Operators Manual

For The

Model 6640Q

Quantum Hall Bridge

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1. INTRODUCTION

1.1. SCOPE

This document describes the operation and maintenance of the 6640Q Quantum Hall room temperature Direct Current Comparator (i.e. DCC) Resistance Bridge.

1.2. GENERAL DESCRIPTION

The 6640Q Bridge can be controlled from the front panel or by a computer system through software. The BridgeWorks Software User's Manual describes the operation of the 6640Q with the software. Once the computer system is installed and connected to the IEEE-488 Interface of the 6640Q Resistance Bridge, full software control of the bridge is possible.

1.3. OVERVIEW

The 6640Q is a microprocessor-based DCC Bridge designed for the automatic measurement and display of the ratio of two resistances to accuracies better than 0.02 ppm. The ratio of the two resistances is determined from a direct measurement of the voltage of the bridge imbalance while an ampere-turn balance is maintained. A microprocessor is used to control the direct-current-comparator, set the bridge measurement currents and measurement configuration, initiate the voltage measurement cycle and maintain the ampere-turn balance. This fully automated measurement process achieves optimum resistance ratio resolution and accuracy at the sub-ppm level.

The 6640Q Bridge is designed for flexibility and ease of use and is based on the direct-current-comparator bridge (DCC) originally developed by the National Research Council of Canada and Guildline Instruments. Guildline designed and manufactured the first commercial DCC Bridge over 50 years ago (i.e. model 9975), and subsequently made major enhancements through several generations of automated DCC Bridges with the Guildline 6675(A), 6622(A) and now the 6640Q. The 6640Q contains additional improvements, which are protected by two patents, and provides the best commercially available room temperature Quantum Hall bridge. Remote access to the embedded microprocessor-controller, through a simple control language command set and GPIB communication interface allows the 6640Q to fully exploit the capabilities of the direct-current-comparator to suit each user requirement while still maintaining optimum resistance ratio measurement accuracy at the sub-ppm level.

The design approach taken for the 6640Q results in an effective bridge measurement accuracy of 27 bits (to a maximum of 32 bits depending on configuration), allowing the resistance ratio of resistances in the range 0.001 Ω to 100 kΩ to be automatically measured.

The balance of the zero ampere-turn flux condition is maintained automatically using an electronic closed loop feedback network operating on the flux detector output to drive a slave power supply for the standard resistor current. The bridge balance (null voltage condition) is maintained automatically by adjusting the number of turns in series with the unknown resistor.

1.4. PRINCIPLE OF OPERATION

A simplified diagram of the automatic direct-current-comparator is shown in Figure 1-1. Two sets of four terminal connections hardware are provided, one set for the standard resistor and one set for the unknown resistance. A current (Ix), set under control of the microprocessor, is passed through the variable turns of winding (Nx) of the comparator and through the unknown resistance (Rx). The isolated slave current (Is) is generated under microprocessor control, as a linear function of the number of turns (Nx) and is forced through the fixed slave windings (Ns) and the reference resistor (Rs). The currents (Is) and (Ix) flowing in the windings (Ns) and (Nx) respectively generate a net magnetic flux imbalance in the flux detector windings (Nd). This flux imbalance is proportional to the net ampere-turn error between the two windings [(Is) x (Ns)] and [(Ix) x (Nx)]. By sensing this imbalance with the sensitive flux detector winding and an electronic peak detector, a voltage signal is generated proportional to the sign and magnitude of the ampere-turn error. This voltage is used in a simple closed loop control configuration to adjust the slave current (Is) to bring the (ampere-turn) error signal to zero. At balance, the ratio of the two currents (Ix and Is) flowing in the two windings is the same as the ratio of the turns set for each winding (Nx and Ns).

Complete electrical isolation between circuit currents is maintained throughout the 6640Q by making full use of fiber optic technology. A fiber optic serial data communication link is used to transfer data between each functional component and the embedded microcontroller.

A link joining the two potential leads of the unknown resistance (Rx) and the reference resistance (Rs) and the nanovoltmeter detector provides the only connection between the two halves of the bridge. Power supply isolation techniques are used throughout to further isolate the bridge halves. The nanovolt detector is a high input impedance (>1 GΩ) amplifier arrangement capable of resolving voltages at the nanovolt level with a typical linearity accuracy of 14 bits (to a maximum of 22 bits). In the automatic direct-current-comparator bridge arrangement this amplifier is used to measure the potential across the reference and unknown resistances. In addition a patent protected technique is used to remove residual magnetism which provides for lower uncertainty measurements.

Knowledge of the reference resistance value (Rs), the effective resistance potential imbalance and confirmation that ampere-turn balance is maintained, with the turns (Nx, Ns) and current (Ix, Is) settings, allows the unknown resistance value (Rx) to be calculated.

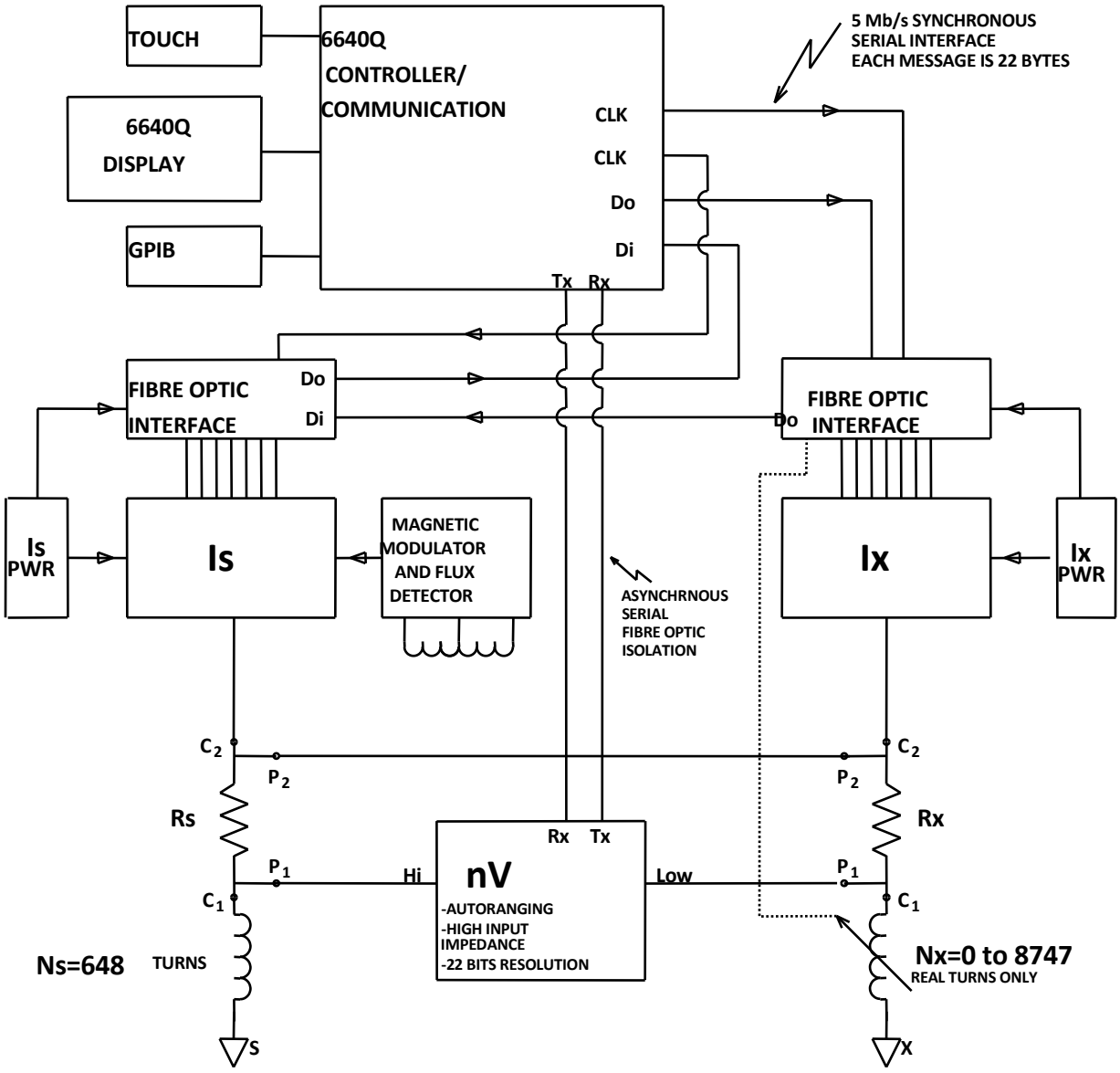


Figure 1-1 : Model 6640Q Block Diagram

2. PERFORMANCE SPECIFICATIONS

2.1. 6640Q SERIES TEMPERATURE MEASUREMENT SPECIFICATION

6640Q QHR	Range 0.1 Ω to 100 kΩ. Specifications are relative and 1 year (except Interchange @ 24 hours), 2 Sigma Level (95 %) and within ±2 °C Temperature. Includes all secondary specifications including noise and linearity.				
Rs / Rx (EITHER CAN BE SELECTED AS STANDARD)	**Ratio / Ratio Uncertainties (± ppm)**				
	Interchange[1] (1:1)	0.1 : 1 [2]	1 : 1	10 : 1	13.4 : 1
1 Ω	0.015	0.05	0.02	0.02	0.02
10 Ω	0.015	0.02	0.02	0.02	0.02
100 Ω	0.015	0.02	0.02	0.02	0.02
1 kΩ	0.015	0.02	0.02	0.02	0.02
10 kΩ	0.020	0.02	0.03	0.05	0.05

1 - Interchange specification is a 24 hour specification (i.e. sometimes referred to as a self-calibration).

2 - Ratio Uncertainties of 0.02 ppm are based on reversing Rs and Rx (i.e. Rx / Rs) connections.

3 - Specifications are based on standard practice use of 30 µA - 100 µA of current for 1:1, 1:10 and 10:1 ratios when compared directly to a QHR.

4 – Specifications are based on 1 mW to 10 mW of power dissipated in resistance standards for tests not using QHR.

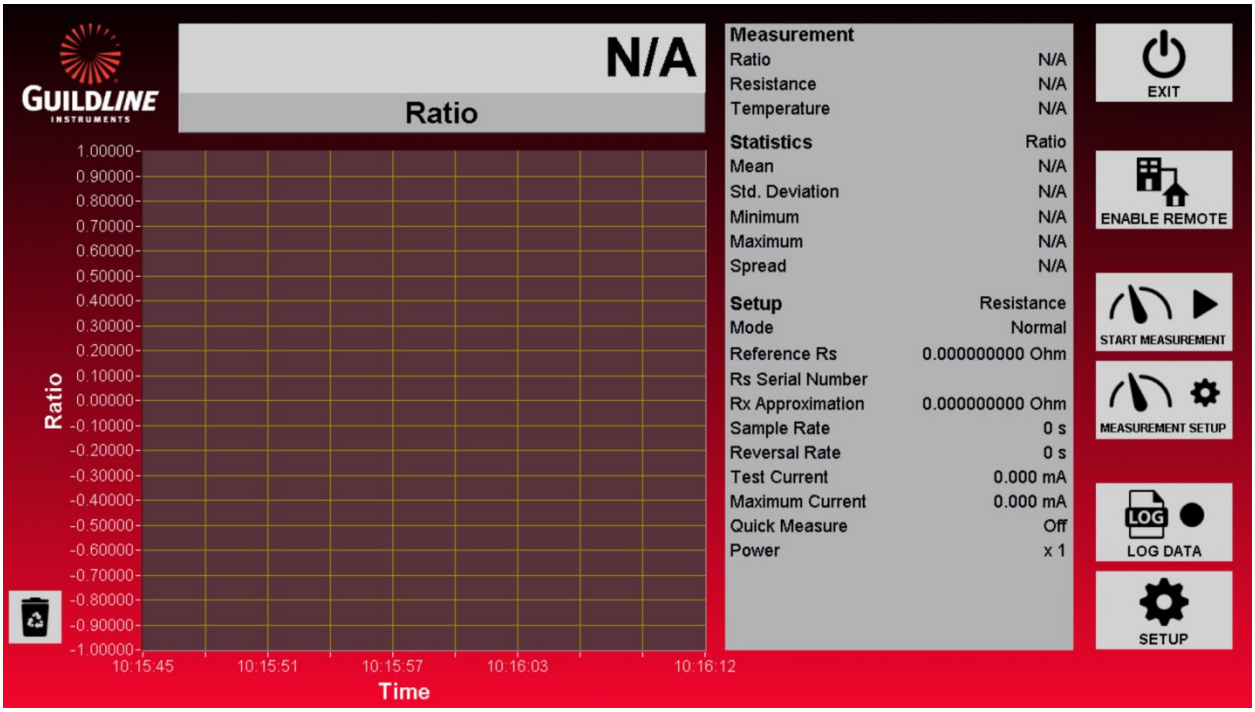
GENERAL SPECIFICATIONS			
Linearity		± 0.005 ppm (1:1 to 13.4:1 Ratios)	
Display resolution (ppm)		Selectable (Programmable) from 0.0001 ppm to 10 ppm	
Temperature Coefficient		0.01 ppm/°C of reading (Outside Operating Temperature)	
Automatic current reversal rate (in seconds)		4 to 1637 programmable, increment of 1 second	
Fastest Measurement Sample Rate		2 seconds	
Communication		USB, IEEE 488.2, SCPI Based Language Instructions	
Test current (for measurements to 100 kΩ)	Range (± 30 Vdc compliance)	10 µA to 150 mA	
	Resolution (µA)	1 µA	
	Accuracy [error(ppm) + offset(A)]	±100 ppm ± 10 µA	
Bridge Operating Temperature to Full Specifications		20 °C to 26 °C	68 °F to 78.8 °F
Bridge Maximum Operating Range (20 % to 50 % RH)		+ 18 °C to + 28 °C	+ 65 °F to + 82 °F
Bridge Temperature Storage Range		- 20 °C to + 60 °C	- 4 °F to +140 °F

Power Requirements	Vac: 100 V, 120 V, 220 V, 230 V and 240 V; All ± 10 % 50 or 60 Hz ± 5 %, Or 45 Hz – 65 Hz		
Dimensions (Width x Height x Depth)		Weight	
440 mm x 200 mm x 465 mm	17.3" x 7.8" x 18.3"	27 kg	59.5 lbs

3. OPERATING INSTRUCTIONS

3.1. FRONT PANEL OPERATING PROCEDURE

The 6640Q Graphical User Interface (or GUI) is provided on a Windows 10 embedded PC which is connected to the bridge hardware. The interface utilizes the color touchscreen interface with on screen keyboard for user control and entry. The GUI user interface software utilizes the full screen as a "Metro" style application common to Windows 8 and Widows 10. Note that this interface runs on Professional (x86 and x64) versions of windows and is not supported in RT versions. The 6640Q GUI replaces the traditional front panel interface with an intuitive and powerful Graphical User Interface optimized for the large embedded touch screen. This interface provides manual control for individual tests.



The GUI consists of the main screen and various set up and configuration screens for controlling the bridge and displaying measurement results. In the diagram below is a full navigation/hierarchy map of the software screens.

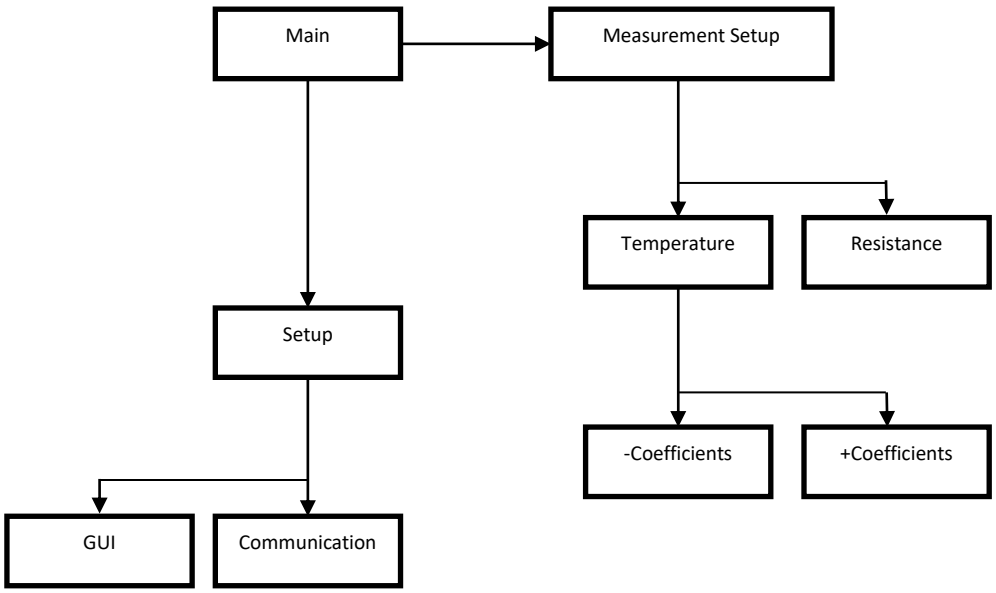


Figure 3-1 : User Interface Navigation Diagram

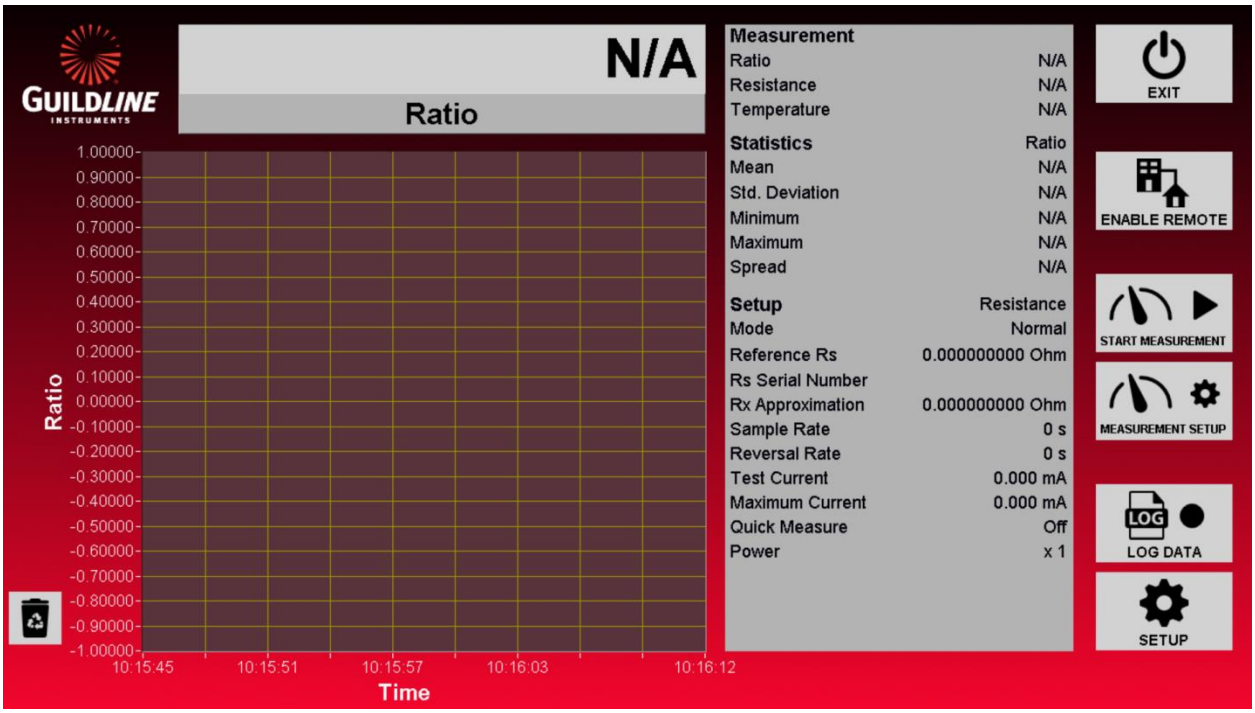
As shown in the diagram above all screens can be easily accessed starting from the main screen of the 6640Q GUI. Note that the Temperature Measurement Setup is an option for the 6640Q.

Also note that this interface can be installed and run on any computer running Windows 7 or newer and can run as a standard desktop app "Windowed", rather than full screen "Metro" mode by changing the "TabletPC" from true to false in the "Bridge6640.ini" file.

Note that to edit this file you will need administrative privileges in Windows.

3.2. MAIN SCREEN

The main screen of the user interface is where you have access to all user features of the 6640Q Quantum Hall Bridge. The screen has operator functions available mainly to the right hand side of the screen with statistics in the middle of the screen and graph to the left. The graph will automatically adjust the scale such that all data will be visible up to a maximum length of hours as defined in the Setup GUI screen. If data is being logged all data is still available in the stored file.



The data on the graph can be cleared by touching the "Trash Bin" icon to the bottom left of the screen. Note that clearing the graph does not remove the data from the stored data if "Log Data" is enabled. Also note that the statistics will be cleared as well. These statistics reflect all the present data in the graph.

The chart will display the bridge measurement in any of several different units relating to the measurement setup probe calibration. The available units can be accessed by the drop menu right below the large reading display.

3.2.1. Exit

The "Exit" button simply exits the 6640Q Graphical User Interface. The 6640Q will continue to retain and/or measure in the last configured test even if the GUI is not running.

3.2.2. Enable Remote

The "Enable Remote" button disables all interactive features of the GUI and allows the 6640Q Bridge to be controlled by another computer via RS-232C, GPIB, or over the network with TCP/IP. Any one of these options can be used at any time. While remote is enabled the GUI will still display the graph, statistics and measurement reading.

3.2.3. Start Measurement

The "Start Measurement" button toggles between "Start Measurement" and "Stop Measurement". This button will place the 6640Q hardware into measurement running and standby conditions.

3.2.4. Measurement Setup

The "Measurement Setup" button opens a screen for setting up and changing the test parameters of the test.

3.2.5. Log Data

The "Log Data" button will begin to store the bath temperature data to a standard comma separated values format file. This file is stored in "C:\Results\YYYY\YYYY-MM\ Bridge6640_DataLog_YYYYMMDD_0001.csv". This path and name is generated automatically where "YYYY" is the year, "MM" is the month, and "DD" is the day. To keep file sizes reasonable and to ensure there are no filename conflicts the name is also given a 4 digit incremental number as well. The "Log Data" button will change to a "Stop Logging" button when there is an active logging operation.

3.2.6. Setup

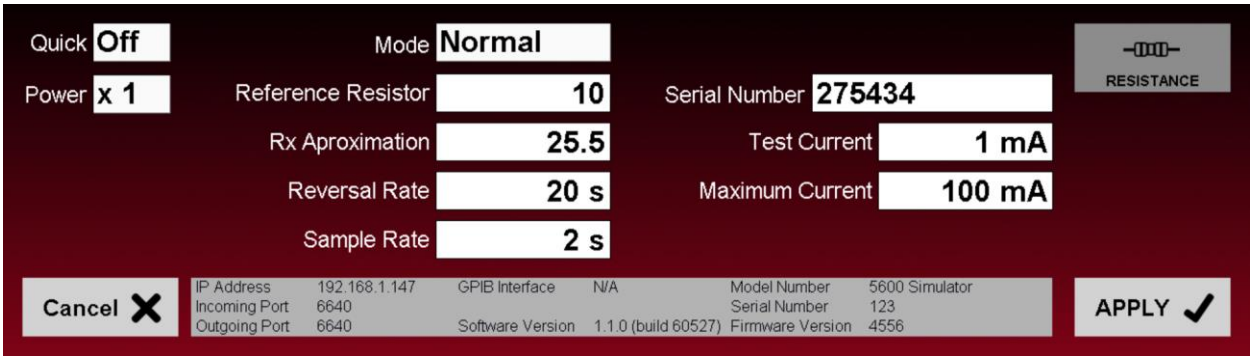
The "Setup" button opens the screens used to configure the system parameters of the 6640Q GUI.

3.3. SETUP MEASUREMENT SCREENS

The Setup Measurement Screens are screens to configure the test setup for the 6640Q. There are 2 operational modes. Pressing the "Measurement Setup" button on the main screen will open the last used mode setup screen. The two modes are "Resistance" and "Thermometry". Resistance is used for measuring stable resistance ratios and this mode is required when working with a Quantum Hall standard. The optional Thermometry mode is best for temperature measurements when you wish to display temperature readout on unknown and moving temperatures, essentially making the bridge operate as a thermometer. Provided on the right of the screen are buttons to toggle the measurement mode from "Resistance" to "Temperature" and navigate to the other relevant Setup Measurement screens.

3.4. SETUP MEASUREMENT SCREEN (RESISTANCE)

The Setup Measurement Screen for resistance mode is a simpler screen for setting up the test as there are no temperature conversion coefficients to enter. To use this screen simply type in the desired test parameters as defined below and press "Apply" to accept. Click on "Cancel" to close the window without changing the values.



The Setup Measurement Screen can easily be accessed directly on the Main Screen by touching the "SETUP MEASUREMENT" button on the right hand side of the screen.

3.4.1. Quick

The "Quick" measure function disables the internal software filters that are invoked for the four cycle precision measurements and are used in the calculation of resistance ratio. Disabling the software filter function decreases the time required to calculate and report the measured ratio. However, the measurement will be noisier when the quick measure is used, and so two least significant digits of available resolution are removed from the display when quick measure is turned on. For low uncertainty measurements with a Quantum Hall System it is recommended that the Quick option be turned off.

3.4.2. Power

The "Power" function is where you can quickly double or reduce to half the excitation current in your probe. This is used with the optional Temperature mode to help determine the self-heating effects of a temperature probe.

3.4.3. Ohms Mode

The "Ohms Mode" control allows you to set up to use a range extender for "Low Ohms" current measurements, or voltage for "High Ohms" measurements, as well as the default, which is current for "Normal" measurements. At this time the only applicable resistance mode in a the 6640Q Quantum Bridge is "Normal". Do not use the other modes as they are there for future expansion for wide range resistance bridges.

3.4.4. Reference Resistor

The "Reference Resistor" field is where you can type in the actual value for the known reference resistor you are using. This field is mandatory as it is used to index the appropriate ratio calibration software coefficients retained inside the 6640Q hardware. The value of the Quantum Hall standard should be entered.

3.4.5. RX Approximation

The "RX Approximation" field is where you can type in the approximate value for the unknown resistor you are measuring. This field is not required as the bridge will auto balance to find this value. Entering an approximate value does speed up the balancing process.

3.4.6. Reversal Rate

The "Reversal Rate" sets the time (in seconds) in which the excitation current polarity is reversed to remove induced errors created by thermal offsets. In most cases the recommended setting for this is 20 seconds. This value can be set from 4 to 7200. This field is mandatory. Note that the 6640Q takes two measurements per reversal so a 20 second reversal rate results in a 10 second measurement rate.

3.4.7. Sample Rate

The "Sample Rate" sets the time (in seconds) in which the bridge reports a reading. This reading rate can be desynchronized from the current polarity reversal to any value entered into this field. If this field is set to zero then the sample rate is synchronized to the reversal rate and will report two times in each polarity. In most cases this is the recommended setting. Values entered in this field must be less than the reversal rate and not smaller than 2 seconds. It is not mandatory, but recommended that any values entered should be a factor of the reversal rate.

3.4.8. Serial Number

The "Serial Number" field is where you can type in the serial number for the known reference resistor you are using. This field is not mandatory.

3.4.9. Test Current

The "Test Current" field is where you can type in the excitation current for the resistor you are measuring. Typically this will be 0.77 mA for a Quantum Hall System. This field is mandatory.

3.4.10. Maximum Current

The "Maximum Current" field is where you can type in the maximum current for the reference resistor you are using. If the bridge detects that the resistor will be excited beyond this value, then the test is automatically stopped. This field is mandatory and the maximum value is 150 mA.

3.4.11. Resistance

The "Resistance" button is a toggle button to switch from "Resistance" mode to the optional "Temperature" mode. This button will change to indicate the currently active mode.

3.4.12. Cancel

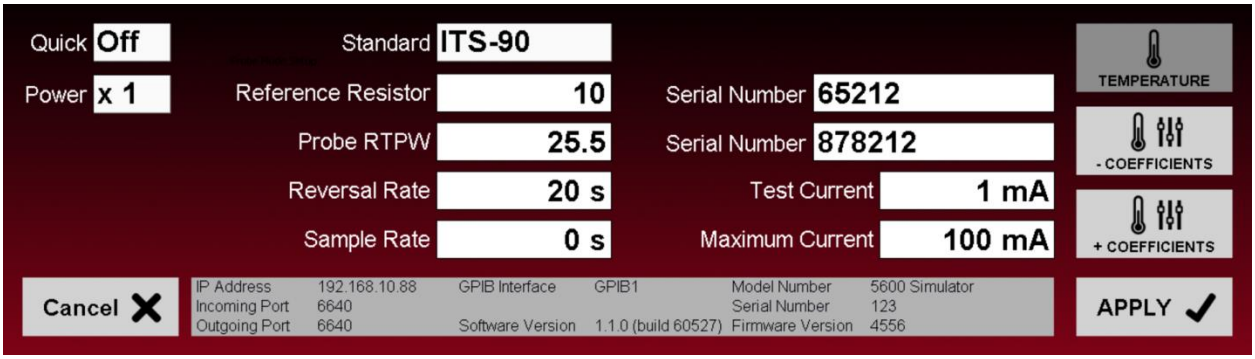
The "Cancel" button will close the Setup Measurement screen without applying any changes.

3.4.13. Apply

The "Apply" button will implement the new Setup Measurement as displayed on the screen.

3.5. SETUP MEASUREMENT SCREEN (OPTIONAL TEMPERATURE MODE)

The Setup Measurement Screen for the optional temperature mode is a more complex screen for setting up the test as there are temperature conversion coefficients to enter. To use this screen simply type in the desired test parameters as defined below and press "Apply" to accept. Click on "Cancel" to close the window without changing the values.



The Setup Measurement Screen can easily be accessed directly on the Main Screen by touching the "SETUP MEASUREMENT" button on the right hand side of the screen.

3.5.1. Standard

The "Standard" function is used to select the temperature conversion standard that is being used to translate a calibrated SPRT's resistance to temperature reading. The available standards for this are ITS-90 and IPTS-68. The "Coefficients" button options to the right of the screen and subsequent screens will change to reflect the scale in use.

3.5.2. Quick

The "Quick" measure function disables the internal software filters that are invoked for the four cycle precision measurements and are used in the calculation of resistance ratio. Disabling the software filter function decreases the time required to calculate and report the measured ratio. However, the measurement will be noisier, and so two least significant digits of available resolution are removed from the display when quick measure is turned on.

3.5.3. Power

The "Power" function is where you can quickly double or reduce to half the excitation current in your probe. This is used to help determine the self-heating effects of the probe in use.

3.5.4. Ohms Mode

The "Ohms Mode" control allows you to set up to use a range extender for "Low Ohms" current measurements, or voltage for "High Ohms" measurements, as well as the default, which is current for "Normal" measurements. Currently the only applicable resistance mode in the temperature mode is "Normal" which is used for low current sourced measurements. Do not use the other modes as they are there for future expansion for wide range temperature/resistance bridges.

3.5.5. Reference Resistor

The "Reference Resistor" field is where you can type in the actual value for the known reference resistor you are using. This field is mandatory as it is used to index the appropriate ratio calibration software coefficients retained inside the 6640Q hardware.

3.5.6. Probe RTPW

The "Probe RTPW" field is where you can type in the known value for the triple point resistance of the probe you are measuring. This field is not required for the bridge to balance and measure. Entering a value for this parameter is required for accurate conversion from resistance to temperature.

3.5.7. Reversal Rate

The "Reversal Rate" sets the time (in seconds) in which the excitation current polarity is reversed to remove induced errors created by thermal offsets. In most cases the recommended setting for this is 20 seconds in thermometry applications. This value can be set from 4 to 7200. This field is mandatory.

3.5.8. Sample Rate

The "Sample Rate" sets the time (in seconds) in which the bridge reports a reading. This reading rate can be desynchronized from the current polarity reversal to any value entered into this field. If this field is set to zero then the sample rate is synchronized to the reversal rate and will report two times in each polarity. In most cases this is the recommended setting for this parameter. Values entered in this field must be less than the reversal rate and not smaller than 2 seconds. It is not mandatory, but recommended that any values entered should be a factor of the reversal rate.

3.5.9. Serial Number

The "Serial Number" field is where you can type in the serial number for the known reference resistor you are using. This field is not mandatory.

3.5.10. Serial Number

The "Serial Number" field is where you can type in the serial number for the SPRT/HTPRT you are using. This field is not mandatory.

3.5.11. Test Current

The "Test Current" field is where you can type in the excitation current for the probe or resistor you are measuring. Typically this will be 1mA or 10mA for SPRT's and HTPRT's respectively. This field is mandatory.

3.5.12. Maximum Current

The "Maximum Current" field is where you can type in the maximum current for the reference resistor you are using. If the bridge detects that the resistor will be excited beyond this value, then the test is automatically stopped. This field is mandatory and has a maximum value of 150 mA.

3.5.13. Temperature

The "Temperature" button is a toggle button to switch from "Resistance" mode to optional "Temperature" mode. This button will change to indicate the currently active mode.

3.5.14. -Coefficients

The "-Coefficients" button appears in "Temperature" mode along with the "+Coefficients" button when using the ITS-90 Standard. Selecting this button opens a screen to select the desired sub-range and to enter coefficients for the chosen sub-range.

3.5.15. +Coefficients

The "+Coefficients" button appears in "Temperature" mode along with the "-Coefficients" button when using the ITS-90 Standard. Selecting this button opens a screen to select the desired sub-range and to enter coefficients for the chosen sub-range.

3.5.16. Coefficients

The "Coefficients" (unsigned) button appears in "Temperature" mode as a single button when using the IPTS-68 Standard. Selecting this button opens a screen to enter coefficients.

3.5.17. Cancel

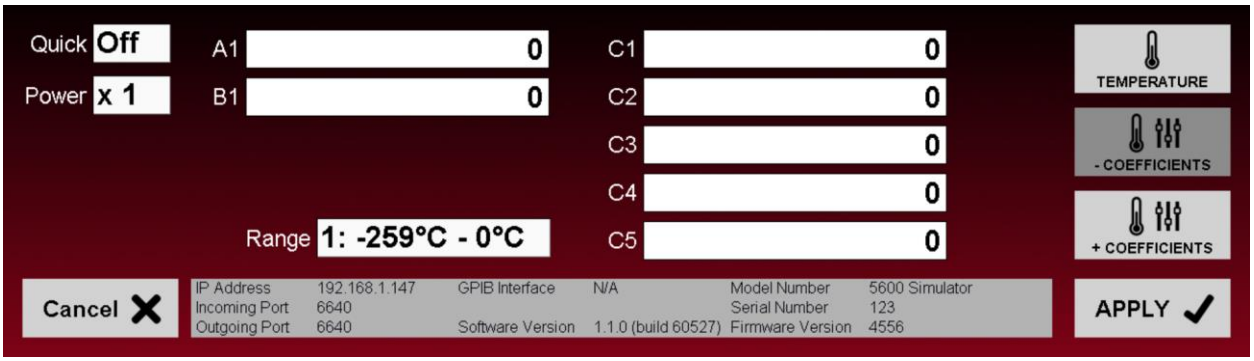
The "Cancel" button will close the Setup Measurement screen without applying any changes.

3.5.18. Apply

The "Apply" button will implement the new Setup Measurement as displayed on the screen.

3.6. - COEFFICIENTS SCREEN

The "-Coefficients" screen allows for you to enter the desired sub-range for measurements below the Triple Point of Water as well as the associated coefficients as defined by the ITS-90 Standard.



Note that the number of A, B, and C coefficients will change based on what range is selected.

3.6.1. Quick

The "Quick" measure function disables the internal software filters that are invoked for the four cycle precision measurements and are used in the calculation of resistance ratio. Disabling the software filter function decreases the time required to calculate and report the measured ratio. However, the measurement will be noisier, and so two least significant digits of available resolution are removed from the display when quick measure is turned on.

3.6.2. Power

The "Power" function is where you can quickly double or reduce to half the excitation current in your probe. This is used to help determine the self-heating effects of the probe in use.

3.6.3. A, B, and C Coefficients

Varying number of A, B, and C Coefficient fields button appears in "-Coefficients" screen when using the ITS-90 Standard dependent on the sub-range selected. Select the appropriate sub-range as listed on the calibration of the PRT and enter the corresponding coefficients.

3.6.4. Range

This control allows for the selection of the sub-range in which the probe calibration data applies.

3.6.5. Cancel

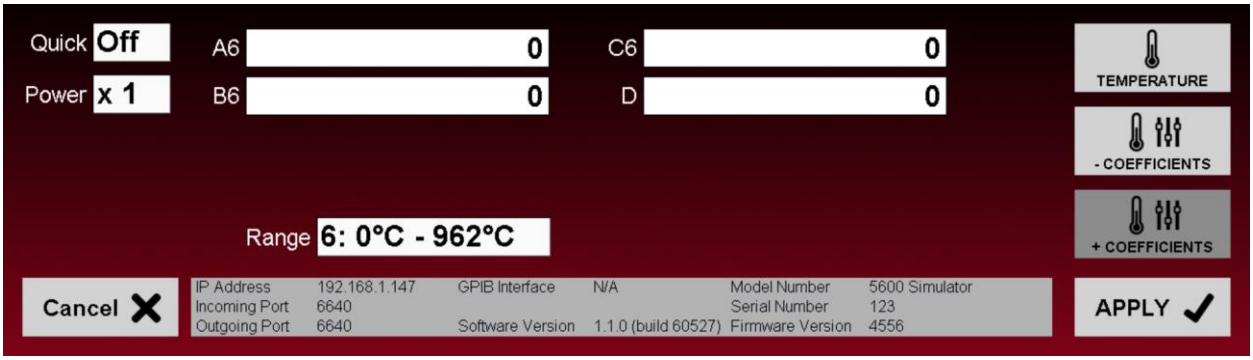
The “Cancel” button will close the “-Coefficients” screen without applying any changes.

3.6.6. Apply

The “Apply” button will implement the new “-Coefficients” as displayed on the screen.

3.7. + COEFFICIENTS SCREEN

The “+Coefficients” screen allows for you to enter the desired sub-range for measurements above the Triple Point of Water as well as the associated coefficients as defined by the ITS-90 Standard.



Note that the number of A, B, C, and D coefficients will change based on what range is selected.

3.7.1. Quick

The “Quick” measure function disables the internal software filters that are invoked for the four cycle precision measurements and are used in the calculation of resistance ratio. Disabling the software filter function decreases the time required to calculate and report the measured ratio. However, the measurement will be noisier, and so two least significant digits of available resolution are removed from the display when quick measure is turned on.

3.7.2. Power

The “Power” function is where you can quickly double or reduce to half the excitation current in your probe. This is used to help determine the self-heating effects of the probe in use.

3.7.3. A, B, C, and D Coefficients

Varying number of A, B, and C Coefficient fields button appears in "+Coefficients" screen when using the ITS-90 Standard dependent on the sub-range selected. Select the appropriate sub-range as listed on the calibration of the PRT and enter the corresponding coefficients.

3.7.4. Range

This control allows for the selection of the sub-range in which the probe calibration data applies.

3.7.5. Cancel

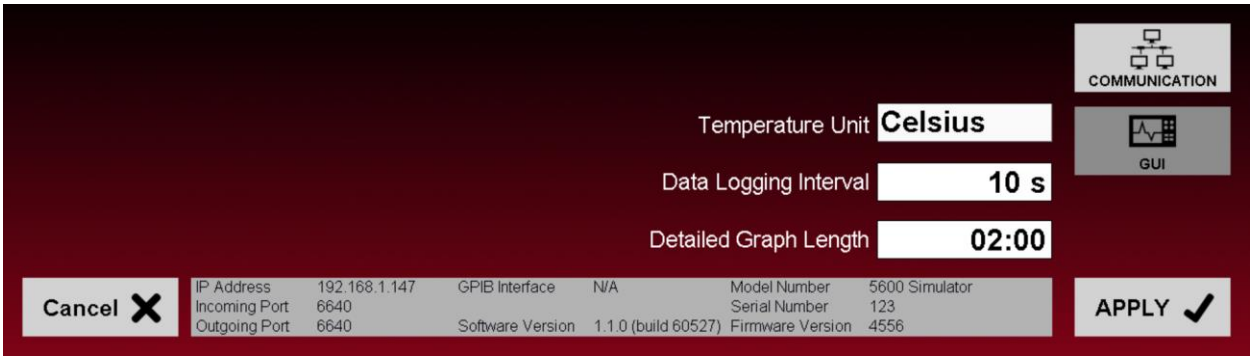
The "Cancel" button will close the "+Coefficients" screen without applying any changes.

3.7.6. Apply

The "Apply" button will implement the new "+Coefficients" as displayed on the screen.

3.8. GUI SCREEN

The GUI screen sets the basic graphing parameters for the main screen. Provided on the right of the screen are buttons to navigate to the other Setup screens.



3.8.1. Temperature Unit

The "Temperature Unit" field is where the operator can set the default thermometry unit reported in the graph and statistics.

3.8.2. Data Logging Interval

The "Data Logging Interval" field is where the operator can set the rate in which the GUI updates the graph and statistics.

3.8.3. Detailed Graph Length

The "Detailed Graph Length" field is where the operator can set the length in time that graph will display and for which statistics are calculated.

3.8.4. Cancel

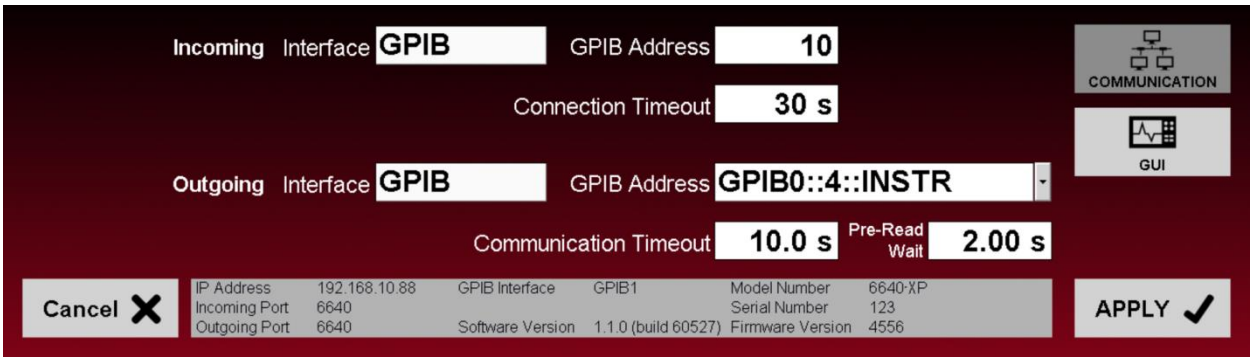
The "Cancel" button will close the Setup screen.

3.8.5. Apply

The "Apply" button will implement the parameters as displayed on the screen.

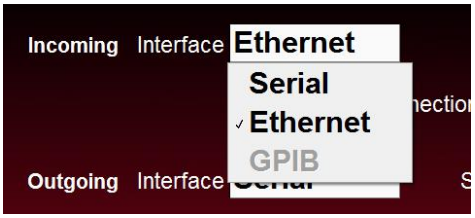
3.9. COMMUNICATION SCREEN

The Communication screen sets the Remote and Internal Communication parameters. Provided on the right of the screen are buttons to navigate to the other Setup screens.



3.9.1. Incoming Interface

The "Incoming Interface" field is drop menu listing all of the available interfaces for connecting the 6640Q Bridge to an external computer for remote control. More detail on how to remotely control the 6640Q is outlined in the Remote Control Section of this manual. You can select the desired interface option based on the installed available option. These can be RS-232C, GPIB, or Network TCP/IP.

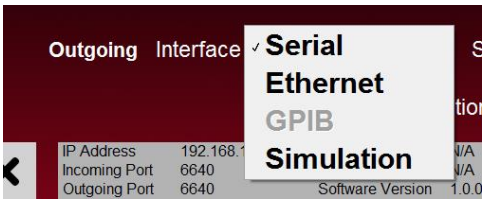


3.9.2. Connection Timeout

The “Connection Timeout” field allows the operator to set the time the GUI will wait for a connection from a remote PC before closing the active connection.

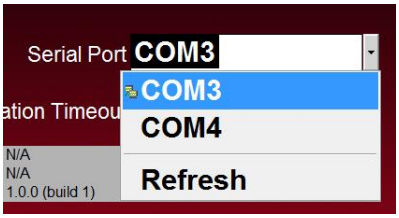
3.9.3. Outgoing Interface

The “Outgoing Interface” field is drop menu listing all of the available interfaces for connecting the 6640Q GUI to the 6640Q internal hardware. You can select the desired interface option based on the installed available option. These can be RS-232C, GPIB, or Network TCP/IP. There is also a “Simulation” option which emulates a connection to the 6640Q hardware.



3.9.4. Serial Port/GPIB Address/ IP Address

The “Serial Port” field (i.e. sometimes called “GPIB Address” or “IP Address”) is a drop menu listing all of the available ports/addresses for connecting to the 6640Q hardware. Note that one of these fields will also appear next to the “Incoming Interface” depending on what interface is chosen.



3.9.5. Communication Timeout

The “Communication Timeout” field allows the operator to set the time the GUI will wait for a response from the 6640Q hardware before reporting a connection error.

3.9.6. Cancel

The “Cancel” button will close the Setup screen without applying any changes.

3.9.7. Apply

The “Apply” button will implement the parameters as displayed on the screen.

3.10. MEASUREMENT OPERATION GUIDE

This section contains information regarding the measurement of resistances in the range of 1 kΩ to 100 kΩ, which are the ohmic values that can be measured directly against a QHR. This guide is provided for manual control of the model 6640Q Bridge. An operation guide for full automatic control of the 6640Q Bridge is provided in the BridgeWorks-ADV Software User's Manual.

Meas. No.	R_X Resistor	R_s Resistor	Excitation Current	Reversal Rate	Meas. Mode
Tests 1 – 8 for 6640Q bridges.					
1	13 kΩ	10 kΩ	0.077	60	Normal Ohms
2	10 kΩ	13 kΩ	0.1	60	Normal Ohms
3	10 kΩ	1 kΩ	0.1	60	Normal Ohms
4	13 kΩ	10 kΩ	0.077	60	Normal Ohms
5	13 kΩ	1 kΩ	0.077	60	Normal Ohms
6	13 kΩ	10 kΩ	0.077	60	Normal Ohms
7	100 kΩ	13 kΩ	0.01	90	Normal Ohms
8	100 kΩ	10 kΩ	0.01	90	Normal Ohms

The maximum allowable interchange closure errors (ppm) for the following resistor pairs are:

Resistor	Resistor	Resistor	Error
13 kΩ	10 kΩ	Interchange	0.05
13 kΩ	10 kΩ	1 kΩ	0.03
100 kΩ	13 kΩ	10 kΩ	0.05

Table 3-1 : Recommended Measurement Test Setup

NOTE: Itest is based on a 0.77 mA excitation for the Quantum Hall standard.

3.11. BRIDGEWORKS-ADV DATA ACQUISITION SOFTWARE

The BridgeWorks-ADV Data Acquisition Software is the control software for the Guildline model 6645Q Quantum Hall System. Using the 6640Q with the BridgeWorks-ADV Data Acquisition Software will increase the functionality and the productivity of the Bridge through a system level support for adding optional 6664C Scanner(s). These, along with other devices, can be added to work along with 6640Q to create a fully automated temperature measurement system all under software control. Before using the model 6640Q system with the computer, ensure that the operation of the software package is well understood. The internal embedded computer can be used to run BridgeWorks-ADV or optionally an external computer can control the system through the IEEE-488 Interface (GPIB) of the model 6640Q Quantum Hall Bridge, and optionally, the model 6664C and 3210T Scanners.

Refer to the BridgeWorks Software User's Manual for a description of the software functions and automated operation of the system under software control.

4. MAINTENANCE

4.1. INTRODUCTION

This section covers troubleshooting, repair and alignment of the model 6640Q Automatic DCC room temperature Quantum Hall Resistance Bridge.

4.2. RATIO VERIFICATION

This section outlines the recommended ratio verification requirements for the 6640Q Bridge.

4.2.1. PURPOSE

The purpose of the procedure in this section is to assure that the model 6640Q Quantum Hall Bridge functions properly and meets the manufacturer's specifications. It is recommended that these procedures be performed after any corrective maintenance activity, or if the operator perceives a problem.

It is recommended that these procedures be performed on an annual basis to verify performance of the model 6640Q and for its recertification.

4.2.2. EQUIPMENT REQUIRED

The following equipment is required for this procedure.

- 10 ohm standard resistor, stable to ±0.01 ppm over a 24 hour period (x2)
- 100 ohm standard resistor, stable to ±0.01 ppm over a 24 hour period (x2)
- 1k ohm standard resistor, stable to ±0.01 ppm over a 24 hour period (x2)
- 10 k ohm standard resistor, stable to ±0.01 ppm over a 24 hour period (x2)
- Temperature controlled environment sufficient to maintain the reference and working standard resistors to their specified uncertainties

Note: The eight standard resistors are available in the optional model 6634A Temperature Stabilized Resistance Standard.

4.3. MODEL 6640Q BRIDGE VERIFICATION

The following procedure is can be automated in using a test sequence BridgeWorks-ADV Data Acquisition Software if the 6640Q is connected through a 6664C scanner.

4.3.1. Set Up

1. Ensure that the model 6640Q is switched on, as well as the optional 6664C and 6634A Resistance Standard if installed. Open the BridgeWorks Data Acquisition Software in the computer.

4.3.2. Inputs-Outputs Verification

1. Have the following resistors ready for connection to the 6640Q or pre-connected to scanner channel leads from the optional 6664C scanner as listed below:

   Resistor
   10 Ω (2)
   100 Ω (2)
   1 kΩ (2)
   10 kΩ (2)

   Set these standard resistors into the controlled temperature environment and allow time for them to stabilize. NOTE that without a tightly controlled temperature environment (e.g. 0.05 Deg C or better) most resistors will not be stable enough to perform a Bridge verification.

2. Use the "Test Sequence" function of the "Configuration" menu of the BridgeWorks-ADV Data Acquisition Software to measure the resistance ratio of each resistor pair with the corresponding excitation current and reversal rate listed below. See the BridgeWorks-ADV Software User's Manual for the particulars of running a test sequence. These measurements can also be made manually. If they are made manually, allow sufficient time for the measurement to settle and ensure that all measurements related to a given closure are within 24 hours of each other.

Meas. No.	R_X Resistor	R_s Resistor	Excitation Current	Reversal Rate	Meas. Mode
Tests 1 – 4 for 6640Q bridges.					
1	10 Ω	10 Ω	0.77 mA or 1.0 mA	20s	Normal
2	100 Ω	100Ω	0.77 mA or	20s	Normal
3	1 kΩ	1 kΩ	1.0 mA	40s	Normal
4	10 kΩ	10 kΩ	0.77 mA or	40s	Normal

3. For each resistor pair, calculate and report the interchange closure error. For example, if the Rx:Rs ratio of the first measurement is R_a and the Rx:Rs ratio of the second measurement, where the two resistors are exchanged with one another, is R_b; then the interchange error e_i in ppm of the nominal ratio is:

$$e_i = (1/2) \times | R_a \times R_b - 1 | \times 10^6$$

4. The maximum allowable interchange closure errors (ppm) for the following resistor pairs are:

Resistor	Resistor	Interchange Error
10 Ω	10 Ω	0.015
100 Ω	100 Ω	0.015
1 kΩ	1 kΩ	0.015
10 kΩ	10 kΩ	0.015

5. REMOTE CONTROL

MODEL 6640 PROGRAMMING COMMAND SUMMARY

A brief description of each of the possible remote IEEE-488 commands and their syntax in BNF (Backus Naur Form) follows:

- words inside angle brackets (ie. < and >) are defined items
- :== means "is defined to be"
- | means "or"
- [] means optional
- required letters are shown in upper case but may be upper or lower case.

<digit>:== 0|1|2|3|4|5|6|7|8|9
<letter> :== A|B|C|...|Z|a|b|c|...|z
<string> :== <letter> | <letter><string>
<boolean> :== 0|1
<unsigned> :== <digit> | <digit><unsigned>
<nr1> :== [+|-]<unsigned>
<nr3> :== <nr1>[.[<unsigned>]][E<nr1>]
<?> :== <letter> | <digit>
<*> :== <?> | [<*>] :not to be confused with *
<DD> :== <unsigned> : limited to range 1...31
<MM> :== <unsigned> : limited to range 1...12
<YYYY> :== <unsigned> : limited to ranges 1999 and up

The STB Bits are as follows:
bit 7 = (unused)
bit 6 = SRQ (service request)
; set when (SRQ_mask|GPIB_STAT_PORT) != 0
bit 5 = ESB (event summary)
; set when bitwise AND of ESE, register is not zero
bit 4 = MAV (message available)
; set when GPIB Tx buffer has data available
; cleared when the buffer is empty
bit 3 = IFL (input buffer full)
; set when input buffer is over 80% full
; cleared when input buffer drops under 20% full
bit 2 = CHK (Checksum calculation complete)
bit 1 = RDY (ready)
; set when unit has a stable reading
; cleared when unit is working
bit 0 = OVR (over range)
; set when over range detected (in ISR)
; cleared when over range cleared

COMMAND	COMMENT
*CLS	clear status register
*ESR?	query, display event status register
*ESE?	query, display event status enable
*ESE <unsigned>	set event status enable
*IDN?	query, display identity of unit
*OPT?	query, display any reportable options
*OPC?	query, operation complete
*OPC	set operation complete bit in event status register
*RST	reset the instrument to a known defined state
*STB?	query, display serial poll status byte
*SRE?	query, display service request mask
*SRE <unsigned>	set the service request mask
*TST?	query, display results of self test
FETCh?	fetch the most recent data value

MEASure - set the measurement parameters

MEASure <state>	select the measurement state <state>:== 0|1 type <boolean> 0 :== OFF 1 :== ON
MEASure?	query, display the measurement state of the instrument
MEASure:UNIT <unit>	select the units of measurement and instrument operation <unit> :== R|O|C|F|K|V type <letter> R:==Ratio O:==Ohms C:==Celsius F:==Fahrenheit K:==Kelvin V:==Volts
MEASure:UNIT?	query, display the units of measurement
MEASure:FILTer <function>	setup the digital filter for the display data

COMMAND	COMMENT
	<function>:== 0|1|2 type <digit> 0 :== Filter OFF 1 :== Decimation 2 :== Simple average
MEASure:FILTer?	query, display the filter setup
MEASure:UPDAte <rate>	set the number of screen updates for each measurement cycle <rate>:== 0|1|2 type <digit> 0:==1 updates/cycle 1:==2 updates/cycle 2:==4 updates/cycle
MEASure:UPDAte?	query, display the screen update rate setting
MEASure:DEVIation <diff>	select the method of reporting the difference data <diff>:==0|1|2|3|4 type <digit> 0 :== disable/normal 1 :== parts per million 2 :== delta change 3 :== ppm from datum 4 :== delta from datum
MEASure:DEVIation?	query, display the method of reporting the difference data
MEASure:RESOlution <prec>	select the precision of reporting the data <prec>:==0|1|2|3|4 type <digit> 0 :== 0.001 ppm 1 :== 0.01 ppm 2 :== 0.1 ppm 3 :== 1.0 ppm 4 :== 10.0 ppm
MEASure:RESOlution?	query, display the precision of reporting the data
MEASure:VOLT <state>	set the state of the nanovoltmeter to measure input voltages at the potential terminals

COMMAND	COMMENT
	0:== OFF 1:== ON
MEASure:VOLT?	query nanovoltmeter status
MEASure:QUICk <state>	select the quick measurement state <state>:== 0|1 type <boolean> 0 :== OFF 1 :== ON
MEASure:QUICk?	query, display the quick measurement state of the instrument

CONFigure - configure instrument operating parameters

CONFigure:DATUm <unit>, <value>	initialize the datum to be used as the set point in all difference calculations <unit> :== R|O|C|F|K|V type <letter> R:==Ratio O:==Ohms C:==Celsius F:==Fahrenheit K:==Kelvin V:==Volts <value>:==<nr3>
CONFigure:DATUm?	query, display the datum used as the set point in all difference calculations
CONFigure:FILTer <size1>,<size2>	initialize the filter coefficients <size1> :== <nr3> decimation filter coefficient <size2> :== <unsigned> N average filter coefficient
CONFigure:FILTer?	query the filter coefficients
CONFigure:RESIstor <md>, <RS_SN>, <SN>, <RX>, <Rev_Rate>, <Tst_Val>, <Tst_Max>	set the active resistor measurement configuration

COMMAND	COMMENT
	<mode>:== 0|1|2| type <digit> 0:==normal mode 1:==high ohms mode 2:==low ohms mode <RS>:==<nr3> ref. resistor value <RS_SN>:==<string> ref. resistor serial # <RX>:==<nr3> approximate value Rx <Rev_rate>:==<nr3> test current reversal rate <Tst_Val>:==<nr3> test current/volts <Tst_Max>:==<nr3> max current(Is)/volts for ref resistor
CONFigure:RESIstor?	query, display active resistor configuration information
CONFigure:RESIstor:DISPlay <unit>, <rate>, <filter>, <size>, <power>	set the active display parameters for resistor measurements <unit>:== R|O

COMMAND	COMMENT
	type <letter> R:==Ratio O:==Ohms <rate>:== 0|1|2 type <digit> 0:==1 updates/cycle 1:==2 updates/cycle 2:==4 updates/cycle <filter>:== 0|1|2 type <digit> 0 :== none 1 :== decimation 2 :== simple average <size>:==<unsigned> size = % for decimation = sample size for simple average <power>:== 0|1|2 type <digit> 0 :== power normal X1 1 :== power X2
CONFigure:RESIstor:DISPlay?	query, display the active resistor display setup
CONFigure:PROBe <RS>, <RS_SN>, <R0>, <PRT_SN>, <Rev_Rate>, <Tst_Val>, <Tst_Max>	set the active probe measurement configuration <RS>:==<nr3> ref. resistor value

COMMAND	COMMENT
	<RS_SN>:==<string> ref. resistor serial # <R0>:==<nr3> Probe resistance at ice point (IPTS68) Or triple point of water (ITS90) <PRT_SN>:==<string> probe resistor serial # <Rev_rate>:==<nr3> test current reversal rate <Tst_Val>:==<nr3> test current/volts <Tst_Max>:==<nr3> max current(Is) for ref resistor
CONFigure:PROBe?	query, display active probe configuration Information; response includes all associated coefficients see CONF:PROB:PCOE? and CONF:PROB:NCOE?
CONFigure:PROBe:DISPlay <unit>, <rate>,	<filter>, <size>, <power> set the active display parameters for probe measurements <unit>:== R|O|C|F|K type <letter> R:==Ratio

COMMAND	COMMENT
	O:==Ohms C:==Celsius F:==Fahrenheit K:==Kelvin <rate>:== 0|1|2 type <digit> 0:==1 updates/cycle 1:==2 updates/cycle 2:==4 updates/cycle <filter>:== 0|1|2 type <digit> 0 :== none 1 :== decimation 2 :== simple average <size>:==<unsigned> size = % for decimation = sample size for simple average <power>:== 0|1|2 type <digit> 0 :== power normal X1 1 :== power X2 2 :== power X0.5
CONFigure:PROBe:DISPlay?	query, display the active probe display setup
CONFigure:PROBe:COEFficient <equation_#>, <coeff_00>, <coeff_01>, .., <coeff_n>	set the active probe conversion coefficients measurements <equation_#>:== <unsigned>: equation_# takes on a value in the range 00 through 11 for the temperature calibration range of the probe <coeff_00>:==<nr3>

COMMAND	COMMENT
	<coeff_xx> are coefficients 01 through n for the probe ITS90 conversion algorithm. When <equation>:==00 the IPTS68 coefficients can be set.
CONFigure:PROBe:PositiveCOEfficient?	query, display the active probe positive temperature coefficients
CONFigure:PROBe:NegativeCOEfficient?	query, display the active probe negative temperature coefficients
CONFigure:VOLTmeter <range>, <zero>, <high>, <ref>	set the voltmeter calibration coefficients <range>:== 0|1|2|3|4 type <digit> 0:== 20V range 1:== 2V range 2:== 200mV range 3:== 20mV range 4:== 2mV range <zero>:==<unsigned> <high>:==<unsigned> <ref>:==<nr1>
CONFigure:VOLTmeter? <Range>	query, display the voltmeter calibration setup <range>:== 0|1|2|3|4 type <digit> 0:== 20V range 1:== 2V range 2:== 200mV range 3:== 20mV range 4:== 2mV range

SYSTem - set the unit system settings

SYSTem:COMMunicate:GPIB <address>, <mode>	setup GPIB communications <address>:== <unsigned> <mode>:== 0|1|2 type <digit>

COMMAND	COMMENT
	0 :== disable 1 :== talk only 2 :== talk/listen
SYSTem:COMMunicate:GPIB?	query, display GPIB set up
SYSTem:TERSe	respond to commands with a minimum data set
SYSTem:VERBose	respond to commands with a minimum data set
SYSTem:VERSion?	query, display the installed software version
SYSTem:DIAGnostic:ROMChecksum?	query, display rom checksum
SYSTem:DIAGnostic:SERialNumber <number>	assign serial number <number>:==<unsigned> Diagnostic Command Set

SOFCAL - set the unit calibration details

SOFCAL:COEF <ratio>, <range>, <corr>, <uncert>	<ratio>: == 0|1|2|3|4|5 0:==0.1:1 ratio 1:==1:1 ratio 2:==1:1 ratio (648 turns) 3:==10:1 ratio (648 turns) 4:==10:1 ratio (81 turns)

COMMAND	COMMENT
	5:==100:1 ratio type<digit> <range>: == 0|1|2|3|4|5|6|7|8 type<digit> 0:==1 ohm Rs range 1:==10 ohm Rs range 2:==100 ohm Rs range 3:==1k ohm Rs range 4:==10k ohm Rs range 5:==100k ohm Rs range 6:==1M ohm Rs range 7:==10M ohm Rs range 8:==100M ohm Rs range <corr>:==<nr3> correction coefficient (ppm of ratio) <uncert>:==<nr3> uncertainty (ppm of ratio)
SOFCAL:COEF? <ratio>, <range>	query, display ratio correction coefficient <ratio>: == 0|1|2|3|4|5 0:==0.1:1 ratio 1:==1:1 ratio 2:==1:1 ratio (648 turns) 3:==10:1 ratio (648 turns) 4:==10:1 ratio (81 turns) 5:==100:1 ratio type<digit> <range>: == 0|1|2|3|4|5|6|7|8

COMMAND	COMMENT
	type<digit> 0:==1 ohm Rs range 1:==10 ohm Rs range 2:==100 ohm Rs range 3:==1k ohm Rs range 4:==10k ohm Rs range 5:==100k ohm Rs range 6:==1M ohm Rs range 7:==10M ohm Rs range 8:==100M ohm Rs range
SOFCAL <beta>	set adc beta <beta>: == <unsigned> 200 <= beta < 300
SOFCAL?	query, display adc beta for the nanovolt detector
SOFCAL:GET	Calculate adc beta for the nanovolt detector
SOFCAL: FREQuency <Hz>	set the line frequency option <Hz>: = = 011 type <digit> 0 : = = 60 Hz 1 : = = 50 Hz
SOFCAL:DATE<YYYY>,<MM>,<DD	set the calibration date <YYYY> calibration year <MM> calibration month <DD> calibration day
SOFCAL:DATE?	query, display the calibration date
SOFCAL:PRIM<state>	set the primary turns lock <state> 0|1|2 type<boolean> 0:== unlocked 1:== locked to 81 turns 2:== locked to 648 turns
SOFCAL:PRIM?	query, display the primary turns lock

Low-Level Hardware Commands

COMMAND	COMMENT
ADconvRead?	query, display adc reading in engineering units
ADconvB?	query, display adc in raw binary units
Filter <function>	set the nano voltmeter filter <function>:==0|1 type <boolean> 0:== OFF 1:== ON
Filter?	query, display the nano voltmeter filter setting
Highres <resolution>	set the high resolution mode <resolution>:==0|1 type <boolean> 0:== OFF 1:== ON
Highres?	query, display the high resolution mode setting
HardWareFilter <status>	set the hardware filter status <status>:==0|1 type <boolean> 0:== OFF 1:== ON
HardWareFilter?	query, display the hardware filter status
IXTurns <turns>	set relay turns <turns>:==<unsigned> 0≤turns≤8747
IXTurns?	query, display relay turns setting
ISDAC <value>	set dac setting <value>:==<nr1> value == ±5 Volts
ISMux <channel>	set the multiplexer channel <channel>:==0|1|2|3|4|5|7

COMMAND	COMMENT
	type <digit> 0:== servo 1:== speedup 2:== offset 3:== +40 Volts 4:== -40 Volts 5:== primary current 7:== calibrate
ISMux?	query, display the multiplexer channel
ISResolution <resolution>	set the resolution <resolution>:==0|1|2 type <digit> 0 :== high 1 :== medium 2 :== low
ISResolution?	query, display the resolution setting
ISSpeed <speed>	set the speed <speed>:==0|1|2|3 type <digit> 0 :== reset 1 :== slow 2 :== moderate 3 :== fast
ISSpeed?	query, display the speed setting
OHmmode <mode>	set the ohm mode <mode>:==0|1|2 type <digit> 0 :== normal 2 :== low ohms
OHmmode?	Query, display the ohm mode
Range <range>	set the nanovoltmeter range <range>:==<unsigned> range any one of 0.002, 0.02, 0.2, 2.0, 20.0

COMMAND	COMMENT
Range?	query, display the selected range
Voltage?	query, display the nanovoltmeter measurement
RESET	reset instrument to power on reset state