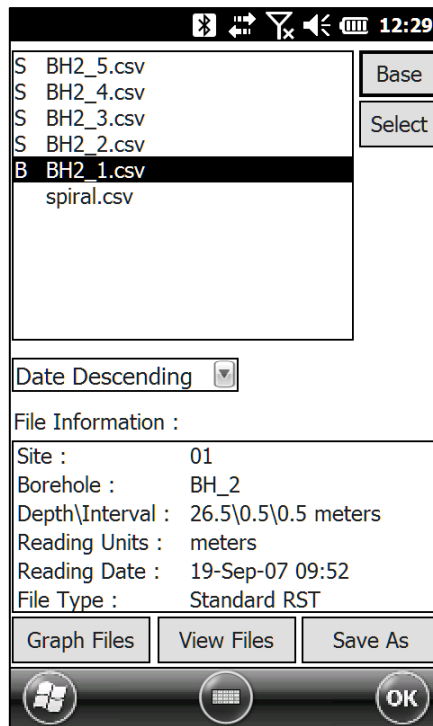


Figure 24 – View Data Screen

All borehole data files associated with the particular borehole that has been selected (from the Main Menu) will appear in the top dialog box. The detailed file information appears on the lower half of the screen and includes *site*, *borehole*, *depth/interval*, *reading units*, *reading date* and *file type*. Filenames can be sorted by date, type or name by selecting the appropriate option in the drop-down box.

In order to display the data, the appropriate files must be chosen from the list. To select a file, first highlight the file in the top dialog box and then press the *Select* button. If the file has been selected, an “S” will appear to the left of that file. To choose a base file, highlight the appropriate file and press the *Base* button. A “B” will appear to the left of the file name confirming that this file is now the base file. Note that the *Base file* and the *Selected files* can be changed at any time by highlighting the file and pressing the *Base* or *Select* buttons. The software only allows the user to have a single *Base File*. To unselect any file, simply highlight that particular file and press either *select* or *base* a second time and the *B* or *S* to the left of the file will subsequently disappear.

The base file represents the original survey of the inclinometer hole, from which all other measurements are compared. Typically, a base file is chosen and kept the same throughout the life of the inclinometer hole in order to quantify any lateral displacements which occur.

Once the appropriate files are chosen, the user can choose to display the data in tabular format by pressing the *View Files* button, or in graphical format by pressing the *Graph Files* button.

Pressing the *Graph Files* button will bring up the following screen:

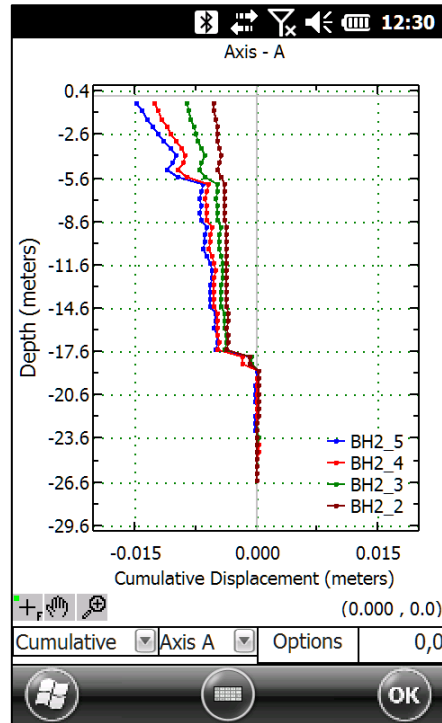


Figure 25 – Graphing Files

Several tools are available in the bottom pull-down menus to allow manipulation of the graph. The left-hand pull down allows the user to choose how the data is displayed, with Mean, Absolute, Cumulative or Checksum options. The centre menu allows the user to choose between plotting either the A or B axis. The third menu *Options*, allows the user to manipulate the cursor, zoom, pan, change the scale, move the legend, or change the appearance of the graph. Three icons also appear in the bottom left of the screen which allow further manipulation of the graph. These are self-explanatory and the user is encouraged to explore these options if required. The default setting for all plots is *auto-scale*.

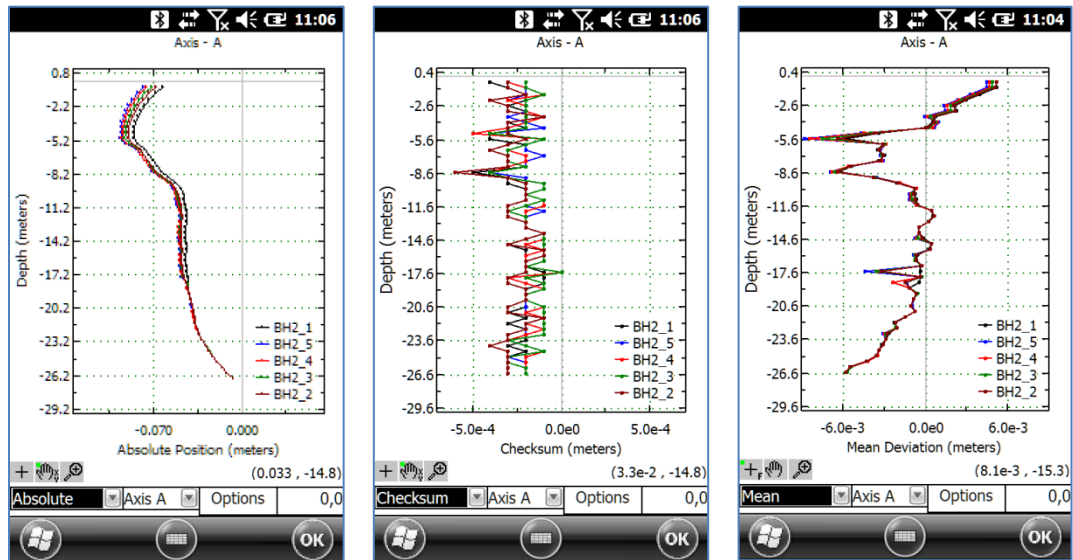


Figure 26 – Other Graph Types

To exit the graphical display, hit the **OK** button in the top right corner of the screen.

Pressing the *View Files* button invokes the following screen:

Raw Data A B:BH2_1.csv			-0.5
Depth-m	Face A+	Face A-	
-0.5	0.0050	-0.0054	
-1.0	0.0050	-0.0053	
-1.5	0.0039	-0.0041	
-2.0	0.0029	-0.0031	
-2.5	0.0020	-0.0023	
-3.0	0.0022	-0.0024	
-3.5	0.0007	-0.0008	
-4.0	0.0004	-0.0007	
-4.5	-0.0001	-0.0001	
-5.0	-0.0036	0.0032	
-5.5	-0.0060	0.0056	
-6.0	-0.0032	0.0030	
-6.5	-0.0036	0.0033	
-7.0	-0.0031	0.0028	
-7.5	-0.0035	0.0032	
-8.0	-0.0055	0.0053	
-8.5	-0.0065	0.0060	
-9.0	-0.0039	0.0036	
-9.5	-0.0022	0.0019	
-10.0	-0.0009	0.0007	
-10.5	-0.0009	0.0007	
Decima	4	Graph	

Figure 27 – Viewing Files

The top left pull-down menu allows the user to change the type of data that is reported in the table. The options include: Raw Data A, Raw Data B, Checksum, Mean, Absolute and Cumulative. The top right pull-down menu is used to choose which of the selected data files is currently being displayed. Please note that the base data file will contain the prefix "B:" so that it can be easily identified.

The bottom portion of the screen has three menus which allow the user to display the data in either decimal or scientific notation, change the number of decimal places displayed, and a *graph* button which takes you to the graph data screen. At any time, you may exit from this screen by pressing *OK* in the top right corner of the screen.

Pressing the *Save As* button invokes the following screen:

- Save As

Filename (File extension not required)

BH2_1

File Type Units

Standard RST (*.csv) meters

- File Information

Filename : BH2_1.csv

File Type : Standard RST

Units : meters

Ok Cancel

Figure 28 – Save As... Option

This function allows the user to edit the filename, file type and the measurement units. For more on file formats please refer to Section 4.2.5.

5 PROBE TYPES

5.1 VERTICAL PROBE

Vertical probes collect data in the A and B axes. They are the most commonly used probes. Readings taken from an inclinometer probe are actually deviations from the vertical over the distance between the upper and lower wheels. When the probe is passed through the inclinometer casing, a reading is taken every 0.5m (or 2ft.). When the probe is at rest, the MEMS accelerometers sense the inclination of the access tube in two planes. This inclination is displayed in terms of *angular deviation*, which is recorded at that particular depth.

5.2 HORIZONTAL PROBE

The function of the MEMS Horizontal Inclinometer Probe is very similar to the standard biaxial (vertical) probe. Each individual survey requires the probe to be drawn or pulled through the casing, then reversed and passed through the casing again (probe is reversed end for end – not rotated axially 180° as in a vertical inclinometer survey). Measurements are collected at 0.5m intervals with the metric probe or 2 ft intervals with the imperial probe.

The readings taken represent the vertical displacement, defined by $(\frac{1}{2}m) * (\sin(a))$, where “a” is the angle between the horizon and the longitudinal axis of the probe.

5.3 INCLINE PROBE

The Incline probe measures inclination in a borehole at 35-degree tilt. Measurements are made in a single pass along the A axis. Since there is only one pass, A- is filled up with A+ readings of opposite sign. The A axis data represent displacements from 35-degree angle on the length of the probe. The B axis data is collected from another vertical sensor. Since that sensor is at an angle too big to read accurately, it is used here for a reference to show that the probe was inserted correctly. Data in B axis should be as close to zero as possible.

There is no need to edit data files to be able to display graphs in Inclinalysis. Inclinalysis can be easily switched to the graph of the A-axis to show the important graph only.

5.4 SPIRAL PROBE

The RST Digital Spiral Probe is designed to complement the RST Digital Inclinometer System. In situations where excessive spiral is present in the inclinometer casing, it becomes important to correct for the spiral in order to have the correct magnitude of displacement in the A and B axes.

The software displays the spiral readings directly in degrees. Logging the spiral data is done in a similar manner as an inclinometer survey. To begin the survey, push *Start* button. The initial position is then measured. *Accept* button needs to be pressed when in manual mode. In *Auto Accept* mode, the probe will sense movements and the reading will be taken automatically without the need to press any buttons. The reading mode can be changed on Options screen. Refer to the RST Digital Inclinometer Spiral Sensor Manual (ICM0039) for further information.

6 DOWNLOADING DATA TO A DESKTOP PC

Windows 7, 8, 8.1, and Windows 10 need Mobile Device Center 6.1. It is highly recommended that the newest updates are downloaded and installed from the Microsoft website. Alternatively, a flash memory stick can be used to transfer data between the Handheld and desktop computer. This is useful option when software installation is not possible due to Windows user rights limitation or other.

6.1 SETTING UP MOBILE DEVICE CENTER ON WINDOWS 7, 8, 8.1, AND 10

Before connecting a desktop PC or laptop to the Ultra-Rugged Handheld, verify that the desktop PC or laptop contains current version of Microsoft Mobile Device Center™. Communication between the two devices is achieved through a USB connection.

Note

Microsoft's Mobile Device Center™ software can be freely downloaded from Microsoft's website. Choose 32-bit or 64-bit version, depending on the operating system.

Important

After installing Microsoft Windows Mobile Device Center (WMDC) in the Microsoft Windows 10 operating system, it is essential to run the WMDC Fixes for Windows 10 utility.

After Mobile Device Center™ is installed, connect the Ultra-Rugged Handheld to the desktop or laptop computer using the USB cable provided with the Digital Inclinometer System. Microsoft Windows™ should detect new connection and display following dialog box.



Figure 29 – Mobile device Center Screen

To synchronize the data in real-time between the Ultra-Rugged Handheld and the desktop PC, you must click on *Set up your device* (Figure 30). If you do not wish to synchronize data and simply use Windows Explorer to copy files to and from the Ultra-Rugged Handheld, click *Connect without setting up your device*. Data files can be copied from the Ultra-Rugged Handheld using File Management, as shown on Figure 31.

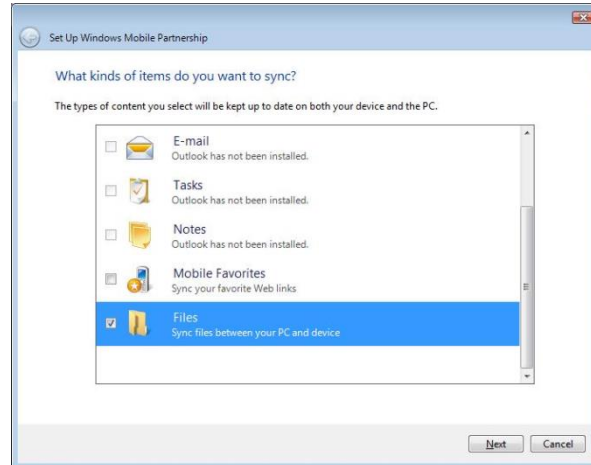


Figure 30 – Synchronization Settings on Windows™ 7, 8, 8.1, and 10

When synchronizing files, decide what type of information you would like synchronized with the desktop computer. If you are only using the Ultra-Rugged Handheld for the purposes of transferring Digital Inclinometer information, uncheck all the options and place a check mark next to the *Files* (see above).



Figure 31 – Accessing Files on Windows™ 7, 8, 8.1, 10

Important

It is extremely important that the user realizes that the synchronized folder created on the desktop is an **active** link to the Ultra-Rugged Handheld. Any changes you make in that folder will be reflected on the Ultra-Rugged Handheld. For example, if you delete a file in the folder, the same file will be deleted on the Ultra-Rugged Handheld. If the Ultra-Rugged Handheld happens to be disconnected at the time, as soon as it is re-connected it will automatically see the missing file in the folder and the file will be deleted during the connection. It is therefore important to exercise good data management. Once the data is synchronized to the PC, move the inclinometer files to a safe location (i.e. a network server or hard drive).

For further instructions regarding synchronizing data between a PC and the Ultra-Rugged Handheld, please refer to the supplied documentation and software which comes with the Ultra-Rugged Handheld.

6.2 FILE MANAGEMENT

Once the Ultra-Rugged Handheld has been synchronized to a desktop computer, file management can be performed using Windows Explorer. Files can be copied and/or deleted easily using the drag and drop features. Using Windows Explorer is the easiest and most effective way of managing the Inclinometer Data on the Ultra-Rugged Handheld. The file structure is straightforward and has the following format:



Figure 32 – File Structure

Where:

- RST = Site Name (user defined)
- Parking Lot = Borehole Data (user defined)

For additional information on the naming of sites and boreholes please refer to Section 4.2.3.

Note

As with any modern digital peripheral device, data management is very important. In order to keep the system un-cluttered, it is extremely important to delete site and/or borehole data files off the Ultra-Rugged Handheld once the data is saved in a safe location on your PC and when the data is no longer required to reside on the Ultra-Rugged Handheld. Any files which are deleted from the synchronized folder on the PC will be deleted on the Ultra-Rugged Handheld.

The Digital Inclinometer Software does not provide a means to delete the data files within the Ultra-Rugged Handheld. Data file management should be performed solely through the desktop PC. Once you have copied the data to a safe location, delete the necessary files/folders within the synchronized folder, and the corresponding files will be deleted on the Ultra-Rugged Handheld.

6.3 POST- PROCESSING THE DATA

The RST Digital Inclinometer system currently stores borehole survey data in a variety of formats, including the *.csv format. Once the data has been downloaded/synchronized to a desktop PC or laptop (see Section 6.1) it can be opened directly with RST Inclinalysis™ Software or Microsoft Excel™. If opened in MS Excel, the data will have a format similar to the one outlined below:

RST Digital Inclinometer Data				
File Version	2.2			
File Type	Digital Inclinometer			
Site	Sample Site			
Borehole	Borehole 1			
Probe Ser	DP20780000			
Reel Serial	DR30050000			
Reading Date	12/03/2018	11:45:06		
Depth	-10	0.5		
Interval	0.5			
Depth Units	meters			
Reading Units	meters			
Operator	JWG			
Comment:				
Comment End:				
Offset Cor	0	Incline Angle	0	
Depth	Face A+	Face A-	Face B+	Face B-
-0.5	-0.01614468	0.01617604	-0.00674	0.006948
-1	-0.01548881	0.01565409	-0.00731	0.007627
-1.5	-0.01612829	0.016258	-0.00773	0.008224
-2	-0.01766475	0.01782721	-0.00781	0.008111
-2.5	-0.01852109	0.01867516	-0.00813	0.008471
-3	-0.01889536	0.01911566	-0.00813	0.00846
-3.5	-0.01924451	0.01943372	-0.008	0.00833
-4	-0.01994934	0.02012129	-0.00804	0.008378
-4.5	-0.0204952	0.02065096	-0.00771	0.008301

Figure 33 – Sample Data File

As shown in, Figure 33, the header information is displayed, followed by the data. In this example, the total hole depth is 4.5 metres, with readings taken at 0.5 metre intervals.

The units that the readings were taken in are displayed at the top of each column (in this case, millimetres). Readings are taking in two directions, as outlined in Section 2.3.

6.4 DATA AVERAGING

The RST Inclinometer software automatically averages the real time inclinometer data streaming up from the probe every second. Pressing the *Options* button in the *Readings* screen allows averaging to be enabled and adjusted. While in the real time data display window, the current status of data averaging can be viewed on the left-hand side of the screen (Figure 21). The bar indicates how stable the readings are. If the bar is full, averaging is being performed and the readings have not yet stabilized. The user should wait until this bar goes down before recording a reading for that section of the borehole. The number displayed under the averaging bar represents *bits*. They are simply there to give the user an indication of the change in bits between subsequent readings. Site conditions and the nature of the installation determine how noisy (or not noisy) the readings are. The software allows the flexibility of going back and re-taking readings if necessary.

The averaging is a running average of the previous readings. To change the amount of averaging that the software performs, simply change the *average number* (Figure 22). With the stylus, select the dialog box and enter in the value using the pop-up keyboard at the bottom of the screen.

7 WHAT DOES THE DATA MEAN?

The system has been developed to accurately measure the lateral movement of earthworks and structures. The probe is passed through the inclinometer casing and takes a reading every 0.5m (or 2ft). When the probe is at rest, MEMS accelerometers sense the inclination of the access tube in two planes. This inclination is displayed in terms of angular DEVIATION, which is recorded at that particular depth.

A+ =	Face A+ deviation
A- =	Face A- deviation
B+ =	Face B+ deviation
B- =	Face B- deviation

7.1 CHECKSUMS

Checksums serve two purposes. The first is to allow the user to visualize the magnitude of the systematic bias that may exist in the probe, just in an informative way, as the checksums are not used in any further calculation. That systematic bias is then cancelled by using the Mean deviation defined below in further calculations such as the Cumulative displacement, the Incremental displacement and the Absolute profile.

The other purpose of the checksums is to act as a diagnosis of the quality of a given survey in the sense that if an individual reading shows a high checksum that was not present at the same elevation in an earlier survey conducted at a previous date, it may mean that one of the two readings in the + or - direction was not done properly, and the user will then be able to repeat that same reading in order to restore the checksum to a similar lower value as in previous surveys.

Checksum in A+/A- plane = A+ plus A-

Checksum in B+/B- plane = B+ plus B-

The checksum should be reasonably constant and of small magnitude, typically less than +/- 2 mm (0.08 in) and preferably less than +/- 1 mm (0.04 in). Large and inconsistent checksums may indicate that a problem exists. However, the consistency of checksums from survey to survey is more important than the actual value of the checksums. Checksum data should be monitored during the survey as a check on data integrity. Note that high checksums can be expected if a settlement coupling has been encountered, a checksum of the order of +/- 4 mm or (+/- 0.16 in) would be reasonable at consecutive depths/couplings.

7.2 MEAN DEVIATION

A+/A- mean deviation in the A+/A- plane = (A+ minus A-)/2.

B+/B- mean deviation in the B+/B- plane = (B+ minus B-)/2.

This represents the mean deviation at each depth, corrected for any systematic bias that can be present in the inclinometer probe as the average of the two measurements opposed at 180 degrees cancel that bias.

7.3 ABSOLUTE POSITION

An absolute position value at a particular depth is the summation of mean deviations starting from the bottom up to that particular depth. Absolute position is the profile of the access tube with respect to the vertical axis in a given plane. Absolute position can also be calculated from the top down if required using Inclinalysis™ software.

7.4 INCREMENTAL DISPLACEMENT

The incremental displacement is the difference in values of mean deviation between the base file (first set of readings taken) and a compatible file (usually the latest set of readings) at each depth. This plot can be generated using Inclinalysis™ software.

7.5 CUMULATIVE DISPLACEMENT

The cumulative displacement is the result of comparing two sets of mean deviations, usually the base file and the latest or comparison file. The profile represents the actual movement (or displacement) which has occurred at all depths between the times that the two sets of readings were obtained.

Note:

The RST Digital Inclinometer Software has the ability to reduce the data in the field on the Ultra-Rugged Handheld itself. Please refer to Section 4.2.8 (View Data) for additional information.

8 SYSTEM COMPATIBILITY

Regardless of the inclinometer system being used, it is imperative that the **probe wheels** be placed at the same locations during each profiling of the borehole (this is not necessarily the same depth marked on the inclinometer cable). Always use a consistent top reference, such as the aluminum cable grip which is provided with all RST Inclinometer systems.

The zero-depth reference on the new RST Digital Inclinometer System refers to the midpoint of the probe (between the wheel assemblies). This is the industry standard. The old RST analog system is referenced to the uppermost set of wheels. Therefore, this *must* be taken into account if the customer wishes to directly compare the two sets of readings. It is very important that the data be within 4mm (0.25"). Otherwise, the data will not match, and the comparison will not be valid.

Note

Customers wishing to compare surveys between RST's old analog system and the new digital system must ensure that the readings of both systems are taken at the same depths (with the proper depth reference). If you are changing over to the new Digital Inclinometer System, as with any new system, it is good practice to survey the borehole with both systems. When it is determined that the data from the new Digital System is satisfactory, the user can stop using the older system and continue from that point forward.

Note

Some competitor's inclinometers have different cable gripping/locating systems resulting in different depth locations. You must be aware of these differences when trying to directly compare data between the two different systems.

9 **BACKING UP THE ULTRA-RUGGED HANDHELD INCLINOMETER DATA**

Data file management between the Ultra-Rugged Handheld and a computer is handled by the mobile device communication software. Windows 7, 8 and 10 require Windows Mobile Device Center (Section 6.1). Data files can be shared or mirrored on both the PC and the Ultra-Rugged Handheld. However, the normal synchronization process does not back up the data. An easy way to backup the data is to always copy synchronized information to a safe location on your desktop PC or network server.

The RST Digital Inclinometer software automatically backs up the most current data files upon returning to the main menu screen. Therefore, anytime the user returns to the main menu screen, the data will be automatically backed up to the non-volatile (Handheld) memory location. The Handheld storage folder is accessible through Windows Explorer when the Ultra-Rugged Handheld is connected to a peripheral computer.

9.1 MANUAL BACKUPS

The RST Digital Inclinometer Software has provision for creating manual backups of the data, in addition to automatic backups.

1. From the main menu of the Digital Inclinometer Software, under the *File* menu select *Backup...* (Figure 34).

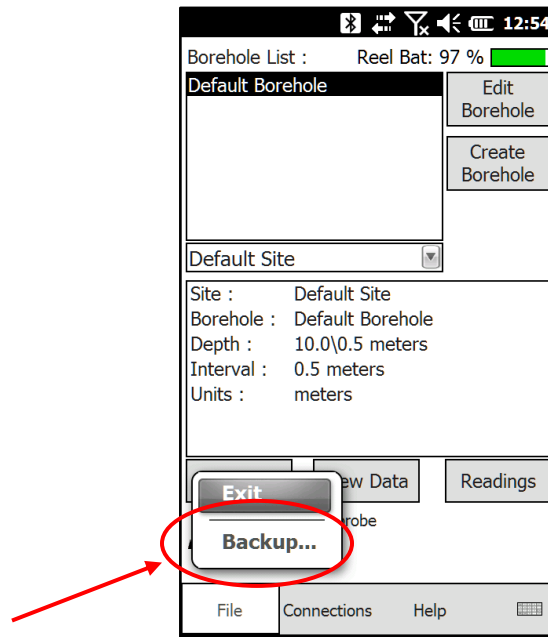


Figure 34 – File Backup

2. Once selected, the File Backup Options screen (Figure 35) will appear.

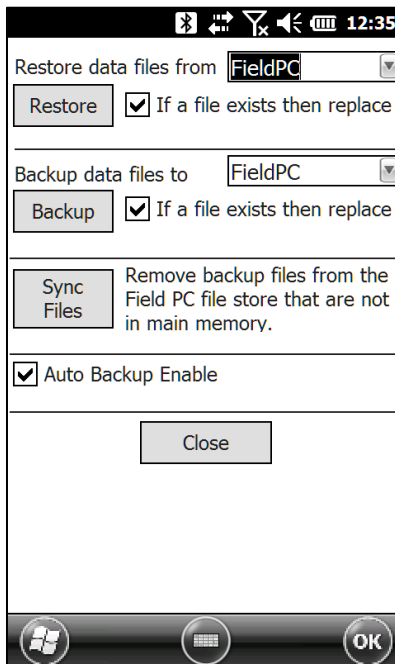


Figure 35 – File Backup Options

3. Using the drop-down box at the top of the screen, select the location which you would like to restore the files from. All Ultra-Rugged Handheld's come with the Handheld storage location however, optional Flash™ Storage Cards are additional and are available through RST.
4. Choose from the several options whether you would like to *Restore*, *Backup* or *Synchronize* the files. Check boxes allow the options of overwriting files if desired.
5. Press the desired button to initiate the function.
6. Press *Close* to exit this screen.

Note

Proper data management is very important. The Ultra-Rugged Handheld, in conjunction with its onboard and optional non-volatile memory storage areas, and its ability to synchronize with a desktop PC, allows several options for backing up the data. At the same time, with all these options, data files can be confused with each other if not managed properly. After taking readings in the field it is always a good idea to back the files up in a safe location (i.e. a network server) back at the office. Additional copies of this information will always be stored in the Handheld memory area should the main memory of the Ultra-Rugged Handheld become erased. Be sure to clear the Handheld memory of unnecessary files on a regular basis to keep the files easily manageable.

Important

Because the Ultra-Rugged Handheld uses some power to maintain files in RAM and the clock, the battery needs to be recharged regularly. Keep the Ultra-Rugged Handheld connected to AC or DC power while you are at your desk. The best policy is to keep the Ultra-Rugged Handheld connected to your computer when working at your desk and carry the AC adapter and DC adapter plug with you when traveling. Your Ultra-Rugged Handheld is shipped with a charge on the battery. You may want to ensure that it is fully charged before synchronizing. The Ultra-Rugged Handheld battery will provide approximately 20 hours of borehole survey time (when connected to the probe).

10 RESTORING FILES ON THE ULTRA-RUGGED HANDHELD

10.1 INSTALLATION THE RST DIGITAL INCLINOMETER PROGRAM

Use the following steps to reinstall the RST Digital Inclinometer Program:

1. Establish a connection to the Ultra-Rugged Handheld using Microsoft Mobile Device Center.
2. Using Windows Explorer, copy the file "Digital Inclinometer X.XX Nautiz.CAB" to the folder on the Ultra-Rugged Handheld (My Documents for example). The "X.XX" will mean the software version.
3. On Ultra-Rugged Handheld, select *Start* and then *File Explorer* from pull down menu.
4. Navigate to the folder where the file "Digital Inclinometer X.XX Nautiz.CAB" was copied to.
5. Click on the "Digital Inclinometer X.XX Nautiz.CAB" file to begin installation.

Note

If an older version of the RST Digital Inclinometer Software is already present, uninstall the previous version by going to *Start*, then *Settings* and tapping on *Remove Programs* located in *System* tab. Highlight the program to be removed and tap *Remove*. If the Digital Inclinometer entry is not present in the list, the program must be manually removed by deleting files in *Windows* directory and shortcut in *Start Menu*.

10.2 RESTORING THE INCLINOMETER DATA FILES

The inclinometer data files are backed up to the Handheld storage area of the Ultra-Rugged Handheld on a regular basis, each time the user returns to the Main Menu Screen of the Digital Inclinometer program. In order to restore the files, the user may navigate to the Handheld storage area using Windows Explorer. This is most easily accomplished when the Ultra-Rugged Handheld is connected to the desktop PC. The procedure is explained below:

1. Using *Windows Explorer*, navigate to:

Mobile Device: My Pocket PC\FieldPC File Store\Digital Inclinometer

The files will be stored in directories according to their *Site Name*.

2. If you need to restore all the files, simply copy the entire folder named "Digital Inclinometer" to the current directory.

The current folder resides in:

Mobile Device: My Pocket PC\My Documents

3. Alternatively, you can copy the folder using File Manager and move it to a safe location on your desktop. The files will automatically be synced to the Ultra-Rugged Handheld.

Data file management between the Ultra-Rugged Handheld and a computer is performed by connecting the two with a USB cable (see Section 6.1). This allows the mirroring of information on both the PC and the Ultra-Rugged Handheld. It makes file sharing easy and efficient between the two platforms. However, the normal synchronization process does not back up the data, it only reflects the current programs found on the Ultra-Rugged Handheld. An easy way to backup the data is to always copy synchronized information to a safe location on your desktop PC or network server.

11 ULTRA-RUGGED HANDHELD BATTERY

It is recommended that whenever the Ultra-Rugged Handheld is not being used in the field, it should be charging. This ensures that the Ultra-Rugged Handheld is always ready to be used in the field. A flashing red light on the front of the Ultra-Rugged Handheld confirms that the battery is being charged. A solid red light indicates that the batteries are at full charge.

The battery status can be checked within Windows Mobile:

1. Under the *Start* menu, choose *Settings*.
2. Touch the *System* tab at the bottom of the screen.
3. Touch the icon labelled *Power*.

The *Power* screen indicates the status of the main battery and the current power settings. The backlight and auto turn-off can be adjusted to conserve power.

The Ultra-Rugged Handheld should be charged on a regular basis. Whenever not in use, the Ultra-Rugged Handheld should be on charge using one of the supplied chargers to maintain a full charge on its battery. The Ultra-Rugged Handheld will warn the user when its battery is getting low. In situations where AC power is not available, use the DC adapter (Figure 1, item 9) to charge the Ultra-Rugged Handheld in the field.

12 CARE AND MAINTENANCE

12.1 PROBE & REEL CONNECTORS

Proper care and maintenance of the digital probe and reel connectors will ensure trouble-free operation of the Digital Inclinometer System. Failure to adhere to the following guidelines can result in premature connector wear, and ultimately connector failure:

- Ensure the keyway is aligned before threading the connector together.
- Never over-tighten the bulkhead connectors when mounting. Snug (hand-tight) is more than sufficient.
- Only twist the brass coupling on the connector, do not twist the signal cable itself.
- Avoid sharp bends at the cable entry to the connector. Failure to do so may result in irreparable damage to the internal cable wires.
- Clean the plugs and receptacles with a mild soap and fresh water on a regular basis. Do not allow the connectors to become excessively dirty. Never thread the connector when there is debris inside.
- Rinse out the connector with alcohol, allowing it to air dry. Replace the dust caps once the connector is dry.
- Lubricate the mating surfaces with the **supplied silicone spray** on a regular basis. **DO NOT GREASE and avoid the use of any solvent based lubricants (such as WD-40).**
- The amount of silicone spray used should be based on the frequency of use of the probe. One light spray to cover all contacts is enough after cleaning the connector. Ensure the connector is clean and dry before applying the silicone spray.
 - Contact RST Instruments to purchase a replacement bottle of silicone spray.
 - The RST recommends *3M Silicone Lubricant (Part # 62467849303)*, or *Haynes Silicone Oil*.
- Elastomers contained in the connector can be seriously degraded if exposed to solvents, direct sunlight, or high ozone levels for extended periods of time. Always replace the dust caps once the connector is clean and dry.
- Always keep the dust caps clean and free of any foreign materials. Do not place the dust caps where they may become contaminated.
- Always use the dust caps and keep the connectors clean to prevent damage in storage and when in use.

Warning

Solvent-based lubricants (such as WD-40) should **NEVER** be used as a lubricant on the connectors. These products will damage the elastomers in the connectors resulting in loss of communication with the digital probe. **ONLY use the supplied silicon lubricant or an RST-approved equivalent.** If ever in doubt or any questions arise, do not hesitate to contact RST Instruments for further information.

12.2 INCLINOMETER PROBE

The digital inclinometer probe consists of high-grade stainless-steel components and is completely sealed; minimal maintenance is required.

- After the borehole survey is complete, wipe all moisture off the probe and replace the protective caps over the connectors. If required, rinse the probe in clean water and dry. If the probe is exceptionally dirty, use a mild soap and fresh water to clean.
- *Never use solvents to clean the probe, wheels, or connectors.*
- Always store the probe in its original case whenever it is not in use. The high precision accelerometers in the probe can be damaged if the probe is subjected to excessive shock or vibration.
- Keep both the probe and its case clean and dry. If the probe is not cleaned and dried in the field, be sure to clean and dry it (including the case) upon return to the office. Do not leave corrosive solutions (i.e. saltwater) on the probe, connectors, and cable; be sure to clean the parts if these conditions exist.

The probe wheels are made with high-grade hardened and heat-treated stainless steel. These are the most robust on the market and are extremely durable. The wheels contain sealed bearings which require no maintenance, except keeping them clean and dry. Exposing the bearings to any particulates should be avoided to avoid contamination.

- The bearings do not require lubrication; **never use a solvent-based lubricant (such as WD-40) on the wheel bearings** as this may accelerate bearing degradation.
- **DO NOT replace a damaged shear pin in the wheel assembly without consulting RST.** Failure to do so may irreparably damage the probe and/or wheel assembly.

12.3 REEL AND CABLE

If required, wipe the cable with a clean rag to dry it off after use. The cable has a durable polyethylene jacket; simply use water and a mild soap to clean it off if necessary.

The spacing between the aluminum cable crimps and the total length of the cable should periodically be measured. This will verify the accuracy of downhole depth measurements and ensure maximum repeatability of the inclinometer system readings. Ferrule spacings should be measured between the downhole edge of each ferrule (i.e. ferrule edges closest to the cable connector) and should be 0.5m for Metric cables and 2ft for imperial cables. Ensure to tension the cable to remove any slack while making these measurements.

Warning

If the surveyed borehole has alkaline groundwater conditions, flush the borehole with fresh water prior to taking readings, and thoroughly rinse the cable with fresh water after the survey is complete. This will help to minimize potential corrosion of the aluminum cable crimps.

12.4 READOUT UNIT

To keep the Ultra-Rugged Handheld in good condition and working properly, please adhere to the following guidelines:

- Keep the Ultra-Rugged Handheld away from excessive moisture and extreme temperatures. Do not expose the Ultra-Rugged Handheld to liquids or precipitation. The supplied *Rugged Handheld* meets the IP54 standard for water and dust resistance, as well as being impact-resistant if dropped up to four feet from the ground.
- Do not place anything on top of the Ultra-Rugged Handheld to prevent damage to the screen.
- Clean the unit by wiping the screen and the exterior with a soft, damp cloth moistened only with water.
- Avoid exposing the Ultra-Rugged Handheld to direct sunlight or strong ultraviolet light for extended periods of time. Also avoid scratching the surface of the screen and banging it against hard objects.
- Only use the Ultra-Rugged Handheld stylus to prevent scratching the screen.

For further reference please see the supplied manufacturer's manuals for the Ultra-Rugged Handheld.

12.5 CALIBRATION

RST strongly recommends that the probe be sent in for calibration annually. Due to the high precision nature of the sensors and the sensitivity of the probe, calibration must be done to ensure quality results and continued performance of the probe. Heavy use in adverse conditions may require calibrations to be done more often.

Calibration should also be performed if the probe has been dropped or become damaged in any way. If checksums become significant and they are not due to errors in probe positioning or noise, the probe likely needs to be re-calibrated.

Calibration should also be performed after any wheel assembly replacement.

12.6 STORAGE & BATTERY LIFE

The Ultra-Rugged Handheld included with the Digital Inclinometer System has a limited battery life. In this regard, it is important to keep the unit charged, otherwise it loses any peripheral programs which are installed on it. This includes the RST Digital Inclinometer Program. Please refer to Section 11 for more information on the Ultra-Rugged Handheld Battery.

Even if the Ultra-Rugged Handheld is turned off, it still consumes power. Therefore, if left "on the shelf" and unused, it will eventually deplete its batteries. The Ultra-Rugged Handheld should be charged on a regular basis. Whenever not in use, the Ultra-Rugged Handheld should be on charge using one of the supplied chargers to maintain a full charge on its battery.

13 BLUETOOTH COMMUNICATION

The Ultra-Rugged Handheld uses Bluetooth technology to establish a wireless radio link between the readout unit and the inclinometer reel. To verify the status of the Bluetooth connection, touch the Bluetooth icon located on the opening screen of the Ultra-Rugged Handheld desktop. Please note that the Ultra-Rugged Handheld is continually undergoing updates and the Bluetooth configuration screens may vary slightly from those shown.



Figure 36 – Handheld Wireless Icon

Clicking on the Handheld Wireless icon opens the following screen:

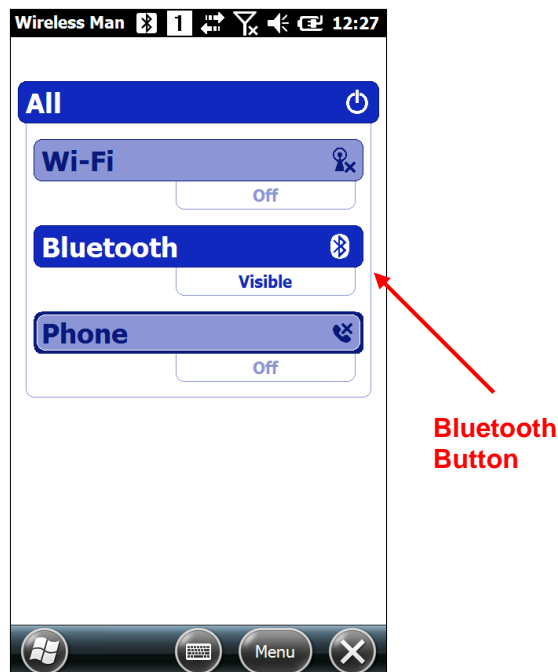


Figure 37 – Handheld Wireless Main Menu

Press the Bluetooth icon to turn on the Bluetooth Radio. When Bluetooth radio is turned on, *Bluetooth Indicator* appears at the top of the screen:



Figure 38 – Bluetooth Indicator

The user has the option of turning the Bluetooth radio on and off and can use the Devices tab to view the current Bluetooth devices within the vicinity of the Ultra-Rugged Handheld. In general, the user is not required to edit any of these settings because the RST Digital Inclinometer software will automatically search and connect to the reel and probe supplied with the system.

13.1 CHANGING THE REEL

Should the situation arise where the reel needs to be changed, the inclinometer software and the Bluetooth radio need to be reconfigured to recognize the new reel. To change which device the inclinometer software connects to, launch the RST digital Inclinometer software. From the *Main Menu Screen* (Figure 11) touch the *Connections* menu and choose *Bluetooth...* The following screen will appear:

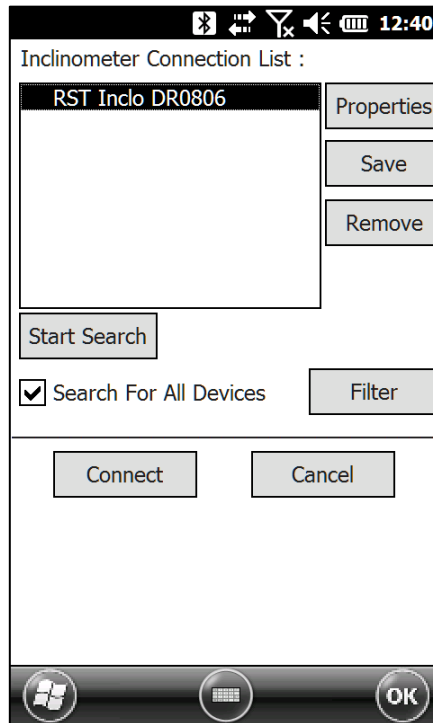


Figure 39 – Inclinator Connection List

The current inclinometer connection list that the software recognizes is displayed. To search for any new devices, press the *Search* button. The window gives the option of searching for all Bluetooth devices, or filtering for only certain types of devices. Press the *Filter* button to specify which devices to search for (i.e. filter by name). Once a device is discovered (this may take a few moments) an “F” will appear to the left of the device if it is currently in the existing list, indicating that it was found. An “N” will appear if a new device is found.

If the user wishes to add a new inclinometer reel to the list, search for this device first and then press the *Save* button once the device is discovered. This saves the new reel in the list so that the software recognizes it the next time the Digital Inclinometer software is launched. To specify which device the software connects to, simply highlight which one you would like in the list and press *Connect*. You can remove any devices from the list by pressing the *Remove* button.

Pressing the *Properties* button invokes the following screen:

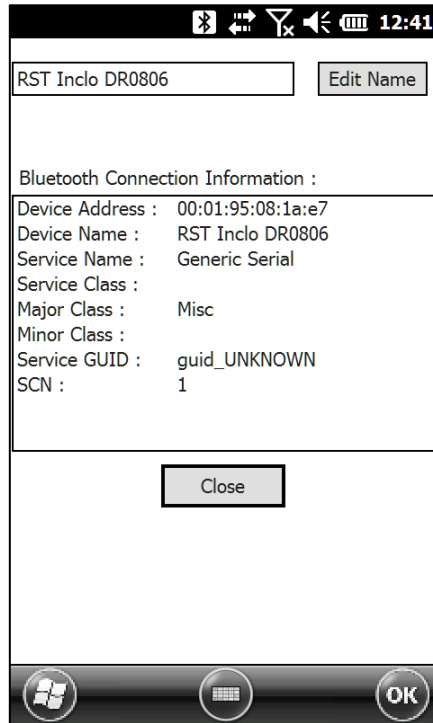


Figure 40 – Inclinometer Reel/Bluetooth Properties

This option allows the user to change the name of Reel if desired. This is simply an identification name that the software uses to distinguish between different devices. The Bluetooth Connection Information is detailed information for use by RST and in most cases is not important for the user.

14 IMPORTING AND EXPORTING FILES

14.1 SAVING AND IMPORTING INCLINOMETER DATA INTO DIGIPRO SOFTWARE

The RST Digital Inclinometer *.csv data files can be imported directly into DigiPro software. For additional information on DMM for Windows and DigiPro software, please consult the appropriate documentation provided with Slope Indicator's software.

14.2 USING SLOPE INDICATOR DATA WITH INCLINALYSIS

Slope Indicator files (in *.rpp format) can be directly imported into RST Inclinalysis Software. Please refer to the Inclinalysis Manual for further information.

14.3 IMPORTING INCLINOMETER DATA INTO GTILT

Standard RST Format Inclinometer files (*.csv) can be imported into GTilt by performing the following steps:

1. Start Gtilt
2. Select *File – New*
3. Select *File – Import*
4. Navigate to the directory containing the RST data files
5. Change *List File Types* to *All Files (*.*)*
6. Select data file to import (*.csv format)
7. Repeat steps 3 to 6 until all files for this borehole have been imported
8. Select *File - Save As* Input file name for this site and borehole
9. Select *Edit - Main header* - Insert 0.5 into Shallowest rdg Depth
10. Select *Edit - Main header* - Insert 25000 into Instrument Constant for Metric Probe
- Insert 20000 into Instrument Constant for Imperial Probe

Note

The *.csv files can also be opened directly in Excel, however, **do not save the files in *.csv format from Excel**. This will change the format of the file and you will no longer be able to import the file into GTilt. Always backup your data.

Note

The inclinometer program also allows the option to save the files in *.rpp format (Section 4.2.5). GTilt also recognizes this format and the files are imported in a similar fashion as described above.

15 SYSTEM SPECIFICATIONS

Inclinometer	
Wheelbase	0.5 m (24 inches)
Probe Length Including Connector	719 mm (32.6 inches)
Probe Diameter	25.4 mm (1.00 inch)
Probe Weight	1.06 kg (2.45 lbs.)
Probe Material	Stainless Steel
Memory	> 1 000 000 readings
System Accuracy	±2 mm per 25m (±0.1 in. per 100 ft.)
Temperature Rating	-40 to +70°C (-40 to +158°F)
Data Resolution	0.005 mm per 500 mm (0.00002 ft. per 2 ft.)
Full Scale Range	±30°
Repeatability	±0.002°
Axis Alignment	Digitally Nulled
Ultra-Rugged Handheld	
Waterproof	IP67
Rugged Case	1.22 m drops onto concrete
Operating Temperature	Optimized for excellent performance in cold temperatures Operating temperature: -22F to 140F (-30C to 60C) Note: Bluetooth® wireless technology is rated to -4F (-20C)
Processor	1.5 GHz Texas Instruments 4470 dual-core processor
Memory	1 GB DDR2 RAM
Internal Flash Disk	4 GB iNAND
Operating System and Software	Microsoft® Windows Embedded Handheld 6.5.3 Microsoft Office Mobile 2010* (Word Mobile, Excel Mobile, PowerPoint Mobile, Outlook Mobile) Multiple languages (English, French, Spanish, German, Portuguese)
Battery	Intelligent Li-Ion battery 3.7VDC @ 5200mAh, 19.2 Whr Operates for up to 20 hours on one charge Charges in 2 to 4 hours Battery easily changeable in field
Wireless Connectivity Options	Bluetooth® wireless technology, Class 2, range greater than 30 feet (10m) Wi-Fi® 802.11b/g/n with extended range Cellular Voice and data, 3.8 G GSM HSPA+/HSUPA or CDMA EVDO Rev A
Navigation	Integrated with stand-alone u-blox GPS
Camera	8 megapixel rear facing camera with autofocus
Connections	USB A Host USB Micro (PC sync and charging) DB9 RS-232 serial 3.5 mm headset (stereo and mic)
Cable	
Cable Diameter	6.4 mm (0.25 inches)
Cable Weight	2.3 kg/50 m (3.1 lbs./100 ft.)
Cable Tensile Strength	1.8 kN (400 lbs.)
Cable Jacket	Polyurethane
Cable stretch suspended in 50m dry borehole	7.0 mm (0.27 inches)

Cable Reel	
Up to 75 m cable reel diameter	310 mm (12.2 inches)
100 to 200m cable reel diameter	380 mm (15 inches)
+225m cable reel diameter	460 mm (18 inches)
Reel weight with 50m (100') cable	4.7 kg (8.4 lbs.)

16 TROUBLESHOOTING

Some common problems and their solutions are outlined below:

Cannot connect to reel:

- Check the status of the Bluetooth Manager (see Section 13). If the icon is not present on the desktop, launch the Bluetooth Manager software under the *Start* menu.
- Make sure that the Bluetooth radio is turned on (Figure 37).
- Exit the Digital Inclinometer software and cycle the power on the reel. Re-start the software and allow it to automatically make the connection to the probe. If this fails, repeat the procedure, this time giving the Ultra-Rugged Handheld a soft reboot (by pressing the power button for about 10 seconds until the menu appears, click soft reset).
- Follow the instructions outlined in Section 13.1, Changing the Reel. This section outlines how to search for Bluetooth devices and establish a new connection.

Cannot connect to the Probe:

- Check the threaded electrical connection between the probe and the reel.
- Ensure that the connector is clean.
- Check the connector for damage.

Cannot connect a desktop PC to the Ultra-Rugged Handheld:

- Check physical connections between the PC and Ultra-Rugged Handheld.
- Microsoft ActiveSync only allows full synchronization between two different PC's and a single Ultra-Rugged Handheld. Ensure you are not trying to make more than two of these types of connections. However, manual data transfer can be accomplished on any PC running the ActiveSync Software. Simply choose not to sync to the Ultra-Rugged Handheld when prompted to do so (please refer to the Ultra-Rugged Handheld reference manual CD-ROM, for further information).

Readings fluctuate and/or are noisy:

- Ensure probe placement is within 4 mm (0.25") at each depth.
- Increase the averaging of the readings (Section 4.2.7).
- Do not perform inclinometer surveys when heavy equipment is moving around the borehole. Choose "quiet" times.

Reset or turn off the Ultra-Rugged Handheld:

- Hold down the power button for about 10 seconds. A menu appears.
- Tap Hard Reset or Power Off.

Manually reset the Ultra-Rugged Handheld:

- In order to completely re-boot the Ultra-Rugged Handheld, hold down the power button for 10 seconds or until the screen goes dark. The Ultra-Rugged Handheld resets after a few seconds. Refer to the Ultra-Rugged Handheld user manual for further information.

Appendix A

CHANGING THE BATTERY (FOR REELS WITH SERIAL NUMBERS UNDER 2500)

Batteries inside reels with serial numbers under 2500 may be removed for recharging. The reel uses a 7.4V lithium-ion camcorder battery. The system comes with a battery housed inside the reel and a charger. Adapters are supplied to allow the charger to function in a vehicle (12V DC), or 110-240V AC power (see Figure 1). Reel batteries should be kept at a state of full charge whenever the probe is not in use.

To remove the battery, simply unscrew the cap off the reel hub by turning it counterclockwise (Figure 41).



Figure 41 – Battery Removal / Installation

Remove the battery and place on the Mach 1™ Speed Charger.

Mach 1 Speed Charger Operating Instructions

Status LED's

Together, the three LED's on the front of the Mach 1 charger will indicate the status of the battery and the charger. The descriptions and diagrams included in the following sections describe the various indicators and their meaning.

Standby Mode

Without any battery installed, the charger will flash the LED on the left, marked *MED*, indicating that the charger is standing by and waiting for a battery to be connected.

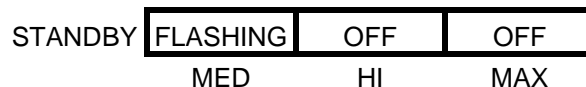


Figure 42 – Standby Mode

Once a battery has been properly connected to the charger, it will determine the status of the battery and begin the proper phase of the charging cycle. There are 3 phases to the charge cycle. The battery may be removed during any of the charging phases without harm to the battery or charger unit.

Phase I – Initial Charge

All 3 LED's flashing in sequence from *MED* (left) to *MAX* (right). If the battery is low, this will be the first charge phase. With high capacity batteries, this phase can sometimes be the longest of the 3 phases. Similarly, with some low capacity batteries and batteries reaching the end of their life, this phase can be very short.

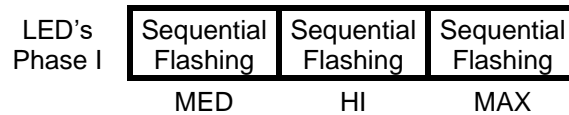


Figure 43 – Initial Charge

Note: When the battery is first connected, the LED's may instantly indicate *MED*, *HI* or *MAX* charge depending on the charge status of the battery. The process will continue normally from that point forward.

Note: It is normal for the charger, AC adapter, or the battery to become warm during charging.

Phase II – MED Charge

The *MED* LED is on continuously and the other LED's are flashing in sequence. At this point the battery is typically about 50% charged. Some very small capacity batteries (650mAh) and worn out batteries can be as low as 10% charged.

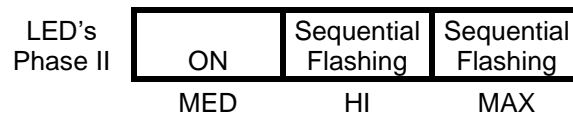


Figure 44 – MED Charge

Phase III – HI Charge

The *MED* and *HI* LED's are on and the *MAX* LED is flashing. At this point the battery is typically about 70% charged.

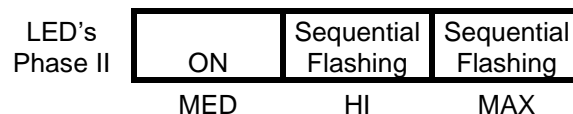


Figure 45 – HI Charge

Charge Complete – MAX Charge

All three LED's are on at the same time. Charging has completed and the battery is fully charged. It is recommended to remove the battery at this time.

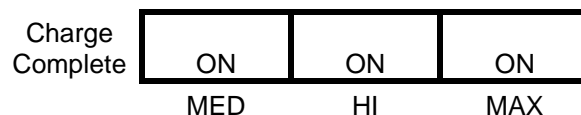


Figure 46 – MAX Charge

Error Condition – Charge Terminated

If the battery is removed before a complete charge has been reached, **the charger will continue indicating the last complete charging phase for up to 1 minute.** After that time, an "Error" indication will appear on the LED's, shown by the *MED* and *MAX* LED's coming on together while the *HI* LED is off.

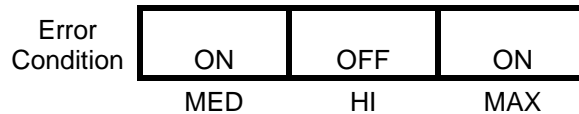


Figure 47 – Error in Charging

The Error Condition will also be indicated if the charger senses a problem with the battery being charged. To reset the error condition, unplug the charger from the power adapter for a few seconds, and then reconnect it. If the Error occurs again, there may be a defect in the battery that will prevent safely charging.

Charging Time

The 7.4V 2200mAh Lithium-Ion batteries supplied with the inclinometer system will take approximately 80 minutes to fully charge if they are depleted.

Note

RST strongly recommends that all batteries should be taken out into the field fully charged at the beginning of each day.

Be aware that cold temperatures can also have an effect on the performance of the batteries. Expect a somewhat shorter operation in extremely cold temperatures. Under adverse conditions, it is recommended that extra batteries be taken to the field, where one can be charging in between readings of several boreholes. The reel batteries are a standard camcorder battery and are readily available.

Note

The batteries will self discharge when not in use whether they are installed in the inclinometer reel or not. Batteries can be kept fresh if recharged on a regular basis.

Upon replacement of the battery, ensure to align the battery contacts with the contacts in the Reel hub to allow proper operation. Installation is the exact opposite of removal. Please ensure that the battery contacts line up with the contacts contained within the hub for correct operation.

Battery Life

A single Reel battery has the ability to last for up to 1 week on standby mode (i.e. no connection to the Ultra-Rugged Handheld). However, it is a good practice to turn off the Reel power whenever the survey is complete, as leaving the power on will eventually drain the battery. At room temperature, while taking readings, battery life is approximately 30 hours. In extreme environmental conditions (extreme cold or hot temperatures) fully expect useable battery life to decrease. It is always a good practice to take 2 or more fully charged batteries out in the field before performing inclinometer survey work.