OPERATION MANUAL

DAKOTA NDT

MultiMax

Ultrasonic Bolt Tension Monitor – 4 Channel MUX

P/N Z-226-0001 Rev 1.00, July 2024

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CHAPTER ONE
INTRODUCTION

The ***MultiMax*** is a 4 channel ultrasonic bolt monitor used to measure the stretch (elongation, load, stress and %strain) of a fastener under tension. This is accomplished ultrasonically by sending an ultrasonic wave down the length of the fastener and accurately measuring the change in transit time between an unloaded versus loaded fastener/bolt, and calculating a physical stretch. The objective for using ultrasonics over typical conventional/mechanical methods is accuracy. Most conventional methods refer to a torque value which has limited accuracy due to the coefficient of friction. The coefficient of friction is difficult to determine, as it depends on the control and application of lubrication. The ***MultiMax*** avoids the coefficient of friction entirely, using the transit time of a wave, Hooke's law, and Young's modulus to accurately calculate the stretch on a bolt. Since the ***MultiMax*** cannot physically stretch a bolt, both conventional/mechanical and ultrasonic methods are complimentary and used in conjunction with one another.

The ***MultiMax*** module has four independent channels to simultaneously measure four independent bolts by rapidly switching between the each channel of the multiplexor (MUX). The ***MultiMax*** modules can be 'stacked' together, for a number of channels, and managed using our ***MultiUI*** java interface software from a local or remote location. Remote monitoring of the modules assumes they are accessible and connected to the 'outside world' via the internet/cloud. Our built-in remote commander operating system provides remote control of the individual modules and their channels. The modules are 'headless' and not equipped with a display screen as standard. The ***MultiUI*** interface software includes the display functionality for setup and monitoring of the modules and bolts. It should be noted that because of the built-in operating system (remote commander) included in every ***MultiMax*** module, it is feasible for a user/company to entirely create their own UI software platform by calling on the command set built into the ***MultiMax*** firmware. While this will be a bit of an undertaking, it's available for the taking considering 'look & feel, customized reporting, control preferences, and overall functionality.

Dakota NDT maintains a customer support resource in order to assist users with questions or difficulties not covered in this manual. Customer support may be reached at any of the following:

Dakota NDT
1500 Green Hills Road, #107
Scotts Valley, CA 95066 USA
Telephone: (831) 431-9722
Facsimile: (831) 431-9723
www.dakotandt.com

1.1 General Disclaimer

The manual should be read and understood prior to using the ***MultiMax***. This operating manual provides the user with all the general information necessary to use and adjust the designed features. However, this manual is not a certified NDT/Bolting training course, nor is it intended to be one. Training, according to company requirements, is recommended. The responsibility for proper use of the instrument rests solely on the user.

1.2 Safety

Using the ***MultiMax*** while standing in water or in a wet environment can result in serious electric shock, injury, and even death.

Operating the ***MultiMax*** with damaged or inadequate cables and power source can result in serious electric shock, injury, and even death.

Failure to read this manual and understand the proper operation of the ***MultiMax*** can result in inaccurate measurements, and lead to decisions which cause property damage, personal injury, or even death.

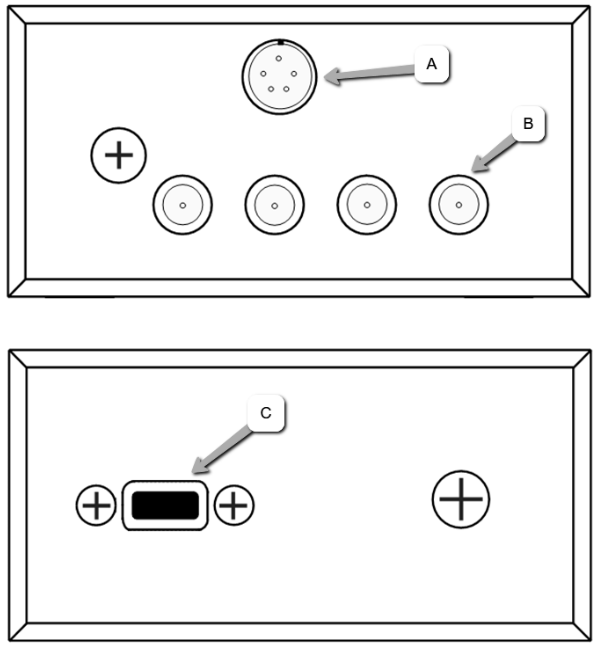
Use of the ***MultiMax*** for any other purpose, or in any other manner than described in this manual invalidates the warranty and can result in serious electric shock, injury, and even death.

1.3 Warranty

The Dakota NDT ***MultiMax*** carries a two year limited warranty. The warranty only applies to ***MultiMax*** units being operated as described in this manual. Software and hardware failures of the unit will be repaired or replaced at Dakota NDT discretion. Dakota NDT will not be held liable for any damage caused, interruption of business, loss of profits, etc., resulting from such failures. Dakota NDT will not be liable to repair or replace a unit, which has been damaged, used inappropriately, or subject to unauthorized repair by the purchaser.

CHAPTER TWO
MULTIMAX HARDWARE CONNECTIONS

2.1 Top & Bottom End Cap Connectors



The top & bottom end caps contain all the connections to the ***MultiMax***. The diagram above shows the layout and description of the connectors:

Temperature Sensor Connector (A) –
The temperature sensor connector is a Shielded custom 5 pin Lemo “1”.

Transducer Connector (B) –
The transducer connectors are board mounted and shielded LEMO “00” connectors using a built-in four channel MUX. Channel 1 is designated at location **B.**

USB-C Connector (C) –
The **USB-C** connector, located on the bottom end cap, provides both power and data to the ***MultiMax*** when connected directly to a computer or USB hub. The cable supplied with the ***MultiMax*** is a USB type C to a USB type A (pt# N-003-0330).

Note: *This connector is also used to upgrade the **MultiMax** with the latest version of firmware.*

CHAPTER THREE
MULTIUI – INTERFACE SOFTWARE

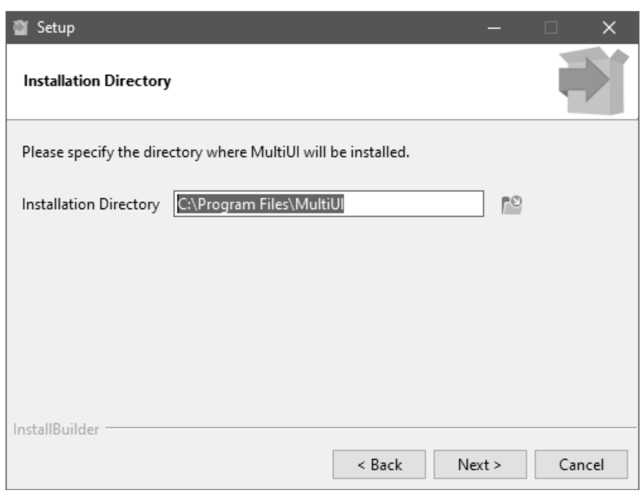
3.1 Overview

MultiUI is a software interface program written to work in conjunction with one or more ***MultiMax*** four channel modules (hardware). Since the ***MultiMax*** module is not equipped with a physical hardware display, the ***MultiUI*** software will take over as the visual component for each module and channel detected. It will become the primary control panel used to monitor the waveforms for setup, recordation of the measurements, and long term surveillance from all identified/connected modules and their respective channels over the service life of the fasteners/bolts. The following sections outline ***MultiUI*** in its entirety.

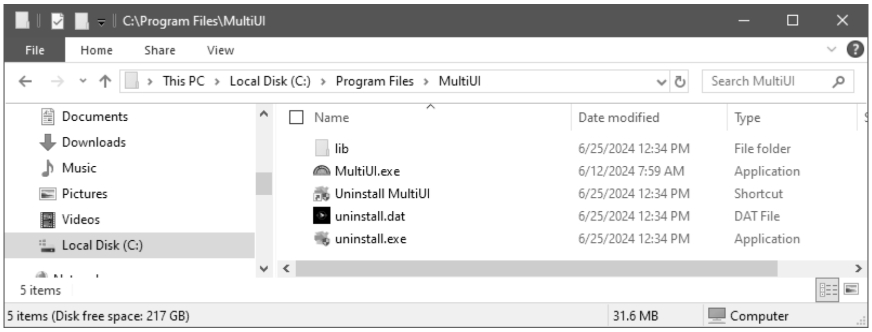
Note: *This chapter will primarily focus on the **MultiUI** interface software and assumes the **MultiMax** hardware module(s) are connected and ready for setup and measurement.*

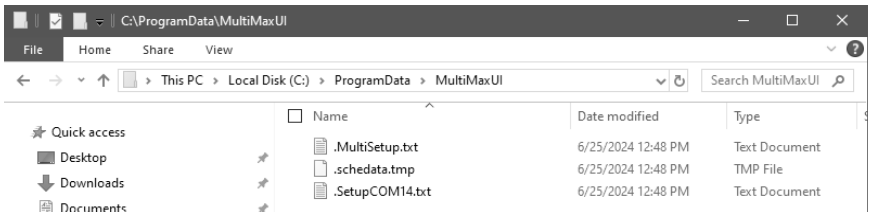
3.2 MultiUI Installation & Files

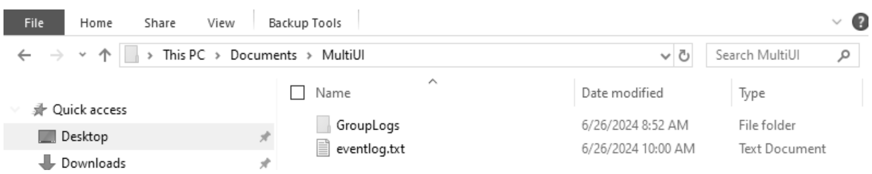
<u>Files Included/Created</u>



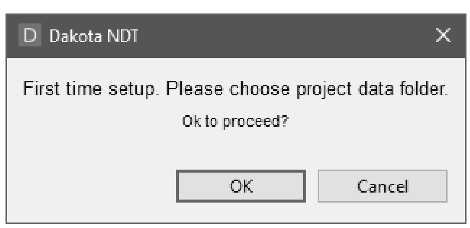
1) Download and install the latest version of ***MultiUI*** PC software directly from the Dakota website.







Note: *During the installation process the user will be prompted to either accept the default installation directory, or select a custom directory location. If a custom folder is selected, all the executable, library, and text configuration files will automatically be stored in the custom folder location. However, if the default directory is accepted, the executable and library and files will be populated in 'ProgramFiles/MultiUI' folder, and the text configuration files in the 'ProgramData/MultiMaxUI' folder, following the initial execution of the MultiUI software.*

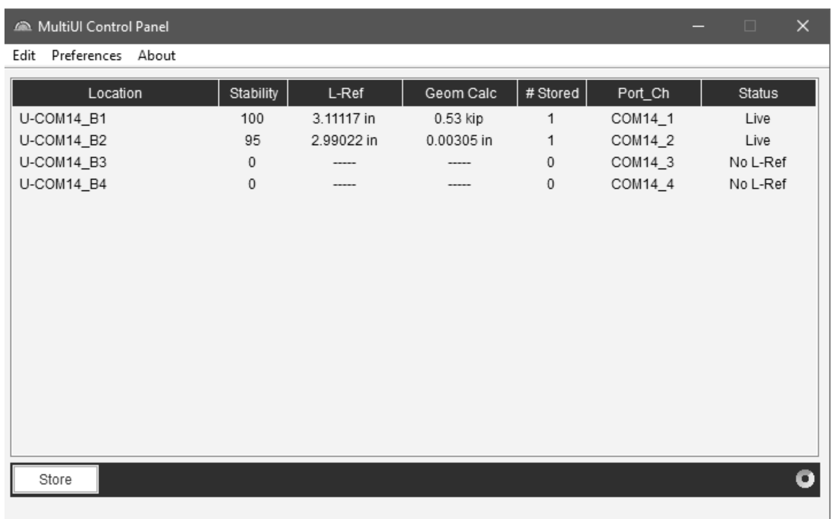


2) Double click on the "*MultiUI*.exe" file to activate the user interface. Select the folder location to store the project data files. If cancel is selected, a folder 'MultiUI' will automatically be created in current users documents

folder when a measurement is stored. The control panel will be displayed, and connected modules and individual channels detected.

Note: *The file ".SetupCOM14.txt" contains all the COM port setup information for the module connected and assigned to COM port 14, "MultiSetup.txt" will maintain the current configuration settings for the **MultiUI** interface itself, and ".schedata.tmp" contains when the last sample/measurement was taken, and when the next is scheduled to be recorded. All these files will be updated and maintained on a continuous basis.*

3.3 Control Panel



The photo above is a snapshot of the main control panel summary page, with a single MultiMax module connected, and the four active channels identified. Bolt #1 & 2 are live and measuring, while #3 & 4 available for use.

Location –
Displays the COM port and individual channels assigned to the module. In the example above, the port assigned to the module is COM14, and the channels/bolts are B1 – B4.

Note: *When a reference length is stored for a given bolt, a new ".SM2" file will automatically be created and stored in the "GroupLogs" folder located in the same directory where the **MultiUI** files are stored. The file name uses the same location* *name as is displayed above (i.e. U-COM14_B1). The file format is proprietary and only viewable using DakView4 reporting software.*

Stability –

Represents the consistency of the measurements returned (0-100), with 100 representing perfect repeatability.

L-Ref –

Displays the initial unloaded ultrasonic length measurement prior to stretching the bolt.

Note: *The ultrasonic length will typically never be perfectly identical to the physical length of the bolt/fastener with slight differences in the bolt type material factors. However, it's also important to note that the calculation for elongation is a delta measurement. Therefore, as long as they are reasonably close shouldn't present any issues.*

Geometry Calculation (GEOM CALC) –

Displays the calculated value based on the quantity selected (elongation, load, stress, or strain). When measuring in a quantity other than elongation, additional values for (load factor, load offset, area, and effective length) will be required to successfully calculate.

Note: *If any of these variables are set to 'zero', a calculation for that quantity cannot be made and will report dashes "-----".* (i.e. load factor = 0, a load cannot be calculated).

#Stored –

Reports the number of stored measurements recorded.

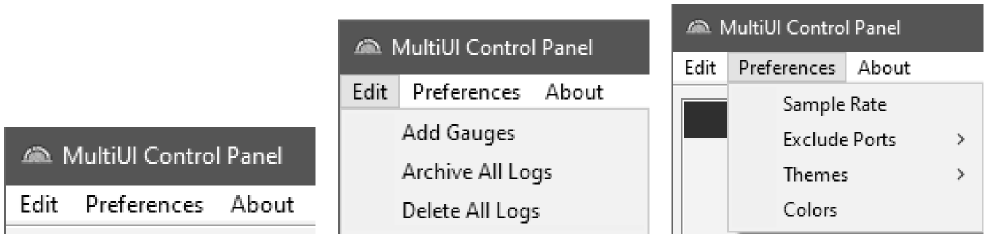
Port_Ch –

Shows the current COM port assigned to the specific ***MultiMax*** module, as well as all the independent channels for each module. The example above shows a single module assigned to COM14 with four independent channels. A number of modules can be connected together at the same time, and ***MultiUI*** will assign independent ports for each module.

Status –

Displays the current state of each specific channel (No L-Ref, Live, or Off-Line). If the channel is active and displaying "No L-Ref", the reference length has not been stored. If the status is registering as "Live", the reference and potentially loaded lengths have been stored. Finally, if the channel is reporting "Off-Line", ***MultiUI*** is not able to connect with that specific channel and attempted recovery initiated.

3.4 Menus & Features



The menu options above (Edit, Preferences & About) contain the menu item features currently available in the ***MultiUI*** control panel and are referenced as follows:

<u>Edit Menu</u>

Add Gauges –

Initiates a search for gauges connected on com port devices. When ***MultiUI*** is first launched, this routine will be run automatically. However, once the search is completed, and gauges/modules discovered, the routine will be completed. If additional modules are connected to the computer at a later time, with the UI control panel already running, this feature will initiate the discovery process for the new devices/modules connected.

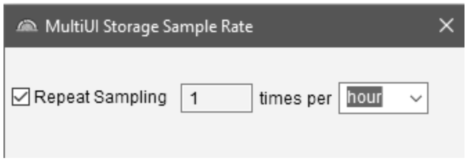
Archive All Logs –

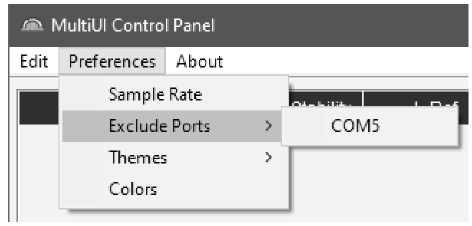
Depending on the sampling rate selected (i.e. 1 time per hour, etc.) the group log files will continue to grow in overall size, and over a given span of time. Considering the sample setting of once an hour, 24 measurements for each active channel will be recorded every day, and stored in the group log files. However, increasing the sample rate to sample of once a minute would result in 1440 measurements in a 24 hour period.

At some point the log file sizes will become very large and require archiving the stored historical data to a file. When this feature is executed a new sub folder is created in the “GroupLogs” folder with a date stamp following “Archives” (Archives’yr/month/day’ or Archives20230606). All the active group log files will automatically be copied into the archives folder for reference history. The active group log files in the folder “GroupLogs” will be cleared of all previously stored measurements, with the exception of the reference lengths (L-Ref’s), and continue storing measurements at the selected sample rate setting. A “history.csv” file will also be created and stored in the archive folder containing all group data archived.

Delete All Logs –

Caution! Executing this option will delete and clear all group log files in their entirety. Use this option only to start fresh from the beginning with zero data collected/stored.





<u>Preferences Menu</u>

Sample Rate –

Sets the number and duration of measurements stored in the group log files. In the example above, one measurement will be stored for all active channels every hour.

Exclude Ports –

If another serial device is connected to the computer that has nothing to do with ***MultiMax*** (i.e. serial converter cable, or Bluetooth device), the com port can be 'excluded' from ***MultiUI*** port scanning, by selecting the com port(s) in the list displayed.

Themes –

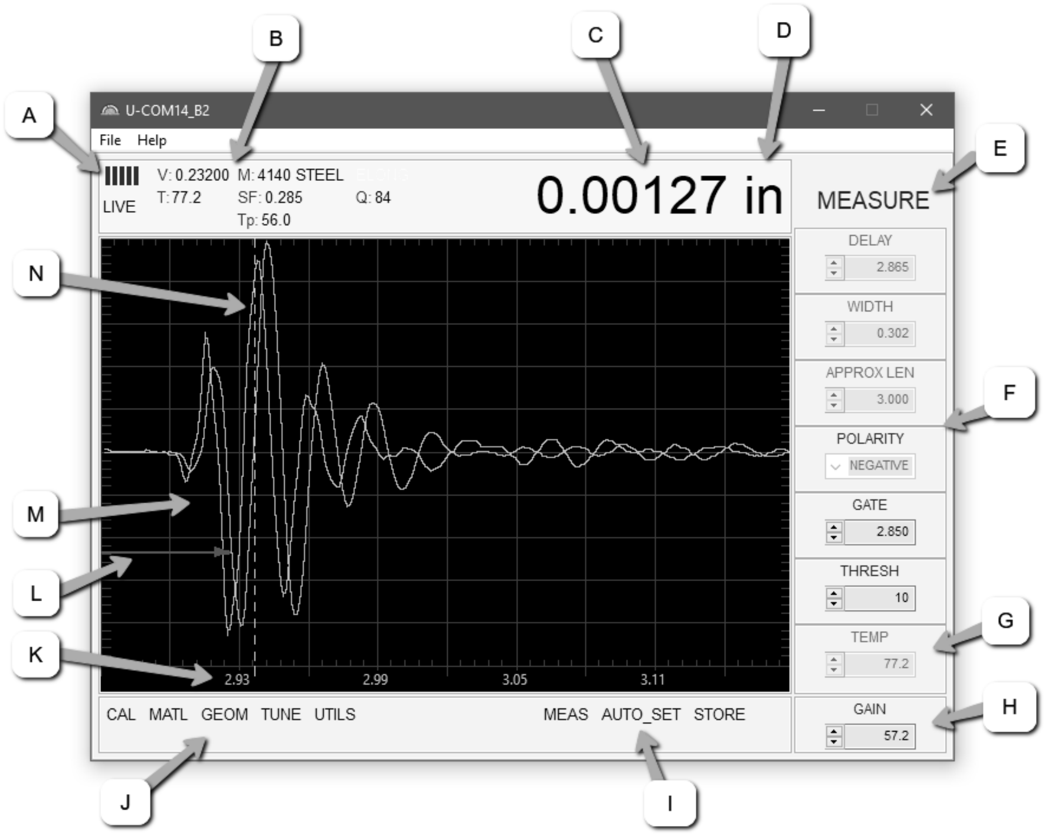
Contains a small selectable list of graphic color scheme options "look & feel".

Colors –

Customize a given color scheme for a desired "look & feel".

About – Displays the ***MultiUI*** software version installed.

3.5 Display Interface & Menus



Navigation and operation of the ***MultiMax*** will be done using the ***MultiUI*** interface display as shown in the diagram above. Opening a specific channel will activate this display window with the settings and status for that specific channel. The following are brief explanations of the feature/items contained in the ***MultiUI*** display window:

A. **Repeatability/Stability Indicator** – Indicates the reliability of the measured bolt length. When all the vertical bars are fully illuminated and the last digit on the digital thickness value is stable, the ***MultiMax*** is reliably measuring the same value on a consistent basis.
B. **Material/Temp/Q factor** – Lists the material type, velocity, stress factor, and temperature coefficient. Additionally displays the current temperature either from the temperature sensor, or manually entered. The Q factor displayed indicates the quality/correlation of the sound path from the position and orientation of the transducer.
C. **Digital Measurement** – Current measurement and units.
D. **Units** – Displays the current measurement units being used (English, Metric), and given the quantity selected (inches, millimeters, KSI, KIPS, %strain, time (nanoseconds).

E. **Tabbed Menu Item** – CAL, MATL, GEOM, TUNE, UTILS, MEAS, shown in (I & J). Click on these options to display the 'hot menu' items (F).

F. **Hot Menu items** – The menu items displayed when clicking on one of the tabbed menu buttons. Clicking on the MEAS button (I) will display the MEASURE menu items, while clicking on the CAL button (J) will display the CALIBRATE menu items.

G. **Temperature** – Displays the 'live' current temperature when the temperature sensor is being used. When the sensor is being used this value cannot be adjusted. However, if the temp mode is set to the 'manual' option, can be adjusted at any time.

H. **Gain** – The gain level can be overridden and adjusted 'on the fly' at any time.

I. **Function Keys** – (MEAS, AUTO_SET, STORE), are specific function keys that perform a specific function. The MEAS key returns to the main measure window and hot menu items at any time, while the AUTO SET is an automatic measurement routine that attempts to locate the detection and set all the scope parameters of the ***MultiMax***. Pressing the STORE key will save the current measurement to the group log file.

J. **Tabbed Menu Items** – (CAL, MATL, GEOM, TUNE, UTILS, MEAS), selecting one of these options will display the 'hot menu' items shown in (E & F).

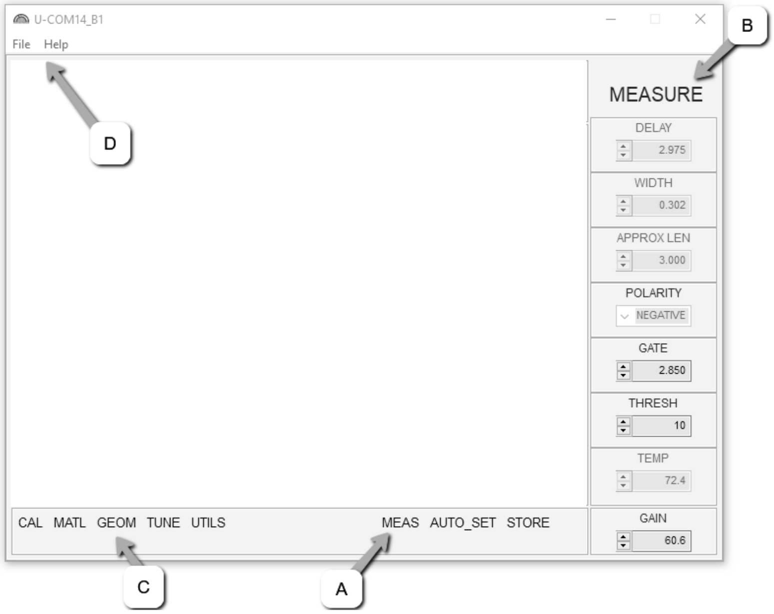
K. **Length Division Markers** – Measurement scale of length.

L. **Gate/Threshold** – The horizontal line with arrow pointing at the detection point is the 'gate', and the height of the line from the center baseline is the 'threshold' level.

M. **RF A-Scan** – Displays the radio frequency sound wave reflection returned from the opposite end of the bolt being measured. The RF view displays both the positive and negative cycles.

N. **Detect** – Broken dotted line indicating where the ***MultiMax*** is currently detecting on the waveform. The combination of the detect line location and gate/arrow, indicate specifically where the ***MultiMax*** is detecting.

3.6 Tabbed & Hot Menu Reference



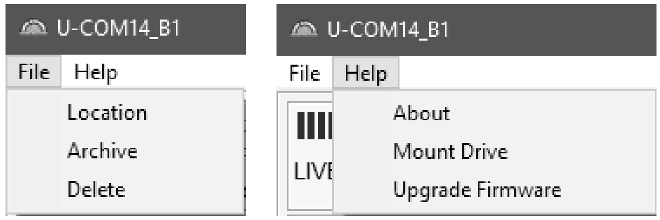
The following table is a quick menu reference guide. The ***MultiUI*** display interface has 6 top level menu labels, and multiple sub menu (hot menu) items for each label. In the photo above, **A** represents the menu tab MEAS, and **B** displays the hot menu items contained in MEAS. The additional tabbed menu options are displayed at **C**, and when selected will display the hot menu items in the column at **B**. These items can be adjusted as necessary unless grayed out as inactive.

The following table is a quick menu reference guide. Refer to 3.5 for additional definitions and information on the display interface and menu items.

Tab Menus	This color
Hot Menu Items	

CAL	**MATL**	**GEOM**	**TUNE**	**TUNE**	**UTILS**		**MEAS**
ZERO MODE	UNITS	QUANTITY	PULSE	PULSE	TEMP MODE		DELAY
ZERO	TYPE	LOAD FACTOR	PULSER VOLTAGE	PULSER VOLTAGE	DEFAULT SETUP		WIDTH
PHYSICAL LENGTH	VELOCITY	LOAD OFFSET	BACKLIGHT	DAMPING			APPROX LEN
AUTO CAL	STRESS FACTOR	AREA	DIGITIZER	GAIN			POLARITY
VELOCITY	TEMP COEF	EFFECTIVE LEN		GAIN STEP			GATE
				DIGITIZER			THRESH
							TEMP

3.7 Display Menu Reference



The menu options above (File, Help) contain the menu item features currently available in the display menu, shown at **D** in the previous section, and are referenced as follows:

<u>File Menu</u>

Location –
The factory default format is ‘U-COM14_B1’, which signifies the current com port of the module, followed by the specific channel (B1, or Bolt 1). Use the location features to rename the channels as necessary. Examples might be in reference to a drawing, location, or serial number sequence/location.

Archive –
Archives only the loaded measurements of the current channel/bolt opened in the display window ‘U-COM14_B1’, but saves the initial unloaded length (L-Ref), and continues recording loaded measurements. The group log for ‘U-COM14_B1’, is stored in the ‘Group Logs” folder with the following format “Archives/Date”, or (Archives’yr/month/day’ or Archives20230606).

Delete –
Deletes all stored measurements, including the initial reference length (L-Ref), and starts from the beginning.

<u>Help Menu</u>

About –
Provides descriptive information regarding the hardware module and interface firmware.

Mount Drive –
Loads the file system of the ***MultiMax*** internal SD card, making the files accessible to open and view the contents on a computer. Firmware upgrade files and all

‘CAL_ZERO_DATA’ files are currently the only things that will be stored on the SD drive. The CAL_ZERO_DATA files are viewable in DakView PC software.

Upgrade Firmware –

Allows the ***MultiMax*** the ability to be upgraded in the field to the latest version of firmware. This is specific to the hardware ***MultiMax*** module, which is separate from the ***MultiUI*** interface software. The file extension is “.bch”, and ‘only one’ file with this extension can be stored on the internal SD card at a time. Older “.bch” files can be saved and stored on the SD card by manually renaming the file using an additional extension like “bch.OLD”.

CHAPTER FOUR
QUICK START GUIDE

4.1 Overview

This section demonstrates the basic procedure for setting up and measuring a bolt using the ***MultiMax*** module in conjunction with the ***MultiUI*** control interface software. More in depth explanations pertaining to the individual functions and features can be found in the chapters that follow.

4.2 Getting the *MultiMax* ready

Making all the connections

In order to get the ***MultiMax*** ready for operation, the following connections must be made:

1) Connect a ***MultiMax*** module directly to the computer, or USB hub connected to a computer. Refer to Chapter Two for hardware connections.

Note: *The **MultiMax** module will power up automatically when connected.*

2) Refer to Chapter Three for reference on installing the ***MultiUI*** interface software on a computer.

3) Double click on the '*MultiUI*.exe' file to activate the control panel.

Note: *Upon activation, the main control window will appear, locate the module, and register all 4 channels.*

4) Connect the transducers and temperature sensor to the ***MultiMax***.

5) Apply couplant and attach the transducer connected to channel #1 (U-COM14_B1) to the 3" cal bar, used as the bolt for the 'quick start' example. The temperature sensor can be attached to the side of the same 3" cal bar.

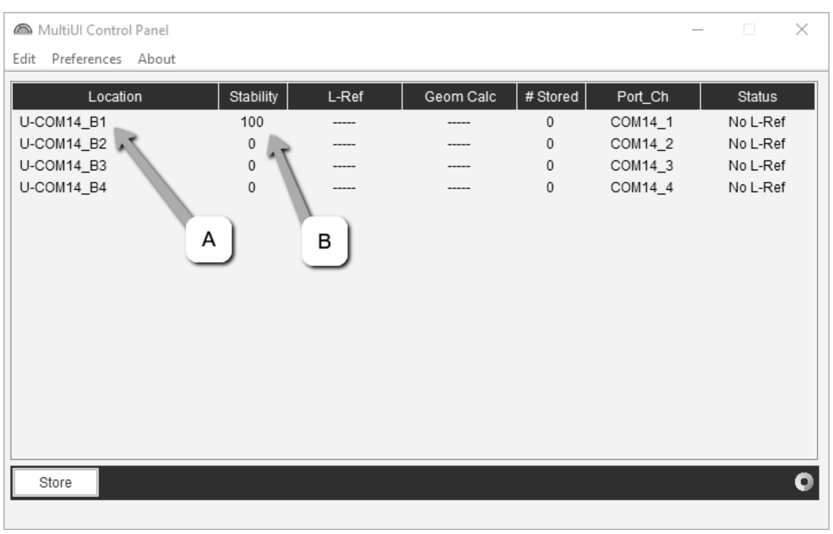
Note: *For live applications using actual bolts, the transducers should be in contact with the bolts/studs using some form of couplant fluid or equivalent. For permanent installation the 'glue on' style of transducers will used. In either case, the transducers should be in contact with the bolts/studs.*

Note: *The temperature sensor is magnetic, and should be magnetically attached to the structure in a location with similar material temperature absorption as the bolts. If the material is non ferrous, another method must be used to assure contact to the structure.*

4.3 Configuring *MultiUI*

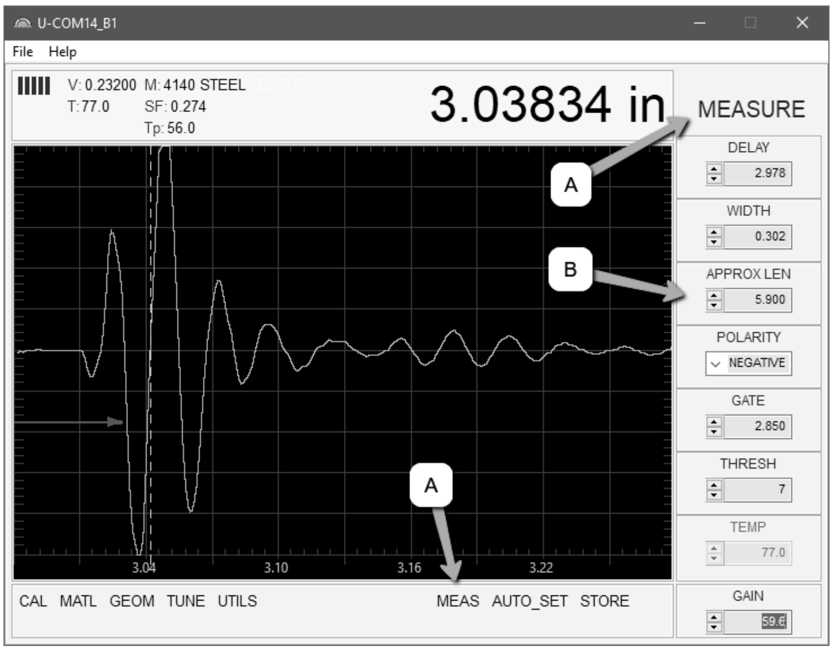
In this section the ***MultiMax*** will be setup in its simplest form. The 3" cal bar, typically used for the system zero calibration, will be used as the bolt in this quick start example. 4340 carbon steel will be selected and used as the bolt material type. A zero/calibration will 'not' be performed in this section, refer to Chapter Nine on zero/calibration.

Setup & Measure



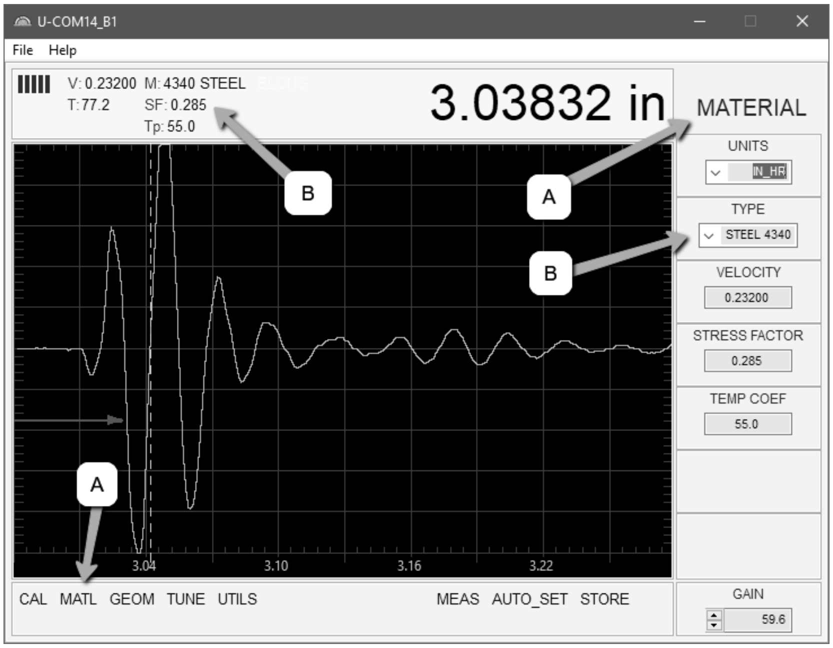
Note: *A review of the overall control panel above shows 4 channels with labels in the location field with com port and channel (U-COM14_B1). In this example* *the port is COM14, and the channel is B1 (bolt #1) by default. The location names can be edited as needed. Since only a single transducer connected to the first channel is coupled to the 3" cal bar, it is the only channel currently measuring and perfectly stable at max stability of 100. No measurements have been made at this point, and demonstrated with dashes for unloaded (L-Ref) and loaded (GEOM CALC), are displayed.*

1) Double click on channel #1, shown at **A**, to open the display interface window.



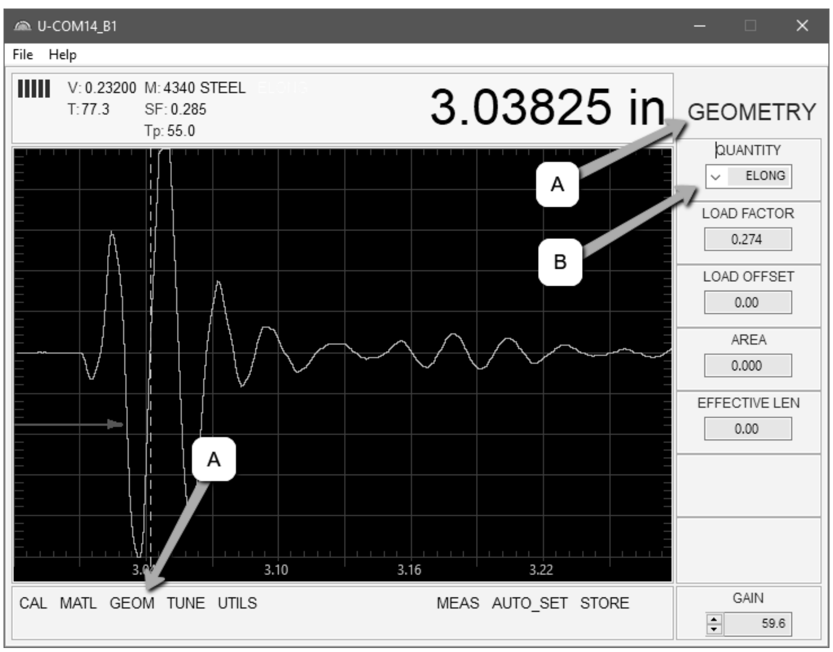
2) Click the **MEAS** tab at **A** to display the MEASURE menu items **A**.

3) Use the auto scroll arrows to increase/decrease the **APPROX LEN** value **B**. Alternatively, click inside the numeric field **B** to edit manually using the keyboard.



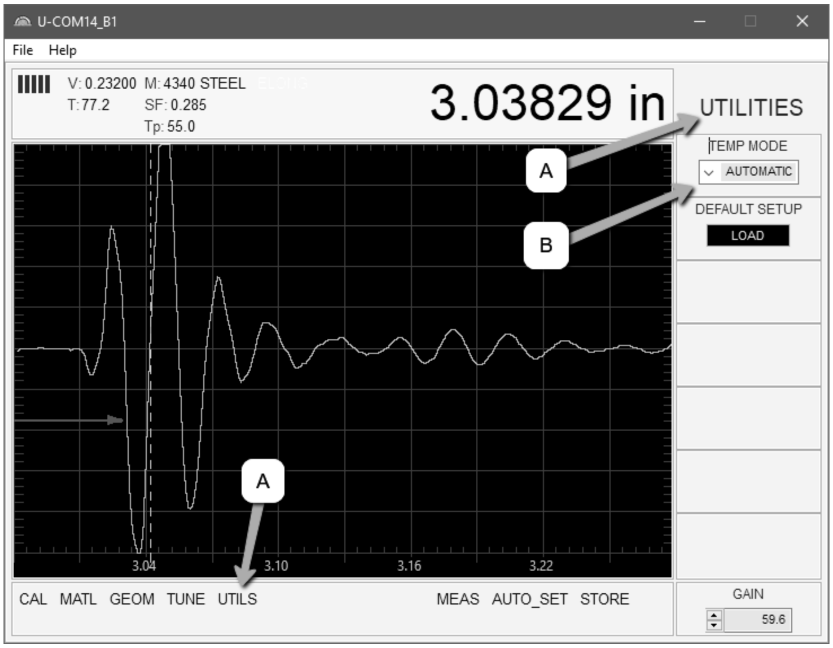
4) Click the **MATL** tab at **A** to display the MATERIAL menu items **A**.

5) Click the down arrow to display the material list, and select the **TYPE** at **B**.



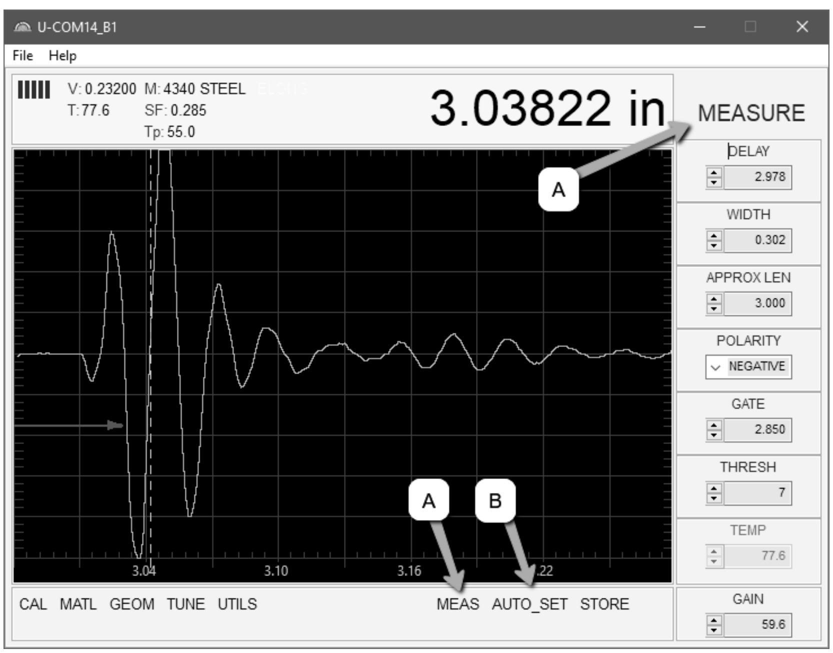
6) Click the **GEOM** tab at **A** to display the GEOMETRY menu items **A**.

7) Click the down arrow to display the quantity list options and select the **QUANTITY** at **B**.



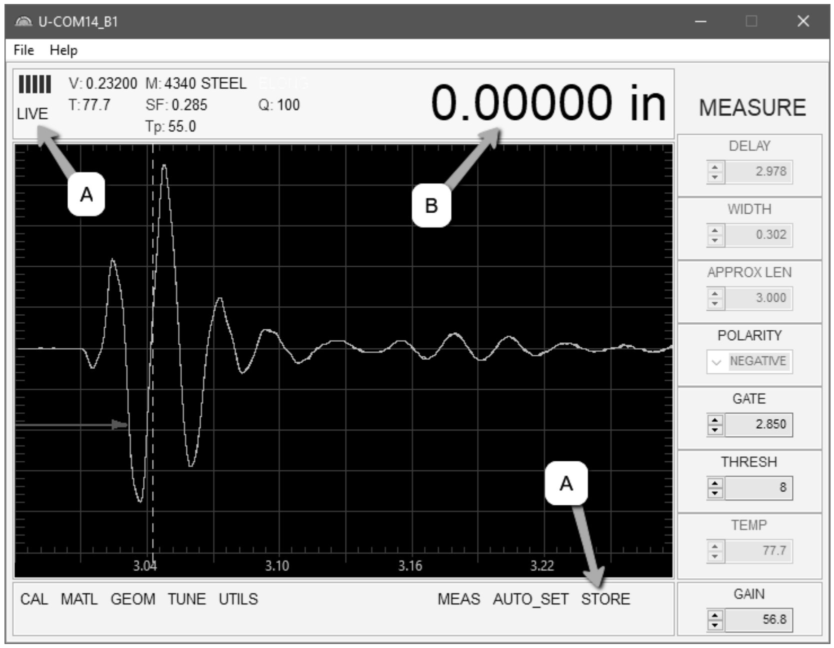
8) Click the **UTILS** tab at **A** to display the UTILITIES menu items **A**.

9) Click the down arrow to display the utilities list options and select the **TEMP MODE** at **B**.



10) The ***MultiMax*** is now configured and ready to measure. Click the **MEAS** tab at **A** to return to the main measure display screen **A**.

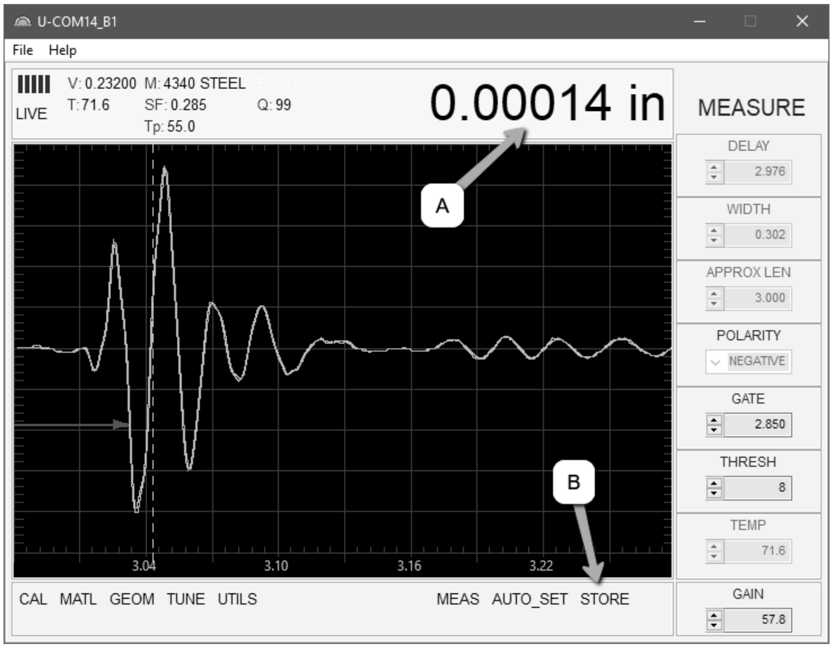
11) Click the **AUTO SET** tab at **B**, to allow the ***MultiMax*** to automatically optimize settings and measure the unloaded reference length (L-Ref).



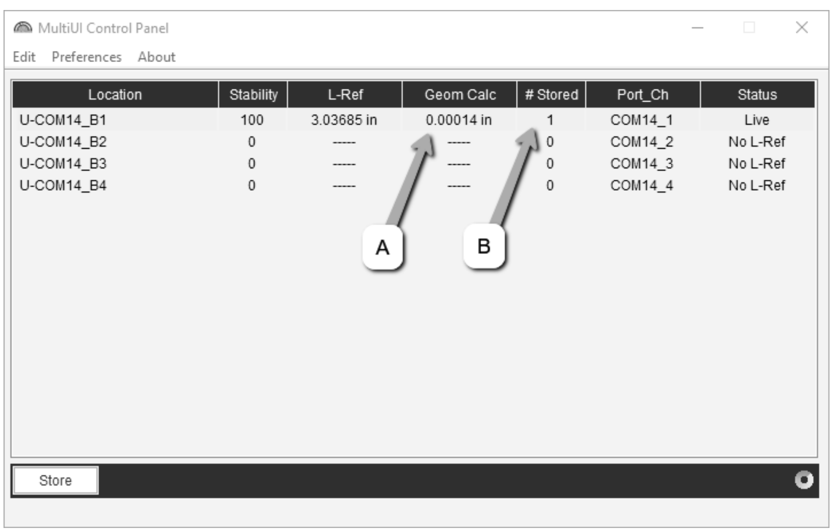
12) Once the **AUTO SET** has completed, the measurement can be stored. Click the **STORE** tab at **A** to record the unloaded length and display **LIVE** at **A**.

Note: When the reference length measurement is stored, a number of parameters will be ‘locked’, and inaccessible. These items will be automatically ‘grayed out’. The reference length must be cleared to make any changes.

Note: *A physical load, using a mechanical method, can now be applied to the bolt/fastener to achieve a target elongation/stretch. In our example the 3” cal bar was used for convenience, and cannot be physically loaded in this quick start example. However, simply holding the cal bar firmly in the palm of your hand will create enough heat to demonstrate the bolt stretching/elongating.*



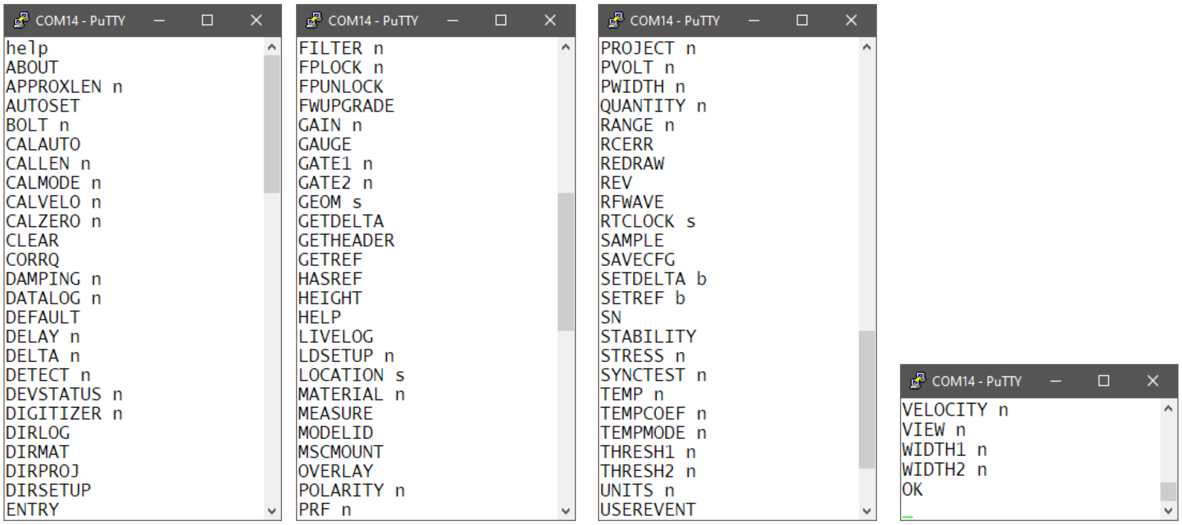
13) Once the target elongation/stretch is reached at **A**, click the **STORE** tab at **B** to record the loaded length and complete the measurement procedure for the first bolt on channel #1.



14) Click on the ***MultiUI*** control panel window to review the recorded results **A**, and number of stored loaded lengths at **B**.

Note: *A group is automatically created and stored in the GroupLogs folder in the directory originally specified. The file name uses the same name as in* *the control panel location column, in this example the default is 'U-COM14_B1'. Additionally, a 'history.csv' file is also automatically created and updated with the group file data for the purpose of importing the file into a number of third party software programs. This will be covered in greater detail in a later chapter that follows.*

CHAPTER FIVE
REMOTE COMMANDER



5.1 Introduction

This section is optional for those who wish to develop their own application software for use with the ***MultiMax***. The ***MultiMax*** has a built-in command structure ‘Remote Commander”, which offers full control of the gauge from any command line terminal software program via a serial connection, and using a USB CDC class driver (Serial over USB). The driver is used to emulate a virtual RS232 port on a Windows® PC. Additionally, other operating systems have equivalent drivers to accomplish the same connectivity to access and use the command structure of the ***MultiMax***. Remote commands are not required if using the MultiUI software.

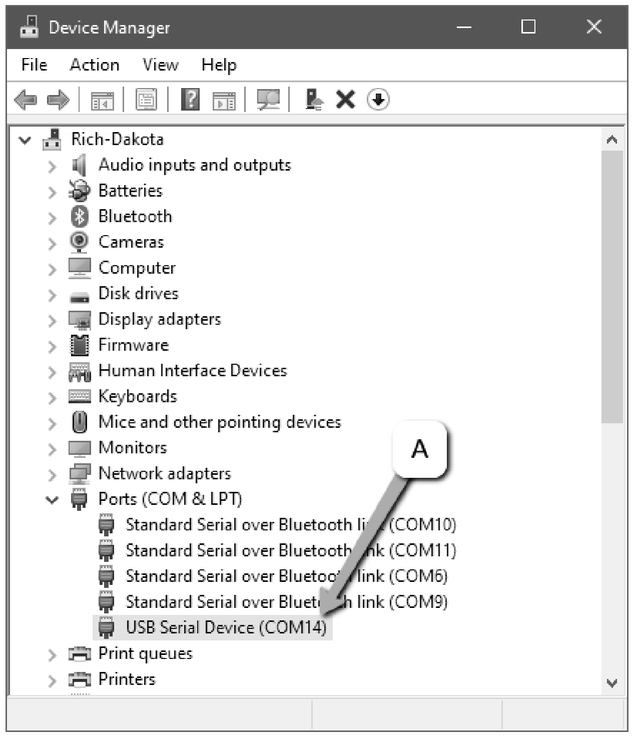
The ***MultiUI*** java interface software utilizes the command structure of the ***MultiMax*** to accomplish all of it tasks. This also opens up the potential for independent integration of the ***MultiMax*** into other custom software applications, where a specific company or partner agency prefers to develop, or has developed their own company specific interface software or script for their application or program.

5.2 Accessing Remote Commands

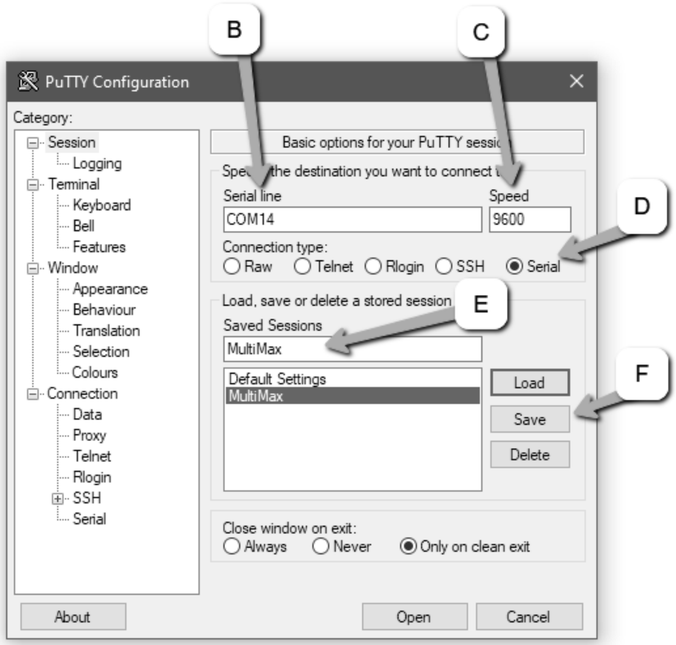
Remote Commander can be accessed using a common terminal interface program. In this section “PuTTY” terminal software will be used for demonstration purposes. It’s a fairly well known open source terminal SSH option, available for multiple operating systems, and readily available on the internet free of charge.

Configuring PuTTY

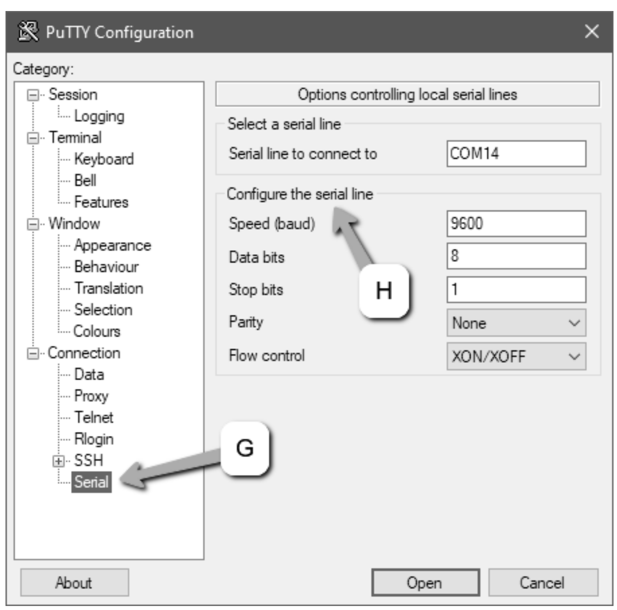
Note: *This section assumes the **MultiMax** is connected to a USB port on a PC, powered on, and PuTTY has been downloaded/installed on the PC connected. Refer to Chapter Two for hardware connections.*



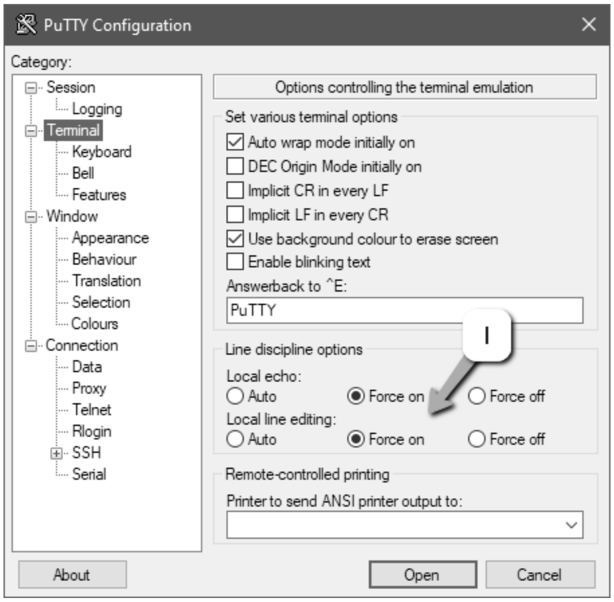
1) Locate the serial port ***MultiMax*** is currently connected to. This can be found in 'Device Manager' on a PC running Windows® at **A**.



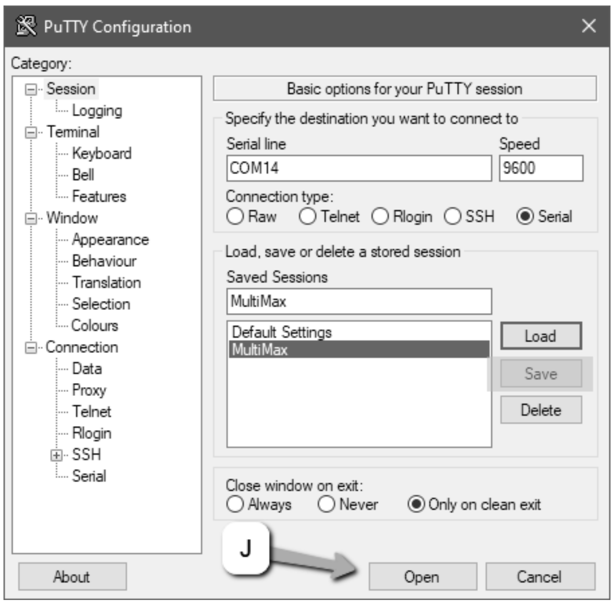
2) Start the PuTTY software program for configuration. Select the connection type **D**, the Serial Line **B**, the Speed **C**, and a name to save the Session to eliminate having to repeat the configuration process again at **E**.



3) Select the Serial option in Category at **G**, and all the Serial Line settings as set and displayed at **H**.

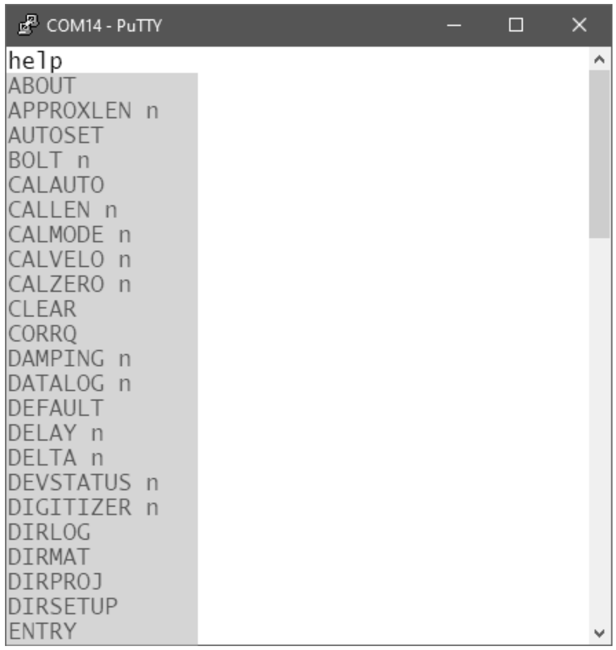


4) Select the Terminal option in Category, followed by selecting Force on for both Local echo and Local line editing at **I**.

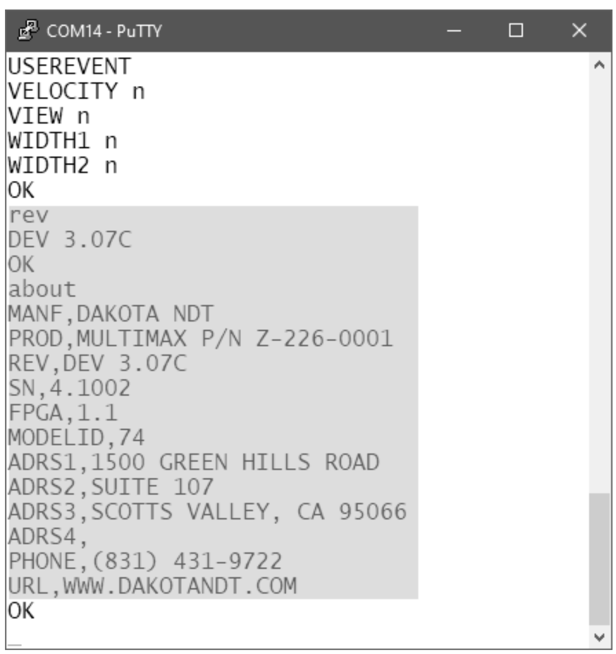


5) Select Session option in Category, and Save to store all settings in the session, and finally launching the terminal shell by selecting Open at **J**.

Note: ***MultiUI*** *cannot be running when attempting to connect to the* ***MultiMax*** *module with PuTTY or other terminal interface program. Close the* ***MultiUI*** *application prior to connecting.*



6) With the terminal shell running, type 'help' enter to display the command list in remote commander.



7) In the example above, the 'rev' command displayed the currently version of firmware 3.07C, and the 'about' command all the gauge and company information.

Note: *Contact Dakota NDT for additional documentation for remote commander.*

CHAPTER SIX
THEORY OF OPERATION

6.1 Ultrasonic Measurement of Bolts

Note: *The terms bolt, fastener, and threaded fastener are used interchangeably.*

Ultrasonic measurement has proven to be the most reliable and cost effective solution when:

- Variations in friction or joint geometry prevent applied torque from controlling the actual clamping force produced by the fastener with the required accuracy.
- The clamping force must be monitored over the service life of the bolt.

Ultrasonic measurement of clamping load is obtained through a predictable decrease in the sound velocity within the body of the bolt as the tensile load is increased. By introducing a sonic pulse at one end of the bolt and accurately measuring the time required for the echo to return from the opposite end, the ultrasonic length is determined. As the fastener is tightened, the change in this ultrasonic length is used to calculate and display the actual clamping force produced.

The physics governing this process are clearly understood, and have been employed for many years in the fields of active sonar, or radar. Send a pulse of energy toward an object (in this case the opposite or reflecting end of the fastener), and then measure the time between the initial pulse and the returning echo.

While the concept is comparatively simple and ultrasonic measurement can produce very accurate results, the selection of the optimum bolt and transducer and their coupling can be difficult. The ***MultiMax*** minimizes these difficulties to the greatest extent possible:

- The variable width pulser system can send the maximum amount of energy to the ultrasonic transducer, allowing the broadest possible range of transducers for a given application.
- The low noise and gain features of the receiver system allow signal detection and measurement in the most difficult applications.
- The digital signal processor optimizes the measurement process.

6.2 Purpose

The ***MultiMax*** measures the actual clamp load produced by tightening a fastener. It is capable of measuring in quantities of time(nanoseconds), elongation, load, stress, or %strain in variety of common materials from approximately 1 inch to 50 feet in length.

6.3 Ultrasonic waves

Ultrasonic measurement requires the transmission of a suitable quantity of ultrasonic energy through the length of the bolt. The relationship of the energy pulse frequency to its penetration is important in energy transmission. Lower frequencies produce wider wavelengths that will travel further through a given substance, while higher frequencies produce shorter wavelengths with less travel. An example might be; AM radio signals are broadcast at relatively low frequencies and can be received hundreds of miles away, over the horizon. Higher quality FM radio and television signals are broadcast at much higher frequencies, and can only be received within a comparatively short line-of-sight or distance.

The same phenomenon exists with ultrasound. A low frequency 1 MHz pulse travels much farther through metal than a 5 MHz pulse. Therefore, a lower frequency transducer is able to achieve an echo in a longer bolt, or in a bolt with higher resistance to sound transmission (attenuation). While the lower frequency has more penetration power, it also produces more unwanted noise. Low frequency energy tends to spread, much like an unfocussed beam of light. When low frequency energy is introduced at the end of a bolt, a significant portion is bounced from side to side within the cylindrical shape, producing a noisy and distorted echo. Higher frequency pulses tend to travel more directly down and back the centerline of a bolt, with less noise and distortion.

6.4 Measurement Mode

The ***MultiMax*** uses a standard pulse-echo (P-E) mode for measurement. This is accomplished by measuring from the initial pulse (sometimes referred to as an artificial zero) to the first echo (reflection). In this mode errors can result from surface coatings applied to the bolt, as well as temperature variations. However, typical protective surface coatings commonly applied to fasteners generally work fine.

CHAPTER SEVEN
BOLT PREPARATION

The best balance between maximum frequency and noise suppression requires selecting the best transducer for bolt measurement. The diameter of the transducer, generally specified by the diameter of the piezoelectric crystal, directly effects energy transmission. Larger diameter crystals have greater ability to send and receive energy (output), and less of the energy tends to spread laterally (directivity). Therefore, direct transmission of the strongest possible pulse with the least amount of noise and distortion.

7.1 Use of Ultrasonic Couplant

Sonic energy at the frequency range used by the ***MultiMax*** travels well through solid materials and most liquids. It does not travel well through air. This variable resistance to the passage of sonic energy is called *sonic impedance*. The sudden change in impedance occurs when the sound pulse attempts to cross the metal / air boundary at the end of the bolt, causing most of the energy to be reflected back to the transducer as an echo.

Any air gap between the face of the transducer and the end of the bolt will prevent the sonic energy from crossing. The gap must be filled with a suitable coupling fluid. Normally, a liquid ultrasonic couplant is applied between the transducer and the bolt. Since liquid is closer in impedance to the transducer and bolt material than air is, it forms a continuous path for the outgoing pulse and returning echo.

Many liquids can serve as an adequate couplant, however liquids with lower sonic attenuation will produce better results (ultrasonic couplant, water, glycerin, etc.). The single purpose of the couplant is to optimize the transfer of sound energy into the bolt. If a viscous couplant is used, be sure to seat and rotate the transducer left/right to squeeze out the excess couplant allowing the transducer to seat flat against the bolt.

7.2 Transducer Contact Requirements

The goal is to transmit as much sonic energy as possible from the transducer into the bolt, and to send that energy, to the greatest extent possible, down and back the center of the bolt, as shown in Figure 1.

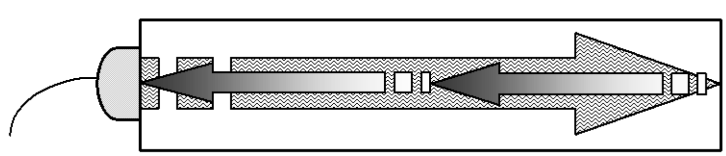


Figure 1 Sound path in a good bolt

Smooth, even surfaced bolt ends that seat the entire active surface of the transducer with minimum gap are required for accurate signal transmission. Bolt ends may need to be cleaned, ground, etc., to achieve the required surface.

Avoid:

- Rough or irregular surface's which prevent adequate contact with the transducer. Irregular or rough surfaces can be filled with couplant, but energy transmission will still be reduced and dispersed causing mode conversions to occur from reflections off the side walls of the bolt, as shown at left of Figure 2.
- Bolt ends not perpendicular to the axis of the bolt, as shown at right of Figure 2. Energy will be transmitted toward the side wall and reflect along the bolt, yielding poor signal quality and possible measurement errors. Avoid alignment errors exceeding 2 degrees.

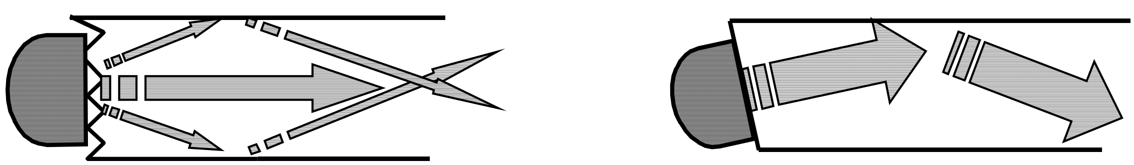


Figure 2 Rough and angled transducer contact

- Rusted, dirty, or thick paint-covered bolt ends. These coatings prevent sonic energy from traveling between the transducer and the bolt. Very thin coating or plating is acceptable.
- Bolt ends with recessed grademarks, as shown at left of Figure 3. Couplant can be used to fill recessed grademarks. Small indentations cause some loss of signal strength, but normal measurement is still possible. Large or numerous indentations cause the signal to be too weak for a reliable measurement.
- Bolt ends with raised grade marks, or indentations with a raised edge, which cause the transducer to be seated at an angle to the axis of the bolt, thus preventing adequate contact, as shown at right of Figure 3.

Figure 3 Effect of lowered and raised grade marks

7.3 Bolt End Reflectors

Smooth, flat reflecting bolt ends that are perpendicular to the axis of the bolt are required for accurate echo reception. Bolt ends may need to be cleaned, ground, etc., to achieve the required surface.

Note: *Misalignment exceeding 2 degrees can cause significant errors.*

Avoid:

- Rough reflecting bolt ends. As shown in Figure 4, if the reflecting end of the bolt is rough or curved, most of the reflected energy will be dispersed and a weak or distorted echo will be received.
- Reflecting bolt ends not perpendicular to the axis of the bolt. Sonic energy will be reflected toward the sidewall of the bolt, as shown in Figure 5.
- Nonperpendicular reflecting bolt ends due to bending of the bolt as shown in Figure 6.

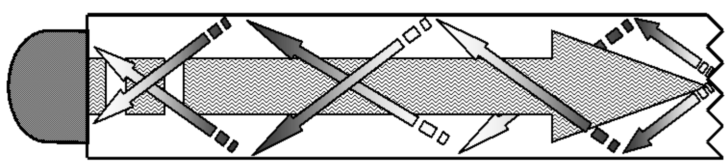


Figure 4 Rough reflective surface

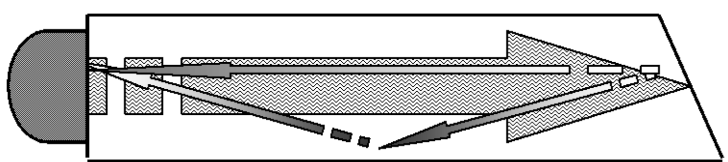


Figure 5 Non Parallel reflecting Surface

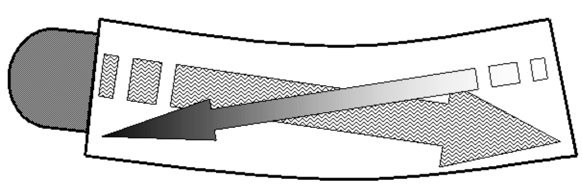


Figure 6 Reflection in a bending bolt

CHAPTER EIGHT
TRANSDUCER SELECTION

8.1 Selecting the Transducer

Transducer selection is an important part of getting the best results from the ***MultiMax***. The frequency and diameter of the transducer should be carefully selected using the following information:

- Select the largest diameter transducer that will nicely seat on the end of the bolt. If there are multiple applications and diameters to consider, select a diameter that will work for as many applications as possible, thus reducing the overall number of transducers needed.
- When selecting the proper frequency, the following items should be taken into consideration:

    Higher frequencies are typically a better choice when measuring smaller diameter bolts as the sound is better focused resulting in less beam spread and more directivity.

    Lower frequencies are more forgiving of potential bending and attenuative materials. This is primarily due to the longer wavelength avoiding smearing or distortion of the waveform. Longer wavelengths require more of a phase shift before distortion will occur. Lower frequencies offer an increased amount of dispersion and a reduced amount of directivity. As this may seem to go against what might typically be considered a good selection, in the case of bending it’s actually the best option overall.

CHAPTER NINE
MEASURING SYSTEM ZERO (CALIBRATION)

9.1 Introduction

This chapter will be focused on establishing a system delay/zero for each bolt/channel, enabling the group data to be portable between different hardware modules with limited measuring error. Data generated using one ***MultiMax***, can be loaded into another ***MultiMax***, using the transducer type (diameter & frequency), similar cable (length & type), a new zero established, and the measurement process continued. Every ***MultiMax***, transducer, and cable will have a slightly different system delay, due to electronic component and material variations. However small, even identical transducers by diameter and frequency may result in different delay times. When porting existing data to another hardware module, it's always optimal to use the same transducer diameter, frequency, and cable length to minimize potential measurement error. These items should be documented for future reference.

While the ***MultiMax*** can be used for a variety of applications, like the ***MiniMax*** and ***Max II*** gauges, it was developed with the intention of those applications seeking some form of 'permanent monitoring' of bolts, in strategic positions, from any location around the globe and not as much for portable applications. While it can also be used for portable applications, its intended purpose is to address those 'permanent' applications, like offshore wind power and remote access areas.

Note: *<u>Setting the Zero Mode to the "Fixed" option effectively disables the zero feature, setting the zero value to "0". Not recommended for continuous monitoring.</u>*

Note: *In remote monitoring applications, an Auto Zero should 'always' be performed on each and every bolt in the event that a transducer, module, or cable fails and needs to be replaced. The same transducer diameter and frequency should be used, as well as the same cable type and length, to limit the variances.*

*If the hardware has changed, the zero should be checked/compared against the previous zero calibration group in the folder CAL_ZERO_DATA stored as a sub folder in the 'GroupLogs' folder on the PC where **MultiUI** software is installed, or on the internal SD card of the **MultiMax**.*

9.2 Calibration / Zero Misnomer

Zeroing the ***MultiMax*** is not equivalent to calibrating the unit. Successfully measuring the calibration bars within a specified tolerance is not the same as calibrating the gauge. However, it does demonstrate linearity or stability of the timing circuitry.

Note: *The **MultiMax** should be sent in for calibration by Dakota NDT, or other authorized service representative, on a periodic basis to verify proper operation of the* *instrument. Check in with your quality department to verify their duration requirement for "Test & Measurement Equipment".*

9.3 Creating a Group to Document Zero (Calibration) data

A project folder named "CAL_ZERO_DATA" will automatically be created as a sub folder in the 'GroupLogs' folder on the PC where ***MultiUI*** software is installed, and on the internal SD card following the completion of an "Auto" calibration…if one doesn't already exist. A group/log will automatically be created inside of the 'project folder' with a 'date/time' stamp, each and every time the zero process has been successfully completed. By default, the group/log will consist of 5 bolts and 10 measurements per bolt, allowing for additional calibration points, verification, and recordation. The group log will contain the zero measurements, as well as the diameter and calculated frequency of the transducer used.

The log files created and stored on both the SD memory card and PC, will remain on the both until manually deleted, and provide the user with additional documentation regarding when the zero process was performed, as well as the outcome of the zero calibration process. When using the 'Archive All Logs' feature, all group and cal zero logs will be transferred to the host PC and stored in a sub folder of 'GroupLogs' in an archive folder with a time and date stamp. This not only acts as a backup for all zero data, but is additionally convenient for reviewing the data in DakView software.

File Name (format): CALZERO230815_132519
Date(yr/month/day)_Time(hr/min/sec)

<u>**Note:**</u> *Refer to Chapter Sixteen for additional information on data storage and editing/viewing files.*

<u>Overview</u>

9.4 Auto - Zero/Calibration

The auto calibration feature uses a single steel 3" calibration bar and two measurements, the second at twice the length (i.e. 3" bar at 3" & 6"). The measurement process is done in an echo-echo mode (E-E) to compensate for temperature. The process is fully automated and easy to use. If valid signals cannot be acquired during the 'auto set' routine, the ***MultiMax*** will report an error. If this occurs, try relocating the transducer to various positions on the end of the 3" calibration bar, and repeat the routine. If a 3" cylindrical carbon steel calibration standard is used, it can sometimes create substantial sidewall noise depending on the transducer size and frequency. Moving the transducer closer to the edge of the cylinder will often times eliminate the noise by shooting down the edge of the cylinder, allowing the ***MultiMax*** to acquire a stable echo.

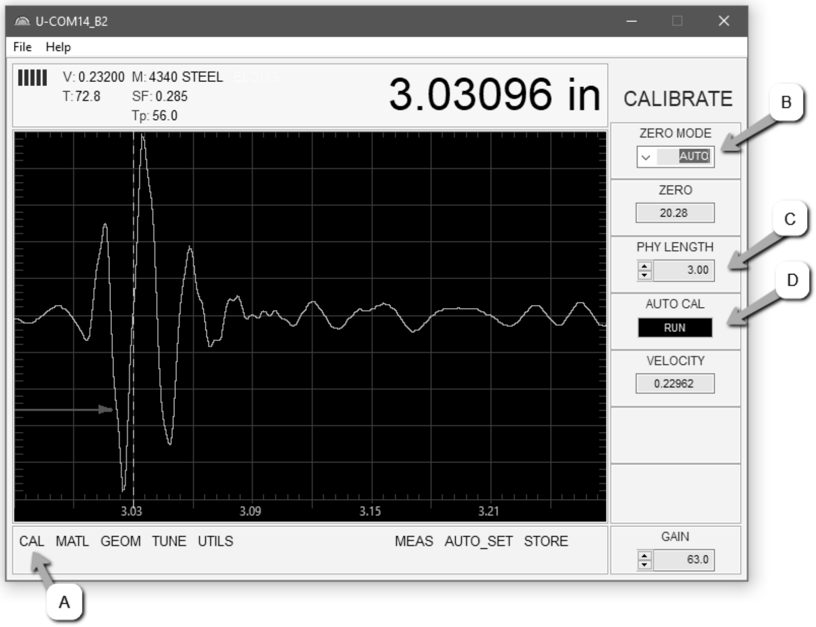
Note: *The Auto Zero/calibration should done for each and every bolt/channel at install. This should only be repeated if the hardware has changed in any way (i.e. gauge, transducer cable, or transducer).*

Note: *The calibration bar noted above is supplied by Dakota NDT. It is supplied primarily for use with the single and two point calibration options. However, since auto mode is the only zero calibration option offered in the **MultiMax**, and measures in echo-echo mode, there are no disadvantages to using a carbon steel calibration standard at 3" in length.*

<u>Caution:</u>

*A very small amount of **"WATER"**, or other non-intrusive fluid with a similar viscosity, should be used as the couplant between the transducer and the end of the 3"* *calibration bar. This will avoid creating a couplant film layer between them, causing an "out of tolerance" condition > +/- 0.001" for the 3" cal bar.*

Auto System Zero

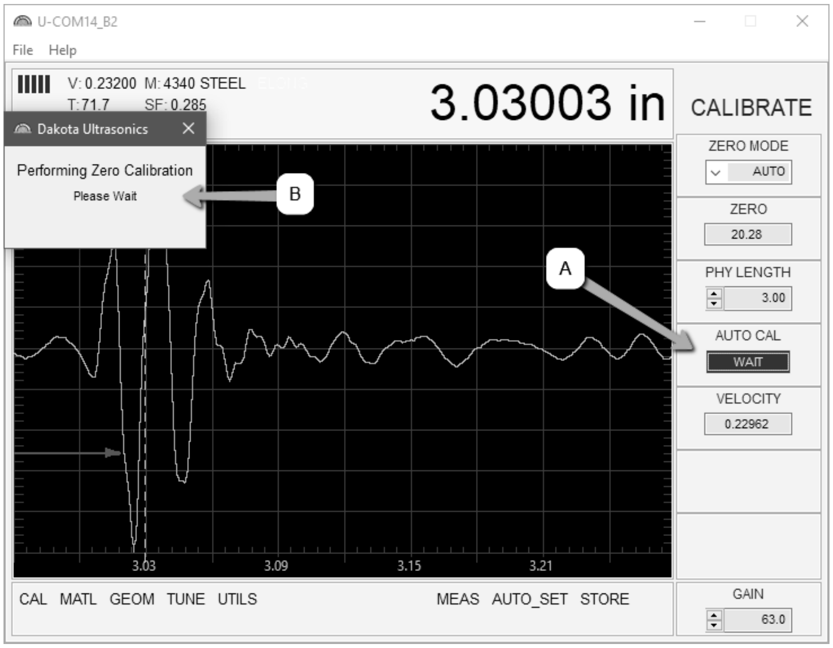


Note: *The auto option will perform a two-point calibration using a single 3" cal bar (pt# X-000-0011) and measurements of 1x & 2x lengths.*

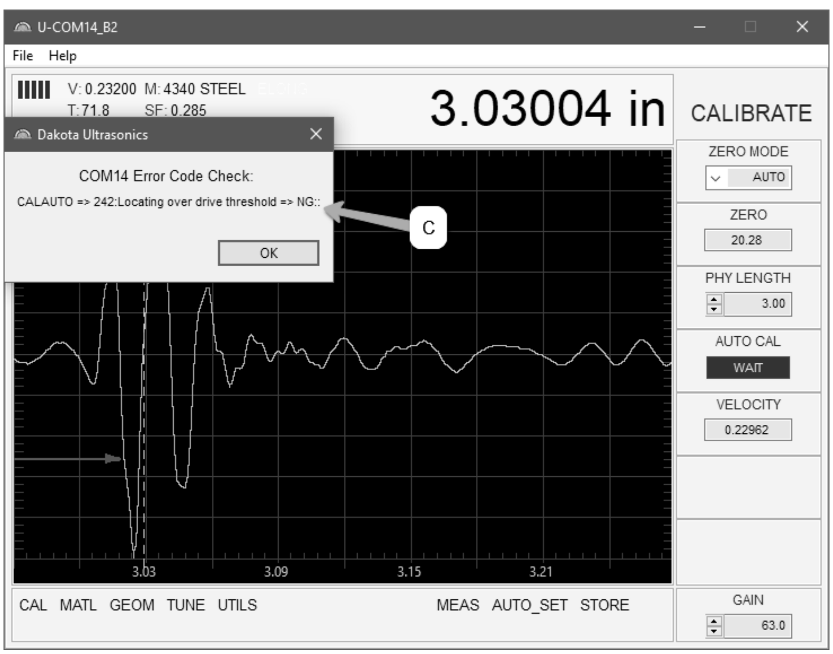
1) Click the **CAL** tab at **A** to display the CALIBRATE menu items.

2) Click the down arrow to display the ZERO MODE options at **B** and select the **AUTO** option.

3) Use the auto scroll arrows to enter the **PHY LEN** at **C** (physical length) of the 3" cal bar. Alternatively, click inside the numeric field at **C** to edit manually using a keyboard.



4) Click the **RUN** button in AUTO CAL to initiate the calibration process. The RUN button will now display **WAIT** at **A**, and a dialog box will appear at **B** as the automated process is underway. Once the dialog box is no longer displayed, the ZERO CALIBRATION has completed.



Note: *If the zero is unsuccessful, a dialog error box will appear at* **C**. *Check that the transducer has sufficient couplant and is seated properly on the cal* *bar. If diameter of the transducer is relatively smaller than the diameter of the cal bar, consider moving the transducer location towards the edge of the cal bar to avoid sidewall noise, and repeat step 4. When the dialog box is no longer displayed, the zero calibration has been successfully completed and documented in the CAL_ZERO_DATA folder. This folder can be found in a sub folder called 'GroupLogs', where the MultiUI java interface software is located.*

Note: *Refer to Chapter Sixteen for additional information on data storage and editing/viewing files.*

CHAPTER TEN
TEMPERATURE COMPENSATION

10.1 Purpose

The temperature of a fastener affects the overall physical length, as well as the velocity of a fastener. As the temperature of a fastener increases, the ultrasonic length increases at a rate greater than the physical change in length. If the user intends to measure the same fastener at different time intervals over the service life of the bolt, temperature compensation is very important to produce accurate results. However, if a fastener will only be measured once, never to be measured again, temperature compensation is not needed, as long as the reference length and elongation are measured at the same temperature.

The thermal expansion of the fastener and the ultrasonic change in velocity, as a result of temperature, are two separate effects. However, for the purpose of the ***MultiMax***, they are combined in a single factor known as the Temperature Coefficient (Tc). The sections that follow outline the procedures for selecting and using the temperature compensation mode with the accessory temperature sensor.

10.2 Temperature Modes

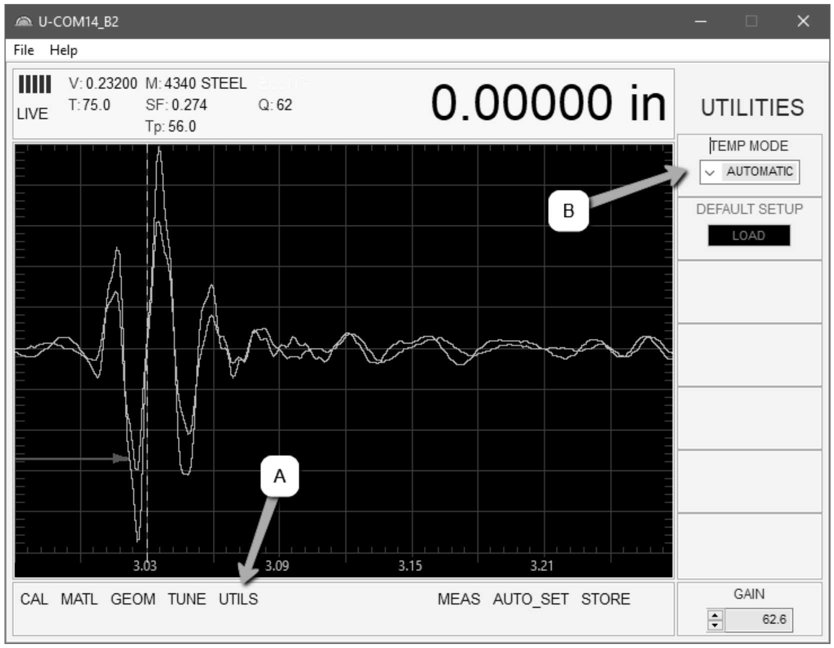
Manual –

The manual mode option relies on the user to externally measure and enter in the current temperature before storing the measurement. Used for applications where temperature compensation is not required, using an external temperature device, or are in a temperature controlled environment. Not recommended for applications with continuous monitoring.

Automatic –

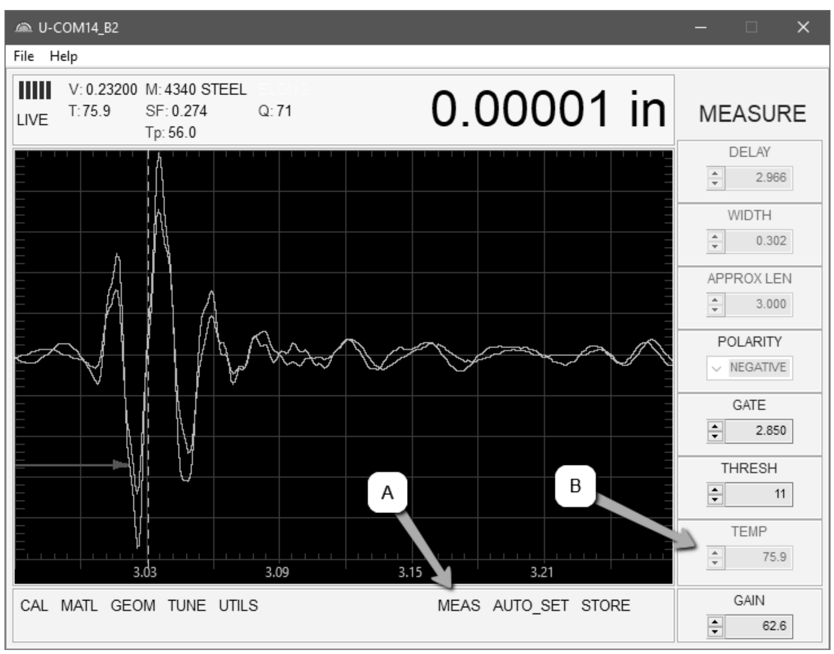
The automatic mode is continuously monitoring and compensating for temperature for every measurement recorded. The ***MultiMax*** is equipped with a single temperature sensor that is used to monitor temperature for all four channels of a given module. The transducers and temp sensor should be located in close proximity to one another for every individual module, and the sensor located near the joint where the bolts are attached with similar material and temperature absorption for the best accuracy.

<u>Selecting Temperature Mode</u>



1) Click the **UTILS** tab at **A** to display the UTILITIES menu items.

2) Click the down arrow to display the TEMP MODE options and select the temperature mode at **B**.



Note: *If the "manual" option is selected and an external temperature device will be used, or in a climate controlled environment, be sure to enter the correct temperature in the **TEMP** field prior to storing a measurements.*

3) Click the **MEAS** tab at **A** to display the MEASURE menu items.

4) Use the auto scroll arrows to ente r the **TEMP** at **B**. Alternatively, click inside the numeric field at **B** to edit manually using a keyboard.

CHAPTER ELEVEN
BOLT MATERIAL CALIBRATION

11.1 Why Calibrate?

The preset bolt types in the ***MultiMax*** contain average factors for the material type. These are approximate values only. In a tightly controlled application where extreme accuracy is required, it is necessary to obtain all the information possible about the fasteners being measured. By calibrating the fasteners, the ultrasonic and physical lengths of the bolts will match. However, if a field calibration is done, a complete calibration is not necessary. An important thing to note is the fact that everything done in the calibration process result in average values. Since a sample of fasteners will be used in the calibration process, and given the slight differences in material, the result will always be an average value of that sample.

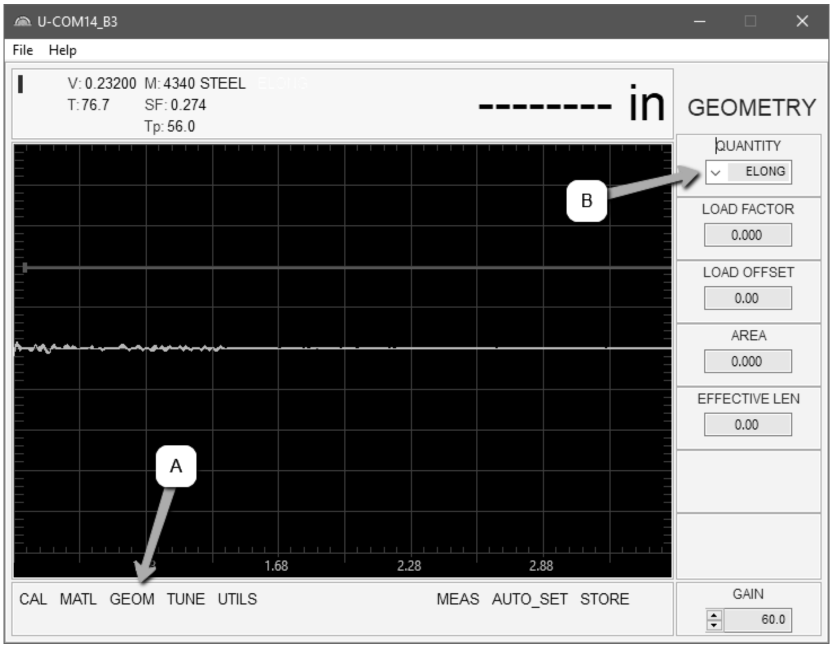
11.2 Material Calibration

The ***MultiMax*** has been configured and setup for the permanent monitoring of fasteners in specialized applications like off-shore wind towers. As a result of the overall data structure and storage, the ***MultiMax*** does not contain the functionality required to perform 'Field Calibrations' easily. Therefore, if these tools are required, please refer to our 'standalone' gauges, MiniMax or Max II, for additional information. Both models will provide the toolkits necessary to perform calibrations, and the parameters can then be entered into the ***MultiUI*** software to display the other quantities (Load, Stress, or Strain). Finally, the majority of the parameters can be manually calculated and estimated by hand, and in combination with using our DakView utility software calculator.

11.3 Velocity Calibration

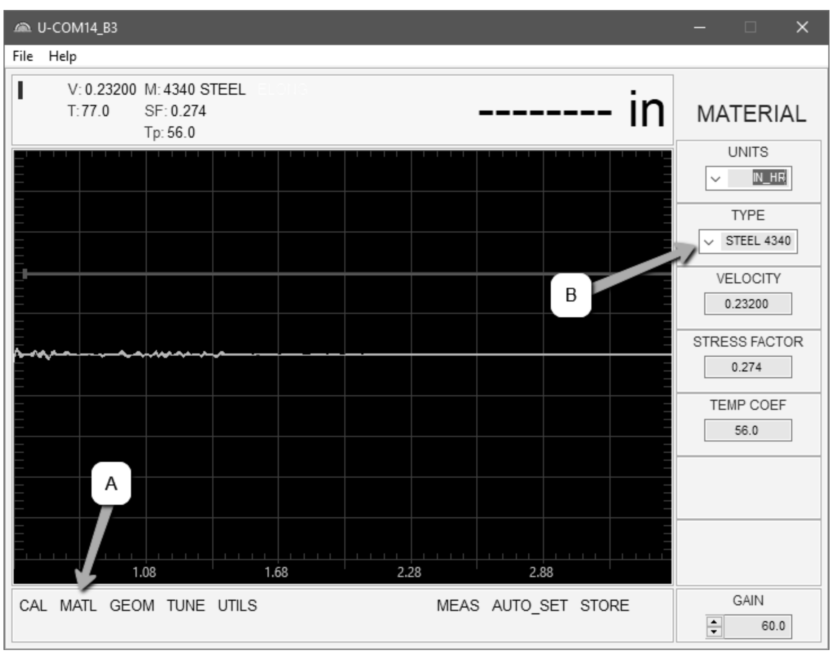
A velocity calibration is generally performed by adjusting the velocity in the ***MultiMax*** to the point where the ultrasonic and physical lengths match. Again, since a sample of fasteners will be used in this process, the velocities will vary by a small amount, thus resulting in an average velocity value. To accurately calibrate the velocity, a calibrated set of mechanical calipers is required to determine the exact physical lengths of the fasteners. The following procedure outlines this process.

Calibrating the Velocity



1) Click the **GEOM** tab at **A** to display the GEOMETRY menu items.

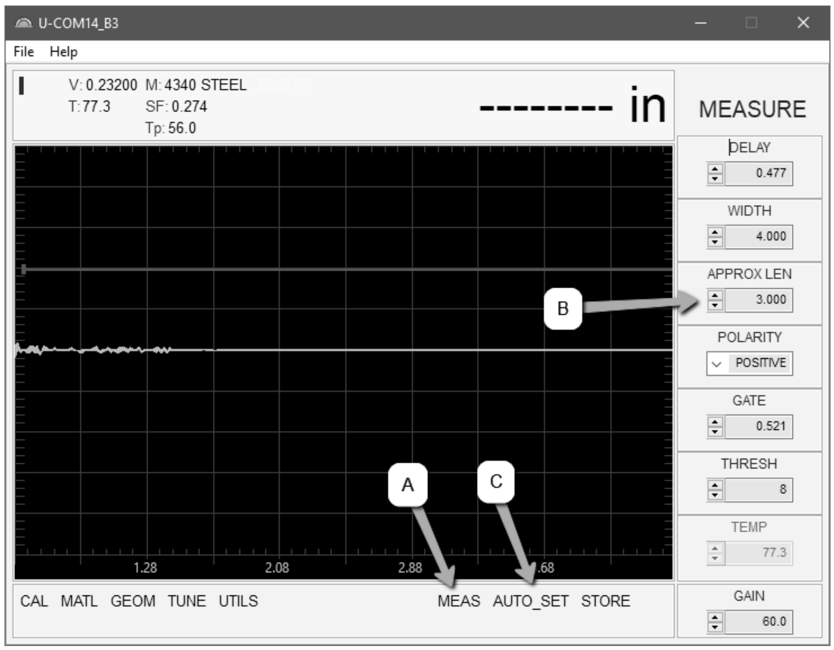
2) Click the down arrow to display the QUANTITY options and select **ELONG** at **B**.



3) Click the **MATL** tab at **A** to display the MATERIAL menu items.

4) Click the down arrow to display the **TYPE** options and select the material type at **B**.

Note: *If the material type is not in the list of types, select a similar type. This step is only to get the velocity value in close proximity – not critical.* ***Write down the velocity of the material type selected. This will be considered the Current Velocity.***



5) Click the **MEAS** tab at **A** to display the MEASURE menu items.

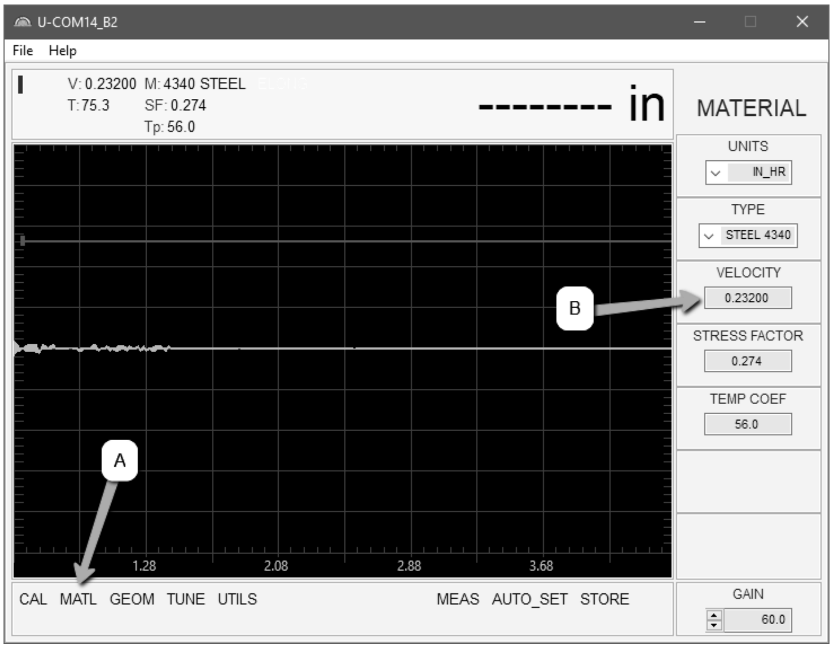
6) Use the auto scroll arrows to enter the **APPROX LEN** at **B**. Alternatively, click inside the numeric field at **B** to edit manually using a keyboard.

7) Apply a drop of couplant to the bolt or transducer, and attach it to one end of the bolt. Rotate the transducer clockwise and counter clockwise applying a small amount of pressure to eliminate any excess couplant between the transducer and bolt surface. *Be sure to always place the transducer in the same location*. *This will help to eliminate any potential measurement errors caused by changing the sound path.*

8) Click the **AUTO SET** tab at **C** to activate the Auto Set routine and display the Ultrasonic Length.

$$\frac{PhysicalLength}{UltrasonicLength} * CurrentVelocity = CorrectVelocity$$

9) Calculate the correct velocity using the equation displayed above.



10) Click the **MATL** tab at **A** to display the MATERIAL menu items.

11) Click inside the numeric field at **B** to manually the correct VELOCITY calculated above.

Note: *The ultrasonic length displayed should now match the known physical length.*

11.4 Stress factor calibration

The sonic stress factor is an empirically determined value for the bolt material, or type of bolt being measured. It expresses the ratio of the actual elongation/stretch of the bolt, to the apparent ultrasonic change in length. Since the change in ultrasonic length is approximately 3 times the change in physical length, due to the change in velocity, a stress factor must be applied to correct the ultrasonic length in the ***MultiMax***.

The following steps determine the Sonic Stress Factor for bolts of a specific bolt material and specific geometry by measurement of the actual change in bolt length.

Required Equipment:

- A laboratory or room in which the temperature can be maintained at between 66° to 70° F.
- A means of applying load to the bolt. Ideally this would be a tensile load machine, capable of measuring the applied load to within 100 lbs. However, since the actual value of the applied load is not used in calculating the stress factor, any means of applying an approximate load to the bolt will suffice. This includes tightening the bolt against a fixture that simulates the actual joint. A mechanical means of traceable measurement of the physical length of the sample fasteners at various tensile loads to an accuracy of plus or minus 0.0001 inch. Examples of such devices include the following
  - Length measurement function of sophisticated tensile test machine
  - Mechanical or electronic height gages
  - Averaged values of length measurement with mechanical and electric micrometers.
- A Dakota NDT ***MultiMax*** Bolt Tension Monitor.
- A minimum of three sample bolts which are representative of the bolt type and geometry for which the Sonic Stress Factor is to be determined.

Notes:

- The Dakota NDT ***MultiMax*** must be calibrated, or zeroed, as described in the Zero Calibration procedure section **Error! Reference source not found.**.
- The Velocity Calibration should be performed prior to determining the Stress Factor. Refer to section 11.2.
- The sample bolts must be left to soak in the controlled temperature environment for a period of not less than 24 hours. Care must be taken throughout the measurement process to avoid significant change in the bolt temperature due to handling of the sample bolts, or the process of applying load.
- The mechanical apparatus for measurement of length must be calibrated in accord with governing QA procedures. The device should be configured so that minimum handling of the sample bolts will be required during the measurement process.

Determination of the Sonic Stress Factor is accomplished by solving the equation:

$$SonicStressFactor = \frac{\Delta L_{MECHANICAL}}{\Delta L_{ULTRASONIC}} = \frac{L_{Ml} - L_{M0}}{L_{Ul} - L_{U0}}$$

$$L_{U0} = UltrasonicLength@ZeroLoad$$
$$L_{M0} = MechanicalLength@ZeroLoad$$
$$L_{Ul} = UltrasonicLength@Load$$
$$L_{Ml} = MechanicalLength@Load$$

Calibrating the Stress Factor

1) *Using the mechanical measuring device, measure and record the Mechanical Length at Zero Load "L_{M0}" for each sample bolt.*

Note: *The following steps assume that the user has performed the steps in the previous section and calibrated the velocity. Therefore, the velocity has been adjusted, approximate length already entered, and the* ***MultiMax*** *is currently setup and ready to measure in elongation mode.*

2) Apply a drop of couplant to the bolt or transducer, and attach it to one end of the bolt. Rotate the transducer clockwise and counter clockwise applying a small amount of pressure to eliminate any excess couplant between the transducer and bolt. *Be sure to always place the transducer in the same location*. *This will help to eliminate any potential measurement errors caused by changing the sound path.*
3) Record the Ultrasonic Length at Zero Load "L_{U0}".
4) **Repeat step 2 & 3** for each sample bolt.
5) *Place the first sample bolt in the loading apparatus. Apply approximately 1/3 of the maximum load, which is to be placed on the bolt under actual*

working conditions. Using the mechanical measuring device, measure and record the Mechanical Length at Load 1 "L_{M1}" for the current sample bolt.

6) Apply a drop of couplant to the bolt or transducer, and attach it to one end of the bolt. Rotate the transducer clockwise and counter clockwise applying a small amount of pressure to eliminate any excess couplant between the transducer and bolt. Measure and record the Ultrasonic Length at Load 1 "L_{U1}"for the current sample bolt.

7) *Increase the applied load to approximately 2/3 of the maximum load, which is to be placed on the bolt under actual working conditions. Using the mechanical measuring device, measure and record the Mechanical Length at Load 2 "L_{M2}" for the current sample bolt.*

8) Apply a drop of couplant to the bolt or transducer, and attach it to one end of the bolt. Rotate the transducer clockwise and counter clockwise applying a small amount of pressure to eliminate any excess couplant between the transducer and bolt. Measure and record the Ultrasonic Length at Load 2 "L_{U2}" for the current sample bolt.

9) *Increase the applied load to approximately the maximum load, which is to be placed on the bolt under actual working conditions. Using the mechanical measuring device, measure and record the Mechanical Length at Load 3 "L_{M3}" for the current sample bolt.*

10) Apply a drop of couplant to the bolt or transducer, and attach it to one end of the bolt. Rotate the transducer clockwise and counter clockwise applying a small amount of pressure to eliminate any excess couplant between the transducer and bolt. Measure and record the Ultrasonic Length at Load 3 "L_{U3}" (Maximum) for the current sample bolt.

11) **Repeat Steps 5 – 10** for the remaining bolts.

12) *Calculate the value of the Sonic Stress Factor at each load on each sample bolt.*

$$SSF_{B1L1} = \frac{L_{M1} - L_{M0}}{L_{U1} - L_{U0}} \quad SSF_{B1L2} = \frac{L_{M2} - L_{M0}}{L_{U2} - L_{U0}} \quad SSF_{B1L3} = \frac{L_{M3} - L_{M0}}{L_{U3} - L_{U0}}$$

13) *Determine the average value of the Sonic Stress Factor by dividing the sum of all SSF values divided by the total number of SSF values.*

11.5 Temperature Factor Calibration

The thermal expansion of the fastener and the ultrasonic velocity change with temperature are two separate effects. However, for the purpose of the ***MultiMax*** they are combined into a single factor known as the Temperature Factor. The important thing to note is that both the thermal expansion and the velocity are changing with respect to changes in temperature. The ***MultiMax*** always measures a fastener at 68° F. If the temperature of the fastener is currently being measured at 108° F, the ***MultiMax*** will compensate, or correct, the measurement back to 68° F.

Note: *This is an arbitrary temperature range only. The primary thing to consider is to use a respectable temperature range with at least 5 different temperature points. The following procedure outlines the process for experimental determination of the Temperature Factor for a bolt made of a specific material type and geometry.*

Required Equipment:

- A means of varying and measuring the temperature of the sample bolts between 48° to 108° F to an accuracy of +/- 2° F. The device must allow for a transducer to be connected to one end of the bolt for the purpose of measuring.

  Many sophisticated temperature chambers are commercially available, and ideally suited for this function. However, a simple and inexpensive method can be achieved by immersion of the sample bolts in a water bath, which can be heated to boiling or cooled by adding ice. At sea level this will reliably vary the bolt temperature between approximately 48° to 108° F depending on water purity and atmospheric pressure. By measuring the temperature of the stirred water bath with a precise mercury thermometer, while reading the ultrasonic length of the bolt, accurate calibration points can be obtained.

- A Dakota NDT ***MultiMax*** Bolt Tension Monitor.

- A minimum of three sample bolts, which are representative of the bolt type and geometry for which the Temperature Factor is to be determined.

Notes:

- The Dakota NDT ***MultiMax*** must be calibrated, or zeroed, as described in the procedure entitled Measuring System Zero in 9.1.
- The sample bolts should be left to soak at the measured temperature points for a period of not less than 20 minutes, to insure that temperature is uniform throughout the sample.
- If a water bath is used, care must be taken to avoid immersion of the ultrasonic transducer.

Determination of the Temperature Factor is accomplished by solving the equation:

$T_p = \frac{(L_0 - L_T)}{L_T (T_0 - T)} \times 10^6$ Temperature Factor	L_0 = *Ultrasonic Length at Beginning Temperature* (T_0) L_T = *Ultrasonic Length at Ending Temperature* (T) T_0 = *Beginning Temperature* T = *Ending Temperature*

Calibrating the Temperature Factor

1) *Stabilize the sample bolt at approximately* 48^0 *F. If the water bath method is used this is accomplished in a stirred bath of ice and water. Measure and record this minimum temperature as* T_0.

Note: *The following steps assume that the user has performed the steps in the previous section and calibrated the velocity. Therefore, the velocity has been adjusted, approximate length already entered, and the* ***MultiMax*** *is currently setup and ready to measure in elongation mode.*

2) Apply a drop of couplant to the bolt or transducer, and attach it to one end of the bolt. Rotate the transducer clockwise and counter clockwise applying a small amount of pressure to eliminate any excess couplant between the

transducer and bolt. *Be sure to always place the transducer in the same location. This will help to eliminate any potential measurement errors caused by changing the sound path.*

3) Record the ultrasonic length “L_0” of the sample bolt at the above minimum temperature - 48^0 F.

4) **Repeat step 1 - 3** at the target temperatures (T_1 through T_5) – 48, 68, 88, and 108 ^{0} F (other similar range with 5 temperatures), measuring the ultrasonic lengths (L_1 through L_5) respectively. This process must be done for each of the sample bolts in the experiment.

5) Use the equation below to calculate a linear regression, using the temperatures and lengths recorded for all the sample bolts to determine the temperature factor.

$$TemperatureFactor = \frac{\sum xy - \frac{\left(\sum x\right)\left(\sum y\right)}{n}}{\sum x^2 - \frac{\sum (x)^2}{n}} * 10^6$$

x = temperature, y = change in reference length, n = number of sample points per bolt

CHAPTER TWELVE
LOAD MEASURMENT

12.1 Calculating Load Factor

The load factor is an empirically determined value for the geometry of the bolt. It is the amount of load required to stretch/elongate the bolt 0.001” in English Units or 0.01mm in Metric Units. The accurate load factor for the bolts being measured is determined by the Calibrate Bolt function.

An approximate value of this geometry dependent factor can be calculated as follows:

$$L_F = \frac{A_\sigma E}{(C_L + D)} \times 10^{-3}$$

Load Factor

A_σ = *Cross Sectional Area of the Bolt*
E = *Modulus of Elasticity*
C_L = *Clamp Length of the Bolt*
D = *Diameter of the Bolt*

Note: *If no load factor has been entered the MultiMax defaults to zero.*

The relationship between load and elongation is a function of the elasticity of the bolt material, and the geometry of the bolt in the application being measured.

Hooke’s Law expresses this relationship:

$P = \frac{\Delta l \times AE}{L_E}$ Hooke’s Law	P = *Load* L_E = *Average length under stress* ΔL = *Change in Length (elongation)* A = *Cross sectional area of the bolt* E = Modulus of elasticity

The cross sectional area of the bolt is defined as the average area of a fastener under stress. This factor is only used in the ***MultiMax’s*** calculation of load. It has no effect on stress or elongation, time, or strain, and is directly proportional to the load measured ultrasonically. If the cross sectional area is off by 5%, the load measurement will also be off by 5% proportionally. For a cylindrical bolt with the same geometry, the area may be approximated as follows:

$A = \pi\left(\frac{D}{2}\right)^2$ Area	D = *minor diameter of the bolt, allowing for threads.*

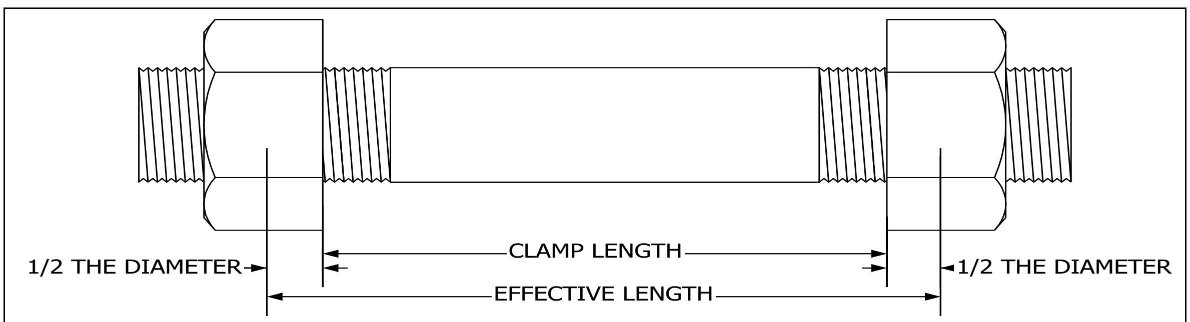
For bolts with complex geometry, the areas should be estimated by averaging each individual area and length. In the case of a hollow fastener, the area of the hole must be subtracted from the overall area. The area of a fastener with complex geometry can be estimated as follows:

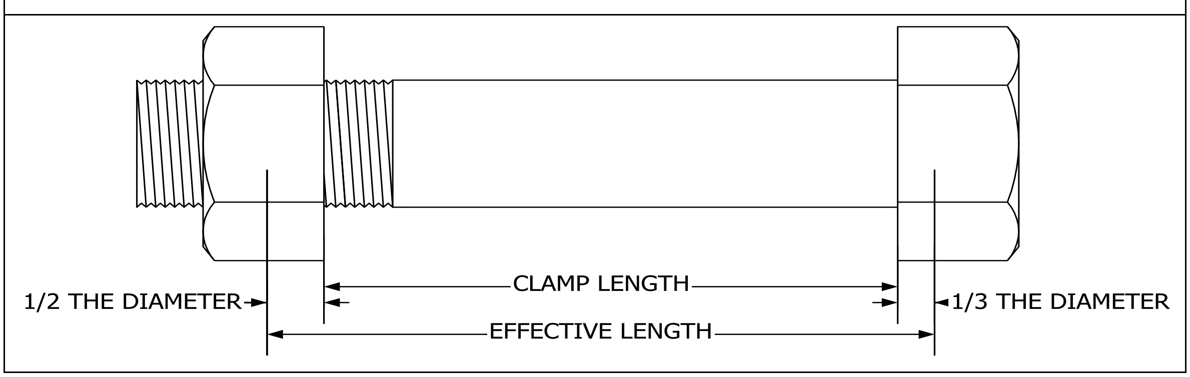
$A_{AVG} = \frac{\sum AL}{\sum L}$ Average Area	*A = Area of a region* *L = Length of a region*

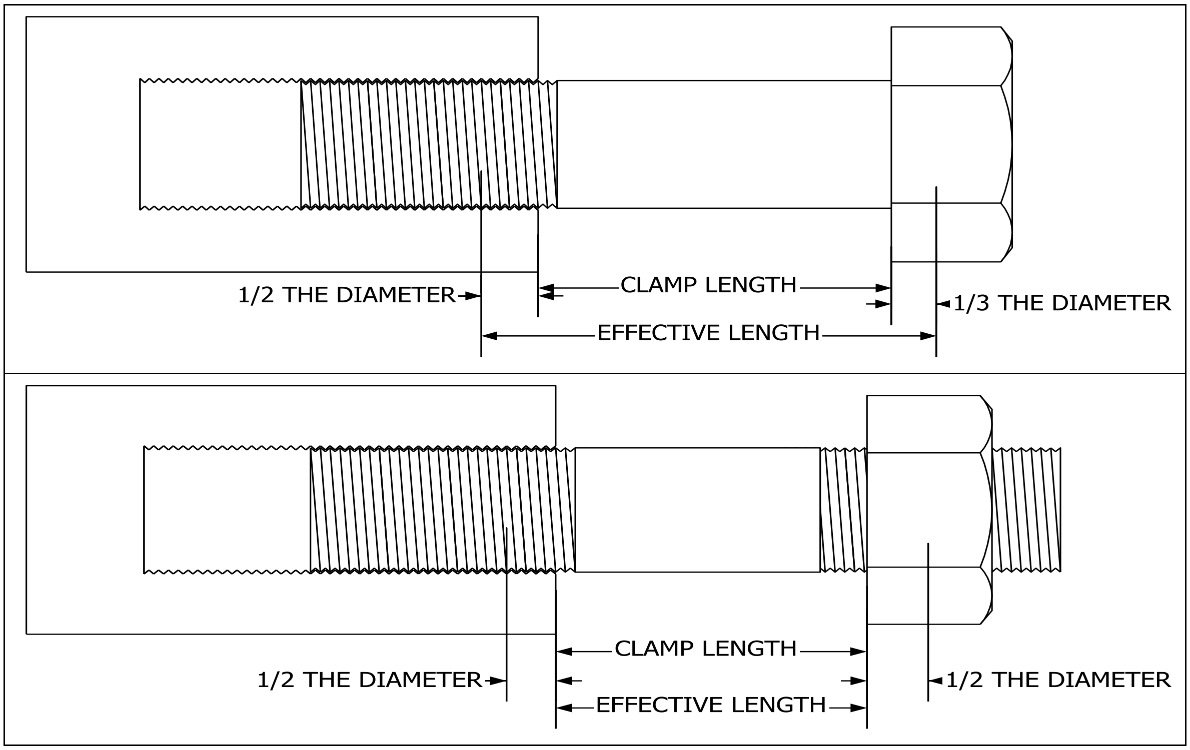
The value for the Modulus of Elasticity, or Young's Modulus, should be provided directly from the manufacturer of the bolts.

E = Modulus of Elasticity of the Bolt Material	*From Manufacturer*

The effective length is the average length of the fastener under stress when a load is applied. For an applied constant load, the elongation of a fastener is directly proportional to the effective length. Therefore, errors in the effective length will result in load errors by a proportional amount. The effective length of a fastener is a combination of the actual clamp length of the joint being fastened, plus that area of stress found in the head, nut(s), and or blind hole of the fastener.







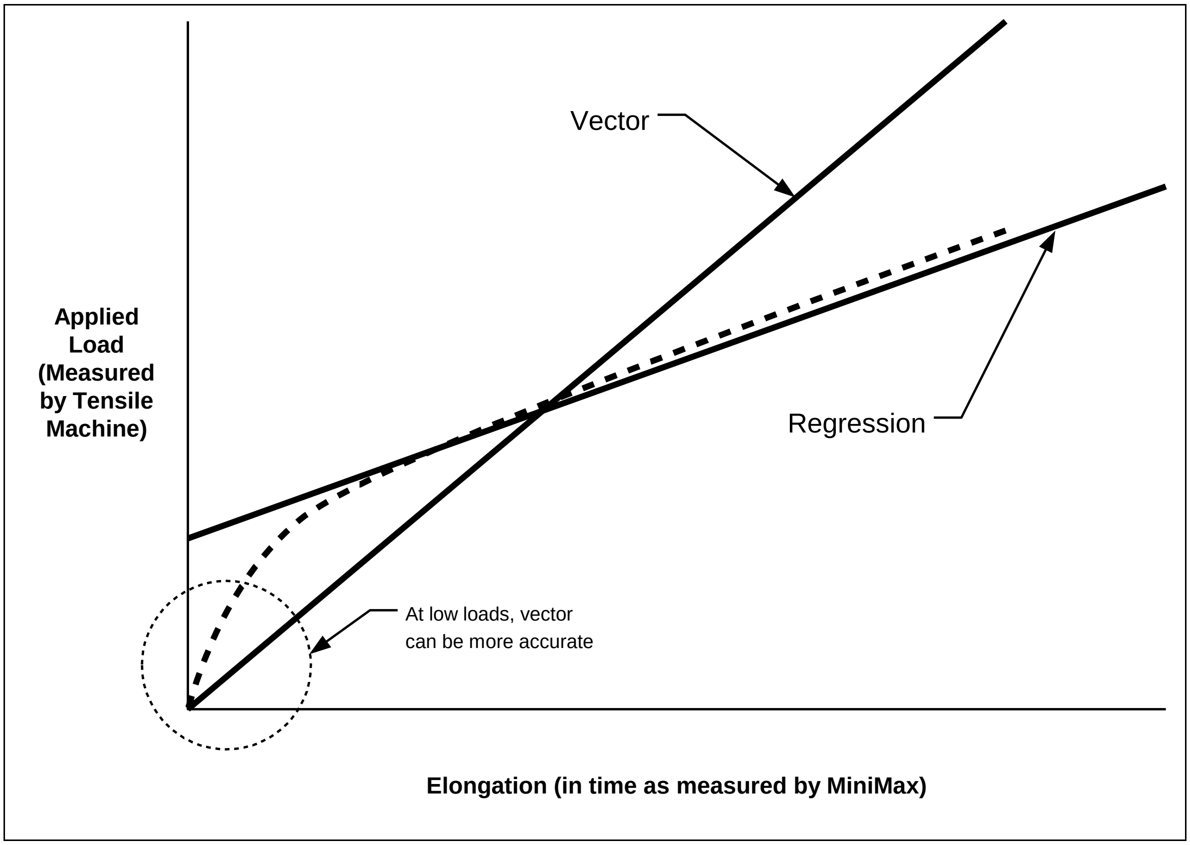
$L_E = C_L + D_X$ Effective Length	L_E = *Average length under stress* C_L = *Clamp length* D_X = *Additional diameter added for head, nut(s), and or blind hole.*

Note: *A convenient way to perform the above Load Factor calculations is to use the bolt calculator included in the DakView PC software. It's important to note that performing the calculations above is only a good approximation at best. In all cases, if possible, a field calibration should be performed if the user intends to perform measurements in terms of load.*

12.2 Calibrating Load Factor (Field Calibration)

The most effective way of calibrating the load factor is by performing a field calibration. Often times, material constants are unknown or cannot be calibrated in a laboratory environment. In cases such as these, a field calibration is the most accurate means of calibration. A field calibration is accomplished using a tensile tester, load cell, or other calibrated load device to compare known loads against ultrasonic elongations. The ***MultiMax*** is equipped with a self- calibrating feature that uses a linear regression or vector equation to produce a best-fit line through the known loads, minimizing error.

The result is an added load offset (intercept), in the case of regression, and a load factor (slope) to correct the ultrasonic measurements to the known loads. The regression produces a load offset and load factor, while the vector sets the offset to zero and produces only a load factor. Why are both options needed? In applications where a small amount of load is applied to the fastener, thus producing very little elongation, the regression option can potentially produce non-linear results. In cases such as these, a vector may sometimes produce better results as the offset is set at zero. It is recommended to use and compare both results, following a field calibration, to determine which method is most suitable for the application and producing the best results.



Note: *This calibration feature/option is not offered as part of the* ***MultiMax*** *platform, as it was designed to be focused as a multi channel platform for permanent monitoring. If bolt material calibrations are required, a separate* ***Max II*** *or* ***MiniMax****, equipped with this functionality, will additionally be needed for calibrations in a lab.*

CHAPTER THIRTEEN
MEASUREMENT FORMULAS

13.1 Measurement Quantities

The ***MultiMax*** has the ability to measure in a number of measurement quantities: Time (nanoseconds), Elongation, Load, Stress, and Strain (in terms of %). While there are a number of quantity options available, the easiest and most fail safe quantities to consider are Time and Elongation. *If Load, Stress, or Strain will be used on a regular basis, a calibration of the bolts for the specific application is required.*

The equations below outline the required factors and constants necessary for each quantity. When measuring in terms of time and elongation very little information is required, as the measurement is simply a difference equation. The stress factor and velocity will typically not vary more than 5%, in total, over the entire range of possible steel fasteners. Therefore the worst case error is 5%. However, when measuring in terms of load, stress, or strain, the error can be enormous if errors in effective length, load factor, or cross sectional area are made. These factors will result in proportional errors overall. Therefore, if the load factor is off by 10%, the load measurement will be in error by the same 10% proportionally.

$X_E = [(S_F)(V_0)]\Delta T$ **Elongation**	X_E = *Elongation* S_F = *Sonic Stress Factor* V_0 = *Material Velocity* ΔT = *Change in time.*

$P = (X_E)(L_F) + L_o$ **Load**	P = *Load* X_E = *Elongation* L_F = *Load Factor* L_O = *Load Offset*

$S = \left(\frac{P}{A}\right)$ **Stress**	S = *Stress* P = *Load* A = *Cross sectional error*

$S_N = \left(\frac{X_E}{L_E}\right) * 100$ **%Strain**	S_N = *%Strain* X_E = *Elongation* L_E = *Effective Length*

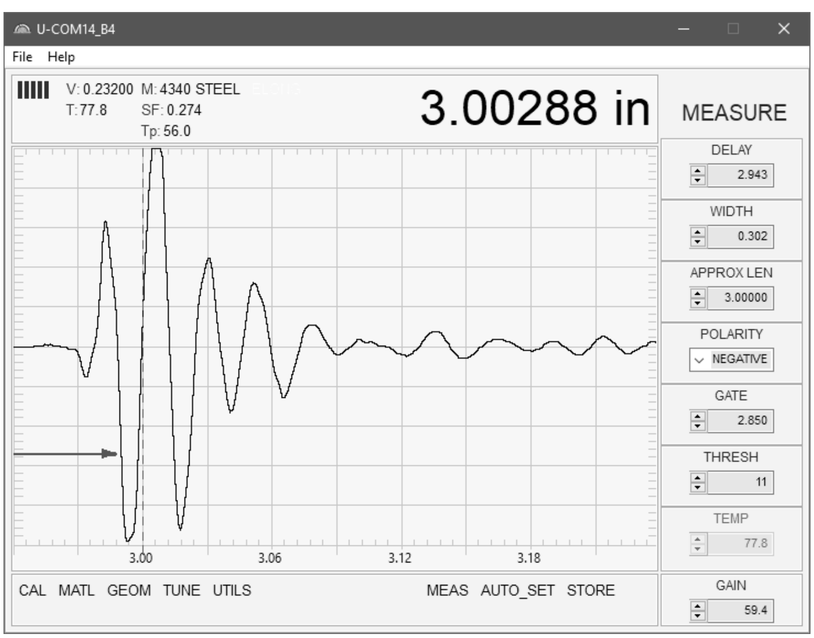
CHAPTER FOURTEEN
WAVEFORM DISPLAY

14.1 RF Waveform Display

The ***MultiMax*** offers a single radio frequency (RF) waveform display with digital readout. The waveform is a graphical representation of the sound reflections traveling through a fastener and echoing back to the transducer/gauge. The sound energy echoed back from the end of the bolt (amplitude) is displayed on the vertical axis, and time is displayed in terms of length on the horizontal axis. The RF waveform offers an overall view of the positive/negative cycles, enabling a clear evaluation of detection, polarity, amplitude, and waveform symmetry. Adjustments can then be made to the transducer position, gain, gates, and threshold to further optimize the overall signal.

All of these features and settings are automated with the use of the AUTO SET function. While the AUTO SET routine will attempt to optimize all the waveform settings, the waveform can be manually 'fine tuned' using the features that that will be further explained in the sections below. However, each of these features will be further explained in the sections that follow. While the majority of the waveform settings are automatically setup using the 'AUTO SET' function, further optimization may be required.

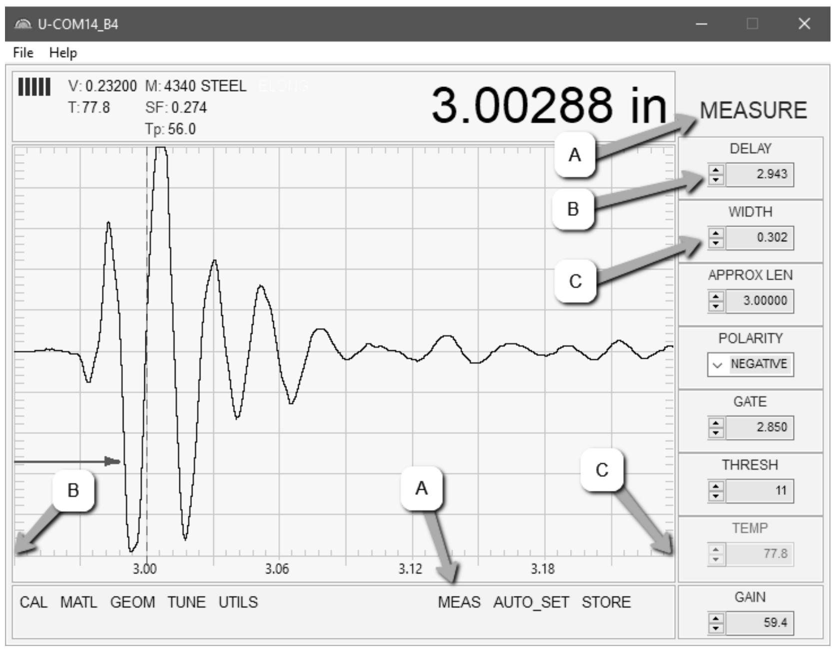
Note: *This chapter will primarily focus on making adjustments to the RF wave. Additional details on the features can be found in Chapter Three, that outlines the **MultiUI** interface software.*



14.2 Display Area (Delay & Width)

The DELAY & WIDTH features are similar to a zoom function. While the DELAY setting specifies where the left side of the A-Scan display area starts on the horizontal X axis, in terms of distance/depth, the WIDTH setting specifies the viewable distance/range starting from the DELAY on the same X axis. Adjustments to these settings offer further optimization of the viewable display area.

Adjusting Delay & Width



1) Click the **MEAS** tab at **A** to display the MEASURE menu items **A**.
2) Use the auto scroll arrows to increase/decrease the **DELAY** setting **B**, or **WIDTH** setting **C**. Alternatively, click inside the numeric field **B** or **C**, to edit manually using the keyboard.
3) Repeat step **2** above for the desired settings.

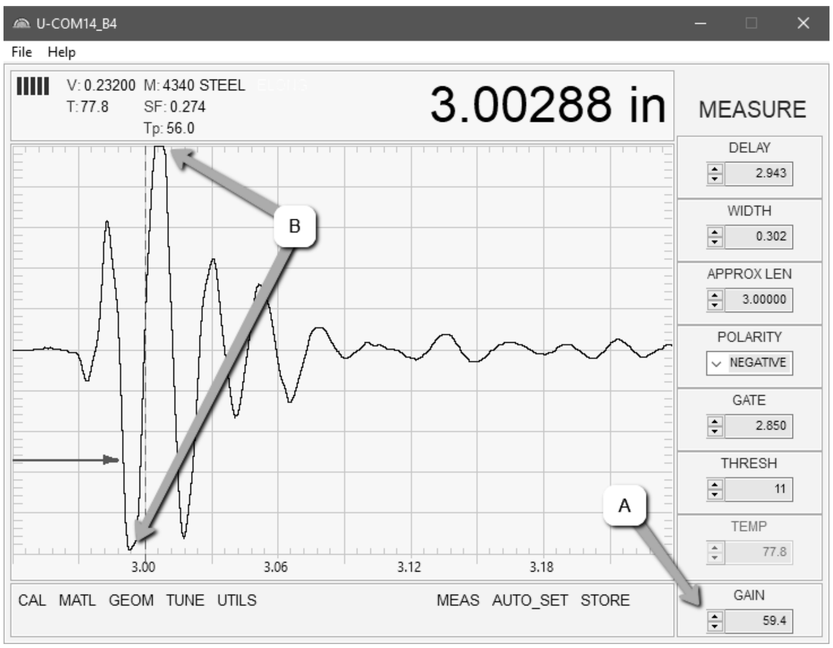
14.3 Gain

The gain controls the amplification of the echoes received. This can be adjusted as needed to achieve a desire level or measurement. While the Auto Set feature determines a suitable starting point for GAIN, the value can be overridden to keep the

RF wave symmetrical, inside of the boundaries of 'full screen height (FSH)', and not 'clipping' or overloading the input. Additionally, if the reflective ends of a fastener are no longer parallel due to deformation or bending, the amplitude lost can often be recovered by manually increasing the gain to maintain the original signal amplitude.

Note: *Excessive levels of gain introduce unwanted additional noise. Lowering the THRESHOLD level would have a similar effect of increasing the GAIN without introducing additional noise. Refer to section 14.5 for additional information.*

Adjusting the Gain



1) Use the auto scroll arrows to increase/decrease the **GAIN** setting **A**. Alternatively, click inside the numeric field **A**, to edit manually using the keyboard.

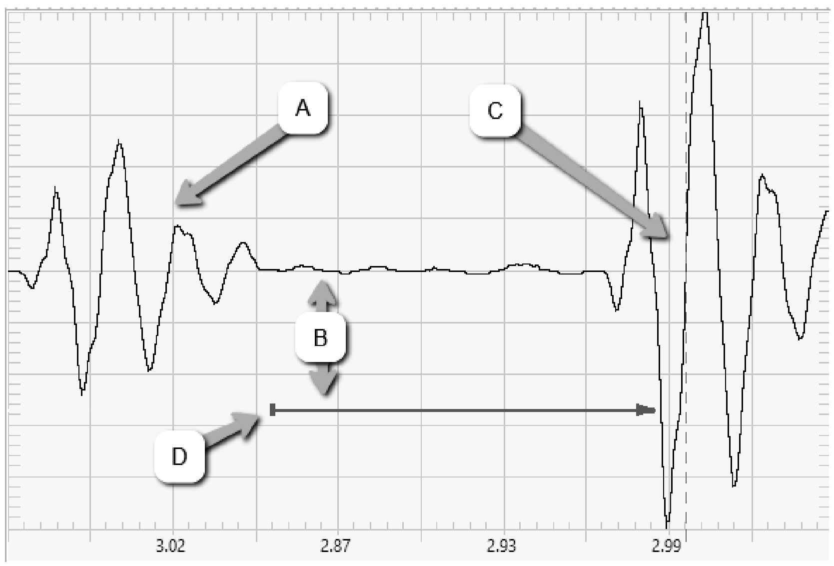
2) Repeat step **1** above to achieve the desired setting.

Note: *In the diagram above, the waveform amplitude is currently at 100% full screen height **B**, at the GAIN level displayed.*

14.4 Gate

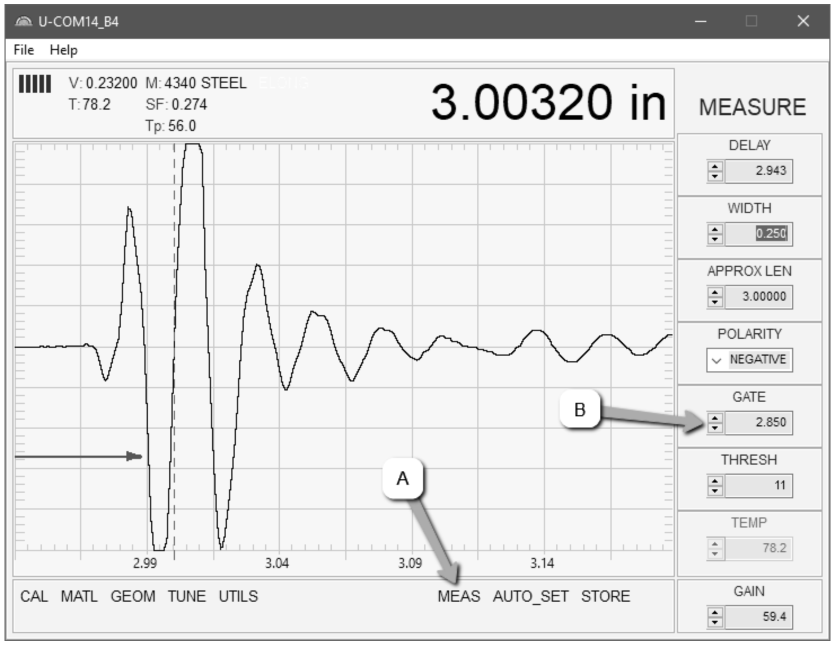
The ***MultiMax*** is equipped with a single gate with a start and threshold level. Detection can occur only within the boundaries of the gate, and is sometimes referred to as a 'blocking gate'. To avoid detection on a signal occurring prior to the desired signal, in terms of length/depth, the start of the gate can be adjusted to occur after the unwanted signal forcing the ***MultiMax*** to look ahead to the next available echo. The unwanted signal could be an artifact created in the construction or geometry of the fastener, noise, etc. Additionally, the echo reflection must have enough amplitude to meet or exceed the height of the threshold of the gate.

A mode conversion echo might also become the target reflection, based on a badly distorted or asymmetrical first echo reflection from the end of the fastener. A mode conversation echo occurs at a slightly later time, as the sound takes a longer path reflecting off the side walls down the length of the fastener. If the first echo is 'unusable', the mode conversion echo would potentially be a favorable option.



The horizontal line at **D** represents the **GATE**. The starting point of **GATE** is adjusted just beyond the unwanted echo **A,** avoiding detection. The next available echo is detected at **C**. The distance from the baseline to the gate represents the threshold (sensitivity) level **B**. The closer the threshold to the baseline, the more sensitive it becomes. In order for a detection to occur, the height/amplitude of the wave must meet or exceed the height of the gate, or threshold.

<u>Adjusting the Gate Start</u>



1) Click the **MEAS** tab at **A** to display the MEASURE menu items.

2) Use the auto scroll arrows to increase/decrease the **GATE** start setting at **B**. Alternatively, click inside the numeric field at **B** to edit manually using the keyboard.

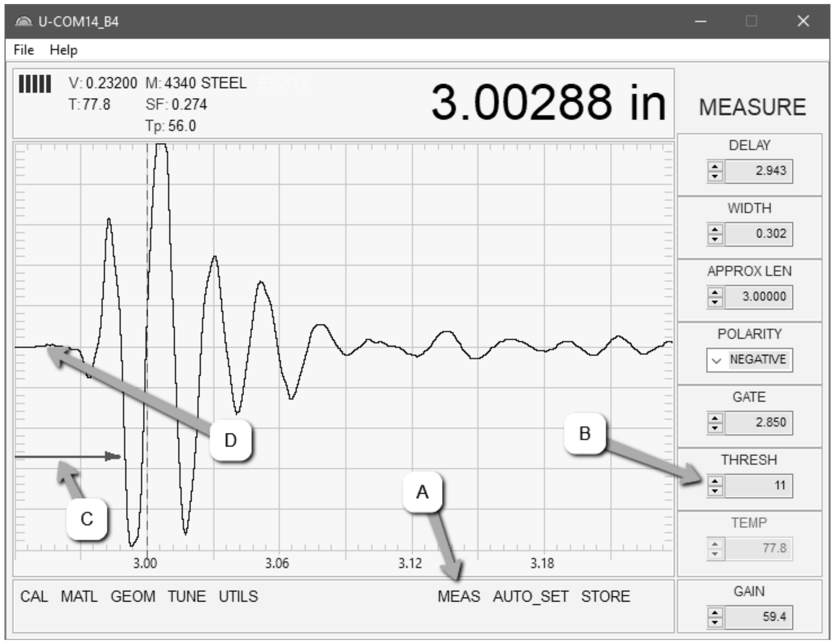
3) Repeat step **2** above for the desired settings.

14.5 Threshold

The amount of signal amplitude required to meet or exceed the gate level, triggering a detection, is the THRESHOLD level. The level is determined by the distance/height of the gate from the baseline of the waveform. The closer the gate is to the baseline, the more sensitive, and the less signal amplitude required for detection. This level can be manually adjusted as needed to trigger on the desired waveform, or signal.

Note: *The THRESHOLD is often used in conjunction with the GAIN, as lowering the THRESHOLD level has a similar effect of increasing the GAIN, and vise versa. Refer to section 14.3 for additional information.*

Adjusting the Thresholds using the Hot Menus



1) Click the **MEAS** tab at **A** to display the MEASURE menu items.

2) Use the auto scroll arrows to increase/decrease the **GATE** start setting at **B**. Alternatively, click inside the numeric field at **B** to edit manually using the keyboard.

3) Repeat step **2** above for the desired settings.

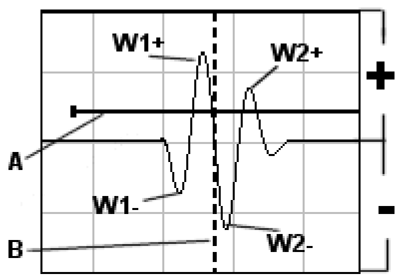
Note: *The THRESHOLD level is indicated at C, and the baseline at D. Decreasing the THRESHOLD level approaches the baseline at D, resulting in increased sensitivity. Less amplitude is required to meet or exceed the THRESHOLD level.*

14.6 Interpreting the Waveform (Polarity)

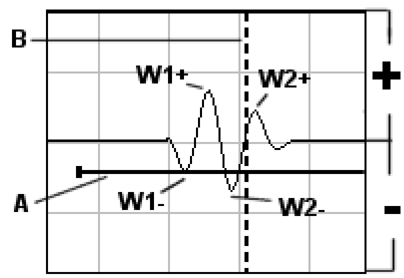
One of the most important things to consider, when using the ***MultiMax***, is how to interpret the waveform in order to choose the proper phase POLARITY and gain settings. It's also important to understand what's taking place during measurement. The user has the option of selecting the phase only once during the **L-REF** (reference length measurement). Once the phase is selected and the **L-REF** stored for a particular bolt, all the elongations and loads taken for that bolt will assume the same phase/polarity. Initially, this might not appear to be that critical. In most instances, with well prepared bolts, this will typically be the case. However, while both phases may look fine at first glance, during the **L-REF** measurement, deformations/bending in the joint can occur when a load is applied to the bolt.

Any deformations in the joint will disrupt the sound path and potentially cause an overall decrease in signal amplitude. When this occurs, the decrease in amplitude can cause the ***MultiMax*** to lose the first half cycle altogether. If the first cycle is lost, the ***MultiMax*** will “peak Jump” to another cycle later in time with greater amplitude. Often times transducers have a very slow ramp up time until reaching maximum energy. In other words, the amplitude of the first cycle is lower in amplitude than the second or third cycle. For this reason, selecting the proper phase is important to avoid losing the original half cycle detection established during the **L-REF** measurement.

The **Auto Set** feature built into the ***MultiMax*** will do a lot of this work for you. However, it’s always a good idea to understand how to interpret the waveform for additional confirmation of the selected settings. The following diagrams offer a brief explanation:



Correct Phase (Polarity) – Fig. 1



Incorrect Phase (Polarity) – Fig. 2

The first thing to note is that the screen shots are split into positive and negative regions. The center baseline is assumed zero, and the two regions in the upper portion of the display are positive, while the two lower halves are negative. Refer to **Fig.1**. Notice that the height or amplitude of **W1+** is greater than the height of **W2+** from the center baseline. These are the positive cycles, as they are in the upper regions. Now consider that the height of **W1-** is lower in amplitude than **W2-**. These are the negative cycles as they are in the lower regions. Keeping that in mind, the ***MultiMax*** uses a zero crossing style of detection. Therefore, the detection will always occur to the right side of the positive or negative cycle being detected. With this said, the detection in **Fig.1 (B)** is occurring on the zero crossing of the positive first cycle **W1+**. In this example, the correct (positive) polarity has been selected.

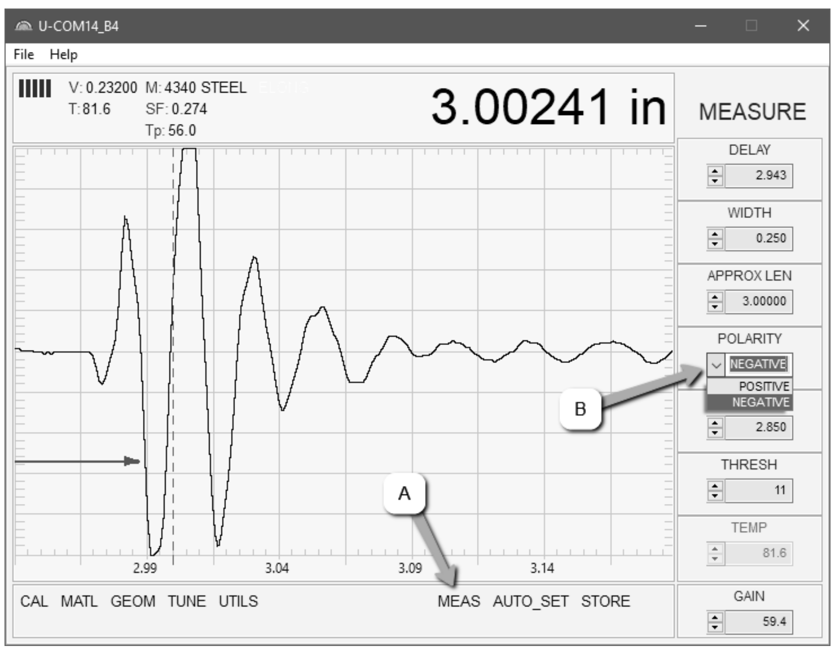
Refer to **Fig.2**. Notice that when the bolt is tightened, the signal amplitude has decreased due to deformation in the joint, and a peak jump has occurred from **W1-** to **W2-** at **(B)**. If we look at the height of **W1-** it has a much lower amplitude than **W2-**. Therefore, when a load was applied to the bolt, the amplitude of **W1-** was decreased beyond the threshold **(A)** and the ***MultiMax*** jumped to the next available signal with sufficient amplitude to meet or exceed the threshold level. However, this could never happen in **Fig.1**, because **W1+** has more amplitude than **W2+**, and a peak jump could never occur without losing the signal entirely.

Note: *Always consider the height of the positive and negative cycles separately. Ask yourself if the first cycle (from left to right) is greater in height (amplitude) than the second. If so, chances are the correct polarity has been selected.*

If an issue does occur, as in **Fig.2** above, and a peak jump is identified while applying a load, increasing the gain or lowering the threshold will generally correct the error and enable detection on the original cycle. However, if it goes unnoticed, all your measurements will be in error. Therefore, it's critical that the user takes the necessary time to select the proper polarity during the initial setup process, and visually confirm detection remains on the same cycle during the loading process.

The Auto Set feature built into the ***MultiMax*** will attempt to optimize these settings for you.

Selecting Polarity



1) Click the **MEAS** tab at **A** to display the MEASURE menu items.

2) Click the down arrow to display and select the **POLARITY** at **B**.

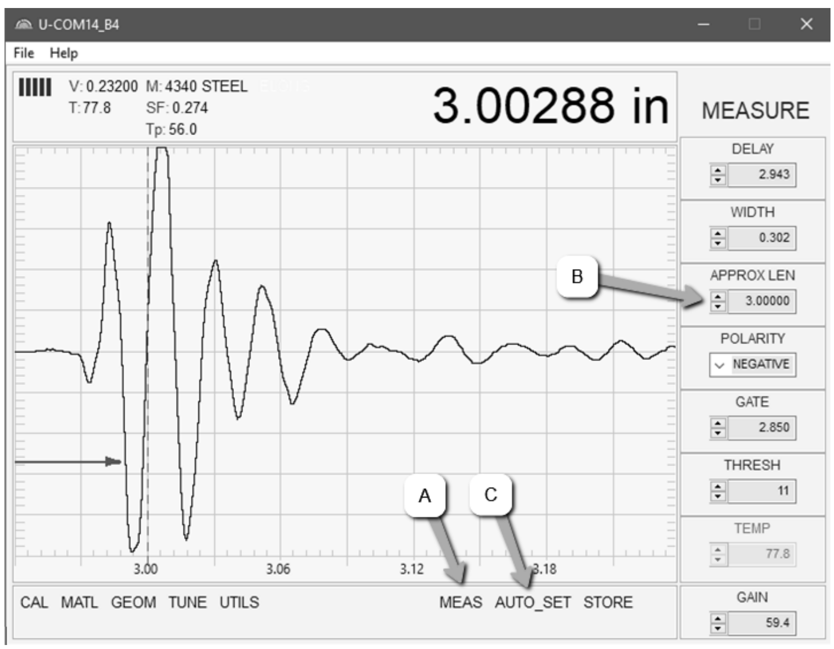
3) Repeat step **2** above for the desired setting.

Note: *Polarity can only be selected when measuring the L-REF (reference length).*

14.7 Automatic Echo Optimization (Auto Set)

The ***MultiMax*** is equipped with a built in Auto Set feature for echo optimization. The AUTO SET uses a variety of algorithms, evaluating the positive and negative cycles to select the best polarity to use for measurement. It also optimizes the gain, sets the delay and width, and activates and sets the gate and threshold levels. This feature not only provides a great starting point, but additionally saves a great deal of time trying to set everything up manually. After execution of this routine, generally only small adjustments are needed, if any.

Auto Set



1) Click the **MEAS** tab at **A** to display the MEASURE menu items.
2) Use the auto scroll arrows to increase/decrease the **APPROX LEN** value **B**. Alternatively, click inside the numeric field **B** to edit manually using the keyboard.
3) Repeat step **2** above for the desired settings.

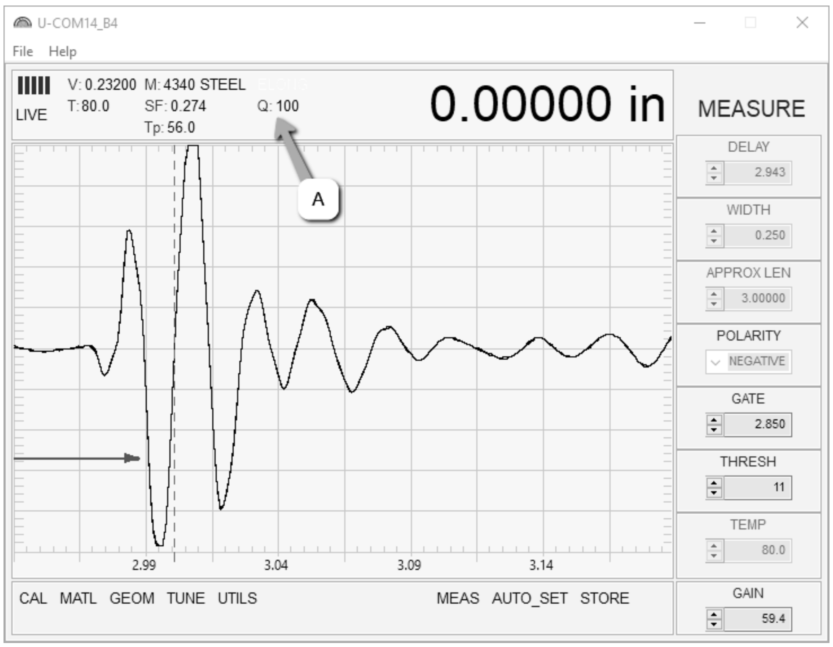
4) Click the **AUTO SET** tab at **C**, to allow the ***MultiMax*** to automatically optimize reference length (L-Ref) settings.

Note: *In order for the AUTO SET to function as intended, the approximate length of the fastener must be set. The approximate length tells the* ***MultiMax*** *where to start looking for the echo, by searching* ***+/- 5%*** *from the value entered.*

CHAPTER FIFTEEN
ADDITIONAL FEATURES

15.1 Quality/Correlation (Transducer Placement)

The auto correlation feature in the ***MultiMax*** is designed to assist the user with returning the transducer back to the original position and orientation where it was during the initial reference length measurement. Since the sound path is changing, in terms of material consistency, returning the transducer to the same location improves the accuracy of the ***MultiMax***, reducing what is referred to as the "placement error".

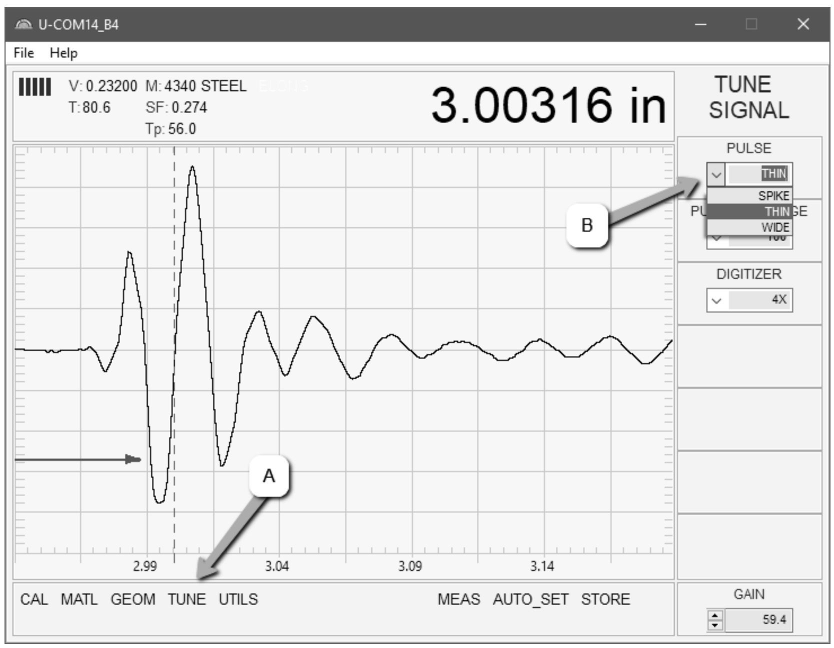


This feature is automatically activated after a reference length is measured and stored. The initial reference length waveform will be grayed out in the background behind the active waveform after moving to one of the columns noted above. The transducer should be placed back in the original estimated position as it was during the initial length measurement. Rotate the transducer clockwise and counter clockwise, making small movements of the transducers position until the active wave matches the symmetry of original wave, and all the while watching the quality indicator (Q) at **A**, as it approaches 100% match. Once the wave symmetries, and quality indicator are as close to 100% as possible, the user should slightly increase/decrease the gain until the peaks of both waves are at the same amplitude level. You'll notice the quality indicator will continue to approach 100% as the gain is adjusted, though may never perfectly achieve the 100% level. However, the primary objective is to return transducer to a position as close to the original location as possible, and achieve a correlated match.

15.2 Pulse Width

The ***MultiMax*** has a 200 volt square wave pulser. Pulse width, refers to the duration of time the pulser is left on. This time results in increased/decreased energy sent into the fastener. There are three pulse width options (**SPIKE, THIN,** and **WIDE**), with adjustable pulser voltages of 100, 150 and 200 volts. Longer bolts with attenuative material may be optimized best using the 200 volt setting with a wide pulse width, while shorter fasteners best optimized using a 100 volt setting with a spike pulse width option. The procedure to change the pulse width is outlined below:

<u>Selecting Pulse Width</u>



1) Click the **TUNE** tab at **A** to display the TUNE SIGNAL menu items.

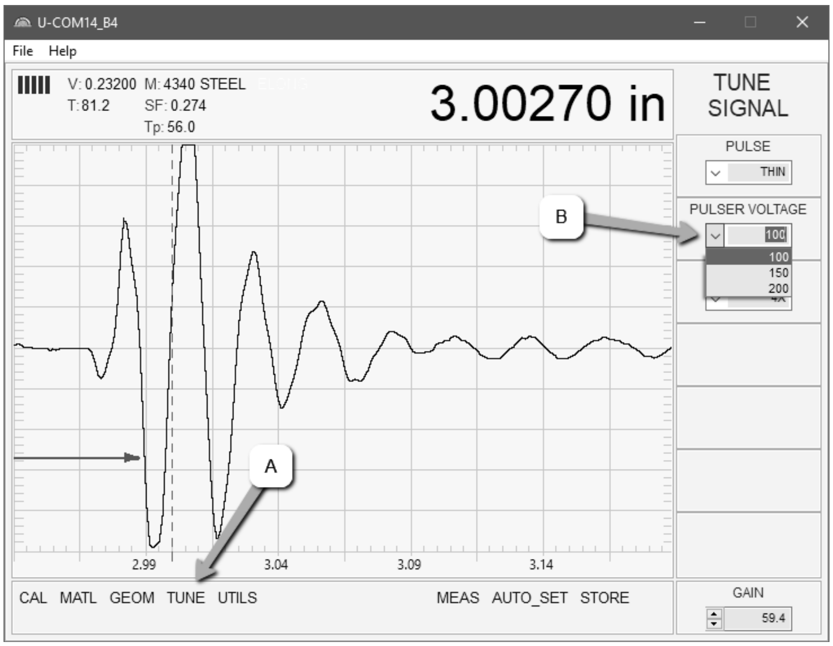
2) Click the down arrow to display and select the **PULSE WIDTH** option at **B**.

3) Repeat step **2** above for the desired setting.

15.3 Pulser Voltage

The ***MultiMax*** has a 200 volt square wave pulser that can be adjusted to increase/decrease output for specific bolt lengths, geometries, materials, transducer size and frequencies. The PULSER VOLTAGE has selectable options of 100, 150 & 200 volts. Lower voltage settings are best for short small diameter bolts, while higher settings are best for longer bolts with attenuative or inconsistent materials. The procedure to change the PULSER VOLTAGE is outlined below:

Selecting Pulser Voltage



1) Click the **TUNE** tab at **A** to display the TUNE SIGNAL menu items.

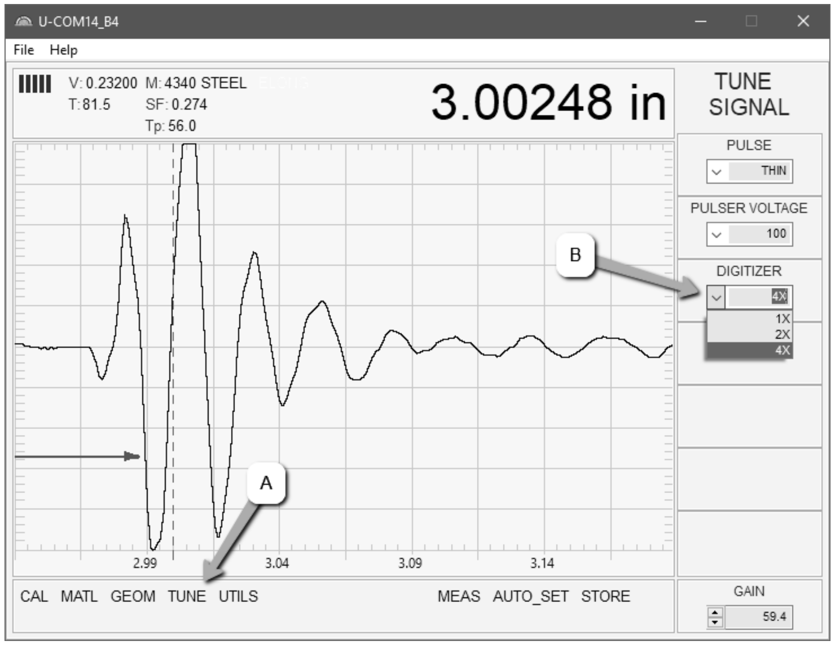
2) Click the down arrow to display and select the **PULSER VOLTAGE** option at **B**.

3) Repeat step **2** above for the desired setting.

15.4 Digitizer

The DIGITIZER provides additional stability to the measurement by increasing the number of samples. This can be beneficial when measuring shorter length fasteners with units set to in/mm hr (high resolution), in order to increase the resolution. The reverse scenario also then applies to longer length fasteners, not requiring the increased sample size/shots. The DIGITIZER has three setting options of 1, 2, 4x, with 4x providing the highest number of samples/shots. It should be noted that increasing the sample size slows down the update speed. For shorter bolts, this won't be as noticeable as using a 4x setting for longer bolts. The procedure to select the DIGITIZER setting is outlined below:

Setting the Digitizer



1) Click the **TUNE** tab at **A** to display the TUNE SIGNAL menu items.

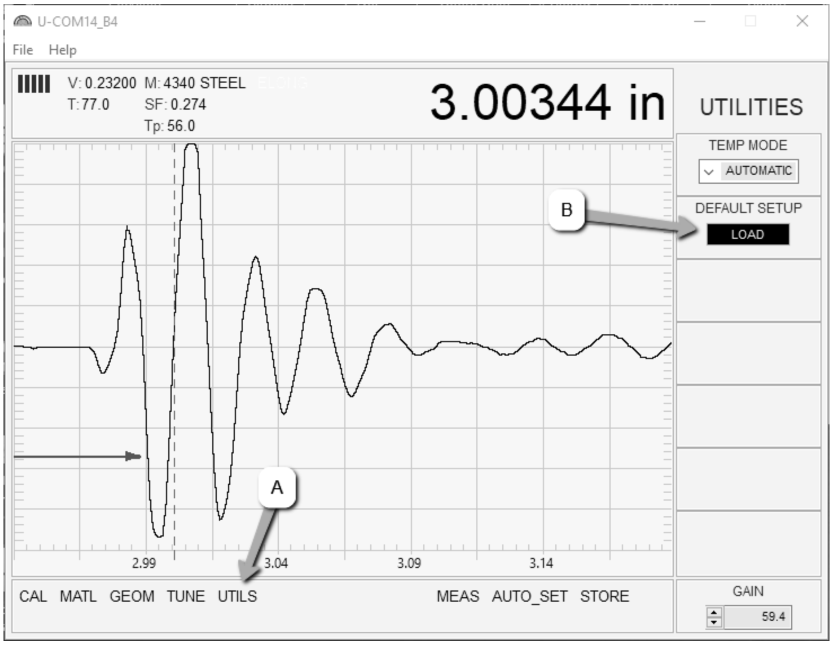
2) Click the down arrow to display and select the **DIGITIZER** setting at **B**.

3) Repeat step **2** above for the desired setting.

15.5 Default Setup

The DEFAULT SETUP option can be used if the configuration settings become scattered during experimentation, trial and error, multiple users, or other. Loading the setup simply restores a factory default configuration as a starting point to then start over with the setup configuration process. The procedure to load the DEFAULT SETUP is outlined below:

Default Setup



1) Click the **UTILS** tab at **A** to display the UTILITIES menu items.

2) Click the LOAD button to load the **DEFAULT SETUP** at **B**.

3) Repeat step **2** above for the desired setting.

CHAPTER SIXTEEN
DATA STORAGE – SETUP, EDIT, & VIEW FILES

16.1 Introduction

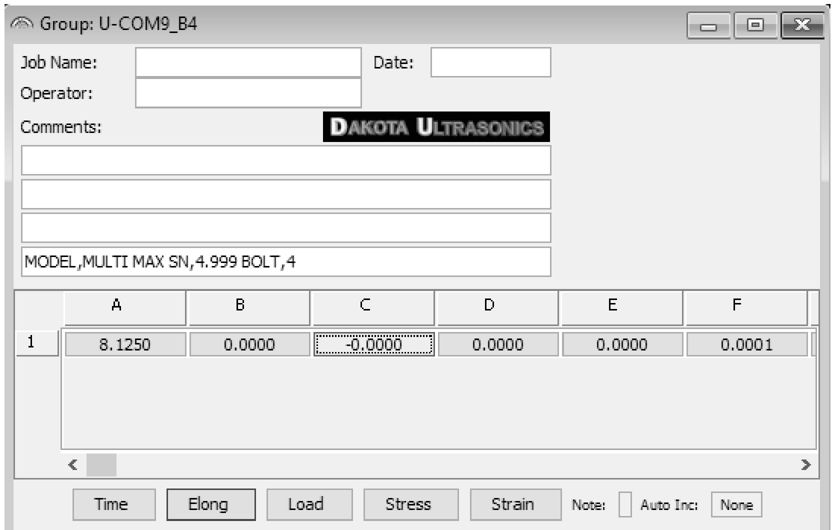
This chapter will assume the ***MultiMax*** hardware module(s) are to be setup and used in conjunction with the ***MultiUI*** interface software, and not with a third party custom software solution. The interface software has the ability to fully record and document all data, calibration, and setup configuration files. It will additionally archive data files automatically after 8000 measurements have been recorded, continue collecting measurements, and infinitely repeat the process for the duration of the monitoring project.

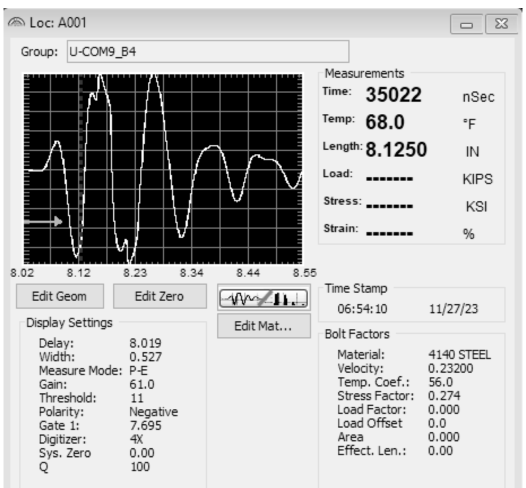
When a four channel ***MultiMax*** is connected to a PC, and ***MultiUI*** running, all four channels will be recognized and assigned to a serial COM port. Once configured, measurements made and stored, individual '.SM2' files will be created and stored in a folder automatically created by ***MultiUI*** named 'GroupLogs'. If measurements have been recorded for each channel, there will be four individual '.SM2' (proprietary format) files created. Additionally, a file named 'history.csv' will be populated in the folder with the same data for all channels/bolts, but as a preformatted comma separated file that can be incorporated into reporting documents.

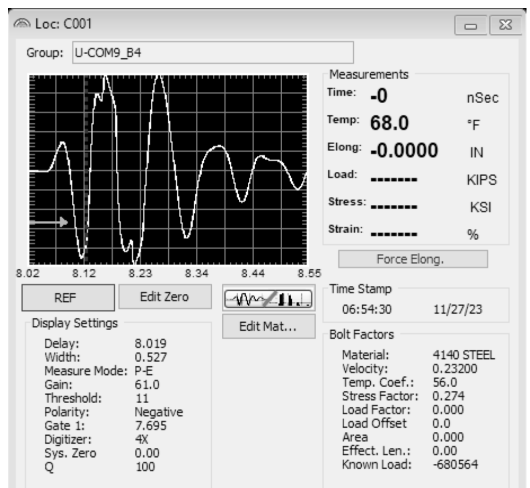
In a similar fashion, when an AUTO CAL is performed for a given channel/bolt, a folder named 'CAL_ZERO_DATA' will automatically be created and populated as a sub folder in the same 'GroupLogs' folder. A copy of the data files will also be stored on the internal SD card in the ***MultiMax***.

16.2 Data File (.SM2)

The '.SM2' data files have a proprietary format and can only be opened and viewed using our DakView interface software available for download on our website. Keep in mind that each and every bolt will be monitored individually for any changes in elongation. The sample rate will determine how often a measurement is recorded, and the data file will be archived automatically when full.







16.3 Data File (.CSV)

The '.CSV' file is a preformatted comma separated file that can be used to import into a number of report editors and spreadsheet programs for documentation or trending.

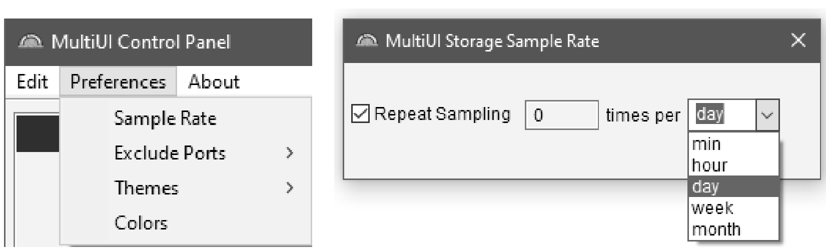
	Date	Time	StoreNum	L-Reference	Elongation	Temperature	Quantity	Location	Status
2	6/5/2023	11:23:45	26	3.11008	-----	0	LOAD	U-COM14	Live
3	6/5/2023	11:23:45	26	2.29883	0.00404	0	ELONG	U-COM14	Live
4	6/5/2023	11:23:45	26	2.44187	0.15559	0	ELONG	U-COM14	Live
5	6/5/2023	11:23:45	26	2.95765	-----	0	ELONG	U-COM14	Live
6	6/5/2023	11:26:58	27	3.11008	-----	0	LOAD	U-COM14	Live
7	6/5/2023	11:26:58	27	2.29883	0.00408	0	ELONG	U-COM14	Live
8	6/5/2023	11:26:58	27	2.44187	0.15555	0	ELONG	U-COM14	Live
9	6/5/2023	11:26:58	27	2.95765	-----	69.5	ELONG	U-COM14	Live
10	6/5/2023	12:40:12	28	3.11008	-----	69.5	LOAD	U-COM14	Live
11	6/5/2023	12:40:12	28	2.29883	0.01005	68.3	ELONG	U-COM14	Live
12	6/5/2023	12:40:12	28	2.44187	0.15385	67.7	ELONG	U-COM14	Live
13	6/5/2023	12:40:12	28	2.95765	-----	69.5	ELONG	U-COM14	Live
14	6/5/2023	12:41:12	29	3.11008	-----	69.5	LOAD	U-COM14	Live
15	6/5/2023	12:41:12	29	2.29883	0.01011	68.3	ELONG	U-COM14	Live
16	6/5/2023	12:41:12	29	2.44187	0.15384	67.7	ELONG	U-COM14	Live
17	6/5/2023	12:41:12	29	2.95765	-----	69.5	ELONG	U-COM14	Live
18	6/5/2023	12:42:12	30	3.11008	-----	69.5	LOAD	U-COM14	Live

history

16.4 Storing Data (Sample Rate)

To automatically store data, set the sample rate to occur at a preferred time interval.

Store Data - Auto

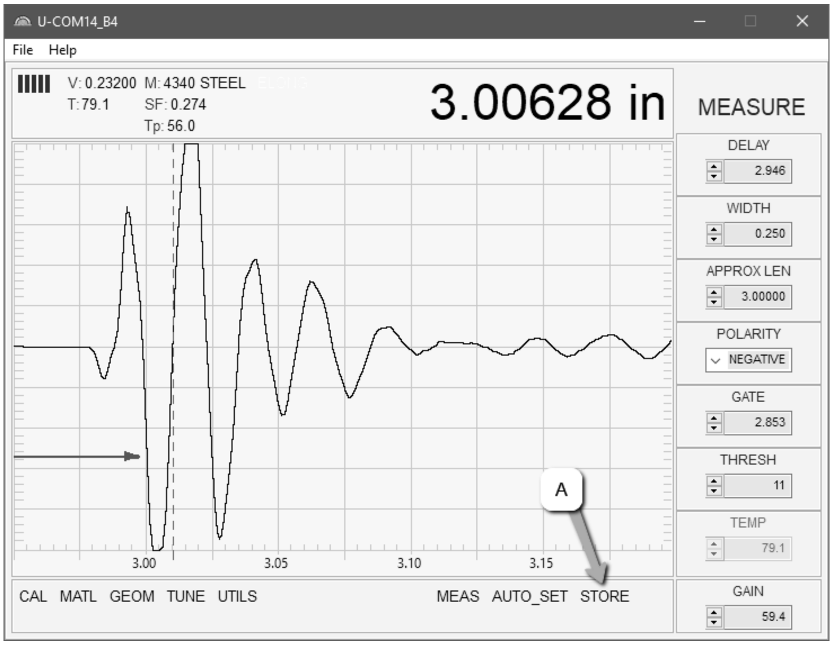


1) Click the **PREFERENCES** menu and select **SAMPLE RATE** to enable and set the time interval.

2) Repeat step **1** above for the desired setting.

16.5 Storing Data (Manual)

Store Data - Manual



1) Click the **STORE** tab at **A** to store an individual measurement for the bolt/channel selected.

CHAPTER SEVENTEEN
SOFTWARE, FILE TRANSFER, & UPGRADES

17.1 Computer System Requirements

MultiUI Sotware – Windows 10 & 11operating systems using Intel or AMD hardware platforms.

DakView Software – Windows 10 & 11 operating systems using Intel or AMD hardware platforms. There is also a version for the MAC OSX platform.

File transfer is standard USB connectivity using a USB-C to USB transfer cable (pt# N-003-0330).

17.2 Installing MultiUI & DakView

Both software packages are available directly on our website for download and installation. Stay current by periodically checking the website for the latest versions. Simply download the .exe file from our website to your computer, and double click the icon to begin installation.

Refer to the online help section in **DakView** for operating instructions.

17.3 MultiMax/DakView Communication

DakView does not electronically connect or communicate with the ***MultiMax*** modules. However, the ".SM2" data files generated by the ***MultiMax*** can be opened and reviewed in **DakView** and used as a file viewer for reporting purposes.

17.4 Line Power

The ***MultiMax*** is powered through the USB-C connector to either a USB or Ethernet hub. If only a single four channel module is used, it can be plugged directly into a USB port on a computer, or into a common mobile phone power adaptor.

Power cable to a PC (USB-C to USB-A) data cable (N-003-0330).

17.5 Upgrading the *MultiMax*

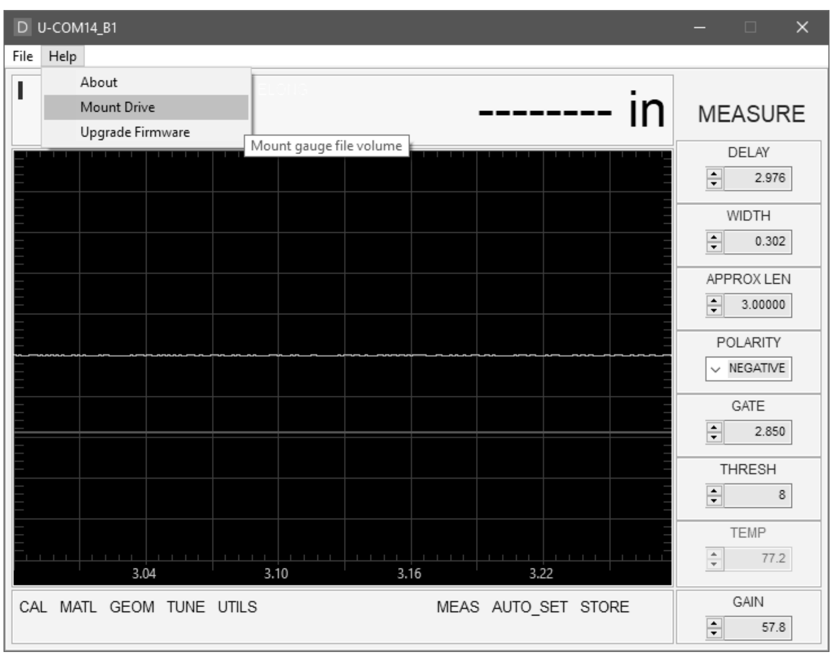
The ***MultiMax*** can be upgraded to the latest revision of firmware available on our website. Download and copy the latest upgrade file directly to the SD card in the ***MultiMax***, and use the upgrade utility located in the **XFER** menu. The process is very easy and convenient to encourage our users to stay current with the latest updates, feature additions, and bug fixes.

The procedure to upgrade the ***MultiMax*** is outlined below:

Upgrading the Firmware

1) Double click on the "*MultiUI*" shortcut to activate the control panel.

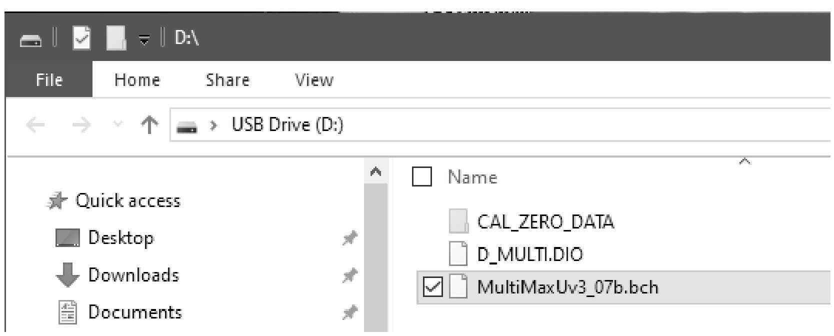
2) Double click on one of the channel location labels **A** to display the ***MultiUI*** interface display window.



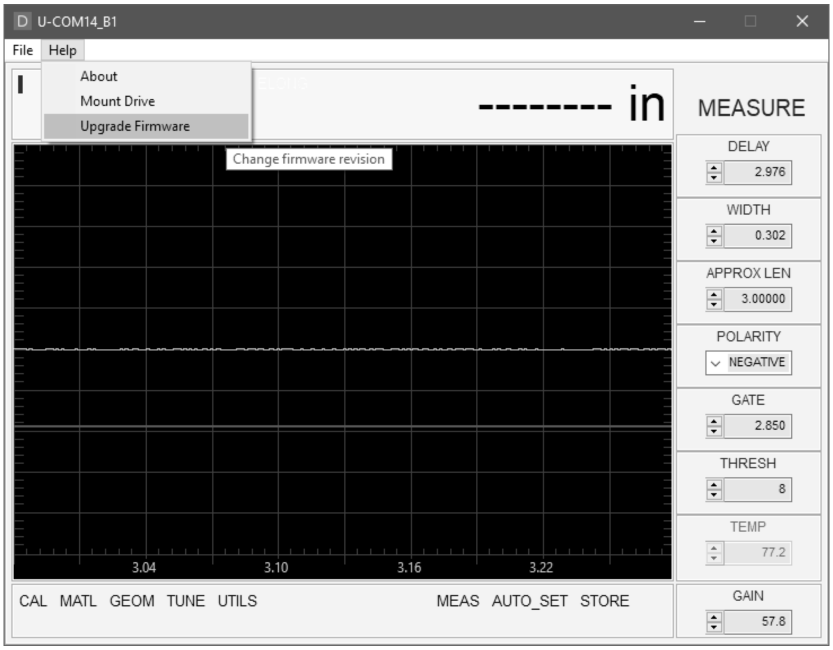
3) Click **HELP** and select **Mount Drive** to activate the SD storage device.

4) Click the **OK** button to mount the drive, or **CANCEL** to abort.

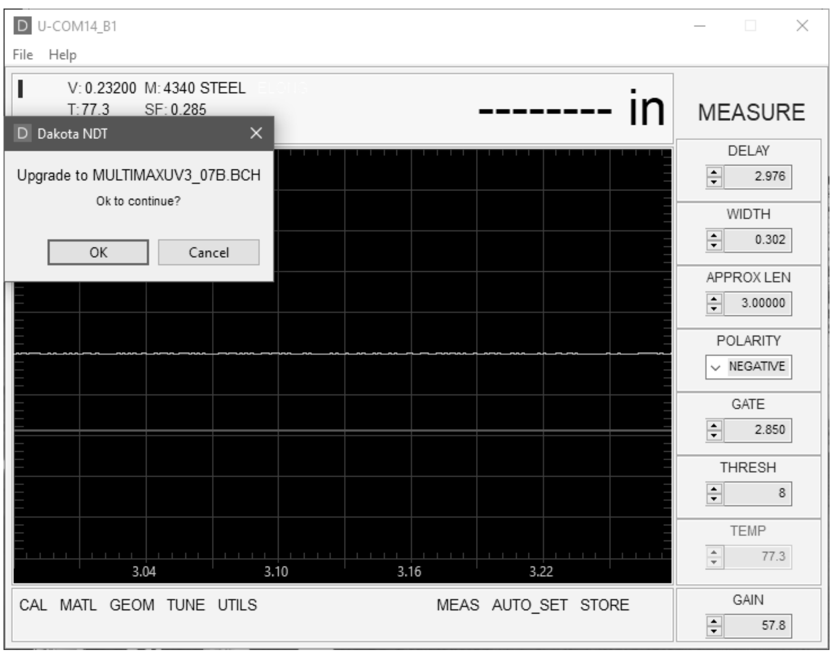
Note: *Once the external drive has been mounted, the directory folder will appear with all the files and directory folders currently being stored on the SD card. There can only be one file with a ".bch" file extension stored on the SD card at a time. Delete or rename (.bch.old) any existing files prior to copying the new upgrade file to the folder.*



5) Drag and drop (copy) the new firmware ".bch" file into the SD card directory folder.

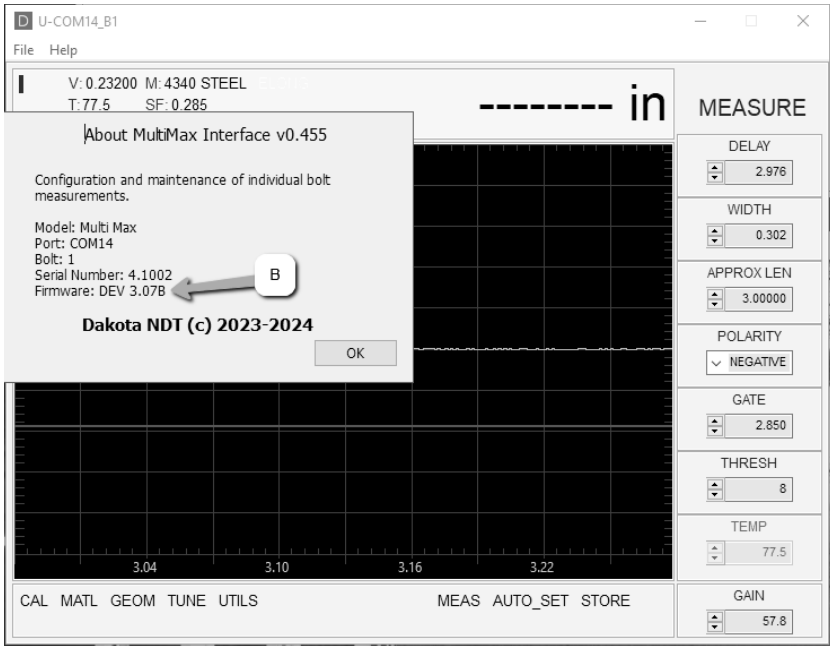


6) Click **HELP** and select the **Upgrade Firmware** option to begin the upgrade process.



7) Click the **OK** confirmation button to start the upgrade, or **CANCEL** to abort.

Note: *A progress and bar and warning message will be displayed during the upgrade process. Do not interrupt the upgrade process until completed.*



8) Click **HELP** and select the **ABOUT** option to display the current version of firmware installed **B**.

WARRANTY INFORMATION

• Warranty Statement •

Dakota NDT warrants the ***MultiMax*** against defects in materials and workmanship for a period of two years from receipt by the end user. Additionally, Dakota NDT warrants transducers and accessories against such defects for a period of 90 days from receipt by the end user. If Dakota NDT receives notice of such defects during the warranty period, Dakota NDT will either, at its option, repair or replace products that prove to be defective.

Should Dakota NDT be unable to repair or replace the product within a reasonable amount of time, the customer's alternative exclusive remedy shall be refund of the purchase price upon return of the product.

• Exclusions •

The above warranty shall not apply to defects resulting from: improper or inadequate maintenance by the customer; unauthorized modification or misuse, or operation outside the environmental specifications for the product.

Dakota NDT makes no other warranty, either express or implied, with respect to this product. Dakota NDT specifically disclaims any implied warranties of merchantability or fitness for a particular purpose. Some states or provinces do not allow limitations on the duration of an implied warranty, so the above limitation or exclusion may not apply to you. However, any implied warranty of merchantability or fitness is limited to the five-year duration of this written warranty.

This warranty gives you specific legal rights, and you may also have other rights which may vary from state to state or province to province.

• Obtaining Service During Warranty Period •

If your hardware should fail during the warranty period, contact Dakota NDT and arrange for servicing of the product. Retain proof of purchase in order to obtain warranty service.

For products that require servicing, Dakota NDT may use one of the following methods:

- Repair the product
- Replace the product with a re-manufactured unit
- Replace the product with a product of equal or greater performance
- Refund the purchase price.

• After the Warranty Period •

If your hardware should fail after the warranty period, contact Dakota NDT for details of the services available, and to arrange for non-warranty service.