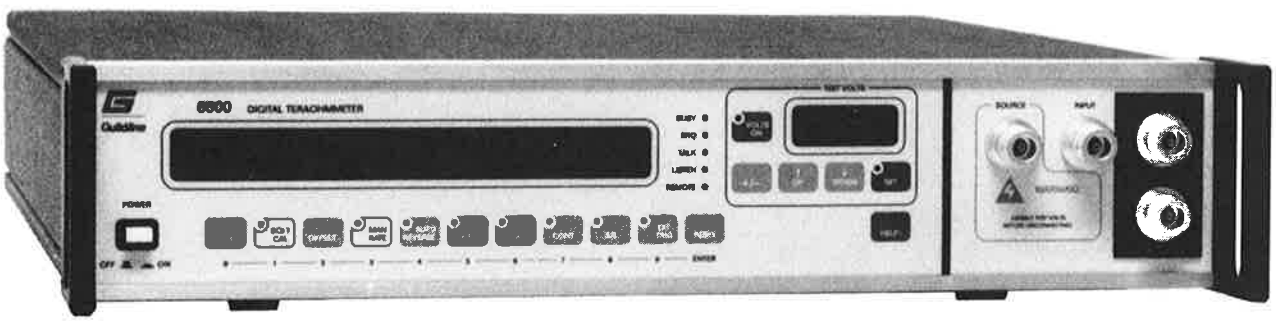
6500



DIGITAL TERAOHMMETER

OPERATING MANUAL

FOR

MODEL 6500

DIGITAL TERAOHMMETER

NOTICE

OM-6500-H-00

CAUTION

The model 6500 Teraohmmeter can generate lethal voltages at the SOURCE connector.
This equipment must not be used or incorporated into a test set-up by unqualified personnel.

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Introduction

INTRODUCTION

This manual provides complete information on the installation and operation of the Guildline Instrument's Model 6500 Teraohmmeter. Also included is a general description of the theory of operation together with instructions for calibration. The Teraohmmeter is based on fundamental work performed by Dr. S. H. Tsao of the National Research Council of Canada, and is manufactured by Guildline Instruments.

1.1 FUNCTIONAL DESCRIPTION

The model 6500 is a microprocessor based, fully automated, high precision device for measuring high value resistors or very small DC currents. It combines the proven technology of the Guildline Model 9520 Teraohmmeter with the latest in microprocessor technology.

The main features of the model 6500 are:

- Autoranging from 10^6 to 10^{16} ohms.
- Autoranging from 10^{-7} to 10^{-12} amperes.
- Built in GPIB and RS232 interfaces.
- Fully controllable through the bus interfaces.
- Internal software routines for measurement error compensation.
- Extensive self diagnostics.
- User friendly interface.

1.2 PHYSICAL DESCRIPTION

The instrument is housed in a 25 pound vinyl aluminum cabinet approximately 17 3/8 inches wide, 3 1/2 inches high and 18 inches deep. All indicators and frequently used controls are located on the front panel together with two connectors for connection of the unknown resistor or current. The power connection is made through a detachable 3-wire cord which plugs into the rear panel. Although the instrument is primarily intended for bench top use, front panel flanges are supplied with the instrument to allow it to be mounted in a standard 19 inch cabinet.

1.3 PRINCIPLE OF OPERATION

A simplified block diagram is given in Figure 1.

When measuring resistance, a known DC test voltage is supplied by the 6500 which causes a current to flow through the unknown resistor into an operational integrator. The current magnitude is determined by the time required for the integrator output to pass between two different threshold voltage points. Knowing the test voltage and current magnitudes, the internal microprocessor can determine the value of the unknown resistor. The test voltage is selectable from 10 standard values from 1 to 1000 volts with either polarity.

Current is measured by connecting it directly to the integrator input without the internal test voltage.

The instrument stability depends on the stability of the test voltage, the integrator, the timing circuit and the threshold voltage detector at the integrator output. Fixed errors in the absolute values of these parameters are compensated by an internal software calibration routine in conjunction with an external calibration resistor of known value. The calibration resistor can be provided by Guildline as an accessory.

The 6500 is fully automated with an internal microprocessor to compute the measurements and make the error compensations. The calculated value of the unknown resistor is displayed on the front panel and is outputted on the control bus. The microprocessor derives its commands from the front panel manual controls or from either one of the two control buses. When measuring resistance, the 6500 can provide enhanced accuracy by automatically computing the average of four sequential measurements made with test voltage polarity alterations. The computed average is displayed on the front panel and fed out on the control bus.

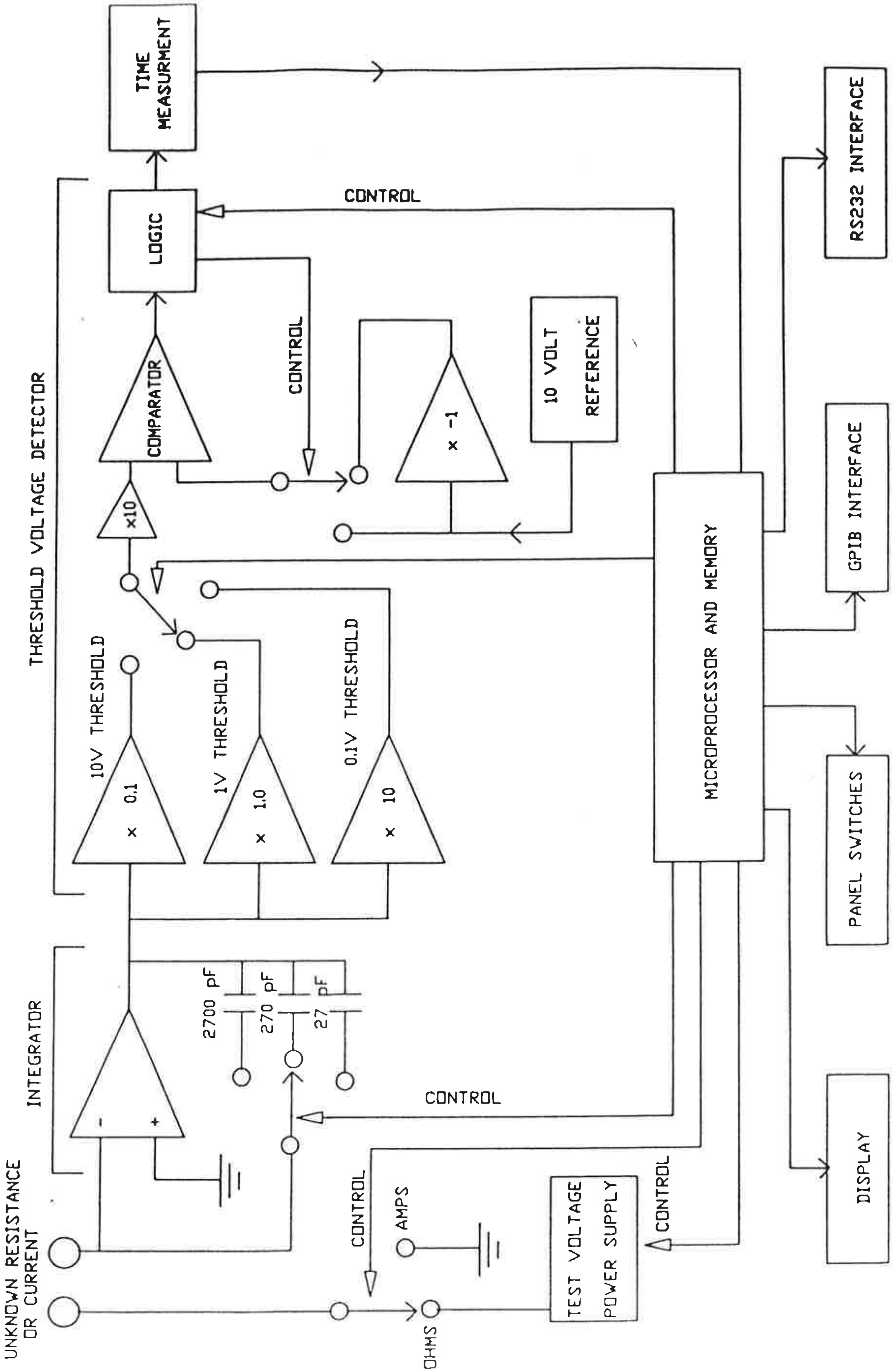


FIGURE 1 - SIMPLIFIED BLOCK DIAGRAM

1.4 MODES OF OPERATION

Although the 6500 is fully automated for simplicity and convenience, the operator or the control bus can override this feature when specific measurement parameters are required.

The instrument can be set to take a continuous series of measurements or to sample once for each request. A sample request can be made with an external synchronizing signal fed to a rear panel connector or by the operator depressing a front panel push-button.

The number of resistance measurements made per data sample output is selectable. The operator can select either one or four (averaged). The resistance test voltage polarity is selectable. When measuring current, either flow direction can be accommodated.

The SOFCAL (software calibration) function permits the operator to calibrate the instrument, to examine the interface (GPIB or RS232) configuration and to review the calibration date and the software revision of the instrument.

1.5 CIRCUIT DISCUSSION

The model 6500 teraohmmeter measures high values of resistance by charging a small capacitor through the resistance to be measured. An operational integrator is shown in Figure 2 which functions as follows:

$$\frac{\text{delta } V_o(t)}{\text{delta } t} = \frac{-V_{in}}{R * C}, \quad (1)$$

(The equality is not exact but is extremely close when the voltage gain is high)

or:

$$R = \frac{V_{in} * \text{delta } t}{C * \text{delta } V_o} \quad (2)$$

Where delta t = a change in time and delta V_o = a change in output voltage over time delta t.

When current is being measured, Vin can be replaced by iR which simplifies (1) to the form:

$$i = \frac{C \text{ delta } V_o}{\text{delta } t} \quad (3)$$

In the Model 6500:

* Vin is the test voltage for resistance measurement.
* C is a stable capacitor selected from the nominal values of 27, 270 & 2700 pF.
* delta V_o is the potential difference between two threshold voltages placed symmetrically above and below ground ($V_o = 2V_{thresh}$ where V_{thresh} is selectable from 0.1, 1 & 10 volts).

In equations (2) and (3), all terms are constant except R, i and delta t. Therefore delta t is proportional to R or inversely proportional to the current i.

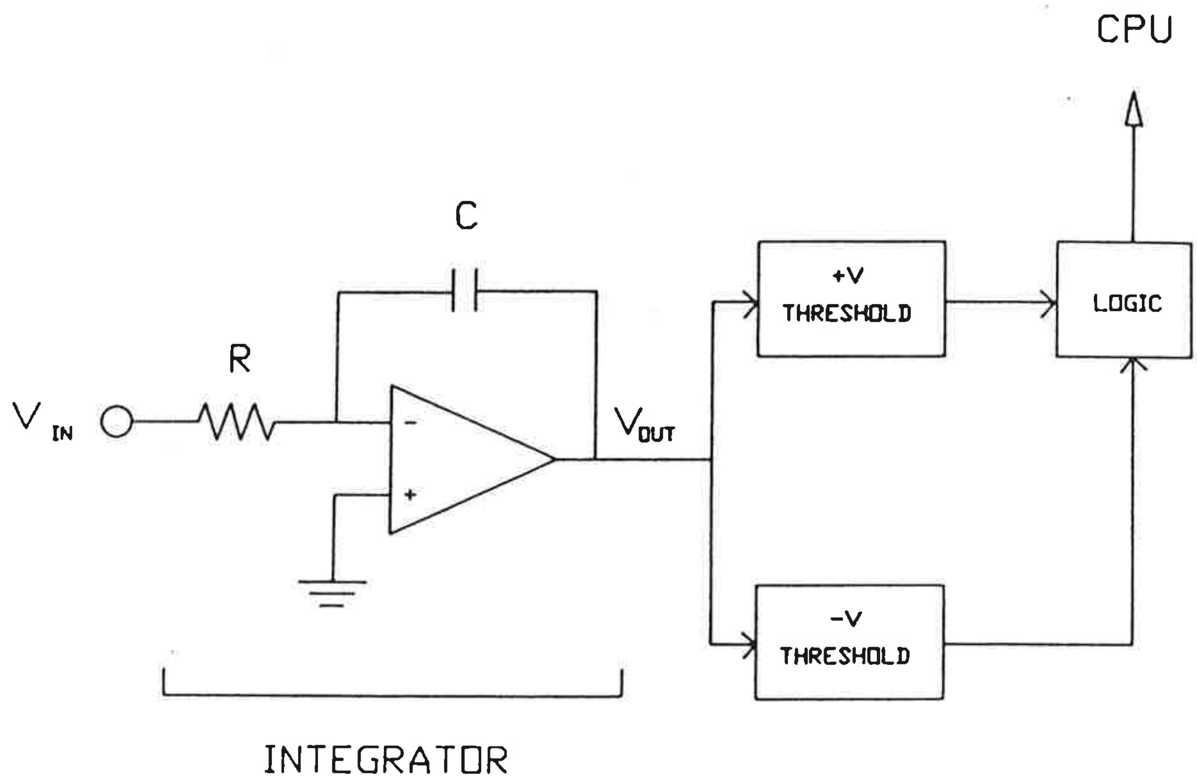


FIGURE 2, OPERATIONAL INTEGRATOR

Chapter 2
Specifications

2.1 POWER REQUIREMENTS

* 50 watts
* 47 - 63Hz
* Nominal voltages selectable at the rear panel are 100V, 120V, 220V and 240V. All voltage settings are operable over a range of 10% above or below the nominal value.

2.2 RESISTANCE SPECIFICATIONS

TABLE 1, RESISTANCE MEASUREMENT ACCURACY

Resistance	Accuracy (PPM)
1M < R < 10M	250
10M < R < 100M	350
100M < R < 1G	500
1G < R < 10G	700
10G < R < 100G	1000
100G < R < 1T	2000
1T < R < 10T	3000
10T < R < 100T	5000
100T < R < 1P	10000

NOTE: These accuracies are applicable when using the auto reversing mode of operation and when the current is no less than one picoampere through the unknown resistor. Many types of high value resistors cannot be measured accurately with the auto-reverse mode because their actual resistance changes slowly for a period of time after a polarity reversal. They can be measured to the full 6500 accuracy potential by allowing sufficient settling time between polarity reversals. This is done under manual control or through either control bus with an external average computation.The accuracy is traceable to NRC or NBS at one calibration point and is inferred throughout the instrument range by the basic linearity and stability of the instrument.

2.3 PICOAMMETER SPECIFICATIONS

TABLE 2, CURRENT MEASUREMENT ACCURACY

Range	Accuracy (percent)
100uA < I < 1mA	0.25
10uA < I < 100uA	0.35
1uA < I < 10uA	0.5
100nA < I < 1uA	0.7
10nA < I < 100nA	1
1nA < I < 10nA	2
100pA < I < 1nA	3
10pA < I < 100pA	5
1pA < I < 10pA	10
I < 1pA	>10
Input resistance: 100 kilohms	

2.4 RESOLUTION

When the Model 6500 is used with short integration time periods, the measurement resolution is limited by the quantizing error in the time measuring circuit (plus or minus one clock period). When the quantizing error is not significant, the display resolution is truncated at a value commensurate with the short term measurement stability. The measurement resolution can be determined from table 3.

TABLE 3, MEASUREMENT RESOLUTIONS (Digits)

INTEGRATING CAPACITY	INTEGRATION TIME				
pF	5.4 ms	54 ms	540 ms	5.4 sec	20,000 sec
27	3	3	4	5	6
270	3	4	5	6	6
2700	4	5	6	6	6
Subtract one digit for resistance measurement without auto-reverse mode.					
Subtract two digits for current measurement.					

2.5 PHYSICAL SPECIFICATIONS

* Size (exclusive of projections such as handles, flanges, connectors, etc.):
  * Width = 17 3/8 inches (44.2 cm)
  * Height = 3 1/2 inches (8.9 cm)
  * Front-to-back = 18 inches (45.7 cm)
* Weight: 25 +/- 3 pounds (11.4 +/- 1.4 Kgm)
* Mounting: Bench top with extra flanges provided separately for 19 inch rack mounting.
* Input Connectors: Front panel with rear panel access optional on request.
* Hidden Power Selection Switch: On rear panel.
* GPIB Bus Address: On rear panel.

2.6 ACCESSORY EQUIPMENT

2.6.1 Adapter For Penn Airborne Resistor

Model 65201

This accessory provides a stable shielded environment for measuring high resistances and the leakage resistance of capacitors.

The sample resistor should be connected between the "Source" and "R" terminals and the lid should be closed before any measurements are started.

CAUTION

Hazardous Voltages may be present at the source terminal. Ensure that the 6500 source is turned off before opening the 65201 cover.

The sample capacitor should be connected between the "Source" and "C" terminals. This inserts a 10 Meg ohm resistor in series with the capacitor to limit inrush currents.

Inside dimensions: 6 3/4 x 3 3/8 x 3 1/2 HT.

2.6.2 Standard Resistors

Two precision standard resistors are available for calibrating the 6500. Each is supplied in a shielded can with two male type N connectors spaced to allow direct connection to the 6500 without cables. The 1 Gigaohm is recommended for general usage.

Model Number	Nominal Value	Actual Value % of Nominal	Certified Accuracy % of Actual	Temp. Coef. (max) ppm/K	Volt. Coef. (max) ppm/V
65206/100M	100 Meg	+/-1%	+/-.01	+/-50	.1
65206/1G	1 Gig	+/-1%	+/-.02	+/-100	.1

2.6.3 Extension Cables

Model 65204/24N and 65204/60N

These extension cables are provided in 24 inch (61 cm) and 60 inch (152 cm) lengths respectively. Each cable is fitted with a male and a female type N connector at opposite ends and is intended to connect the 6500 to a remote resistor or current to be measured.

2.6.4 Extension Cables With Clips

Model 65204A/18 and 65204A/60

These cables are similar to the 65204's but are provided with alligator clips for attachment to the circuit or device under test. They are available in 18 inch (45 cm) and 60 inch (152 cm) lengths.

2.6.5 Sample Shielded Enclosure

Model 65205

Inside dimensions: 5 1/4 x 4 1/4 x 2 1/4 HT.

Description: See 65201

2.6.6 Connector Adapter

Model 65209

This is a between-series-adapter to permit a BNC type connector to be attached to the type N jack on the 6500. It is type N male to type BNC female.

2.6.7 Adapter Cable, N Male to GR

Model 65207

This accessory permits the 6500 to be connected to devices or circuits which are fitted with GR type connectors. They are particularly useful to allow the Model 6500 Teraohmmeter to be used with accessories designed for the Model 9520. The accessory includes one cable only and two are required to make a complete connection.

2.6.8 Adapter Cable, N Female to GR

Model 65208

This accessory is similar to the Model 65207 except for the connector polarity. It is used to connect the Model 6500 accessories to the Model 9520 Teraohmmeter.

Chapter 3
Installation

3.1 Installation

The 6500 Teraohmmeter is an instrument intended to be used in a laboratory environment and is specified to be operated within an environmental temperature range of $23^{o}C$ +/- $5^{o}C$ only. High humidity can degrade the accuracy of the instrument. The 6500 must be mounted with an angle of inclination of no more than 30^{o}.

3.2 Preliminaries

Pry open the power receptacle on the rear panel as shown in Figure 3.

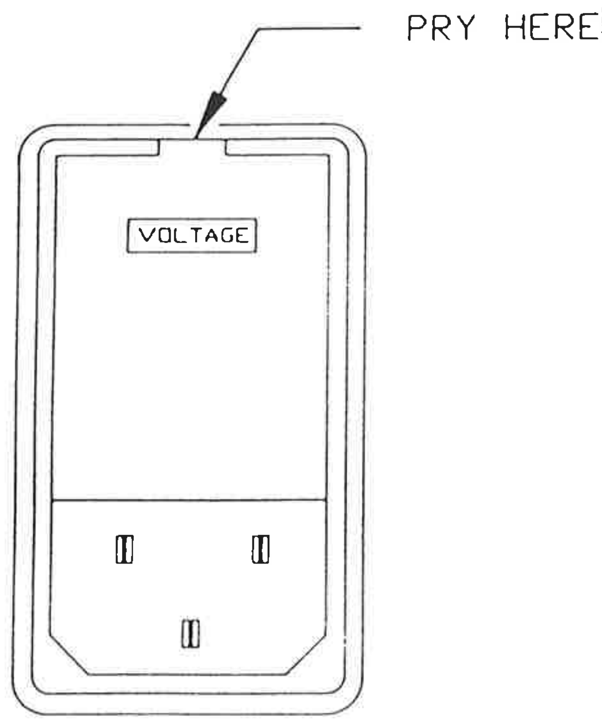


FIGURE 3, OPENING THE POWER RECEPTACLE

Check to see that the fuses inserted in the receptacle correspond to the correct type specified in table 4 .

TABLE 4, POWER FUSE SELECTION

LINE VOLTAGE	FUSE TYPE REQUIRED
100V 120V	1 Amp Slo-Blo (MDL-1A/250V)
220V 240V	1/2 Amp Slo-Blo (MDL-1/2A250V)

Only fuses of the specified type are to be used. Set the voltage selector drum so that the proper line voltage indication will be visible through the receptacle rear window when the receptacle cover is closed. This is important because the drum selects the proper transformer connection for the required voltage.

The supplied molded line cord should be plugged into the 3 pin power receptacle on the right hand side of the rear panel of the instrument. Plug the line cord into a receptacle with the required voltage and a protective ground connection.

Where the molded plug on the supplied line cord does not match the power outlet receptacle the plug may be removed and replaced with a 3-pin plug of the correct type.

The plug should be wired as follows:

Brown	- High voltage
Blue	- Neutral
Green/Yellow	- Ground (Earth)

3.2 PRECAUTIONS

The instrument should be disconnected from the line supply before any attempt is made to remove the cover. Lethal voltages are present at several points within the instrument and under some operating conditions at the source connector. Therefore ONLY QUALIFIED PERSONNEL WHO ARE AWARE OF THE NECESSARY PRECAUTIONS SHOULD BE GIVEN ACCESS TO THIS EQUIPMENT.

Operation of the instrument with the cover removed will result in degraded performance due to the lack of shielding from radiated electrical interference.

3.3 CONTROLS AND INDICATORS

The front panel of the 6500 Teraohmmeter has a prominent sixteen character alphanumeric display which provides a visual readout of data and status. Additional status information is presented by individual front panel LED lamps and a four character numeric display which shows the magnitude and polarity of the test voltage when it is present on the SOURCE connector.

3.3.1 Switch functions

3.3.1.1 POWER

The on/off pushbutton is the only function which cannot be controlled by the the bus interfaces.

3.3.1.2 LOCAL

This key is used in the measuring mode to restore control from the bus interface to the front panel of the instrument. Note: it is possible for the remote controller to lock out this key (see Section 7 remote commands, LOCKOUT).

In the manual SOFCAL mode this key is used to enter the numeral zero.

3.3.1.3 SOFTCAL

This key places the instrument in the SOFCAL mode. The SOFCAL functions are described in section 6 of this manual.

Once in the SOFCAL mode, this key can be used to enter the numeral one.

3.3.1.4 OFFSET

Used in the SOFCAL mode only for the purpose of entering the numeral two.

3.3.1.5 MAN RATE

This key is an alternate action switch used to override the automatic ranging function of the instrument and allow the operator to select the internal integrating capacitor, voltage ramp threshold and test voltage (and hence the range) of the instrument. When the LED located at the corner of the pushbutton is lit, the instrument is in the manual mode and will not autorange.

When in this SOFCAL mode, this key is used to enter the numeral three.

3.3.1.6 AUTO REVERSE

In the ohms measurement mode, this is an alternate action key used to select a display derived from a single measurement only or alternatively derived from an average of a group of four measurements with polarity reversals in order to improve the accuracy. When the LED is lit, the instrument is in the auto reverse mode.

In the SOFCAL mode, this key is used to enter the numeral <u>four</u>.

3.3.1.7 OHMS

In the measurement mode, this is an alternate action key that activates or deactivates the resistance measurement function. When the LED located at the corner of the pushbutton is lit, the ohms mode is activated.

In the SOFCAL mode, this key is used to enter the numeral <u>five</u>.

3.3.1.8 pA

In the measurement mode, this is an alternate action key which activates or deactivates the current measurement function. When the current mode is activated the LED is lit and the SOURCE connector is disconnected from the test power supply and becomes the return path for the externally applied current under measurement. Note this key and the ohms key are mutually exclusive: activating one mode will deactivate the other.

In the SOFCAL mode, this key is used to enter the numeral <u>six</u>.

3.3.1.9 CONT

In the measurement mode, this is an alternate action key that selects a repetitious or alternatively a single measurement mode. When the LED is lit measurements are automically done repetitiously.

In the SOFCAL mode, this key is used to enter the numeral seven.

3.3.1.10 S/S

In the measurement mode, this key allows the operator to manually trigger a single measurement or a single average of four measurements. This key and the CONT key are mutually exclusive (pressing one will automatically cancel the other).

When the key is pressed, the LED will light until the triggered measurement is complete.

In the SOFCAL mode, this key is used to enter the numeral eight.

3.3.1.11 EXT TRIG

In the measurement mode, this is an alternate action key that activates or deactivates the external trigger function. When the LED is lit the action is similar to the S/S function axcept the instrument will make one reading each time the rear panel EXT TRIG connector is grounded.

In the SOFCAL mode this key is used to enter the numeral nine.

3.3.1.12 RESET

In the measurement mode, this key has two functions. One function aborts any function that is in progress and starts again.

This is useful when the device under test has been disturbed in such a way as to invalidate the measurement and the time required to complete the measurement will be long. The second function is used when the device under test has an electrical charge before it is connected to the 6500. This charge may cause the 6500 to lock up when the device is connected. This condition can be remedied by pressing this key.

When in the SOFCAL mode, it is also used as the enter key.

3.3.1.13 VOLTS ON

This is an alternate action key which has an identical purpose in the OHMS and SOFCAL modes of operation. When the LED is lit, the internally derived test voltage will be present on the front panel SOURCE connector. To the right hand side of the key, the four numeral LED will display the magnitude of the voltage, when the key is activated. When the key LED is not lit, the voltage will not be present at the SOURCE connector and the magnitude display will be turned off.

CAUTION IS REQUIRED BECAUSE POTENTIALLY LETHAL VOLTAGE MAY BE PRESENT AT THE "SOURCE" CONNECTOR.

3.3.1.14 +/-

This key is used either to change the polarity of the test voltage in the OHMS mode or to accommodate both current directions in the pA mode of operation.

It is also used to climb levels in the SOFCAL mode.

3.3.1.15 UP

This key is active in most instrument modes for selecting ranges, voltages etc.

In SOFCAL mode this key is used for scrolling through the possible choices at any given level.

3.3.1.16 DOWN

This key is active in most instrument modes for selecting ranges, voltages etc.

3.3.1.17 SET

This key is used to lock into a specific range, voltage etc. in most operating modes of the instrument.

In the SOFCAL mode this key is used to exit to the measurement mode.

3.3.1.18 HELP

This button is a software reset of the system which restores the hardware and software to the initial state, that was present at power turn-on.

3.3.2 Status Indicator LEDS

The five LEDs located between the main data display and the test volts display area of the front panel are used to give status of the instrument and GPIB control interface.

3.3.2.1 BUSY

This LED indicates that the instrument is in the process of auto-ranging or is taking a measurement.

3.3.2.2 SRQ

This LED indicates when the instrument is generating a service request on the GPIB bus.

3.3.2.3 TALK

This LED indicates when the instrument is addressed to send data out onto the GPIB bus.

3.3.2.4 LISTEN

This LED indicates when the instrument is addressed to receive data from the GPIB bus.

3.3.2.5 REMOTE

This LED indicates that front panel control is no longer available and that the GPIB bus is in exclusive control.

3.3.3 Displays

3.3.3.1 Vacuum Fluorescent Display

The main display is a 16 character vacuum fluorescent which shows the measured data and useful information feedback to the operator in the software calibration and system initialization procedures.

3.3.3.2 TEST VOLTS Display

The TEST VOLTS display is a four digit seven segment LED display which is used to indicate the voltage present at the SOURCE connector when the VOLTS ON key is activated. During the self-test routine at start-up, the display will show all of the available test voltage sequentially.

3.4 Terminals

3.4.1 SOURCE Terminal

Lethal voltages of up to 1000 Volts may be present at this output and appropriate precautionary measures are necessary. UNQUALIFIED OR UNINFORMED PERSONNEL SHOULD NOT BE GIVEN ACCESS TO THIS EQUIPMENT. The selected voltage is present at the

SOURCE connector whenever the TEST VOLTS display indicates its numeric value. While the source can only generate three or four milliamperes at a steady rate, the output filter capacitors, can produce considerably greater currents for short periods of time.

3.4.2 INPUT Terminal

Although there is sufficient protective circuitry to handle even a short circuit to the instrument´s 1000 volt supply of the the sensitivity and very high impedance of this terminal requires careful handling. Large static discharges to this connector should be avoided.

3.4.3 External Trigger Terminal

This rear panel connector works in conjunction with the front panel EXT TRIG key to initiate a measurement each time the connector is grounded. Internally, the connector is fed + 5V through an LED and a 330 ohm resistor. The following diagrams show typical external trigger circuits.

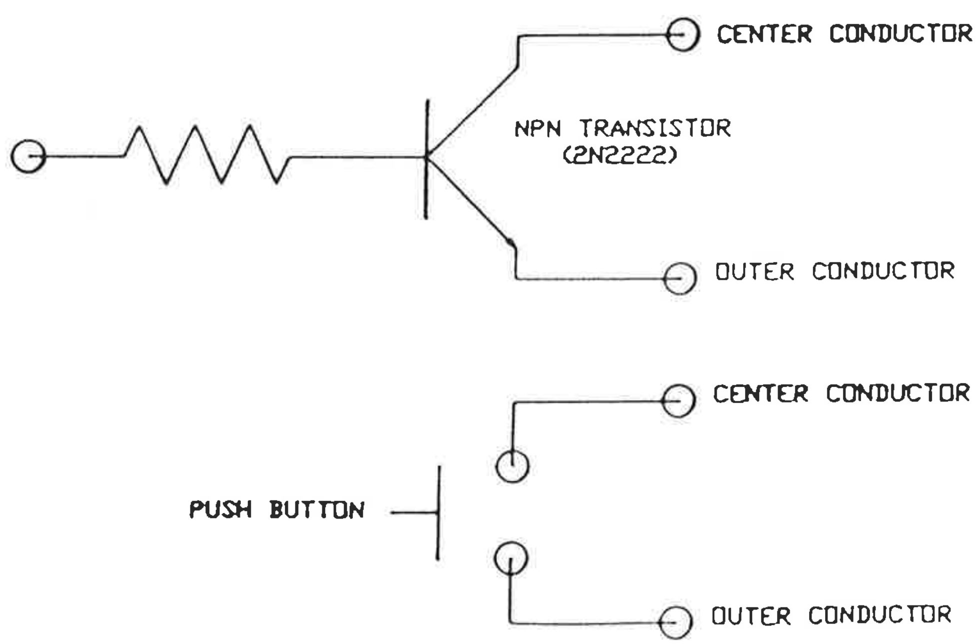
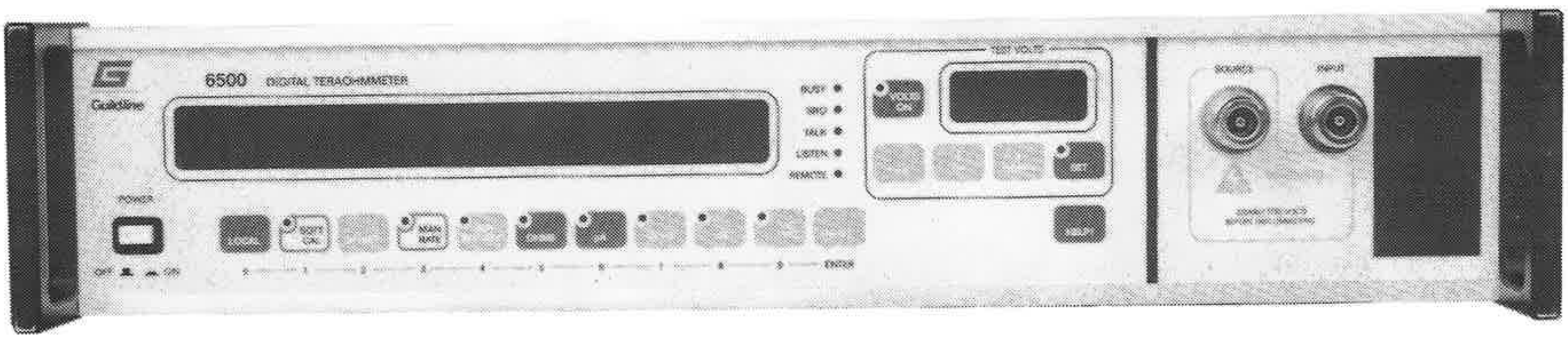
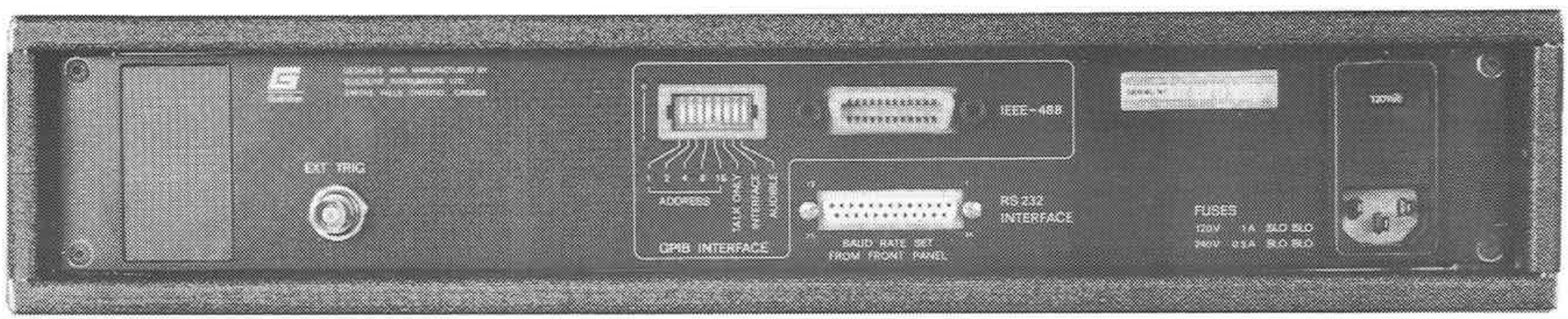


Figure 4, TYPICAL EXTERNAL TRIGGER CIRCUITS



6500 FRONT PANEL



6500 BACK PANEL

Chapter 4
Operation

4.0 INSTRUMENT OPERATION

The operation of this instrument is straightforward because it usually gives the operator a prompt for the next required key stroke or it automatically performs the required function.

CAUTION: DANGEROUS VOLTAGE CAN BE PRESENT AT THE SOURCE CONNECTOR. THIS EQUIPMENT MUST NOT BE OPERATED BY UNQUALIFIED PERSONNEL.

4.1 INITIALIZATION

When the instrument is turned on it automatically performs a sophisticated self-diagnostic routine, checking the power supplies, reference voltage and system memory in addition to giving a visual check on the Vacuum Fluorescent and LED displays. Any errors found will be indicated and the unit should be serviced before further usage. If the display shows CORRECT CHK SUM ?, it indicates the calibration data in the memory has been corrupted and the operator should reenter the proper coefficients (see SOFCAL). Malfunctions visible on the front panel (such as non operating display segments) will not be apparent to the control unit and operation with them will still be possible.

4.2 MEASURING RESISTANCE

The 6500 Teraohmmeter is a very sensitive resistance measurement instrument hence care should be taken to shield any device which is to be measured. Inadequate shielding will result in noisy readings.

4.2.1 Resistance, Autoranging

The simplest approach to making a resistance measurement is to utilize the autoranging capability of the 6500 Teraohmmeter. To measure a resistance with autoranging, use the following instructions.

1) Activate the POWER ON switch and wait for the self check.

2) Depress the OHMS key.

3) Deactivate AUTO REVERSE by pressing the alternate action key if that feature is not wanted.

   The auto-reversing mode may give faulty readings when measuring very large value resistors because these resistors frequently have excessive charge storage characteristics. This is a fault of the resistors, not the 6500.

4) The instrument will suggest a maximum test voltage which will show on the main display with flashing numerals. If the suggested value is unsuitable for the device under test, the operator can select a different value by using the UP or DOWN keys. When the desired maximum is displayed, it is locked-in by pressing the SET key. When autoranging, the instrument will select a test voltage that will optimize the accuracy but not exceed the maximum test voltage displayed.

5) The instrument will prompt the user to depress the VOLTS ON key but connect the device to be tested before doing so: remember that **POTENTIALLY LETHAL VOLTAGES CAN BE PRESENT AT THE SOURCE CONNECTOR.**

6) Depress the VOLTS ON key. The instrument will search for the optimum range within the constraints set by the maximum test voltage and proceed to take continuous measurements of the resistance of the device under test. When the measurement has been completed, **PRESS THE ALTERNATE ACTION VOLTS ON SWITCH TO REMOVE THE TEST VOLTAGE BEFORE ATTEMPTING TO DISCONNECT THE DEVICE UNDER TEST.** If a number of devices are to be tested, always check to **VERIFY THAT THE TEST VOLTAGE IS NOT ACTIVATED BEFORE ATTEMPTING TO CONNECT OR DISCONNECT ANY DEVICE TO BE TESTED.**

4.2.2 Resistance, Manual Ranging

Manual ranging of the 6500 Teraohmmeter is more complex than using the autoranging function. To fully understand the manual mode, Section 1.3 (Principle of Operation) should be reviewed.

The manual mode permits the operator to select the test voltage, the threshold voltage and the integration capacitor. The operator may also select these constants through the GPIB or RS232 bus. The instrument then measures the integration time and calculates the value of the unknown resistance. If the operator selects inappropriate measurement constants, the full accuracy potential of the instrument may not be achieved. To make a good selection, an approximate value of the unknown resistor is required. This may be obtained from a prior knowledge or from a repetitive sequence of measurements starting from any assumed value.

The instrument works best if the integration time is between 0.5 and 5.0 seconds, however it will work at reduced accuracy with integration time as short as 5.4 milliseconds or as long as 1000 seconds. The integration capacitor may be selected from 27, 270 or 2700 picofarads. The 2700 pF capacitor is the most stable and should be used if possible.

The threshold may be 0.1, 1.0 or 10.0 volts. The test voltage may be selected between the limits of 1 to 1000 volts in steps that are decimal multiples of 1, 2 and 5.

The integration time is affected by the selection of the capacitor, threshold and test voltage according to the formula:

$$T = \frac{2.0 \quad C \quad R \quad V_{threshold}}{V_{source}}$$

Where: T is the integration time in Seconds,

R is the unknown resistance in Ohms,

C is the integration capacitance in Farads,

$V_{threshold}$ is the threshold voltage in Volts,

V_{source} is the test voltage in Volts.

The operator may use the timing diagram in Figure 5 to select the measurement constants without calculations. For example, if the unknown resistor value is approximately 100 megohms, the operator will find the sloping 100 megohm line on the test voltage graph (top of the page). The intersection of the 100 megohm line with the horizontal 10 V test voltage line gives an input current of 100 nA (vertical line). Following the 100 na line to the 2700 pF threshold voltage graph (center of page) it can be seen that selecting a 10 V threshold will give

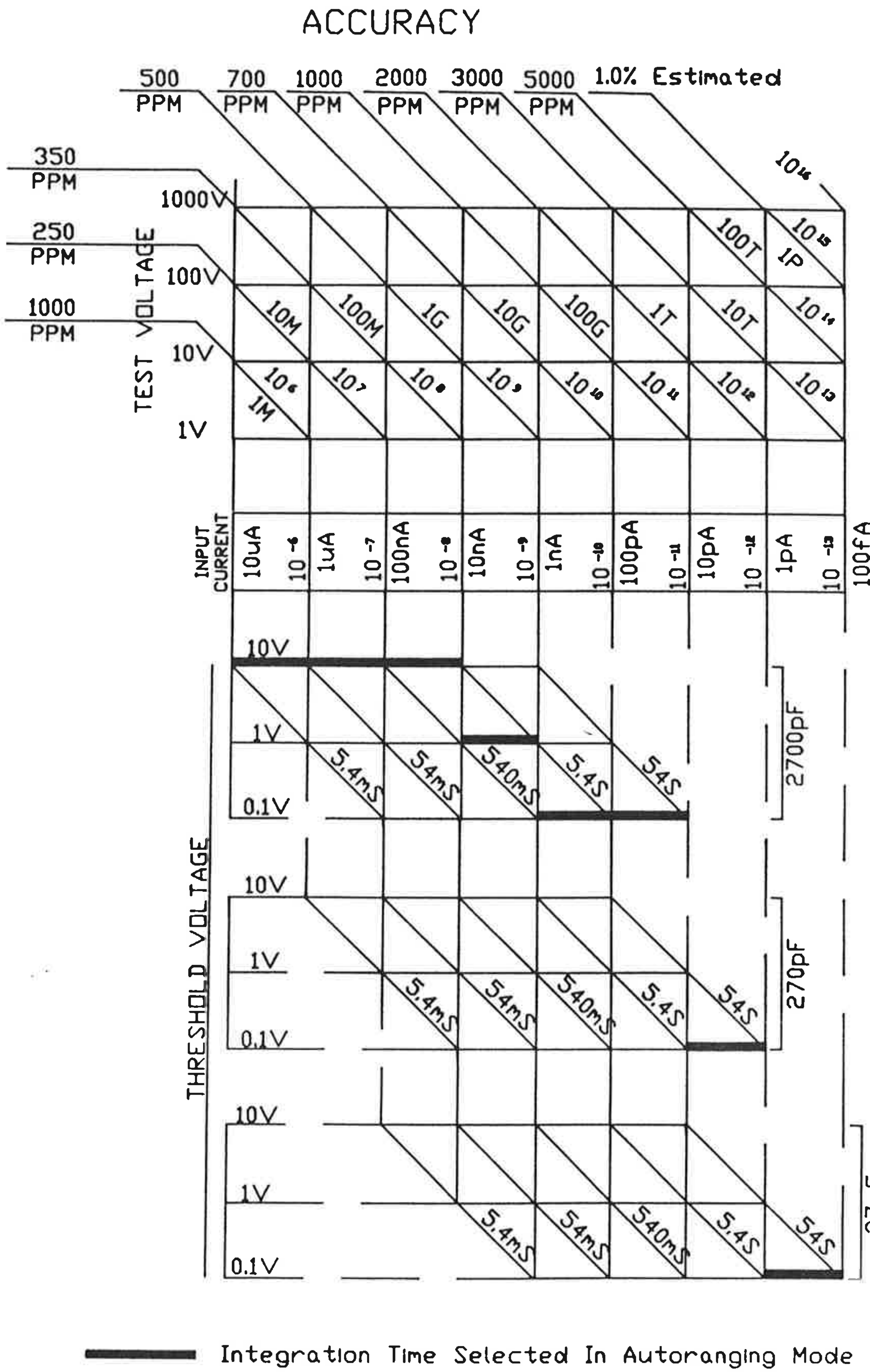


Figure 5. Time Diagram

an integration time of 540 mSec which is within the optimum range of 0.5 to 5 seconds. The selection of the 0.1 V threshold should be avoided because it would give an integration time of 54 mSec.

To measure a resistance with manually selected constants proceed with the following instructions.

1) Activate the POWER ON switch.
2) Activate the MAN RATE key.
3) Deactivate the AUTO REVERSE if that feature is not required. The auto-reversing mode may give faulty readings when measuring a very large value of resistance because resistors of this type frequently have excessive charge storage characteristics.
4) Press the OHMS key.
5) The instrument will display a suggested maximum value for the test voltage. It is presumed that a number of items are to be measured using different test voltages but that the operator does not want to inadvertently exceed the value displayed. If the displayed maximum voltage is unsuitable, it can be modified with the UP or DOWN keys. When an acceptable value is displayed, press the SET key.
6) A suggested value for the integration capacitor is then displayed. A different value can be selected using the UP or DOWN keys. When an acceptable value is displayed, press the SET key.
7) A suggested value for the threshold voltage is then displayed. A different value can be selected with the UP or

DOWN keys. An appropriate value is accepted by pressing the SET key.

8) The first device to be measured should be connected to the instrument.

9) The lowest possible test voltage will be displayed. If this value is unsuitable for the first device to be measured, different values can be selected using the UP or DOWN keys. When the correct value is displayed, it is locked in with the SET key.

10) Using the integrator parameters that the operator has selected, the instrument will display the optimum measurement range of resistance. If this is satisfactory , it is accepted by pressing the SET key. In most cases, the instrument will operate outside of the indicated range with reduced accuracy. If the operator decides to move the instrument into a higher or lower range, it can be done by pressing the UP or DOWN keys which will return the instrument to step 6 allowing the operator to reconsider the choices made. When the most satisfactory range is displayed, it is accepted by pressing the SET key.

11) The instrument is ready to make a measurement and will prompt the operator to activate the VOLTS ON key. The test voltage will then be applied to the device under test and the selected test voltage will be displayed. The instrument will begin to make continuous resistance measurements.

CAUTION

The instrument may be damaged if the Source connector is shorted to the instrument.

12) When the measurement is complete, the test voltage is removed by pressing the alternate action VOLTS ON key. A number of devices can be measured with the previously selected integration parameters but the operator must be careful to deactivate the test voltage via the VOLTS ON key before connecting or disconnecting any device under test.

    The test voltage should be kept in the deactivated state whenever the instrument is not connected to an item to be measured.

13) If a different test voltage is required, press the UP key in order to return to step 9. If a complete reselection of integration parameters is required , press the UP, SET and UP keys sequentially to return to step 6.

4.3 MEASURING PICOAMPERES

The secondary function of the 6500 Teraohmmeter is capable of being used to measure very low DC currents flowing to the ground. The 6500 input resistance is approximately 100 kilohms and will reduce the expected current flow significantly unless the resistance of the external circuit is much higher. To connect the unit as a picoammeter, the current source is fed into the center pin of the INPUT connector. The SOURCE connector pin is the current return path to the ground of the external circuit. A coaxial cable to the INPUT connector makes a simple approximation to the ideal circuit configuration when the center conductor is connected to the current source and the coaxial shield is connected to the ground of the external circuit. A slight degradation of accuracy may be incurred by using this configuration due to noise.

4.3.1 Auto Ranging

The simplest technique for measuring low currents is to use the auto ranging feature of the 6500.

1. Connect the unknown current source.
2. Depress the pA key on the instrument. The 6500 will proceed to determine the correct range and take continuous measurements.
3. Current magnitude that changes slowly will be tracked by the autoranging feature but if the value changes suddenly by a large amount, or if the polarity changes, the instrument must be forced to autorange again by pressing the pA key twice.

4.3.2 Manual Ranging

Manual ranging of the 6500 Teraohmmeter is more complex than using the autoranging function. The timing diagram shown in Figure 5 is useful when operating the 6500, especially in the manual ranging mode. In order to manual range an approximate value of the current to be measured must be known.

Knowing the current the user must then select an integration capacitor, and an integration threshold voltage for the measurement. The integration capacitor may be selected from 27, 270 or 2700 picofarads. The threshold may be 0.1, 1.0 or 10.0 volts.

The selection of the capacitor, and the threshold affects the integration time according to the formula:

$$T_{integration} = \frac{2.0 \quad C * V_{threshold}}{I}$$

Where: $T_{integration}$ is the integration time in Seconds,

I is the unknown current in Amperes,

C is the integration capacitance in Farads,

$V_{threshold}$ is the threshold voltage in Volts.

The instrument works best if the integration time of the electrometer is between 0.5 seconds and 5.0 seconds however integration times as short as 5.4 milliseconds or as long as 1000 seconds may be used. The 2700 pF capacitor is the most stable and should always be used if possible.

The following steps are used to measure current.

1. Press the MAN RATE key to allow manual ranging.

2. Press The pA key.

3. Select the integration capacitor with the UP and DOWN keys, then press the SET key. If possible always select the 2700pF capacitor for best instrument accuracy.

4. Select an integration Threshold with the UP and DOWN keys then Press the SET key.

5. The current polarity will be indicated at the extreme left hand side of the main display. It can be reversed by pressing the +/- key (the polarity convention is that positive polarity means the INPUT connector pin is at a positive voltage with respect to ground. The polarity may be reversed by pressing the +/- key.

6. The instrument will now display the polarity selected and the current range based on the integration parameters previously selected. Pressing the UP key will return the process to step 3) allowing a re-selection of the integration parameters. If the range displayed is satisfactory press the SET key. The instrument will usually measure values outside the selected range at reduced accuracy.

7. The instrument will commence taking continuous measurements of the unknown current.

Chapter 5
SOFCAL

5.0 PURPOSE OF SOFCAL

Sofcal is a computer program installed in the 6500 teraohmmeter. Its primary purpose is to help calibrate the instrument and to determine its system errors so that measurements can be corrected digitally with data adjustment before they appear on the display or are fed to either control bus. A second purpose is to help manage the data flow in and out of the instrument.

When in the SOFCAL mode of operation, the front panel keys are redefined to do other functions. In addition to the normal keys there are three hidden keys enabled. These keys are located on the lower right hand side of the keyboard between the RESET and HELP keys as shown in Figure 6.

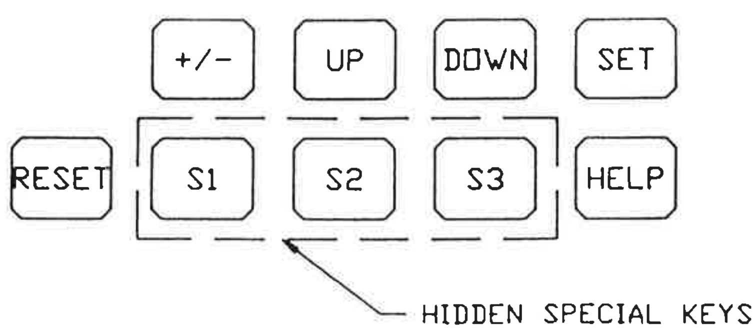


FIGURE 6, LOCATION OF SPECIAL HIDDEN KEYS

5.1 ERROR COMPENSATION

After each reading of a resistance the integration time is converted to a resistance. The conversion is done with the formula:

$$\text{Resistance} = \frac{V_{test} * T_{integration}}{2.0 * C_{integrator} * T_{integrator}} - R_{protection}$$

Where: Resistance is the value of the unknown resistor

V_{test} is the test voltage from the 6500 source

$T_{integration}$ is the time for the integration

$C_{integrator}$ is the value of the integration capacitor

$T_{integrator}$ is the threshold of the integrator and

$R_{protection}$ is the value of the protection resistor.

Nominally the value of each of the items in the equation are known and in addition the variance from the nominal value is known. The system software calls up the nominal value of each item and multiplies by a correction factor before computing the resistance.

5.1 Determining Errors

The value of the protection resistor can be measured by the instrument and entered into the instrument´s Non-Volatile memory. The variance of the test voltage from its nominal value is determined at calibration time by turning on each possible output voltage and measuring its absolute value with a precision voltmeter. The variance of the output voltage from its nominal value is computed in Parts Per Million (PPM) and entered into the instrument´s Non-Volatile memory either from the front panel or through one of the bus interfaces (RS232 or GPIB). It should be noted that there are twenty (20) different variances computed, and stored in the instrument, one for each voltage of each polarity.

The exact value of the reference resistor, used to compute the capacitor and threshold variances, is entered into the instrument´s Non-Volatile memory either from the front pannel (see section 6.0.3) or through one of the bus interfaces (see section 7.2.1).

The variance of the integration capacitors is computed by the instrument. A known reference resistor (about 1 GigaOhm) is connected between the instrument´s source and input terminals. The instrument then takes 20 readings of the resistance and computes an average resistance value with corrections for only the source voltage variance and the protection resistor. Using the average resistance value and the reference resistance value a number representing the variance of the capacitor from its nominal value is computed. The capacitor variance is automatically stored into the instrument´s Non-Volatile memory.

The variance of the integration thresholds is also computed by the instrument. A known reference resistor (about 1 GigaOhm) is connected between the instrument´s source and input terminals. The instrument then takes 20 readings of the resistance and computes an average value with corrections for the source voltage variance, the integration capacitor variance and the protection resistor. The average value and the reference value are used to compute a number representing the variance of the threshold from its nominal value. The threshold variance is automatically stored into the instrument´s Non-Volatile memory.

5.3 Instrument calibration

The instrument calibration procedure is:

1. Enter the nominal value of the reference resistor into the instrument's Non-Volatile memory (see section 6.0.7).
2. Assume that the protection resistor is its nominal value of 100 kilohms and store this value into the instrument's Non-Volatile memory (see section 6.0.3).
3. Determine each of the source errors and with an external precision voltmeter and to enter each of the error values into the instrument's Non-Volatile memory (see section 6.1 to enter the correction coefficients).
4. Measure the reference resistor with the 10.0 Volt integration threshold and each of the integrator capacitors, determine the variances and store these values into the instrument's Non-Volatile memory (see section 6.0.4).
5. Measure the reference resistor with the 2700 picofarad integration capacitor and the 0.1 and 1.0 volt integration thresholds, determine the two variances and store these values into the instrument's Non-Volatile memory (see section 6.0.5).
6. Measure a short circuit to determine the actual value of the protection resistor, and enter this value into the instrument's Non-Volatile memory (see section 6.0.3).

5.4 OPERATING LEVELS

In order to examine, modify or execute a portion of SOFCAL, the operator must go to the desired part of the SOFCAL program by a path that descends through different levels of choices. This concept is shown diagramatically in Figure 7.

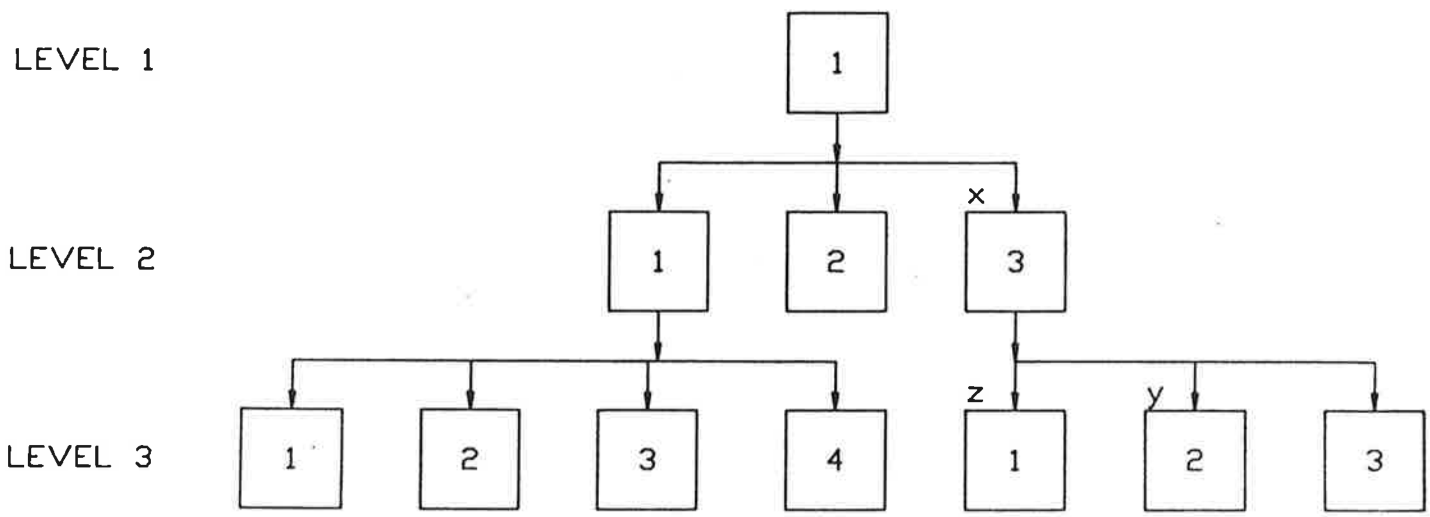


FIGURE 7, TYPICAL SOFCAL OPERATING LEVELS

Each level in a path is called a branch. Some paths descend through more levels than others. When the instrument is at a particular SOFCAL branch, the operator can select any part of the branch by scrolling with the UP key. For example in Figure 7, if the instrument is at position X, pressing the UP key repetitively will move the instrument sequentially to positions Y, Z, W, X, etc.

Alternatively the instrument can be moved directly to any position on the branch from any other position on the same branch by pressing the appropriate key. For example, the operator can move to position Z from W, X or Y by pressing the 4 key once.

5.4.1 Descending Levels

Each time the enter key is pressed, the 6500 moves down one level. For example in Figure 7 if the 6500 is at position V, pressing the ENTER key once will move it to the branch WXYZ. If the ENTER key is pressed while the 6500 is at any position in the bottom level of a path, it will usually execute the indicated function or allow a value to be examined or changed.

5.4.2 Ascending Levels

The 6500 can go upwards along a path if the operator presses the +/- key. For example, if the 6500 is at position X, the operator can move it to V by pressing the +/- key once.

5.5 EXITING SOFCAL

Pressing the SET key while in the SOFCAL mode will return the instrument to the normal operational waiting mode with SELECT OHMS/PA on the display.

Chapter 6
SOFCAL

6.1 Normal Mode

In this mode of SOFCAL, the GPIB and RS232 formats may be examined or modified, various system error parameters may be examined or remeasured, the last 6500 calibration date can be displayed or changed and the instrument software revision level can be displayed.

This branch of SOFCAL can be entered by pressing the front panel SOFTCAL key. This will give a display that alternates between NORMAL MODE and SELECT FUNCTION.

A function may be displayed by scrolling with the +/- key or directly by pressing a numeral key from Table 5:

TABLE 5, SOFCAL NORMAL MODE FUNCTIONS

key number	Function
0	GPIB STATUS
1	CONFIGURE RS232
2	ZERO ERROR (6500 input resistance)
3	CAP ERROR (integrating capacitor)
4	THRESH ERROR (threshold voltage)
5	CALIBRATION DATE
7	REFERENCE RES

Any of the above functions may be selected for examination or alteration by pressing the ENTER key once when the desired function is displayed. To exit back to the operator mode, press the SET key.

6.0.1 GPIB STATUS

When this function is selected, the GPIB address and talk/listen status can be examined. The GPIB status can only be changed with the rear panel GPIB INTERFACE switch. When the switch positions are altered, the display will reflect the change immediately, but the new status will not be in effect on the bus until the 6500 exits from the SOFCAL program (by pressing the SET key, HELP key or turning the power off momentarily.

The address and talk/listen status may be obtained by scrolling with the +/- key or by direct key entry from the following menu:

key number	status
0	GPIB address
1	talk/listen

The talk/listen status can be changed by setting the rear panel switch from Table 6:

TABLE 6, GPIB TALK LISTEN SWITCH SETTING

TALK ONLY	INTERFACE	STATUS
1	1	TALK ONLY
0	1	TALK AND LISTEN
1	0	GPIB NOT CONFIGURED
0	0	

The 1 position is when the lower part of the switch rocker is pushed in. The desired GPIB status should be verified visually on the display.

If the talk only mode is selected the GPIB controller will be configured to send each reading to the GPIB bus.

If any printing character is received on the RS232 bus while the Talk Only switch is set then each reading will be routed to the RS232 output. This will cancel the routing of the readings to the GPIB.

6.0.2 Configure RS232

This function allows the operator to examine or alter the data format on the RS232 bus. When this function is selected (by pressing the enter key once with CONFIGURE RS232 on the display), the various RS232 format characteristics can be examined by scrolling with the +/- key or by direct key entry from the following menu:

key #	Display	
0	BAUD RATE	status
1	DATA BITS	status
2	STOP BITS	status
3	PARITY	status
4	ECHO	status
5	FLOW CONTROL	status

The status of any RS232 format characteristic may be changed by the following procedures.

6.0.2.1 BAUD RATE

The baud rate may be changed by pressing the ENTER key once while BAUD RATE is on the display. The desired rate is then displayed by scrolling with the +/- key or by direct key entry from the following menu:

key #	BAUD RATE (BITS per second)
0	9600
1	50
2	75
3	110
4	150
5	300
6	600
7	1200
8	2400
9	4800

The desired rate is then selected by pressing the ENTER key once when it is desplayed. This will also exit to the SOFCAL branch containing the other RS232 parameters.

6.0.2.2 DATA BITS

The number of data bits may be changed by pressing the ENTER key once while DATA BITS is on the display. The desired number of data bits is then displayed by scrolling with the +/- key or by direct key entry from the following menu:

key #	DISPLAY
0	DATA BITS 8
1	DATA BITS 5
2	DATA BITS 6
3	DATA BITS 7

The desired number of data bits is then selected by pressing the ENTER key once while it is displayed. This will also return the 6500 to the SOFCAL containing the other RS232 parameters.

6.0.2.3 STOP BITS

The number of stop bits may be changed by pressing the ENTER key once while STOP BITS is on the display. The desired number of stop bits is then displayed by scrolling with +/- key or by direct key entry from the following menu:

key #	DISPLAY
0	STOP BITS 2
1	STOP BITS 1

The correct number of stop bits is then selected with a single depression of the ENTER key while it is on display. This will also exit to the SOFCAL branch with the other RS232 parameters.

6.0.2.4 PARITY

The parity check may be changed by pressing the ENTER key once while PARITY is on display. The desired parity characteristic is then displayed by scrolling with the +/- key or by direct key entry from the following menu:

key #	DISPLAY
0	PARITY NONE
1	PARITY ODD
2	PARITY EVEN

The correct parity characteristic is then selected by pressing the ENTER key once while it is on display. This will also exit to the SOFCAL branch with the other RS232 format characteristics.

6.0.2.5 ECHO

The echo status may be changed by pressing the ENTER key once while the ECHO status is on the display. The desired echo characteristic is then brought to the display by scrolling with the +/- key or by direct key entry from the following menu:

key #	DISPLAY
0	ECHO ON
1	ECHO OFF

When the desired echo status is visible on the display, it is selected by pressing the ENTER key once. This will also exit to the SOFCAL branch containing the other RS232 characteristics.

6.0.2.6 FLOW CONTROL

The flow control status may be changed by pressing the ENTER key once while it is on the display. The desired status is then brought to the display by scrolling with the +/- key or by direct key entry from the following menu:

key #	DISPLAY
0	X ON
1	RTS
2	RCK

When the desired status is on the display, it is selected by pressing the ENTER key once. This will also exit to the SOFCAL branch containing the other RS232 characteristics.

6.0.3 ZERO ERROR

This is the value of the internal resistance presented by the 6500 between the input connector and ground. The 6500 maintains a stored value for this resistance in its memory and subtracts it from all resistance measurements before the final value is put on the front panel display or fed to either control bus. If the ZERO ERROR resistance should change or if the stored value should become corrupted in the memory, the 6500 is capable of remeasuring the true value and entering the true value into memory.

6.0.3.1. <u>examining the stored ZERO ERROR</u>

When the ZERO ERROR is on the display, the stored value can be displayed by pressing the ENTER key <u>once</u>. The display will then alternate between the stored value and the prompt SHORT CKT I/P (apply a short circuit between the input and source connectors). If it is not necessary to change the value, press the +/- key after the old value has been displayed. This will exit to the SOFCAL branch with the other NORMAL mode parameters without disturbing the stored value.

6.0.3.2 <u>remeasuring and reentering THE ZERO ERROR</u>

When the display alternates between the old stored value and the prompt SHORT CKT I/P, the true value of zero error can be measured and the new value placed in memory in place of the old value by connecting the short circuit and pressing the ENTER key <u>once</u>. This will initiate a series of zero error measurements. During this two minute routine, the 6500 calculates and displays a running average of the measurements. When all of the measurements are taken the 6500 places the final average value in its memory and returns to a display alternating between the new stored value and the prompt to short circuit the input. Press the +/- key to exit to the SOFCAL branch with the other normal mode parameters. It should be noted that if the zero error measurements are interrupted before completion, a check sum error may be generated which will cause subsequent self-checks to fail. Should this occur, follow the instructions for sum check correction (page 4-1).

6.0.4 CAP ERROR

This is the percentage error in the true value of the three integrating capacitors used in the 6500. The three error values are stored in the instrument's memory and are used to compensate resistance measurements. If the capacitor values should ever change or if the value in memory should become corrupted, the SOFCAL program is able to measure the true value and reenter the new value into the 6500 memory in place of the old stored value.

6.0.4.1 examining the stored CAP ERROR

When the CAP ERROR is on the display the stored values for the three capacitor errors may be examined by pressing the ENTER key once. This will cause the display to alternate between a display of one of the integrating errors and the prompt CONNECT REF RES (connect the reference resistor - not required at this stage). All three capacitor errors may be examined by scrolling with the UP key or alternatively, the three values may be read in a specific sequence by direct key entry from the following menu:

key #	Display	Alternates To
0	27PF	% error
1	270PF	% error
2	2700PF	% error

If the stored values do not need to be changed, press the +/- key once in order to exit to the SOFCAL branch with the other NORMAL MODE parameters without disturbing the values in memory.

When the old stored value of one of the capacitors is being displayed, a new value can be measured by connecting the reference resistor (see 6.0.7) and pressing the ENTER key once. The 6500 will make a series of resistance measurements of the reference resistor. Since an accurate value of the reference resistor is already in the 6500 memory, any apparent discrepancies are translated to capacitor error by the 6500. When all of the measurements are completed for this one capacitor, the 6500 calculates an average resistance, converts it into capacitor error, enters the new value into memory in place of the old value and then proceeds to alternate the display between the new value and the prompt CONNECT REF RES. A new capacitor can then be selected for examination or remeasurement by scrolling as in paragraph 6.0.4.1. Exit to the SOFCAL branch with the other NORMAL MODE parameters by pressing the +/- key once.

6.0.5. THRESH ERROR

This is the error of the threshold voltages occurring at integrator output. The values 0.1, 1.0 and 10 volt errors are stored by the 6500 and are used to correct resistance and current measurements. To examine stored values or to remeasure and enter new values, press the ENTER key when THRESH ERROR is on the display. This will give a display alternating between a prompt to CONNECT REF OHMS (connect the reference resistor between the SOURCE and INPUT connectors) and the value of one of the threshold voltage errors.

Each threshold voltage can be examined without the reference resistor by scrolling with the UP key or by direct key entry from the following menu:

key #	DISPLAY
0	T 0.1 V error %
1	T 1.0 V error %

When a particular threshold voltage error (0.1, or 1.0V) is being displayed, a new value can be obtained and entered into the memory by connecting the reference resistor and pressing the ENTER key <u>once</u>. This will reset the old stored value to zero and initiate a series of new measurements. When the measurements are complete, the 6500 will calculate an average value which will store in its memory and display at the front panel. It will also return to the SOFCAL branch with the other threshold voltages. It should be noted that interrupting the measurements before they are completed will generate a check sum error which will show whenever the 6500 does a self check. A new threshold can then be selected for examination or remeasurement by scrolling as in paragraph 6.0.4.1. Exit to the SOFCAL branch with the other NORMAL MODE parameters by pressing the +/- key <u>once</u>.

6.0.6 <u>Calibration Date</u>

This is the date of the last calibration. If a new calibration date is to be entered press the ENTER key. This will give a display of the last calibration day with the date flashing. A new day may be keyed in and the ENTER key pressed <u>once</u>. The calibration month and year may be entered by scrolling with the UPkey and then following the above procedure. Exit to the SOFCAL

UPkey and then following the above procedure. Exit to the SOFCAL branch with the NORMAL MODE by pressing the +/- key once.

6.0.7 Reference Res

When the REFERENCE RES is displayed, pressing the ENTER key will bring to the display the value that is stored in memory. By pressing the ENTER key again the number will be flashing and may be altered by pressing a new sequence of numbers followed by pressing the ENTER key. Exit to the SOFCAL branch of the NORMAL MODE by pressing the +/- key once.

6.1 CALIBRATION MODE

In this mode of SOFCAL various system error parameters may be examined and/or modified.

The calibration mode of SOFCAL is entered by pressing the SOFCAL key followed by the S2 and S3 keys. The S2 and S3 keys are not marked on the keyboard and are only active in the SOFCAL mode. They are located on the lower right side of the 6500 front panel between the RESET and HELP keys as shown in Figure 8. This will give a display that alternates between CALIBRATION MODE and SELECT FUNCTION. A function may be displayed by scrolling with the +/- key or directly by pressing a numeral key from the following menu:

key #	Function
0	Serial Number
1	Software Rev
2	Output Errors

Any of the above functions may be selected for examination by pressing the ENTER key once when the desired function is displayed. To exit back to the operate mode press the SET key.

6.1.1 Serial Number

When the SERIAL NUMBER is displayed pressing the ENTER key will bring to the display the S/N that is stored in the memory. By pressing the ENTER key again the number will be flashing and may be altered by pressing a new sequence of numbers followed by pressing the ENTER key. Exit to the SOFCAL branch of the CALIBRATION MODE by pressing the +/- key once.

6.1.2 Software Revision

This is the revision of software that has been installed in the 6500. This information may be viewed only. It cannot be changed by the customer. Exit to the SOFCAL branch with the other NORMAL MODE by pressing the +/- key once.

6.1.3 Output Errors

When OUTPUT ERRORS is displayed pressing the ENTER key will bring to the display MINUS VOLTAGES or PLUS VOLTAGES. The UP key will toggle the display between these two. If when PLUS VOLTAGES is displayed the ENTER key is pressed the unit will display the error in memory of the +1 V. Pressing the ENTER key again will cause the error to flash. A new value may now be entered by pressing the number keys followed by the ENTER key. Press the UP key to go to the next voltage. The different voltages are 1, 2, 5, 10, 50, 100, 200, 500, 1000 in both polarities. The manual set-up for this calibration routine is to connect a DVM to the output to measure the voltage and use the following equation to calculate the value to enter for each voltage range.

$$\text{number to be keyed into display} = \frac{\text{DVM reading} - \text{Ideal Voltage}}{\text{DVM reading}} \times 10^6$$

The simplest way to do this calibration due to the large number of points to be measured, calculated and entered is by using one of the interface busses.

Chapter 7
Interfaces

7.1 Serial Poll Register

The serial poll register can be accessed by the GPIB system controller with a serial poll command, in addition the contents of the serial poll register may be read from either the GPIB or the RS232 interfaces with the "*STB?" command.

```
  MSB                                         LSB
 -----------------------------------------------
 |  7  |  6  |  5  |  4  |  3  |  2  |  1  |  0  |
 -----------------------------------------------
```

The serial poll register is organized as eight single bit flags where flag zero is the least significant bit of the register and flag 7 is the most significant bit of the flag register. Each flag has a specific meaning as outlined below.

FLAG

7. unused
6. SRQ (service request)
   - set when SRQ_mask OR Serial_Poll_Register is not zero
5. ES (event summary)
   - set when a measurement is completed
   - cleared when "Value?" command executed

4. MAV (message available)

- set when GPIB transmit buffer is not empty
- cleared when GPIB transmit buffer is empty

3. IFL (input buffer full)

- set when the input buffer is more than 80% full
- cleared when the input buffer is less than 20% full

2. CRC (calculating CRC)

- set at beginning of CRC computation
- cleared at end of CRC computation

1. RDY (ready)

- set when 6500 has stable reading (busy LED off)
- cleared when 6500 working (busy LED on)

0. DSP (display changed)

- set when the contents of the display changed
- cleared when "Display?" command executed

7.2 COMMANDS

The 6500 is capable of processing many different remote commands. In general any command which can be identified will be processed. The portions of the commands shown in upper case characters are required and the portions shown in lower case characters are optional. Punctuation marks such as asterisk (*) and question mark (?) are required parts of commands. The command parser in the instrument uses white space (such as spaces and tabs) to delimit words, hence it is important to not imbed whitespace into commands. A quick reference table to the following commands with some definitions is given in paragraph 7.3.

7.2.1 *IDN?

This command instructs the instrument to reply with a self identification. The identification reply is comprised of four parts separated with commas. The first part is the manufacturer (Guildline), the second part is the model number of the instrument (6500), the third part is the instruments serial number and the fourth part is the internal software revision level.

7.2.2 *SRE? Service Request Enable Query

This command allows a programmer to determine the current contents of the Service Request Enable Register. A decimal number between 0 and 63 or between 128 and 191 will be returned.

7.2.3 *SRE <nrl> Service Request Enable Command

The service request enable command allows the 6500 to generate a service request on the GPIB interface under a limited set of conditions. The limitations on the conditions are defined by the numeric parameter following the *SRE command. The numeric parameter is a decimal integer in the range 0-255. The numeric parameter when expressed in base 2 (binary) represents the bit values of the Service Request Enable Register. For all bits (except bit 6) a bit value of one (1) indicates an enabled condition and a bit value of zero (0) represents a disabled condition. *SRE? is the companion query.

7.2.4 *STB? Read Status Byte Query

This program allows the programmer to read the status byte and master summary bits.

The response from this command is a decimal integer in the range 0-255. This decimal integer when expressed in base 2 (binary) represents the bit values in the Status Byte Register. Note that the Master Summary Status bit and Not RSQ is reported in bit 6. The Status Byte Register can also be read with the Read serial Poll hardware command on the GPIB Interface.

7.2.5 AnalogueVolts? <channel>

This command allows the programmer to read the internal voltages of the 6500 on the Analogue side of the opto-isolators.

channel	function
0	+5 V DC supply
1	-5 V DC supply
2	+15 V DC supply
3	-15 V DC supply
4	Precharge Voltage
5	High Voltage Monitor
6	Integrator Output
7	10.0 Volt Reference

7.2.6 Beep [<nrl>]

The Beep command instructs the instrument to produce an audible tone lasting <nrl> milliseconds. The beep time can be between 1 and 30,000 milliseconds. If the beep time is not supplied a 100 millisecond tone will be produced. Several Beep commands in a row will produce a longer tone with no pauses, however the amount of time outstanding should never exceed 30,000 milliseconds.

7.2.7 CHecksum 0|1

This command computes the checksum for one of the two ROMs on the 6500. Note: Computing the checksums is computationaly intensive and will take either 17 or 34 seconds (dependant upon ROM size). A status bit in the status byte is set during the computation period to inform the controller that no commands are being processed. The correct value for the checksums is dependant upon software revision and will be printed on the calibration report with each 6500.

parameter	description
0	CPU card ROM checksum
1	Memory card ROM checksum

7.2.8 Capacitor?

The result from this query command displays the current capacitor selected in the electrometer.

7.2.9 Capacitor <nrl>

This command allows the programmer to select the value of the integration capacitor. Values are expressed in picoFarads. When this command is executed manual ranging mode is implied.

value	capacitor selected
27	27 picoFarad
270	270 picoFarad
2700	2700 picofarad

7.2.10 DigitalVolts? <channel>

This command allows the programmer to read the internal voltages of the 6500 on the Digital side of the opto-isolators.

channel	function
0	+5 V DC supply
1	-5 V DC supply
2	+15 V DC supply
3	-15 V DC supply

7.2.11 Display?

This command gives an instrument the ability to determine what message is displayed on the front panel of the 6500. An instrument programmer can determine when the message on the front panel display has changed by examining the status byte with either the *STB or with a serial poll.

7.2.12 Display <string>

This command gives an instrument programmer the ability to change the characters on the front panel display of the 6500. In general if string is less than 16 characters, then the characters will be converted to upper case and the string will be centered on the display. If the string is longer than 16 characters then only the first 16 characters will be displayed in the upper case. The default centering and conversion to upper cas can be disabled by enclosing the string in double quotes ("). A double quote character can be displayed by placing two double quote characters in a row ("").

7.2.13 EeromChecksum?

This command computes a checksum for the data (calibration coefficients) in the EEROM. This computed checksum is compared with the checksum stored in the EEROM, if the checksums match a pass indication is returned otherwise a fail indication is returned.

7.2.14 HV_START

This command enables the high voltage output for testing purposes. This command will normally only be used by the factory calibration software.

7.2.15 HV_CONTINUE

This command must be sent repetatively after a HV_START command to maintain the High voltage output. If this this command is not received periodically the high voltage output will be shutdown. This is a safety feature.

7.2.16 Hv_disable

This command is the companion command to the HV_START command. Hv-disable will shut down the High voltage output.

7.2.17 Identify?

This command is a synonym for the *IDN? command paragraph 7.2.1.

7.2.18 Local?

This query command will return the status of the Local flag (ON or OFF).

7.2.19 Local ON|OFF

This command will enable (ON) or disable (OFF) the front panel controls of the 6500. Note: It is NOT possible to disable the "VOLTS ON" key, this is an operator safety feature.

7.2.20 MaxVoltage?

This query command will return the current setting of the maximum test voltage.

7.2.21 MaxVoltage <nrl>

This command will set the maximum test voltage for the auto range software. The maximum voltage will be set to the voltage equal to or just less than the magnitude of the numeric parameter.

7.2.22 Measure?

This command will return a flag indicating whether the instrument is measuring Ohms or Amps.

7.2.23 Measure OHms|AMps|Stop

This command will start or Stop a measurement. If auto ranging is in effect a "Measure Ohms" or "Measure Amps" command will cause the instrument to auto range and make a measurement. If the auto reverse flag is in effect the instrument will make 4 readings. If the continuous flag is in effect the instrument will make make repeated measurements.

The "Measure Stop" command will stop measurements.

7.2.24 OutputVoltage?

This command will return the current output voltage.

7.2.25 OutputVoltage <nrl>

This command will set the current output voltage. Execution of this command will place the instrument in manual range mode.

Value	Voltage
0	no voltage
1	1V
2	2V
5	5V
10	10V
20	20V
50	50V
100	100V
200	200V
500	500V
1000	1000V

7.2.26 Polarity?

This query will report the current output polarity (positive or negative and the status of the auto reverse flag.

7.2.27 Polarity +|-|Auto

This command will set the instruments polarity.

parameter	description
+	instrument will generate a positive test voltage (not autoreversing)
-	instrument will generate a negative test voltage (not autoreversing)
Auto	instrument will auto reverse (ohms mode only)

7.2.28 Range?

This query command returns the currently selected range mode.

7.2.29 RESET

This command has the same effect as a power on reset or pushing the HELP! key. After a reset command the 6500 will execute its power on diagnostics. Care should be taken not to send further commands to the 6500 until after it has completed its diagnostic tests.

7.2.30 Range AUto|MAnual

This command allows the programmer to set either Auto ranging mode or manual ranging mode. A typical scenario for measuring multiple resistors of about the same value might be to allow the instrument to auto range for the first resistor, then to send the "Range Manual" command, this will lock the current range settings. For subsequent measurements the Auto Ranging time will be saved.

7.2.31 SOFCAL (must be expanded to one of the following:)

7.2.31.1 SOFCAL CAPACITOR <nr1> [<nr1>]

Requests calibration factor for integration capacitor.

7.2.31.2 SOFCAL DATE [<nr1>/<nr1>/<nr1>]

Request revision date of instrument software.

7.2.31.3 SOFCAL PROTECTION [<nr1>]

7.2.31.4 SOFCAL REFERENCE [<nr3>]

Requests calibration factor for the reference voltage.

7.2.31.5 SOFCAL SERIAL [<nr1>]

Requests the instruments serial number.

7.2.31.6 SOFCAL THRESHOLD <nr1> [<nr1>]

Requests the calibration factor for the threshold voltage.

7.2.31.7 SOFCAL VOLTAGE <nr1> <nr1> [<nr1>]

7.2.32 THreshold?

This query command reports the currently selected integrator threshold.

7.2.33 TRigger Continuous|Single|External

This command has the same effect as pushing the same key on the front panel. Repeated single measurements can be selected by repeatedly sending the command "Trigger Single".

7.2.34 Time?

This query command reports the actual integration time in seconds for the most recent reading. This value is not corrected. If the instrument is in auto reverse mode the time reported will be for the last of the four readings.

7.2.35 TRigger?

This query command reports the status of the trigger mode.

7.2.36 THreshold <nr3>

This command accepts as its parameter a single number which selects the integrator threshold. Execution of this command places the instrument in manual range mode.

parameter	threshold selected
0.1	0.1 Volts
1.0	1.0 Volts
10.0	10.0 Volts

7.2.37 Value?

This query command returns the value of the most recent reading either in Ohms or Amps.

7.3 REMOTE COMMAND QUICK REFERENCE TABLE

<> encloses a keyword

[] encloses an optional item

| indicates a choice (OR)

:== means "is defined as"

<digit>	:==	0|1|2|3|4|5|6|7|8|9
<char>	:==	A...Z|a...z
<string>	:==	["]<str>["]
<str>	:==	<char>[<str>]
<sign>	:==	+|-
<prom>	:==	0|1
<channel>	:==	0...7
<nr1>	:==	<digit>[<nr1>]
<nr3>	:==	[<sign>]<nr1>[.[<nr1>]]]E\e[<sign>]<nr1>]

*IDN?	- display identity of unit
*SRE?	- display service request mask
*SRE <nr1>	- set service request mask
*STB?	- display serial poll status byte
AnalogueVolts? <channel>	- display results from A/D converter
Beep [<nr1>]	- make noise
CHecksum 0|1	- compute ROM checksum (CRC)
Capacitor?	- display selected integrator capacitor
Capacitor <nr1>	- set integrator capacitor
DigitalVolts? <channel>	- display digital voltages
Display?	- display contents of VF display
Display <string>	- set contents of VF display
EeromChecksum?	- display EEROM checksum (CRC)
HV_START	- enable High Voltage output

HV_CONTINUE	- keep High Voltage On
Hv_disable	- disable High Voltage Output
Identify?	- display identity of unit
Local?	- display status of local flag
Local ON|OFF	- set or clear local flag
MaxVoltage?	- display the maximum test voltage
MaxVoltage <nr1>	- set the maximum test voltage
Measure?	- display current measurement mode
Measure OHms|AMps|Stop	- set current measurement mode
OutputVoltage?	- display current output voltage
OutputVoltage <nr1>	- set current measurement voltage
Polarity?	- display current measurement polarity
Polarity +|-|Aut	- set measurement polarity
Range?	- display ranging mode
RESET	- reset the instrument
Range AUto|MAnual	- set ranging mode
SOFCAL	- set/display calibration coefficients
CAPACITOR <nr1> [<nr1>]	- set/display capacitor errors
DATE [<nr1>/<nr1>/<nr1>]	- set/display the calibration date
PROTECTION [<nr1>]	- set/display value of protection resistor
REFERENCE [<nr3>]	- set/display value of reference resistor
SERIAL [<nr1>]	- set/display serial number
THRESHOLD <nr1> [<nr1>]	- set/display threshold errors
VOLTAGE <nr1> <nr1> [<nr1>]	- set/display output errors
THreshold?	- display the measurement threshold
TRigger Continuous|Single|External	-set trigger mode
Time?	- display the integration time
TRigger?	- display trigger status

THreshold <nr3> - set the measurement threshold

Value? - display the measurement value

7.4 Interface Bus Operation

The 6500 Teraohmmeter can be remotely controlled via two standard busses:

1. GPIB conforming to IEEE 488/1978.
2. A serial interface conforming to RS-232

The GPIB address switches and connector are on the rear panel. The GPIB address is configured by the DIP switch. The configuration can be confirmed from the front panel (see section 6.0.1).

The RS-232 connector is also on the rear panel. It is configured from the front panel (see section 6.0.2).

The instrument can be operated in a system where there are both GPIB and RS232 controllers attached to the interfaces however unpredictable results may occur since remote commands are processed on a first come, first served basis.

7.4.1 IEEE 488/1978 (GPIB)

The IEEE 488 interfacing standard applies to the interfacing of instrumentation systems (or portions of them) in which the:

1. Data exchanged amoung the interconnected apparatus is digital.
2. Number of devices connected to one contiguous bus does not exceede 15.
3. Total transmission path length over interconnecting cables does not exceed twenty meters.
4. Data rate across the interface on any signal line does not exceed 1 Mbit/S.

7.4.2 Controller

There can be only one designated controller on the GPIB for a maximum of 15 devices. This device exercises overall bus control and is capable of both receiving and sending data. The rest of the devices are designated as listener, talker or talker/listener.

The controller can address other devices and command them to listen, address one device to talk and wait until data is sent. Data routes are set up by the controller but it need not take part in the data interchange.

7.4.3 Interconnecting Cable and GPIB Connector

The interconnecting cable of the IEEE 488/1978 consists of 24 conductors, 16 conductors are signal paths and eight are ground. The individual cable assembly may be up to four meters long and should have a plug/receptacle type connector at each end of the cable. Each connector assembly is fitted with a pair of captive locking screws.

IEEE 488/1978 Pin Designations

Pin No.	Name	Description
1	DIO1	Data Input/Output line 1
2	DIO2	Data Input/Output line 2
3	DIO3	Data Input/Output line 3
4	DIO4	Data Input/Output line 4
5	EOI	End Or Identify
6	DAV	DAta Valid
7	NRFD	Not Ready For Data
8	NDAC	Not Data Accepted

9	IFC	InterFace Clear
10	SRQ	Service ReQuest
11	ATN	ATtenTion
12	SHIELD	Screening on Cable (Connected to Saftey Ground)
13	DIO5	Data Input/Output line 5
14	DIO6	Data Input/Output line 6
15	DIO7	Data Input/Output line 7
16	DIO8	Data Input/Output line 8
17	REN	Remote Enable
18	GND	Wire of twisted pair with DAV
19	GND	Wire of twisted pair with NRFD
20	GND	Wire of twisted pair with NDAC
21	GND	Wire of twisted pair with IFC
22	GND	Wire of twisted pair with SRQ
23	GND	Wire of twisted pair with ATN
24	GND	Instrument Logic Ground

The GPIB interface consists of 5 management lines, 8 data input/output lines ane 3 handshake lines for transfer of data.

Data Input/Output lines - The 8 data lines form the data bus over which the various devices communicate under the supervision of the controller. The message bytes are carried on the DIO signal lines in a bit-parallel, byte serial form, asynchronously and bidirectionaly.

Handshake or Data Byte Control - Three interface lines are used to effect the transfer of each byte of data on the DIO signal lines from a talked, controller or one or more listeners.

1. DAV (DAta Valid) is used to indicate the condition of (availability and validity) of information on the DIO signal lines.
2. NRFD (Not Ready For Data) is used to indicate the condition of readiness of devices to accept data.
3. SRQ (Service ReQuest) is used by a device to indicate the need for attention or to interrupt the current sequence of events.
4. REN (Remote ENable) is used by a controller in conjunction with other messages to select between two alternate sources of device programming data.
5. EOI (End Or Identify) is used by a talker to indicate the end of a multiple byte transfer sequence or by a controller in conjunction with ATN to execute a polling sequence.

7.4.4 Address and Talk/Listen Selection

On the rear panel the address can be set as desired. The first five switch positions are for the GPIB address. The next switch selects Talk only mode, if this is desired. The switch position marked "Interface" enables the GPIB interface, and the last switch enables or disables the audible annunciator.

To select a bit or a function, press the switch rocker in at the bottom.

If any changes are made in the switch positions, the instrument must either be powered up again or given a software reset via the "HELP!" key before the changes take effect. The switches are only read during the initialization phase and hence no changes will be reflected without a restart.

```
Example      Switch Settings for - Address 3
                                 - Talk/Listen Mode
                                 - GPIB interface selected
                                 - Annunciator enabled

  0        1   2   3   4   5   6   7   8
          ---------------------------------    X means rocker
          |   |   | X | X | X | X |   |   |      is pressed
          | X | X |   |   |   |   | X | X |      in.
          ---------------------------------
  1        1   2   3   4   5          ----- AUDIBLE
          |_              _|       -------- INTERFACE
              ADDRESS        -------------- TALK ONLY
```

If there is no controller and the 6500 is hooked up to a printer for hard copy then the talk-only mode should be selected. For the GPIB interface to be enabled the "Interface" switch should be in the ON position.

7.4.5 <u>Interface functions</u>

SH1 - Source Handshake.

AH1 - Acceptor Handshake.

T5 - Basic Talker, Serial Poll, Talk Only mode, Unaddressed in MLA

TE0 - No address extension talker mode.

L4 - No Listen Only.

LE0 - Not an extended Listener.

SR1 - Service request

RL1 - Remote/Local.

PP0 - No Parallel Poll capability.

DC1 - Device Clear.

C0 - Not a controller.

7.5 RS232 Pin Designations

Pin	Name	Function	Direction
1	CHG	Chassis Ground	-
2	TxD	Transmit Data	In
3	RxD	Receive Data	Out
4	RTS	Request To Send	In
5	CTS	Clear To Send	Out
6	DSR	Data Set Ready	Out
7	GND	Signal Ground	-
8	DCD	Data Carrier Detect	Out
20	DTR	Data Terminal Ready	In

The 6500 Teraohmmeter is data communication equipment (DCE), ie. TxD is an input.

Chapter 8
Maintenance

8.0 Maintenance

This Operation Manual is intended to cover only the operational procedures for the 6500. The technical manual must be consulted for maintenance information. However, it should be stated here that after the teraohmmeter has been in service for some time, dust and other airborne contaminants will settle on the electrometer circuit and its associated front panel connector causing symptoms such as inability of the 6500 to display appropriate values for test resistors known to have very high values of resistance. This is due to contaminants creating unwanted leakage that upset the resistance measurement. When this happens, full performance of the 6500 can be restored by cleaning both sides of the electrometer circuit board and the insulating bushing inside the front panel connector with a soft brush and a suitable solvent such as freon.

Appendix 1 - Sample Bus Control Program

```
100  REM  BASIC Example Program - for Guildline Tera Ohm Meter
105  REM
110  REM  You MUST merge this code with DECL.BAS.
115  REM
120  REM  Assign a unique identifier to device and
125  REM  store in variable DVM%.
130  REM
135     BDNAME$ = "TOHM"
140     CALL IBFIND (BDNAME$,TOHM%)
145  REM
150  REM  Check for error on IBFIND call.
155  REM
160     IF TOHM% < 0 THEN GOSUB 2000
170  REM
180  REM  Clear the device.
185  REM
190     CALL IBCLR (TOHM%)
195  REM
200  REM  Check for an error on each GPIB call to be
210  REM  safe.
215  REM
220     IF IBSTA% < 0 THEN GOSUB 3000
230  REM
240  REM  Reset the TOhm meter so we know what state
250  REM  the internals are set to (defaults).
255  REM
260     WRT$ = "RESET" : CALL IBWRT (TOHM%,WRT$)
270     IF IBSTA% < 0 THEN GOSUB 3000
280  REM
290  REM  Sleep for a while so that the TOhm meter can finish
295  REM
300     FOR I=1 TO 10000 :NEXT I
320  REM
330  REM  Tell the TOhm meter to measure resistance
340  REM
350     WRT$ = "MEASURE OHMS" : CALL IBWRT (TOHM%,WRT$)
360     IF IBSTA% < 0 THEN GOSUB 3000
380  REM
390  REM  Loop on reading the status byte until
400  REM  the TOhm meter says that the reading is complete
410  REM
420     CALL IBRSP (TOHM%,SPR%)
430     IF IBSTA% < 0 THEN GOSUB 3000
440  REM
450  REM  Now test the status byte (SPR%).
460  REM  If SPR% has bit 5 set then the TOhm meter
470  REM  has finaly finished its reading otherwise loop around
480  REM
490     IF SPR% AND &H20 THEN GOTO 500
495 GOTO 420
```

```
500   REM
510   REM Ask the TOhm meter to give us the next measurement
520   REM
525      WRT$ = "VALUE?" : CALL IBWRT (TOHM%,WRT$)
526      IF IBSTA% < 0 THEN GOSUB 3000
530      RD$ = SPACE$(48) : CALL IBRD (TOHM%,RD$)
540      IF IBSTA% < 0 THEN GOSUB 3000
550   REM
560   REM  Print out the reading and loop around to catch
570   REM  the next reading
580   REM
585      PRINT VAL(MID$(RD$,12,15))
590      GOTO 420
2000     REM  A routine at this location would notify
2010     REM  you that the IBFIND call failed, and
2020     REM  refer you to the handler software
2030     REM  configuration procedures.
2040     PRINT "IBFIND ERROR" : RETURN
3000     REM  An error checking routine at this
3010     REM  location would, among other things,
3020     REM  check IBERR to determine the exact
3030     REM  cause of the error condition and then
3040     REM  take action appropriate to the
3050     REM  application.  For errors during data
3060     REM  transfers, IBCNT may be examined to
3070     REM  determine the actual number of bytes
3080     REM  transferred.
3090     PRINT "GPIB ERROR" : RETURN
5000     END
```

Appendix 2

A.2. LARGE VALUE RESISTOR MEASUREMENT TECHNIQUE

The measurement of very large value resistors presents special challenges for the operator. The measurement is often rendered meaningless unless certain precautions are taken.

A.2.1 Environment

The test equipment and the test sample should be located in a clean dry area where the temperature is relatively constant near 23^{o}. The air humidity should be low. Ionized air and ionizing radiation should not be present in the test area.

A.2.2 Sample Preparation

It is very important to prepare the test sample properly so that unwanted parallel leakage paths are reduced as much as possible. The condition of the insulation surface between the sample terminals is very critical since this usually forms a significant source of electrical leakage. The surface must be dry and free of conductive salts or other deposits.

A.2.3 Test Lead Routing

Although it is good general practice to use guarded test leads (shielded wires with the shields connected to ground) it is especially important with higher value test resistors. Guarded test leads shunt unwanted leakage current away from the electrometer circuit.

A.2.4 Capacitive Test Samples

Test samples that store electrical charges and have long time constants cannot be measured using the auto-reverse feature of the teraohmmmeter. Instead, the 6500 should have its auto-reverse key deactivated (LED unlit) until a stable resistance reading is displayed with one test voltage polarity. The reading should be recorded and an average computed with the next reading using the reverse polarity. The auto reverse key is then be pressed to initiate a test voltage polarity reversal. When the polarity reversal is displayed the key should be pressed once again to lock the test voltage into the reverse polarity. The resistance display reading must then be allowed to restabilize at a new value. The true resistance of the sample is the numerical average calculated from the two readings taken. This technique allows the sample sufficient time to be measured properly.

A.2.5 Electrometer Circuit Cleanliness

See Section 8.