TECHNICAL MANUAL

FOR

MODEL 6560

"RESISTANCE CALIBRATOR"

TM6560-J-00

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1 INTRODUCTION

1.1 SCOPE

This manual contains technical specifications, detailed description and maintenance information and diagrams for the Guildline Instrument's 6560 Resistance Calibrator.

1.2 GENERAL DESCRIPTION

The 6560 Resistance Calibrator provides a wide range of high precision resistors selected for use in calibrating ohm-meters. All of the resistors may be selected under remote control from the GPIB interface, this is especially useful in automated calibration setups.

Uses for the 6560 Resistance Calibrator include:

- Maintaining a set of precision reference resistors.
- Automatic calibration of precision resistance measurement apparatus.
- Providing an easy to use resistance standard.

In addition to the front panel manual controls, the Resistance Calibrator can be controlled from a GPIB (IEEE-488) bus interface. Remote control commands include monitoring the current resistance as well as selecting alternate resistances.

Specifications for Guildline Instruments 6560 Resistance Calibrator		
Operating Temperature	23 ± 5	°C
	70 ± 8	°F
Operating Humidity	< 70%	R.H.
Power Requirements	50	Volt Amps
Voltage Requirements	100,120, 220, 240 ± 10%	VAC 50/60 Hz
Dimensions	44.2 X 45.7 X 8.9 high	cm
	17.4 X 18 X 3.5 high	in
Weight	11	kg
	25	lbs

Table 2.1: Basic Instrument Specifications

Other features include:

- Bench top mounting or rack mount with extra flanges provided separately.
- Hidden voltage selection switch on rear panel.
- GPIB Bus Address selectable from rear panel.

Each resistance element will be within 0.1% of the nominal value. The actual resistance values will be displayed on the instrument's front panel readout with an uncertainty which is the sum of the following:

1. the uncertainty of the original calibration.
2. the error due to the stability of the resistance element and the time elapsed from the date of last calibration.
3. the product of the temperature coefficient (the fourth column of Table 2.2) and the change in ambient temperature from the temperature at which the instrument was calibrated.

The computation of total uncertainty is based on the following assumptions:

1. the relative humidity of the environment is <70% and the instrument has been in a controlled environment for at least 72 hours.
2. the resistance elements have not been stressed beyond their maximum current ratings at any time since calibration.
3. the resistance elements have not been stressed by large changes in their ambient conditions (temperature and humidity) at any time since calibration.

Resistance Specifications (4-wire mode) for Guildline Instruments 6560 Resistance Calibrator					
Nominal Value (Ω)	Stability[1] (23°C ±2 K)			TC/K[2] (±ppm)	Maximum Current (mA)
	24 Hrs (±ppm)	90 Days (±ppm)	1 Yr (±ppm)		
Short	0[3]	0[3]	0[3]	0	500
1.0	10	70	100	6	400
1.9	9	65	90	6	300
10.0	4	25	30	2.5	100
19.0	3	20	30	2.5	100
100.0	1	10	15	1.5	25
190.0	1	10	15	1.5	25
1.0 k	1	8	10	1.5	10
1.9 k	1	8	10	1.5	10
10.0 k	1	8	10	1.5	2.5
19.0 k	1	8	10	1.5	2.5
100.0 k	1	8	10	1.5	0.5
190.0 k	1	8	10	1.5	0.25
1.0 M	2	10	15	1.5	0.05
1.9 M	3	10	15	1.5	0.025
10.0 M	6	25	50	3	0.005
19.0 M	6	25	50	4	0.005
100.0 M	14	110	150	10	0.005
Open[4]					

[1] Does not include uncertainty of calibration.
[2] Add Temperature Coefficient (TC) to stability specification
[3] 0.1 mΩ maximum resistance.
[4] Maximum Voltage 500 Volts.

Table 2.2: Resistance Specifications (4-wire Mode)

3 OPERATING INSTRUCTIONS

3.1 INSTALLATION

Place the Resistance Calibrator on a solid bench. Where the Resistance Calibrator is to be used in a rack, attach the mounting brackets provided. "To attach the rackmounting flanges (brackets), the original screws holding the handles to the instrument are removed and the flanges attached over the handles with the longer screws supplied. The instrument has to be supported in the rack/cabinet with adjustable support angles or a support bar. In case of interference with other equipment mounted directly below the instrument, the 4 feet must be removed. This requires that the bottom skin of the instrument is lowered to get access to the nuts which hold the feet." Install the unit in the rack.

Refer to Section 3.4.1 for proper line voltage selection. Connect the line cord to an electrical outlet. Press POWER push button and observe that the display shows the currently selected resistance (after displaying the status of the power on self tests).

Connect the resistance measuring device to the four front panel terminals (P_1, C_1, P_2, C_2 and optionally GUARD and GND).

WARNING

For best performance the P_1 and C_1 terminals should always be at a potential approximately equal to the potential at the GND (ground) terminal. When measuring resistances above 190kΩ the P_2 and C_2 terminals should have the high potential applied to them, if the guard circuit is used the GUARD terminal should be tied to a potential source the same as the potential applied at the C_2 terminal (the GUARD terminal is often tied to the C_2 terminal).

3.2 FRONT PANEL INDICATORS

There are numerous visual indicators on the front panel of the 6560. These indicators display the value and status of the currently selected resistance, the status of the guard circuits, and the status of the remote interface.

3.2.1 DISPLAY WINDOW

A sixteen-digit vacuum-fluorescent display shows either the actual value of the resistance selected or the value of the number being entered from the keyboard. After power on or reset the display will first light up all segments then light up all segments of each of the sixteen display digits sequentially from left to right.

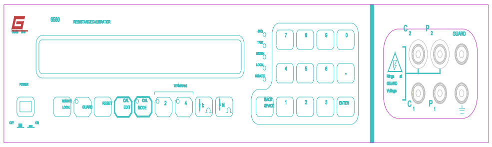


Figure 3.1: Keyboard and Display

3.2.2 GUARD INDICATOR

A red LED indicates that the guard circuit is currently enabled.

3.2.3 CAL MODE INDICATOR

A red LED indicates that the instrument is currently in the calibration mode. Great care should be exercised in this mode since the stored value of any resistor may be easily modified in this mode. It is not possible to enter this mode if the keyswitch on the rear panel is in the NORMAL position.

3.2.4 2-TERMINAL INDICATOR

A red LED indicates that values displayed on the front panel of the instrument are for measurements taken in a two-wire configuration.

3.2.5 4-TERMINAL INDICATOR

A red LED indicates that values displayed on the front panel of the instrument are for measurements taken in a four-wire configuration.

3.2.6 SRQ INDICATOR

A red LED indicates that the 6560 is requesting service from the remote-control bus (Service ReQuest). See Section 4.2.9 for a description of the service request enable command.

3.2.7 LISTEN INDICATOR

A red LED indicates that the 6560 is receiving data from the remote control interface (GPIB). When the instrument is controlled from the GPIB interface the LISTEN indicator is lit when the interface is addressed as the listener (listener active state) and extinguished when the remote controller unaddresses the 6560.

3.2.8 TALK INDICATOR

A red LED indicates that the 6560 is sending data to the remote control interface (GPIB). When the 6560 is controlled from the GPIB interface the TALK indicator is lit when the interface is addressed as the talker (talker active state) and extinguished when the remote controller unaddresses the 6560.

3.2.9 REMOTE INDICATOR

A red LED indicates that the 6560 has received commands from the remote interface (GPIB) within the last minute. The LED is extinguished if no commands have been received over a period of one (1) minute.

3.2.10 LOCAL INDICATOR

A red LED indicates that the instrument keyboard is enabled (i.e. it is possible to control the instrument from the keyboard). When the indicator is extinguished all of the keys on the keyboard (except the REMOTE/LOCAL key, see Section 3.3.2) are disabled.

3.3 FRONT PANEL CONTROLS

The controls on the front panel consist of an alternate action power switch and twenty-two momentary push buttons mounted in the front panel membrane. Some of the membrane push buttons have integral LED indicators.

3.3.1 POWER SWITCH

Connects AC power to the 6560 when depressed.

3.3.2 REMOTE LOCAL KEY

This key will return local control when pressed and extinguish the remote red Led indicator unless the remote controller has disabled the entire keyboard.

When the LOCAL red LED indicator is lit the other keys on the keyboard will be enabled.

3.3.3 GUARD KEY

The guard key alternately enables and disables the guard circuit, the guard LED (see Section 3.2.2) will be extinguished when the guard circuit is disabled.

3.3.4 RESET KEY

When this key is pressed the microprocessor performs a complete reset. Normally it is only necessary to enter this sequence after the GPIB address has been changed.

3.3.5 CAL EDIT KEY

When the instrument is not in CAL mode (see Section 3.3.6) this key alternately changes the display so that resistance is displayed to the nearest tenth of a part per million or the nearest part per million.

When the instrument is in CAL MODE mode pressing this key will cause the instrument to flash the current resistance value, prompting the user to enter a new value which will be permanently stored in the instruments memory. Pressing the key a second time will cancel the flashing . It is not possible to enter this mode unless the instrument is in calibration mode (see Section 3.3.6)

3.3.6 CAL MODE KEY

When this key is pressed the instrument will alternately enter or exit CAL MODE. It is not possible to enter CAL MODE unless the key switch on the rear panel is set to the CAL position.

When the instrument is in CAL MODE all controls and indicators operate normally and the CAL EDIT key is made operative.

3.3.7 2-TERMINAL KEY

Pressing the 2-TERMINAL key causes the instrument to display the value of the currently selected resistor as if it were measured by a two-terminal ohmmeter. In CAL MODE if the two-terminal mode is selected then any values entered will be stored in the two-terminal coefficient table, the four-terminal coefficient will not be affected.

3.3.8 4-TERMINAL KEY

Pressing the 4-TERMINAL key causes the instrument to display the value of the currently selected resistor as if it were measured by a four-terminal ohmmeter. This does not affect the actual resistance. In CAL MODE if the 4-terminal mode is selected then any values entered will be stored in the 4-terminal coefficient table, the two-terminal coefficient will not be affected.

3.3.9 ¯kW KEY

Pressing the ↓kΩ Key when the instrument is displaying a resistance value will cause the instrument to select the next lower resistance. After the resistance has been lowered to zero Ω further pressing of this key will have no effect.

When a number is being entered pressing this key will add a K suffix, effectively multiplying the entered value by 1 000.

3.3.10 -MW KEY

Pressing the ↑MΩ Key when the instrument is displaying a resistance value will cause the instrument to select the next higher resistance. After the resistance has been raised to open circuit further pressing of this key will have no effect.

When a number is being entered pressing this key will add an M suffix, effectively multiplying the entered value by 1 000 000.

3.3.11 0-9 DIGIT KEYS

Used to select the required resistance or to enter the value of a calibration coefficient. Press to enter numbers 0 through 9.

3.3.12 ENTER KEY

This key is pressed after the required resistance has been entered. After the Enter Key has been pressed the instrument will select the closest available resistance.

3.3.13 BACK SPACE KEY

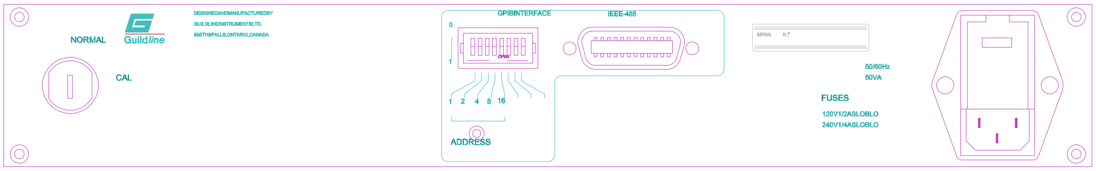
This key can be pressed during the entry of a resistance or a calibration coefficient, the last key stroke will be deleted. If all key strokes are deleted the display will revert to the previous display mode.

3.4 REAR PANEL CONTROLS

The rear panel (Figure 3.2) of the instrument has a number of controls which are used to configure the input line voltage, configure the GPIB bus and to enable instrument calibration.

3.4.1 VOLTAGE SELECTION DRUM

This drum allows the 6560 operator to select the input voltage of the instrument from one of 100, 120, 220, or 240 volts. It is important that the correct input voltage be selected before any attempt is made to operate the instrument. To change the selected input voltage, after removing the line cord from the receptacle, pry open the power receptacle as shown in Figure 3.3.


NORMAL
Guildline
CAL
DESIGNEDANDMANUFACTUREDBY
GUILDLINEINSTRUMENTSLTD.
SMITHSFALLS,ONTARIO,CANADA
GPIBINTERFACE
IEEE-488
0
1
OPEN
1 2 4 8 16
ADDRESS
SERIAL N.º
50/60Hz
50VA
FUSES
120V1/2ASLOBLO
240V1/4ASLOBLO

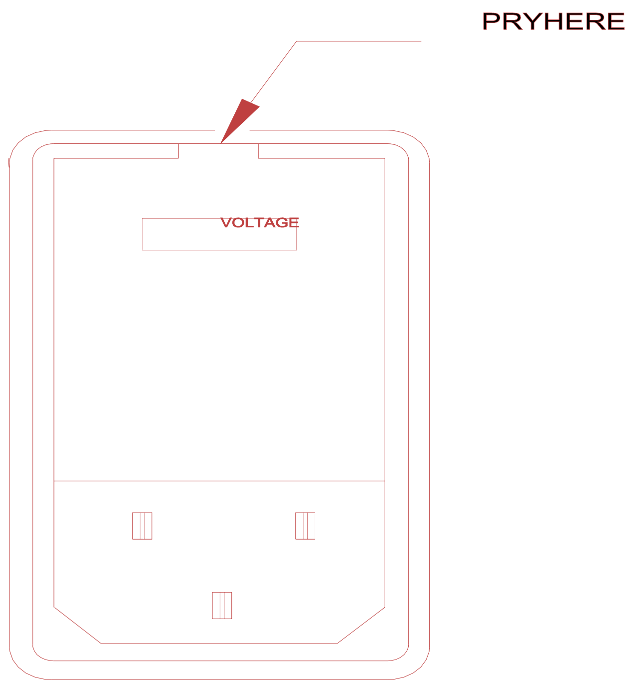


Figure 3.3: Opening the Power Receptacle

Check to see that the fuses inserted in the receptacle correspond to the type specified in Table 3.1. Only fuses of the specified type should be used.

LINE VOLTAGE	FUSE TYPE REQUIRED
100 Volts 120 Volts	½ Amp Slo-Blo (MDL-½ A 250 V)
220 Volts 240 Volts	¼ Amp Slo-Blo (MDL-¼ A 250 V)

Table 3.1: Recommended Fuses

In order to rotate the drum it must be removed completely from the receptacle. Set the voltage selector drum so that the proper line voltage indication will be visible through the receptacle window when the cover is closed.

Where the supplied line cord does not match the power outlet receptacle the plug may be removed from the line cord and replaced with a 3-pin plug of the correct type. The plug should be wired as shown in Table 3.2.

CODE WIRE COLOUR	POTENTIAL VOLTAGE
Brown	High Voltage
Blue	Neutral
Green/Yellow	Ground (Earth)

Table 3.2: Line Cord Wiring

3.4.2 GPIB ADDRESS SWITCHES

The GPIB address and mode is set through the switches on the rear panel (Figure 3.4). Switches 1 through 5 set the address, in order to compute the address use Equation 1 where S_n is either 1 or 0 depending upon the position of switch n. When a switch is in the open position it is a 1, when a switch is closed it is a 0.

$$\text{address} = S_1 2^0 + S_2 2^1 + S_3 2^2 + S_4 2^3 + S_5 2^4 \qquad (1)$$

The GPIB mode (disabled, talk-only, or talk/listen) is set by switches 6 and 7, the possible settings for the switches are shown in Table 3.3. The 6560 does not support the talk-only, or listen-only modes, the modes are available only for consistency with other instruments manufactured by Guildline.

The last switch (S_8) enables or disables the audible feed back when a key is pressed. If S_8 is in the 1 position then as any key is pressed the instrument will "beep", if S_8 is in the 0 position then the instrument will not "beep" when a key is pressed.

Since the membrane keys on the 6560 have no tactile feel it is often difficult for an instrument operator to be sure that a key has been activated when the audible feedback is disabled. For this reason it is recommended that the audible feedback always be enabled.

It is not possible to disable the audible "beep" emitted from the instrument during power on diagnostics and error notifications.

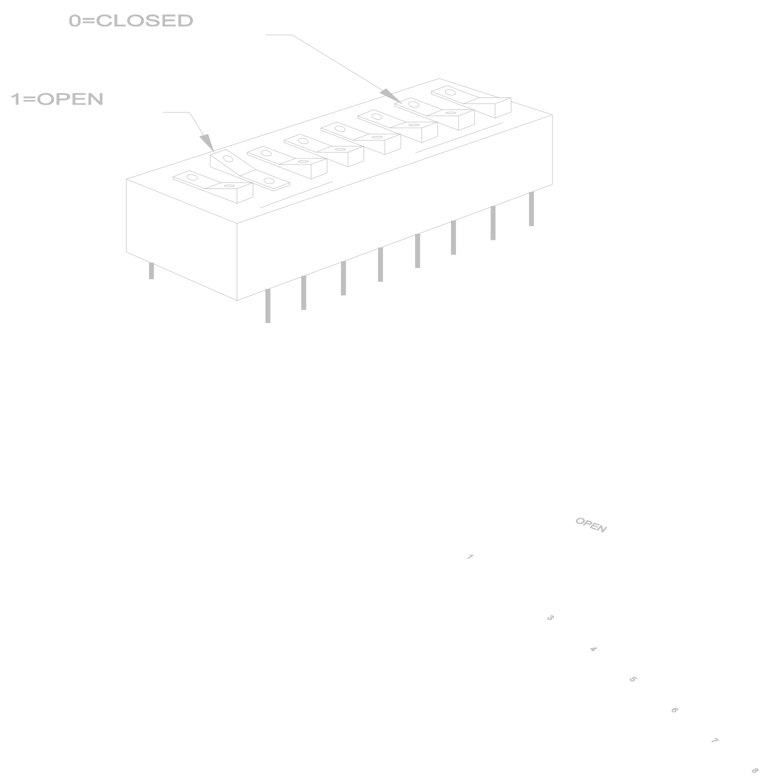


Figure 3.4: Switch Settings

S_6	S_7	GPIB mode
0	0	Interface Disabled
0	1	Talk-only
1	0	Interface Disabled
1	1	Talk/Listen

Table 3.3: GPIB Mode Switches

3.4.3 NORMAL/CAL KEY SWITCH

The NORMAL/CAL switch is activated with a key, the key may be removed (for security) when it is in the vertical (NORMAL) position. When the key is in the NORMAL position it is not possible to change the calibration coefficients from the bus or from the front panel. When the key is in the horizontal (CAL) position it is possible to change the calibration coefficients.

3.5 FRONT PANEL CONNECTORS

The connectors on the front panel provide access to the internal resistance element. The internal connections to the resistance element are shown in Figure 3.5.

Figure 3.5: Ideal Circuit

Internally (and externally) the connections to the resistance element have a finite (and significant) resistance. In order to compensate for these error resistances four access terminals are provided. The measurement of resistance is based upon Ohms Law (V = IR) the resistance of any element can be measured by applying a reference current to the element and measuring the voltage drop across the element.

The reference current is applied across the C_1 and C_2 terminals, if there is a series resistance in the leads (represented by R_1 and R_4 in Figure 3.6) the current flowing through the resistance element (R in Figure 3.6) will not be affected, hence the contribution of R_1 and R_4 to the measurement can be ignored. If the potential across the resistance element is measured at the P_1 and P_2 terminals the resistances R_2 and R_3 can be ignored since the potential measurement current should be zero, and there is no voltage drop across either R_2 and R_3.

Figure 3.6: Functional Circuit

An additional source of measurement error are the leakage resistances (represented by R_5 and R_6 in Figure 3.7). In order to remove the effects of the leakage resistance, a potential equal to the potential at P_2 is applied to the guard terminal and the potential at P_1 is made equal to ground, hence there is no potential difference across R_5 or R_6 and no current flows into or out of the current terminals.

There will be a current flowing from the GUARD to the GND terminals through the guard resistance R_G.

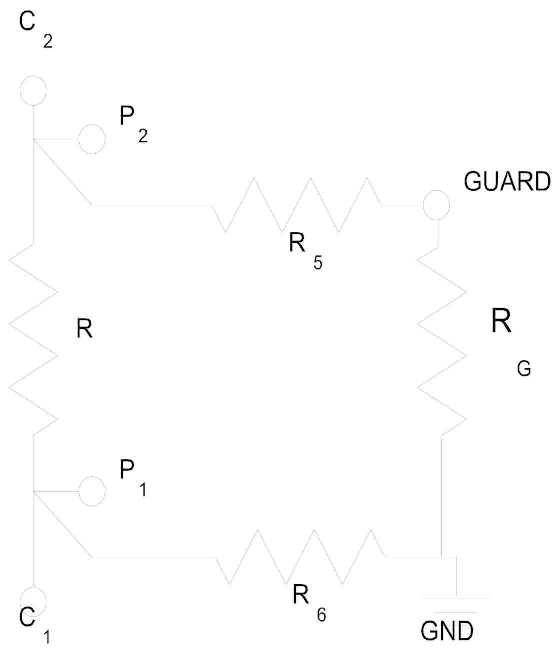


Figure 3.7: Leakage Circuit

The magnitudes of the lead resistances (R_1, R_2, R_3, and R_4) shown in Figure 3.6 are about 100 mΩ. The leakage resistances (R_5 and R_6) shown in Figure 3.7 are about 10 TΩ. The guard resistance (R_G in Figure 3.7) will be approximately equal to the resistance element.

3.5.1 C_1 - CURRENT TERMINAL 1

This terminal is used to apply the reference current through the resistor element. The potential at C_1 should be close to the voltage at the GND terminal.

3.5.2 C_2 - CURRENT TERMINAL 2

This terminal is used to apply the reference current through the resistor element. The potential at C_2 should be close to the voltage at the GUARD terminal.

3.5.3 P_1 - POTENTIAL TERMINAL 1

This terminal is used to measure the potential at the resistor element. The potential at P_1 should be close to the voltage at the GND terminal.

3.5.4 P_2 - POTENTIAL TERMINAL 2

This terminal is used to measure the potential at the resistor element. The potential at P_2 should be close to the voltage at the GUARD terminal.

3.5.5 GUARD TERMINAL

The GUARD terminal on the front panel is connected to the guard circuit.

3.5.6 GND - GROUND TERMINAL

The GND (ground) terminal on the front panel is internally tied to the electrical ground of the processor and the GUARD circuit. The processor ground is at the same potential as GPIB ground.

3.6 REAR PANEL CONNECTORS

There are two connectors on the rear panel of the 6560. These connectors are for AC line power and for computer communications (GPIB).

3.6.1 GPIB DATA CONNECTOR

The signals at the GPIB data connector are described in detail in Section 4.1.

3.6.2 POWER INLET CONNECTOR

The signals at the POWER inlet connector are described in detail in Section 3.4.1.

3.7 SELECTING A RESISTANCE

The resistance presented at the front panel can be selected in one of two ways, either by direct entry or by scrolling through the available resistances until the desired resistance is shown.

The direct entry method of selecting resistance is invoked simply by pressing the digit keys, (to edit use the backspace key), and the ↓kΩ or ↑MΩ keys until the desired resistance is shown, then pressing the ENTER key. The instrument will then select the value of resistance closest to the entered resistance.

An alternate technique used to select a resistance is to depress the ↓kΩ key to scroll to the next smaller resistance or to depress the ↑MΩ key to select the next larger resistance. These keys can be pressed repeatedly until the desired resistance is shown in the display window.

3.8 CHANGING CALIBRATION COEFFICIENTS

Changing the calibration coefficients is a similar operation to selecting a resistance value. The following steps must be performed to change the coefficients:

1. Ensure that the rear panel keyswitch is in the CAL position.

2. Select the resistance value for which the calibration value is to be modified (be sure that the 2-,4-terminal selection is correct).

3. Press the CAL MODE key, the red LED should light up. If the message "ACCESS DENIED" appears then the keyswitch on the rear panel is in the NORMAL position and must be turned.

4. Press the CAL EDIT key, the displayed value should start to flash.

5. Using the 0-9 digit keys, the decimal point key (.), the BACK SPACE key and the ↓kΩ and ↑MΩ keys enter the desired value. The new value should be flashing at all times.

6. Press the ENTER key. This will permanently store the new value for the selected resistor in the instrument memory. The display will stop flashing and the new value will be displayed.

Repeat the above steps as necessary until the values for all resistor elements have been entered and stored, then press the CAL MODE key to return the instrument to NORMAL mode. The CAL MODE red LED should be extinguished. Return the rear panel keyswitch to the NORMAL position to prevent accidental entry of resistance values.
It should be noted that when the instrument is in CAL MODE and the CAL EDIT key has not been pressed (the display is not flashing) it is possible to select a new resistance using the normal key sequences as outlined in Section 3.7.

NOTE: The calibration coefficients that were entered at the time this instrument was manufactured are listed on sheet 2 of the Report of Calibration.

4 REMOTE CONTROL

The 6560 has a remote control interface (GPIB). This chapter describes the interface and the commands to which the 6560 will respond. The setting of the GPIB address and mode is described in Section 3.4.2.

4.1 GPIB INTERFACE

The 6560 meets the subsets of the GPIB interface specifications IEEE-488.1 shown in Table 4.2. The pin connections on the GPIB interface connector are shown in Table 4.1.

SH1 - the 6560 has complete source handshake capabilities.

AH1 - the 6560 has complete acceptor handshake capabilities.

T5 - the 6560 has talker capabilities with a single primary address in the range 0 to 30. Extend addressing is not implemented.

L3 - the 6560 supports basic listener with unaddress if MTA (My Talk Address). The talk and listen addresses will always be the same. The 6560 does not support extended Listen addresses.

SR1 - the 6560 has complete service request generation capabilities.

RL1 - all functions except Power on the front panel of the 6560 can be locked out by the GPIB controller. The 6560 does not have an indicator on the front panel to indicate when it is in the local lock out state.

PP0 - the 6560 has no parallel poll capabilities.

DC1 - the 6560 has full device clear capabilities.

DT0 - the 6560 has no device trigger capability.

C0 - the 6560 will never become the bus controller.

E2 - the 6560 has all required electrical interface capability.

PIN	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	EIO	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 safety 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	GND6	Ground wire of twisted pair with DAV
19	GND7	Ground wire of twisted pair with NRFD
20	GND8	Ground wire of twisted pair with NDAC
21	GND9	Ground wire of twisted pair with IFC
22	GND10	Ground wire of twisted pair with SRQ
23	GND11	Ground wire of twisted pair with ATN
24	GND	Logic Ground

Table 4.1: IEEE-488.1 Pin Designations

Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T5
Listener	L3
Service Request	SR1
Remote Local	RL1
Parallel Poll	PP0
Device Clear	DC1
Device Trigger	DT0
Controller	C0
Electrical Interface	E2

Table 4.2: GPIB Device Capabilities

4.1.1 GPIB INPUT BUFFERING

The GPIB input buffer is 256 bytes long, the input full bit is set when the buffer is above 75% full (64 bytes remaining), hence if the programmer limits messages sent to the 6560 to 32 bytes and checks the IFL bit in the status register before sending each message then under normal operating conditions the buffer should never overflow. If the buffer is full and the programmer sends more data the 6560 will perform the necessary handshaking but the received data WILL be lost. In this instance it is assumed that:

1. if the buffer is full, the system programmer is probably in error since the 6560 input buffer should never become full (the 6560 interprets most commands in under 150 milliseconds)

2. the measuring system will continue to run since the 6560 will never lock up the GPIB bus.

4.1.2 GPIB OUTPUT BUFFERING

Output from query commands are placed in a 256 byte output buffer. When the GPIB bus controller reads data from the 6560 the responses will come from the output buffer in "first-in first-out" order. If for some reason the controller does not read responses from its query commands the 6560 output buffer will overflow, in this case the first data into the buffer will still be valid and the later data will be lost. When output data are lost the query error bit in the status register will be set. When the output buffer is not empty then the message available (MAV) bit will be set in the status register.

4.1.3 GPIB DEADLOCK

If the GPIB bus controller demands a byte of data from the 6560 and the output buffer is empty and this condition persists for a period of 8 seconds, the 6560 will place the current resistance (see Resistor? command) into the output buffer and use this value to satisfy the controllers demand for data. The format of the data is set by the current state of the Terse/Verbose flag (see Terse and Verbose commands).

4.1.4 GPIB DEVICE CLEAR

The 6560 will assume the following state when it receives a Device Clear signal from the GPIB interface:

- open circuit selected
- guard function set to OFF
- 4 wire mode selected
- Terse Response is selected

4.1.5 GPIB DEVICE TRIGGER

When the 6560 receives a device trigger from the GPIB controller the 6560 will complete the required handshaking and will set the Executive Error (EXE) in the Event Status Register (*ESR). No other action will be taken by the 6560 upon receipt of a Device Trigger.

4.1.6 REMOTE AND LOCAL OPERATION

The 6560 can be operated using the front panel keys or it can be operated remotely using a remote controller. In addition the 6560 can be placed in a local lockout condition at any time by a command from the controller. When combined, the local, remote, and lockout conditions yield four possible operating states:

(1) LOCAL - The 6560 responds to local and remote commands. This is also called "Front Panel Operation". Only remote commands that do not affect the state of the 6560 are allowed to execute. (For example the command "Resistor?" is allowed to operate but the command "Resistor 19.0" which would change the instrument's state is not allowed.) If the controller sends a command which would affect the instrument's state while in local, the command will be ignored, and no error indication will be given.

(2) LOCAL WITH LOCKOUT - Local with lockout is identical to Local except that the 6560 will go into remote with lockout instead of the remote state when the 6560 receives a remote command. The local with lockout state is entered by sending a IEEE-488 LLO+REN command from the controller to the 6560.

(3) REMOTE - When the Remote Enable (REN) line is asserted and the controller addresses the 6560 as a listener, the 6560 enters the remote state. The REMOTE LED on the front panel of the 6560 will be lit when the 6560 is in the remote state.

Front panel operation is restricted to the use of the POWER switch and the REMOTE LOCAL key. Pressing the REMOTE LOCAL key or sending the GTL (Go To Local) interface message returns the 6560 to the local state.

(4) REMOTE WITH LOCKOUT - The remote with lockout state can be entered from remote or local with lockout, but not directly from local. Remote with lockout is similar to the remote state but restricted; the REMOTE/LOCAL key will not return to the local state. To return the 6560 to the local with lockout state the controller must send a GTL interface command. To return the 6560 to the local state the controller must unassert the REN control line.

The possible Remote/Local state transitions are summarized in Table 4.3.

FROM	TO	IEEE-488 Interface Command
Local	Remote	MAL + REN
Local	Local/ Lockout	LLO + REN
Remote	Local	GTL or LOCAL key
Remote	Remote/ Lockout	LLO +REN
Local/ Lockout	Remote/ Lockout	MLA + REN
Remote/ Lockout	Local	REN
Remote/ Lockout	Local/ Lockout	GTL

Table 4.3: Remote/Local State Transitions

4.1.7 UNRECOGNIZED GPIB COMMANDS

When the 6560 receives a command from the GPIB controller which is not recognized by the command parser the Command Error (CME) in the Event Status Register (ESR) will be set.

4.1.8 GPIB COMMAND PARSER

The command parser in the 6560 will accept most command short forms, and misspellings (see cautionary note in Section 4.2.20).

4.1.9 GPIB END OF MESSAGE TERMINATOR

The 6560 will place a Line Feed (0X0A) at the end of each reply. The EOI flag will not be set.

4.2 GPIB COMMANDS

4.2.1 *ESE - SET EVENTS ENABLE REGISTER

This command sets the standard event status enable register bits. When the bits in the Event Status Enable (ESE) register are "ANDed" with the bits in the Event Status Register (ESR) if the result is non-zero then the Event Status Bit (ESB) in the Status Byte Register (STB) is set (see Figure 4.1).

The values accepted for the *ESE command are between 0 and 255, all other values are considered to be an error, and will set the Execution Error (EXE) bit in the Event Status Register.

4.2.2 *ESE? - EVENT STATUS ENABLE QUERY

This command reports the current value of the Event Status Enable Register. The value returned will be between 0 and 255.

4.2.3 *ESR? - EVENT STATUS REGISTER QUERY

This query allows the programmer to determine the current contents of the event status register (see Table 4.4). Reading the Event Status Register clears it.

BIT LOCATION		NAME	DESCRIPTION
0	LSB	OPC	OPeration Complete. This event bit is generated in response to the OPC or *OPC? command. It indicates that the 6560 has completed any pending operations and that the parser is ready to accept more program messages.
1		RQC	ReQuest Control. This event bit indicates to the GPIB controller that the 6560 is requesting permission to become the controller in charge. The 6560 will NEVER set this bit.
2		QYE	QuerY Error. This bit indicates that an attempt is being made to read data from the output queue when no output is either present or pending, or that data in the output queue has been lost (queue overflow). See also GPIB Deadlock.
3		DDE	Device Dependent Error. Not Used.
4		EXE	EXecutive Error. Set when 1) a program data element is evaluated to be outside the legal input range or is inconsistent with the 6560's capabilities, 2) a valid program message could not be properly processed.
5		CME	CoMmand Error. Set when 1) a syntax error has been detected by the parser, 2) a semantic error has occurred indicating that an unrecognized header has been received, 3) A Group Execute Trigger was entered into the input buffer inside of a program message.
6		URG	User Request. Set when any key is depressed on the 6560 keyboard.
7	MSB	PON	Power ON. This bit is set after the 6560 is powered up.

Table 4.4: Event Status Register

Figure 4.1: Event Status Bit Operation

4.2.4 *IDN? - IDENTIFICATION QUERY

This command causes the 6560 to reply with an identification string. The identification string is built up of four (4) fields delimited by commas (,). The first field is the manufacturer (e.g. Guildline Instruments), the second field is the model (eg 6560), the third field is the serial number (e.g. 55065) and the final field is the firmware revision (e.g. A). A typical response might read:

Guildline Instruments, 6560, 55065, A

The reply string will be shorter than 73 characters.

4.2.5 *OPC - OPERATION COMPLETE

This command will cause the 6560 to set the Operation Complete bit (bit 0) in the Event Status Register. Since the 6560 processes all commands sequentially the operation complete bit will be set as soon as the command is parsed.

4.2.6 *OPC? - OPERATION COMPLETE QUERY

This query will place a numeric 1 in the output buffer indicating that all pending operations are complete.

4.2.7 *OPT? - REPORT AVAILABLE OPTIONS

This query command reports the presence or absence of various options. The format of the reply is a series of arbitrary ASCII response fields separated by commas. The first field reports the presence of the optional 8087 Numeric Data Processor (NDP), the second field reports the frequency of the AC line (50 or 60 hertz).

No NDP, 60 Hz

with all options enabled the response is:

NDP, 50 Hz

The NDP option denotes the presence of a Numeric Data Processor (8087) in the processor cluster.

The software performs many computations with 64 bit floating point arithmetic and has floating point software routines, however if an 8087 is present at U206 then the software will automatically use the floating point hardware. The processor has enough computing capacity to perform all required operations without the 8087 but the presence of an 8087 will improve response to many of the bus commands.

Guildline Instruments does not supply a numeric data processor. The standard Intel Math Coprocessor for IBM PC and Compatibles with 5 MHz 8086 or 8088 will operate in the 6560. The Intel order number is PCPN8087.

4.2.8 *RST - DEVICE RESET

This command is intended to return the 6560 to a known state, specifically a return to Terse mode. This command will not affect the following:

1. The Output Queue

2. The state of the IEEE-488 interface

3. The selected address of the 6560

4. The *SRE setting

5. The *ESE setting

6. Calibration data that affects device specifications

4.2.9 *SRE - SERVICE REQUEST ENABLE COMMAND

The service request enable command allows the 6560 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 command.

4.2.10 *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.

4.2.11 *STB? - READ STATUS BYTE QUERY

This command allows the programmer to read the status byte and master summary bits (shown in Table 4.5).

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 RQS is reported in bit 6. The Status Byte Register can also be read with the Read Serial Poll hardware command on the GPIB interface.

4.2.12 *TRG - GROUP EXECUTE TRIGGER

This command performs the same action as a group execute trigger on the GPIB interface. Since the 6560 processes all commands when they are received (execution is not delayed) this command will set the execution error bit in the event status register (bit 4).

4.2.13 CAL? - DISPLAY THE DATE OF THE LAST CALIBRATION

This query command displays the date and time of the last change to the calibration coefficients. The value displayed is the date and time that a calibration coefficient was changed, the date and time is taken from the internal real-time clock (see Date and Time command) and corrected for the current timezone (see TimeZone command).

In Verbose mode the reply will be:

DDD MMM dd hh:mm:ss YYYY ZZZ

or in terse mode the reply will be

YYYY/MM/dd hh:mm:ss

where the value YYYY is the year (e.g. 1990), DDD is the day of the week (e.g. Wed), MMM is the month name (e.g. Sep), MM is the month number (e.g. 08), dd is the day of the month (e.g. 22), hh is the hour of the day (e.g. 14), mm is the minute of the day (e.g. 36), ss is the second of the day (e.g. 05), and ZZZ is the timezone currently in effect (e.g. EST).

LOCATION		NAME	DESCRIPTION
0	LSB	TIME	System Time has Changed. This bit is set once each second as the real time clock ticks, and is cleared by the execution of the Time? command.
1		unused	Always zero.
2		CHK	Checksum Computation Complete. This bit is set once after instrument power on after the completion of the computation of the ROM checksum and is cleared by the ROM Checksum? command.
3		IFL	Input full. This bit is set when the input queue is over 75% full and cleared when the queue drops below 25% full.
4		MAV	Message Available. This bit is set when the output queue is not empty.
5		ESB	Event Status Bit. This bit is set when the result of a bitwise AND of the Event Status Enable Register is not zero.
6		RQS	ReQuest for Service. This bit is set when the results of a bitwise AND of the Status Byte Register and the Service Request Enable Register is not zero.
7	MSB	unused	Always zero.

Table 4.5: Status Byte Register

4.2.14 DATE - SET THE SYSTEM DATE

The date command allows the programmer to set the real time clock date registers (see also the Time command). The format of a valid Date command is:

date YYYY/MM/DD

where YYYY, MM and DD are the year, month and day of the month respectively.

4.2.15 DATE? - DISPLAY THE 6560 INTERNAL DATE

This command will report the date maintained in the system real-time clock in the terse format:

YYYY/MM/DD

or if verbose mode is enabled

Date YYYY/MM/DD

where YYYY, MM, and DD are the year , month and day respectively.

4.2.16 KEY? REPORT LAST KEY PRESSED

This query command will report the value of the key most recently pressed on the keyboard. In terse mode the response will be one of:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, B, C, D, E, F, M, R, S, T, U, X, ?

where ? indicates that no keys have been pressed since the 6560 was last Reset. The verbose reply will be preceeded with "KEY". The meanings of the various key characters are shown in Table 4.6.

CHARACTER	KEY NAME
0-9	Numeric Digit Keys
B	Back Space
C	CAL EDIT
D	↓kΩ
E	Enter
F	Four Terminals
G	GUARD
M	CAL MODE
R	Remote/Local
S	RESET
T	Two Terminals
U	↑MΩ
X	Decimal Point

Table 4.6: Keyboard Character Designations

4.2.17 KEY <KEYNAME> ENTER A KEYSTROKE

The Key command causes the 6560 to perform actions similar to the actions performed when a front panel key is pressed. Allowable values for <keyname> are:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, B, C, D, E, F, M, R, S, T, U, X, ?

where each of these is a single ASCII character. Multiple <keynames> may be placed on the key command line and they will be processed in the order given, for example the command:

KEY 1900E

will change the resistance to 1.9 kΩ. The meanings of the various key characters are shown in Table 4.6.

4.2.18 OPTIONS? - DISPLAY THE OPTION SWITCH SETTINGS

This query command displays the status of the 8 position option switch SW301. The decimal reply is between 0 and 255. If the reply is expressed as a binary number each 1 bit represents an open switch position.

In Verbose mode the reply will be:

Options 203

or in terse mode the reply will be:

203

where the value 203 is dependant upon the current switch settings.

4.2.19 RESISTOR - SELECT A RESISTOR

This command changes the value of the currently selected resistor. A typical command might be:

Resistor 1.9000345

or

Resistor 1900.0345e-03

where the value 1.9000345 is dependant upon the resistor desired. Almost any resistance can be specified, however the instrument only has a limited set of available resistors, therefore the closest available resistor will be selected. Care should be taken to ensure that the resistor desired is actually selected, for example if the 1.9 Ω nominal resistance is desired and the command Resistor 1.45 (half way between two values) is sent the 1.0 Ω may be selected depending upon: 1) the round-off errors, and 2) the actual values of the 1.0 Ω and the 1.9 Ω resistors.

The 6560 will not change between 2-wire mode and 4-wire mode when attempting to select the closest available resistor. After the relays have been changed (about 200 ms) the OPC (Operation Complete) Bit in the Event Status Register (see Section 4.2.3) register will be set. If the numeric value is missing or unrecognizable the CME (Command Error) bit in the Event Status Register will be set. If the numeric value is out of range (i.e. negative) then the EXE (Execution Error) error will be set for a program data element out of range error.

4.2.20 RESISTOR? - DISPLAY THE CURRENTLY SELECTED RESISTOR

This query command displays the value of the currently selected resistor. The value displayed will include the compensation for the 2-wire or 4-wire measurement depending upon the status of the 2/4 wire selection. This number is the same as the number displayed on the front panel.

In verbose mode the reply will be:

1.9000345 Ohms

or in terse mode the reply will be

1.9000345

where the value 1.9000345 is dependant upon the current resistor selected. Cautionary note: The GPIB command parser will accept almost any reasonable spelling of a command, hence the command "Resistance?" instead of "Resistor?" will be confused with the "RomChecksum?" command since both commands start with "R" and have a "C" in the body of the word.

4.2.21 ROMCHECKSUM? - DISPLAY THE ROM CHECKSUM

This query command will give the checksum of the ROM. Since the checksum algorithm is quite involved, the processor computes the checksum in its "spare" time, depending upon the bus activity this takes about five minutes after power up (or reset). In order to determine if the computation of the checksum is complete the programmer may either poll the checksum until the value stops changing or wait for the CHK bit in the Status Byte Register to be set to one (1). It should be noted that the CHK bit will only be set once after the 6560 is powered on, hence simply waiting for the CHK bit to become set may not always work if the RomChecksum had been previously read. Normally this command is only used for diagnostic purposes. The verbose reply will be:

ROM checksum 1234

The terse reply will be:

1234

where the value 1234 will change as the checksum is computed.

4.2.22 SINCE? - DISPLAY THE TIME THE 6560 WAS LAST RESET

This query command will display the time the 6560 was last powered up (or reset). The verbose reply will be:

SINCE Thu Jun 2, 10:55:22 1988

or the terse mode:

Thu Jun 2, 10:55:22 1988

where the date displayed will depend upon the startup date. Under normal conditions the 6560 should be able to operate for months or years without a reset, therefore this command reflects when the last power failure occurred.

4.2.23 SERIALNUMBER - SET THE 6560 SERIAL NUMBER

This command accepts an integer in the range -200000 to +200000, this number will be reported in the serial number field of the *IDN? command.

4.2.24 SOFCAL™*

- SET CALIBRATION COEFFICIENTS

The SOFCAL command allows the user to set the calibration coefficients.

WARNING

Great care should be taken when using this command since the 6560 can not check that the values of the parameters are reasonable.

The following restrictions apply when trying to set a coefficient:

1. The Key Switch on the rear panel of the Resistance Calibrator must be in the CAL position.

2. The values modified are either the 2-wire coefficients or the 4-wire coefficients dependant upon which operating mode the instrument is in at the time the command is executed.

3. The value will not be stored if it is outside the range of the nominal value ±10%. If the instrument is in 2-wire mode an additional 0.5 Ω is allowed to compensate for external wiring.

***SOFCAL is a Registered Trademark of Guildline Instruments.**

A valid SOFCAL command is:

SOFCAL 19.00176

where the value 19.00176 is dependant upon the desired calibration value.

If the numeric parameter is missing from the command, or does not meet the conditions enumerated above, then the EXE (Execution Error) bit in the Event Status Register will be set and no calibration coefficients will be modified.

The SOFCAL command will update the calibration date reported by the "CAL?" command.

4.2.25 SOFCAL? - EXAMINE CALIBRATION COEFFICIENTS

The SOFCAL? query command will return the actual value (as stored in by Calibrate command) closest to the given nominal value. The values returned will be either the 2-wire coefficient or the 4-wire coefficient dependant upon which operating mode the instrument is in at the time the command is executed.

A valid SOFCAL? command is:

SOFCAL? 19.0

where the value 19.0 is dependant upon the desired calibration value.

The terse reply will be:

19.000345

The verbose reply will be:

19.000345 Ohms

where the value 1.9000345 is dependant upon the actual calibration values stored.

Normally this command is to review the calibration values which are displayed when a resistance is selected, without actually selecting a resistance.

If the numeric parameter is missing from the command, or is not close to one of the available nominal values, then the EXE (Execution Error) bit in the Event Status Register will be set and no calibration coefficient will be returned.

4.2.26 TERSE - TURN OFF VERBOSE MODE
This is the default mode for the 6560 after reset. Typically query commands will return very little information in terse mode.

4.2.27 TIME - SET THE TIME SYSTEM
This command will set both internal clocks in the 6560. The format of the time command is:

Time HH:MM:SS

where HH, MM and SS are the hours, minutes and seconds respectively. The hours should be expressed in 24-hour format.

4.2.28 TIME? - DISPLAY THE SYSTEM TIME
This command will report the time maintained in the system real-time clock in the terse format:

HH:MM:SS

or the verbose format:

Time HH:MM:SS TimeZone

where HH, MM and SS are the hours, minutes and seconds in 24-hour format, and TimeZone is the current timezone (see TimeZone command).

It should be noted that the 6560 maintains two real-time clocks, one is battery backed up and is read only at power up, the other clock counts AC Line interrupts and divides by either 50 or 60 (dependant upon the option switches). If you notice that the time is correct at power up than gains or loses time (at a rate of 5:6) then the option switch is set incorrectly.

4.2.29 TIMEZONE - SET THE OPERATIONAL TIMEZONE
Internally the 6560 maintains all times as a 32-bit integer representing the number of seconds since January 1st 1970 Greenwich Mean Time (GMT). When a time is input or displayed it is converted either to or from local time. In order for the 6560 to be able to perform this conversion the instrument must know the current timezone.

The TimeZone command has the form:

TimeZone aaabbbccc

where aaa is the 3-letter abbreviation for the local standard timezone (e.g. CST) and bbb is a number from -23 to +24 indicating the value that is added to GMT in order to obtain local standard time. Both aaa and bbb are required but ccc is the abbreviation for the local daylight-savings timezone (e.g. CDT) and it should be present only if daylight-savings time is currently in effect.

4.2.30 UPTIME? - DISPLAY HOW LONG THE 6560 HAS BEEN RUNNING
This query command will reply with the number of seconds since the last power failure (or reset). Verbose mode the response will be:

Uptime 23461 Seconds

and in the Terse mode the response will be:

23461

where the number 23461 will change to reflect the actual up time. Note: The number of seconds can get quite large, as large as $2^{31} - 1 = 2147483647$ however the number of seconds in a year is only 30758400 hence it will take nearly 70 years to overflow this number.

4.2.31 VERBOSE - SET VERBOSE MODE

The VErbose command causes the output of all subsequent commands to contain additional information, this mode should be used for determining problems with programs and when the instrument is being used interactively.

4.3 PROGRAMMING HINTS

In general a simple way to get the 6560 to select a resistance, or to program a calibration coefficient is to use the KEY command (see Section 4.2.17) and send the same keystrokes that would be used from the front panel. This technique allows the system programmer to easily tryout the command sequences from the front panel before coding the necessary controller routines.

5 OPTIONS

5.1 DIP SWITCHES

The 6560 has an 8 position piano style switch located as shown in Figure 5.1 on the Control pcb. Each of the 8 switches enable or disable an option.

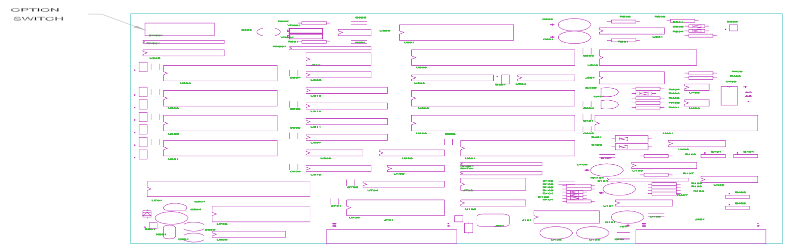


Figure 5.1: Location of Option Switch on Control PCB

5.1.1 OPTION SWITCHES 1 TO 4 - RESERVED

The current software in the instrument does not use option switches 2 through 4, however to maintain compatibility with future software releases these switches should be left in the closed position.

5.1.2 OPTION SWITCH 5 - 50/60 Hz SELECT

This option switch determines if the instrument will be operated from a 50 Hz power source or a 60 Hz source. If the switch is set incorrectly the instrument will perform normally except that the real time clock will operate at the wrong rate (by a ratio of 5:6).

5.1.3 OPTION SWITCH 6 - LAST RESISTANCE

This option switch determines if the instrument will default to the last selected resistance after power on or reset. If the option switch is in the open position then after power up the 6560 will select the last used resistance. If the option switch is in the closed position then after power up the 6560 will select either an open circuit or a short circuit (depending upon the state of option switch 7).

5.1.4 OPTION SWITCH 7 - OPEN/SHORT

This option switch determines if the instrument will default to the open circuit or short circuit position after power on or reset. If the option switch is in the open position then after power up the 6560 will select an open circuit. If the option switch is in the closed position then after power up the 6560 will select a short circuit. This switch will have no effect if option switch 6 is in the open position.

5.1.5 OPTION SWITCH 8 - FACTORY CALIBRATION

Operation of this option switch is reserved for use by the factory technicians for testing, initializing and calibrating the instrument. Normal operation of the instrument requires that the switch be in the Closed position at all times. The instrument will NOT operate correctly with this switch in the open position.

Switch	Position	Description
1,2,3,4	Closed	These switch positions are reserved by Guildline Instruments for future expansion. They should be left in the Closed position.
5	Closed	Instrument expects a 60 Hz power source.
	OPEN	Instrument expects a 50 Hz power source
6	Closed	Instrument selects either open circuit or short circuit after power on or reset (see switch 7).
	Open	Instrument selects last used resistance after power on or reset.
7	Closed	Instrument selects short circuit after power on or reset (unless switch 6 is open).
	Open	Instrument selects open circuit after power on or reset (unless switch 6 is open).
8	Closed	Normal instrument operation. This switch should always be closed.
	Open	Factory calibration mode, not normally used.

Table 5.1: Option Switches

6 SPECIFICATION VERIFICATION

6.1 ULTIMATE SPECIFICATIONS

The ultimate specifications for the 6560 Resistance Calibrator can be verified by measuring the value of each resistance element with respect to a primary standard. This section below outlines the recommended procedure for measuring and verifying the accuracy of the resistance elements in the 6560 Resistance Calibrator.

6.1.1 EQUIPMENT REQUIRED

The following equipment is required to verify the accuracy of the resistance elements within the 6560 Resistance Calibrator.

1. A set of Guildline Instruments 9330 STD resistors, with up to date Calibration certificates

   (a) 10 ohms
   (b) 100 ohms
   (c) 1 kilohms
   (d) 10 kilohms
   (e) 100 kilohms
   (f) 1 megohms
   (g) 10 megohms

2. Guildline model 9975 Current Comparator

3. Guildline model 99755 Interface Plug

4. Guildline model 9732VT Oil Bath

5. Guildline SCW shielded copper wire (10 meters)

6. Guildline model 9607 High Voltage Reversing Switch

7. High Voltage Supply

8. Voltmeter

6.2 RESISTANCE MEASUREMENT WITH A 9975 CURRENT COMPARATOR

The front panel of the 9975 is shown in Figure 6.1.

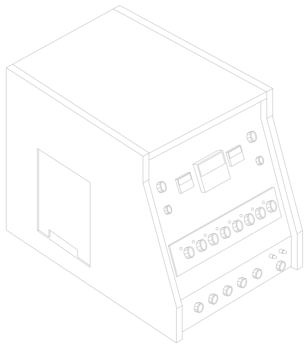


Figure 6.1: 9975 Current Comparator

6.2.1 10 kW AND BELOW

The following section describes the steps which must be followed in order to measure resistance less than or equal to 10 kΩ. The set up for these measurements is shown in Figure 6.2.

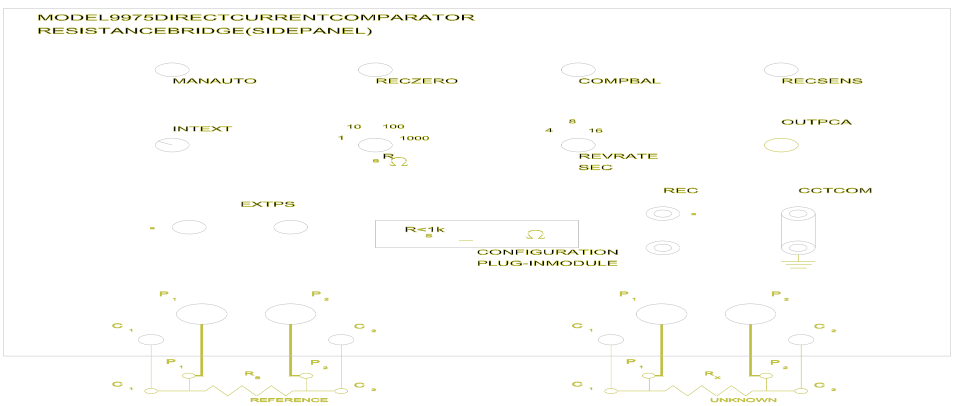


Figure 6.2: 9975 Current Comparator connections for measurement of resistances up to 10 kΩ

1. Set the 9975 Current Comparator power switch to the OFF position.

2. Using Guildline low thermal wire, connect the four 6560 Resistance Calibrator terminal leads to the 4 terminals labeled R_x, on the side panel of the 9975 Current Comparator, where C_1P_1 identifies one current-potential pair and C_2P_2 identifies the other current-potential pair. Refer to Figure 6.2.

3. Select a reference standard (R_s) and connect its C_1 P_1 and C_2 P_2 terminals to the R_s C_1 P_1 and C_2 P_2 terminals on the side panel of the 9975 Current Comparator.

Provision is made for R_s values of 1 Ω, 10 Ω, 100 Ω and 1 kΩ. Normally the R_s value is selected such that the ratio of resistances between R_s/R_x is between 1 and 10 this will bring all of the dials on the 9975 into play to ensure the best possible measuring precision.

4. Plug the configuration module into the Configuration Module socket on the side panel of the 9975 with the $R_s \leq 1$ kΩ side up.

5. Set the R_s switch on the left side panel of the 9975 to the value of the standard resistor (R_s).

6. Set the MAN AUTO switch on the on the side panel of the 9975 to the current reversal mode desired. The automatic mode is satisfactory for all measurements of resistances in the 6560.

7. Set the REV RATE SEC switch to the desired frequency. Normally a setting of 4 seconds is used for low values of R_x (1 Ω - 10 kΩ).

8. Turn the OUT PCA switch to the OUT position to open the input circuit to the photo-cell amplifier.

9. Set the GALVANOMETER SENSITIVITY switch to the X1 position (the lowest sensitivity).

10. Set the I_x switch to the 0 position.

11. Set the GALVANOMETER switch to the D1 position in order to observe any offset on the galvanometer due to thermal emfs.

12. Set the bridge power switch to the ON position and insure that the OSC indicator is illuminated.

CAUTION

If the OSC indicator should go out while the 9975 is turned on, the power to the 9975 should be immediately turned off.

13. Set the galvanometer to approximately zero by adjusting the ZERO control on the photocell amplifier itself (right side-door).

14. Set the ratio dials as close as possible to the anticipated R_x/R_s.

15. Set the OUT PCA switch back to the PCA position to complete the feedback circuitry of the galvanometer.

16. Set the GALVANOMETER switch to the D2 position and set either the galvanometer or the external recorder to zero by using the REC ZERO control on the side panel of the 9975. (NOTE: if both the galvanometer and the recorder are to be used simultaneously then the recorder must be positioned independently by its own zero control).

17. Turn the GALVANOMETER D1/D2 switch to D1 and set the unknown resistor current (I_x) to the desired value by means of the CURRENT I_xmA switch (e.g. 1 mA). In general the I_x current should be made as large as possible to minimize circuit noise effects, but within the constraint that it must not produce excessive self heating in the unknown resistor.

18. Adjust the HIGH TRACK control until the pointer on the AMPERE TURN BALANCE meter gives no deflection or returns to the same position when the I_x current is reversed. The rest position of the pointer need not be on zero in order to get a true ratio, but if desired it can be set to zero by adjusting the COMPARATOR BALANCE control on the left side panel of the 9975.

19. Compensate for thermal emfs by adjusting the GALV BALANCE control until the galvanometer deflects equally on each side of center scale.

20. Adjust the 8 R_x/R_s dials until there is no change in the galvanometer deflection, or the needle returns to the same position, upon current reversals.

21. Increase the GALVANOMETER SENSITIVITY and re-adjust the R_x/R_s dials and GALV BALANCE as necessary.

22. Repeat the adjustment at higher settings of the GALVANOMETER SENSITIVITY switch up to the setting that will yield the required measuring sensitivity.

23. Adjust the TRANSIENT SUPPRESSION control to minimize the transient impulse on the galvanometer.

24. Now that the 9975 is roughly balanced turn the CURRENT I_xmA switch to zero and with use of a chart recorder, make a zero trace for a minimum of ten minutes.

25. Having made the zero trace, turn the CURRENT I_xmA switch back on and rebalance the R_x/R_s dials on the 9975 so that the balanced condition will correspond to the zero trace.

6.2.2 19 kW AND 100 kW

The following section describes the steps which must be followed in order to measure resistances of 19 kΩ to 100 kΩ. The set up for these measurements is shown in Figure 6.3.

1. Set the 9975 Current Comparator power switch to the OFF position.

2. Connect the three 6560 Resistance Calibrator terminal leads (P_2, C_2 and C_1) to the 3 terminals labeled R_x, on the side panel of the 9975 Current Comparator, where C_2P_2 identifies one current-potential pair and C_1 identifies the current lead. Refer to Figure 6.3.

3. Select a reference standard (R_s) and connect it's P_2 and C_2 terminals to the R_s P_2 and C_2 terminals on the side panel of the 9975 Current Comparator. Connect the C_1 terminal to the C_1 terminal of R_x on the 9975.

<u>CAUTION</u>

The resistance of the leads connecting the C_1 terminals of the resistors to the 9975 is included in the measurement. These two leads must be constructed of the same material and be of the same length to avoid measurement errors.

4. Plug the configuration module into the Configuration Module socket on the side panel of the 9975 with the $R_s \geq 10$ kΩ side up.

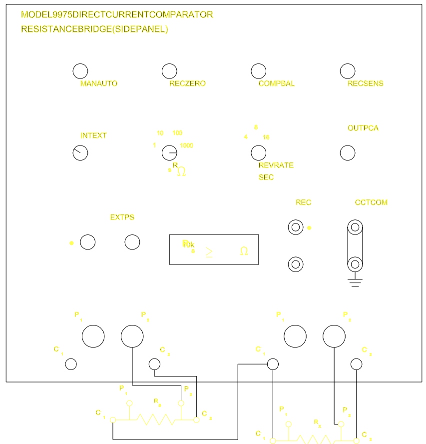


Figure 6.3: 9975 Current Comparator connections for measurement of resistances between 19 kΩ and 100 kΩ

5. Set the R_s switch on the left side panel of the 9975 to the 1 000 Ω position.

6. Set the MAN-AUTO switch on the side panel of the 9975 to the current reversal mode desired. The automatic mode is satisfactory for all measurements of resistances in the 6560.

7. Set the REV RATE SEC switch to the desired frequency. Normally a setting of 4 seconds is used for low values of R_x (1 Ω-10 kΩ).

8. Turn the OUT PCA switch to the OUT position to open the input circuit to the photocell amplifier.

9. Set the GALVANOMETER SENSITIVITY switch to the X1 position (the lowest sensitivity).

10. Set the I_x switch to the 0 position.

11. Set the GALVANOMETER switch to the D1 position in order to observe any offset on the galvanometer due to thermal emfs.

12. Set the bridge power switch to the ON position and ensure that the OSC indicator is illuminated.

<u>CAUTION</u>

If the OSC indicator should go out while the 9975 is turned on, the power to the 9975 should be immediately turned off.

13. Set the galvanometer to approximately zero by adjusting the ZERO control on the photocell amplifier itself (right side-door).

14. Set the ratio dials as close as possible to the anticipated R_x/R_s.

15. Set the OUT PCA switch back to the PCA position to complete the feedback circuitry of the galvanometer.

16. Set the GALVANOMETER switch to the D2 position and set either the galvanometer or the external recorder to zero by using the REC ZERO control on the side panel of the 9975. (NOTE: if both the galvanometer and the recorder are to be used simultaneously then the recorder must be positioned independently by its own zero control.)

17. Turn the GALVANOMETER D1/D2 switch to D1 and set the unknown resistor current (I_x) to the desired value by means of the CURRENT I_xmA switch (e.g. 1 mA). In general the I_x current should be made as large as possible to minimize circuit noise effects, but within the constraint that it must not produce excessive self heating in the unknown resistor.

    When the configuration module is in the $R_s \geq 10$ kΩ position the CURRENT I_x mA switch controls the voltage applied to the standard and unknown resistors. The translation between the CURRENT I_x mA switch position and the applied voltage is shown in Table 6.1. The x1 x√2 switch can be used to scale the applied voltage by the usual factors.

CURRENT I_xmA	Applied Voltage
0.001 mA	2.2 Volts
0.003 mA	6.6 Volts
0.01 mA	22 Volts

Table 6.1: CURRENT I_x mA to Applied Voltage Conversion

18. Adjust the HIGH TRACK control until the pointer on the AMPERE TURN BALANCE meter gives no deflection or returns to the same position when the I_x current is reversed. The rest position of the pointer need not be on zero in order to get a true ratio, but if desired it can be set to zero by adjusting the COMPARATOR BALANCE control on the left side panel of the 9975.

19. Compensate for thermal emfs by adjusting the GALV BALANCE control until the galvanometer deflects equally on each side of the center scale.

20. Adjust the 8 R_x/R_s dials until there is no change in the galvanometer deflection, or the needle returns to the same position, upon current reversals.

21. Increase the GALVANOMETER SENSITIVITY and re-adjust the R_x/R_s dials and GALV BALANCE as necessary.

22. Repeat the adjustment at higher settings of the GALVANOMETER SENSITIVITY switch up to the settings that will yield the required measuring sensitivity.

23. Adjust the TRANSIENT SUPPRESSION control to minimize the transient impulse on the galvanometer.

24. Now that the 9975 is roughly balanced turn the CURRENT I_x mA switch to zero and with use of a chart recorder, make a zero trace for a minimum of ten minutes.

25. Having made the zero trace, turn the CURRENT I_x mA switch back on and

rebalance the R_x/R_s dials on the 9975 so that the balanced condition will correspond to the zero trace.

6.2.3 ABOVE 100 kW

The following section describes the steps which must be followed in order to measure resistances greater than 100 kΩ. The setup for these measurements is shown in Figure 6.4.

NOTE: The output of the 9607 High Voltage Reversing Switch generates very large transient impulses upon reversals. It is necessary to damp these transients at the terminals of the High Voltage Reversing Switch with a pair of resistors (3.3 MΩ) and a capacitor (0.01 µf) as shown in Figure 6.4. The absolute values of the damping resistors and capacitor do not affect the measurement accuracy of the 9975 Current Comparator.

1. Set the 9975 Current Comparator power switch to the OFF position.

2. Select a reference standard (R_s) and connect its P_2 and C_2 terminals to the R_s P_2 and C_2 terminals on the side panel of the 9975 Current Comparator.

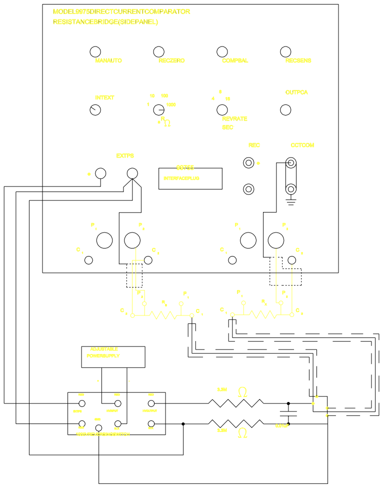


Figure 6.4.: 9975 Current Comparator connections for measurement of resistances greater than 100 kΩ.

3. Connect the positive high voltage output of the 9607 High Voltage Reversing Switch to the C_1 terminal of the R_s, and to the C_1 terminal of R_x (where R_x is the 6560 Resistance Calibrator), these connections should be made with shielded cable, and the shield should be connected to ground.

4. Connect the P_1 and C_1 terminals of the 6560 Resistance Calibrator to the R_x P_1 and C_1 terminals on the side panel of the 9975, again these connections should be made with shielded cable, and the shield should be connected to ground.

5. Connect the positive output of the external power supply to the RED input terminal of the 9607 High Voltage Reversing Switch. Connect the negative output of the external power supply to the Black input terminal of the 9607 High Voltage Reversing Switch. The external power supply used must have a floating output since the positive and negative outputs will alternately be connected to the ground of the 9975 Current Comparator through the 9607 High Voltage Reversing Switch.

6. Connect the two EXT PS terminals of the 9975 Current Comparator to the EXT PS terminals on the 9607 High Voltage Reversing Switch, the terminal on the 9975 with a RED dot adjacent to it should be connected to the RED terminal of the 9607.

7. Connect the Black HV output terminal of the 9607 to the non-marked EXT PS terminal of the 9975.

8. At this point there should be 2 wires connected to the non-marked EXT PS terminal on the side panel the 9975.

9. Plug a 99755 configuration module into the Configuration Module socket on the side panel of the 9975.

10. Set the PS switch on the side panel of the 9975 to the EXT position.

11. Set the $R_s\Omega$ switch on the side panel of the 9975 to the 1 000 position.

12. Set the MAN-AUTO switch on the side panel of the 9975 to the current reversal mode desired. The automatic mode is satisfactory for all measurements of resistance in the 6560.

13. Set the REV RATE SEC switch to the desired frequency. Usually a setting of 8 or 16 seconds is used for high values of R_x (1 MΩ-100 MΩ).

14. Turn the OUT PCA switch to the OUT position.

15. Set the GALVANOMETER SENSITIVITY switch to the X1 position.

16. Set the I_x switch to the 0 position.

17. Set the GALVANOMETER switch to the D1 position.

18. Set the bridge power switch to the ON position and ensure that the OSC indicator is illuminated.

CAUTION

If the OSC indicator should go out while the 9975 is turned on, the power to the 9975 should be immediately turned off.

19. Set the galvanometer to approximately zero by adjusting the zero control on the side of the photocell amplifier itself.

20. Set the OUT PCA switch back to the PCA position.

21. Set the ratio dials as close as possible to the anticipated R_x/R_s.

22. Set the Galvanometer switch to the D2 position and set either the galvanometer or the external recorder to zero by using the REC ZERO control on the side panel of the 9975. (NOTE: if both the galvanometer and the recorder are to be used simultaneously then the recorder must be positioned independently by its own zero control.)

23. Set the I_x dial to the 0.01 position and adjust the External Power Supply to the voltage required to obtain the desired measurement current.

24. Adjust the HIGH TRACK control until the pointer of the AMPERE TURN BALANCE meter gives no deflection or return to the same position after each current reversal. The rest position of the pointer need not be on zero in order to get a true ratio, but if desired it can be set to zero by adjusting the COMPARATOR BALANCE control on the side panel of the 9975.

NOTE: The HIGH TRACK may have to be turned fully clockwise for very high values of R_x.

25. Compensate for thermal emfs by adjusting to GALV BALANCE control until the galvanometer deflects equally on each side of center scale.

26. Adjust the 8 R_x/R_s dials until there is no change in the galvanometer deflection, or the needle returns to the same position upon current reversals.

27. Increase the GALVANOMETER SENSITIVITY and re-adjust the R_x/R_s dials as necessary.

28. Repeat the adjustment of the GALVANOMETER SENSITIVITY switch up to the setting that will yield the required sensitivity.

29. Now that the 9975 is roughly balanced turn the external power supply off and with use of a chart recorder, make a zero trace for a minimum of ten minutes.

30. Having made the zero trace, turn the External Power Supply back on and rebalance the R_x/R_s dials on the 9975 so that the balanced condition will correspond to the zero trace.

NOTE: This is a timely procedure and for values of 1 MΩ and higher, can take 2-3 hours for one measurement. It is suggested that one R_x/R_s dial be turned at time with at least 6

minutes between dial turnings. It is also suggested that the TIME CONSTANT dial be set to the 3S position. This is due to the fact that the 9975 is very sensitive, at very high values of R_x, to nearby motion and vibration. A TIME CONSTANT setting of 3S will filter most of this out.

6.3 BASIC SPECIFICATIONS

The basic specifications for the 6560 Resistance Calibrator can be verified by measuring the value of each resistance element with respect to a recently (24 hrs) calibrated long scale DMM (Datron 1281). When using this method care must be taken to ensure that the stability of the DMM and the calibration uncertainty are sufficiently good to give the 6560 calibration adequate reliability.

6.4 COMPUTING RESISTANCE VALUES

After each resistance value in the 6560 has been measured the correct values should be computed and entered into the non-volatile memory.

The value of a resistor is the product of the Rx/Rs dial setting and the actual value of Rs from the calibration certificate supplied with each standard resistor.

To enter the resistance values into the 6560 follow the procedure outlined in Section 3.8.

7 PRINCIPLES OF OPERATION

7.1 INTRODUCTION

The 6560 consists of the following functional blocks:

a) Power Supply - generates +5 volts, and ±12 volts.

b) Control pcb - consisting of a microprocessor with its input/output latches, random access memory, read only memory, GPIB interface and keyboard/display interface.

c) Front Panel - with keyboard and display, and interface to resistor/relay pcb.

d) Resistor/Relay pcb - with precision resistors,relays and relay selector logic.

e) Software - a general description of the operating software.

The functional blocks are described below.

7.2 POWER SUPPLY

The power supply module is a model HBAA-40W-A built by Power-One Inc. and has the following capacities: +5.0 V DC at 3.0 amperes, and ±12 V DC at 1.0 amperes, with a total capacity of 40 watts. This is more than enough power to satisfy the requirements of the 6560. The primary side of the transformer can be wired to accept one of the following voltages: 100 V AC, 120 V AC, 220 V AC, or 240 V AC. A single transformer with two secondary windings drives three standard series-pass regulated supplies. The three supplies each have a rectifier, filter, and regulator. The ±12 V DC and +5 V DC outputs are controlled by a series pass transistor and an LM723 Regulator Control IC. The LM723 regulator control IC provides over current shutdown, to protect the power supply in the event of a load failure.

7.3 CONTROL pcb

The control pcb contains a microprocessor, memory and input/output devices. The input/output devices include: a keyboard display interface, an AC line (power) interface, a chart recorder interface, a GPIB (IEEE-488) interface and two serial interfaces (RS-232C and Current Loop). These sections of the control pcb are represented on several pages of schematic drawings (dwg. no. 18726.01.04).

7.3.1 POWER AND CONTROL

The power and control section of the Control pcb (100 series components) monitors the AC line and synchronizes the output to the control Triacs with the AC line zero-crossings.

BROWN-OUT DETECTOR - When the AC line voltage drops, the voltage of the junction of R102, R103 (which is proportional to AC line voltage) will drop below the voltage at the junction of RN101 and R104 (a fixed reference voltage) and the output (pin 7) of U101 will go high indicating a brown-out condition.

AC SIGNAL CONDITIONING - The signal at the junction of D101, D102 and R101 is a truncated sine wave and the output of U101 (pin 12) should be a square wave at 60 Hz (50 Hz). C108 provides hysteresis so that the square wave is reasonably immune to noise an the AC line.

ZERO CROSSING DETECTOR - The output of U102 (pin 3) is a short positive going pulse at each edge transition of the output of U101 (pin 12). These pulses should be at a rate of 120 Hz (100 Hz).

MISSING CYCLE DETECTOR - The retriggerable one-shot (U103) and the associated timing components (R107 and C106) form a missing cycle detector. If the output of the zero-crossing detector is not active for a period of 12 milliseconds the power fail signal (U103-7) will become active, in addition if a brown-out condition is detected then the PFAIL signal will become active. The missing cycle detection and brown-out detection circuitry is used to protect the non-volatile memory.

7.3.2 CENTRAL PROCESSING UNIT

The control pcb CPU is based on an Intel 8088 processor design. The following sections describe the major functional blocks, however a detailed timing analysis is far beyond the scope of this manual. If a problem is suspected in this section then checking the subsystems in the order which they are presented is recommended.

CLOCK GENERATION I.C. U202 contains a crystal oscillator, a digital divider and the memory ready generation logic. Normally pin 12 should be 14.7456 MHz square wave (the crystal frequency). Pin 8 should be a 1/3 duty cycle wave at 4.9152 MHz, pin 2 (PCLK) should be a square wave at 2.4576 MHz. The memory ready signal (Pin 5 RDY) should be always high since all memory on the control pcb is zero-wait-state memory.

CONTROL SIGNAL GENERATION I.C. U207 contains the required logic to convert the status outputs of the CPU to read and write strobes for the memory and input/output devices. During normal system operation the MRDC signal (pin 7) should show the most activity, since the processor should be continually fetching instructions from the program ROM. The MWTC signal (pin 9) should show a reasonable amount of activity as the processor writes to RAM. The IORC (pin 13) signal should show fairly low amounts of activity as the processor reads data from the input/output devices and finally the IOWC signal (pin 11) should show very low quantities of activity as the processor writes to the input/output devices. The input signals to the system controller (U207) are encoded bus functions and all three status lines (S0, S1, S2) should be active.

PROCESSING CLUSTER The processor cluster U205 and U206 form a CPU and a Numeric Co-processor respectively. The numeric co-processor U206 is optional, and its presence will speed up operations such as GPIB bus responses.

The software performs many computations with 64-bit floating point arithmetic and has floating point software routines, however if an 8087 is present at U206 then the software will automatically use floating point hardware.

The processor has enough computing capacity to perform all required operations without the 8087 but the presence of an 8087 will improve response to many of the bus commands.

Guildline Instruments does not supply a numeric data processor. The standard Intel Math Co-processor for IBM PC and compatibles with 5 MHz 8086 and 8088 will operate in the 6560. The Intel order number is PCPN8087.

ADDRESS AND DATA BUFFERS Addresses from the CPU cluster are latched by the three octal latches U209, U210 and U211. This latching operation demultiplexes the address/data bus of the CPU cluster into separate address and data busses for the peripherals. I.C. U212 is an octal bidirectional buffer which transfers data from the peripheral circuitry to the CPU cluster and vice versa.

IO ADDRESS DECODING I.C. U213 is one of eight decoders which decodes the three most significant input/output addresses from the CPU cluster into eight chip- selects for up to eight input/output devices.

INTERRUPT CONTROLLER I.C. U201 is a priority interrupt controller. The priorities are hardwired with the temperature interface at highest priority and the RS-232C interface at the lowest priority.

7.3.3 MEMORY

The memory section of the control pcb consists of four general purpose 28-pin sockets which allow up to 192 kbytes of ROM with 32 kbytes of RAM,or 96 kbytes of RAM with 64 kbytes of ROM, or a number of intermediate compromises. In addition the memory includes an 8-section piano switch which can be used to select various options.

The 6560 is configured with 62 kbytes of ROM, 32 kbytes of RAM and 8 kbytes of non-volatile memory.

ADDRESS DECODING I.C. U306 is a one-of-eight decoder which is connected to the three most significant address lines (A17, A18, A19). CPU addresses are decoded to chip selects for the four memory sockets.

OPTION SWITCHES Switch bank SW301 contains eight switches which can be gated onto the bus by U305 when the processor reads the appropriate input/output port.

MEMORY SOCKETS The strapping options for the sockets U301, U302, U303 and U304 can be set as per the table on the schematic. In addition U302 can have a smart socket (which converts a RAM to a non-volatile RAM (battery backup)) or a smart watch (which has a real time clock and battery backup for the RAM).

I.C. U304 must always be ROM since the processor performs its boot from location 0xFFFFO and U301 must always be RAM since the processor always needs some RAM.

7.3.4 SERIAL INTERFACES (OPTIONAL)

The control pcb has two serial channels, one of the channels is a full RS-232C interface with hardware hand shaking signals, the other channel can be a current loop interface or a 3-wire (ground, TxD and RxD) RS-232C interface without hand shaking.

SERIAL COMMUNICATIONS CONTROLLER (OPTIONAL) The two serial channels are controlled by U401 which is a dual serial channel controller, most of the handshaking lines are not used. Baud rates are internally derived from the system clock (PCLK). The interrupt output is inverted by U102.

RS-232C BUFFERS (OPTIONAL) I.C.s U402 and U403 are standard RS-232C buffers which convert TTL signal levels to RS-232C signal levels and RS-232C signal levels to TTL signal levels. D401 and D402 protect the control pcb in event of a failure such as connecting 120 V AC to the transmit data pin.

SAIL INTERFACE (OPTIONAL) The SAIL interface can be connected to pins 9 and 10 of the RS-232C connector by setting jumpers E401, E402 and E403 to the appropriate positions. The SAIL interface is optically isolated and requires an external current source, otherwise operation is straight forward. Diode bridge D403 rectifies the current so that pins 9 and 10 may be connected in either polarity.

It is also possible to connect the +12 V and -12 V supplies to the RS-232C connector (pins 9 and 10) to power small pieces of equipment (such as limited distance modems) as long as the current drawn is constant and under 20 mA.

7.3.5 KEYBOARD INTERFACES

The keyboard interface section contains a watch-dog, and an interface to the keyboard/display card.

WATCH-DOG The watch-dog is built up of two one-shots, the first one-shot is a retriggerable one-shot which must be retriggered periodically by the CPU otherwise the output (U501 pin 7) will become active triggering the second one-shot. When the output (U501 pin 10) of the second one-shot is active, transistor Q501 will be turned on resetting the CPU. The power fail signal is also diode "ORed" into Q501 and will reset the CPU if either a brown-out condition or a missing zero-crossing condition occurs.

KEYBOARD/DISPLAY INTERFACE The Keyboard/Display interface is comprised of a general purpose parallel port chip U503. Not all of the ports are required to operate the keyboard and display pcb.

PROGRAMMABLE TIMERS In addition to the general purpose input/output bits U503 has three 16-bit timers internally. These timers are used to generate interrupts for refresh of the display, scanning the keyboard and examining the status of the GPIB interface.

7.3.6 CHART RECORDER OUTPUT (OPTIONAL)

The chart recorder output is generated by a 12-bit analogue-to-digital converter U601 and converted to a voltage in the range -10 volts to +10 volts by operational Amplifier U602. The potentiometer VR601 allows adjustment of the zero and full scale outputs of the chart recorder.

7.3.7 GPIB INTERFACE

The GPIB interface is built up from a Motorola 68488 controller IC (U701) and two buffers (U702 and U703). The GPIB address is gated onto the processor data bus by U704. U102 inverts the polarity of the interrupt output for the system interrupt controller.

7.4 FRONT PANEL pcb

This assembly is complete with display, keyboard, and interface to the Resistor/Relay pcb. In order to turn a display, or LED, (or Resistor Relay) on the processor must provide an address and data. These signals are provided from the processor at J1, where the address is presented on the 'A' signal lines (A0-3) and the data is provided on the 'C' signal lines (C0-3). ICs U1, U2 and A5 form an address decoder for the addresses presented by the processor.

7.4.1 VACUUM-FLUORESCENT DISPLAY

The vacuum-fluorescent display (DIS1) has sixteen characters with sixteen segments each. The power to the vacuum-fluorescent display is provided by the power supply module PS1. The control signals to the vacuum-fluorescent display are sourced from the display driver ICs A1-4.

The processor can turn on one of the digits of the sixteen segment vacuum-fluorescent display by presenting an address in the range 0-15, these addresses correspond to the sixteen display characters, where 0 corresponds to the right-most character and 15 corresponds to the left-most character.

The segments of a particular character are selected by the processor by latching data into the dual four-bit latches U3 and U4. The latches latch the data which the processor has presented on the data lines (C0-3) when the processor presents the correct address on the address lines (A0-4). The addresses for the various latches are decoded by U2.

7.4.2 KEYBOARD

The keyboard is arranged as an array six columns wide and four rows high of keyswitches, normally the processor activates one of the six columns and reads back the four rows on the 'B' data lines (B0-3).

Pressing a key couples the active digit strobe on a column onto a row of the keyboard matrix. The program samples the input rows periodically, looking for high signal levels on any line. The software debounces the key by waiting for a whole scan back to the originally noted column before accepting the key stroke.

7.4.3 LIGHT EMITTING DIODES

The status of a particular Light Emitting Diode (LED) is selected by the processor by latching data into the dual four-bit latches U5, U6 and U7. The latches latch the data which the processor has presented on the data lines (C0-3) when the processor presents the correct address on the address lines (A0-4). The addresses for the various latches are decoded by U2. ICs U8 and U10 act a drivers for the LEDs.

7.4.4 DISPLAY TO RESISTOR pcb INTERFACE

The address (Y0-2) sent from the display card to the resistor pcb is decoded from two-bits latched into U5 (at pins 21 and 23), and decoded by U9. The data sent to the resistor pcb (Q0-3) is latched by U6 at pins 5, 7, 9, and 11. The decoded data and address are sent to the resistor pcb from the display at J2.

7.5 RESISTOR/RELAY pcb

This assembly is complete with precision resistors, relays and relay selector logic. The control signal which operate relays (and select one of the precision resistor elements) are sent from the display pcb and arrive at the resistor/relay pcb at J1. The control signals consist of an address (Y0-2), which activates one of the three decoders (U1, U2, and U3), and four data lines (Q0-Q3), which select one of the sixteen outputs on the selected address decoder.

The outputs of the decoders are buffered by high current drivers (U4-14) and routed to the resistor selection relays (K0-12, and K19-20). The outputs of some of the drivers are inverted by transistors (Q1-12) and routed to the remaining relays (K13-18, and K25). Most of the relays are latching relays (K0-12, and K19-24) and hence only have a control signal applied for a short time (100 mS). The remaining relays (K13-18, and K25) are non-latching and the control signals for these relays are applied continuously when these relays are selected.

7.6 SOFTWARE

The control program within the 6560 is the "glue" which joins the interfaces and the microprocessor together. The major interfaces to the processor are the keyboard and display (ultimately the user), and the remote computer interface (IEEE-488).

The 6560 control program is approximately 42-thousand bytes long. It is written in the "C" programming language and stored as binary numbers in the 27C512 read only memory (U301).

The program accepts keyboard entries of resistance and turns the correct relays on or off to select the desired resistors. At the same time, it reads the GPIB interface and processes commands.

Most of the time, the microprocessor is in a tight loop, testing inputs and refreshing the display.

8 TROUBLESHOOTING AND MAINTENANCE

8.1 TROUBLESHOOTING

SYMPTOM POSSIBLE CAUSE AND CURE

NO DISPLAY Instrument not plugged in. Instrument not turned on. Cable between CPU and display not connected. Power supply not operating correctly. Faulty display pcb.

DISPLAY ON, but keyboard does not respond. Keyboard locked out by remote controller. Cable from keyboard to display not connected. Faulty display pcb.

DISPLAY ON, most keys operative with some exceptions. Cable from keyboard to display not connected properly. Faulty display pcb.

GPIB bus does not respond. Incorrect address on switches. Talk/Listen mode not selected. GPIB cable not connected to instrument correctly. Internal switch and GPIB cables not connected correctly. Faulty CPU pcb.

INSTRUMENT DOES NOT "BEEP" when key pressed. Audible configuration switch on rear panel is closed position. Jumper JP1 on display pcb open. Faulty display pcb.

NO POWER TO CPU pcb Instrument not plugged in. Instrument not turned on. Incorrect voltage range selected at power inlet connector. Blown fuse. Faulty power supply module. Power cable not plugged into CPU pcb.

CAN NOT ENTER CALIBRATION CONSTANTS Key switch not in "CAL" position. Attempting to enter values which differ by more than 10% from the nominal values. Faulty understanding of calibration constant entry procedure (see Section 3.8). Faulty CPU pcb.

8.2 SOFTWARE DIAGNOSTICS

If the microprocessor and display/keyboard are operational then some diagnostics can be run to aid debugging of the system. In order to enter the diagnostic mode perform the following steps:

1. Ensure that the instrument is not in CAL-EDIT mode (the LED in the CAL EDIT key is extinguished).

2. Press the unmarked key which is located between the ↑MΩ key and the BACKSPACE key. The display should read "ENTER TEST NUM".

3. Press any key. The display should read "KEY 'X' PRESSED" followed by either "ENTER TEST NUM" or the start of one of the special tests as outlined below.

   Pressing the ENTER key will return the instrument to it's normal operating mode.

8.2.1 SETTING THE INTERNAL REAL TIME CLOCK

The 6560 Resistance Calibrator maintains an internal real time clock so that the date and time of the last calibration can be maintained automatically. The real-time clock can be set from the GPIB bus interface or the front panel. In order to set the real-time clock first enter diagnostics mode (see 8.2), press the '0' key, then, at the prompts, enter the year, month, day, hour, minute and second.

8.2.2 CHECKING THE ROM CHECKSUM

The software in the 6560 Resistance Calibrator is stored in a Read Only Memory (ROM) device. The integrity of the data stored in the ROM is essential to the correct operation of the instrument. It is possible to test the ROM data by first entering diagnostics mode (see Section 8.2), then pressing the '1' key, the instrument will spend about 20 seconds computing a CRC (Cyclic Redundancy Checksum) for the data in the ROM after which the instrument will announce the result as a good or bad ROM.

8.2.3 TESTING THE NON-VOLATILE MEMORY (EEROM)

The calibration coefficients in the 6560 Resistance Calibrator are stored in a Electrically Erasable Read Only Memory (EEROM) device. The integrity of the data stored in the EEROM is essential to the correct operation of the instrument.

It is possible to test the EEROM memory device by first entering diagnostics mode (see Section 8.2), then pressing the '2' key, instrument will spend about 20 seconds writing random data into the EEROM and reading the data back to check for correctness after which the instrument will announce the result as good or bad.

8.2.4 TESTING THE RELAY DRIVERS

It is possible to test the relay driver logic on the resistor pcb from the front panel diagnostics mode. This can be done by entering diagnostics mode (see Section 8.2) then pressing either the '3' key or the '4' key. When the '3' key is pressed each of the relay drivers will be enabled sequentially. When the '4' key is pressed the instrument will prompt the user for the number os the relay driver he wishes to enable, the instrument will then activate the desired relay driver.

WARNING

After a relay driver has been activated an incorrect relay may be left opened or closed, this will cause the instrument to present the wrong resistance at the front panel terminals. This condition can be corrected by stepping through all of the available resistances from zero Ω through open with the ↑MΩ key. It is recommended that the procedure of stepping through all available resistances be followed each time the relay drivers are tested.

8.2.5 TESTING THE DISPLAY

It is possible to test the display and the LED indicators by entering diagnostics mode (see Section 8.2), then pressing the '5' key. The instrument will light each of the displays in the following order:

1. the 16 display characters sequential from left to right
2. the LED in the GUARD key
3. the LED in the CAL EDIT key
4. the LED in the '2' key
5. the LED in the '4' key
6. the audible indicator
7. the SRQ indicator LED
8. the TALK indicator LED
9. the LISTEN indicator LED
10. the LOCAL indicator LED
11. the REMOTE indicator LED

8.2.6 TESTING THE GPIB SWITCHES

It is possible to test the display and the Rear Panel switches by entering diagnostics mode (see Section 8.2), then pressing the '6' key. The instrument will display the following information:

1. the GPIB address currently selected (base 10)

2. the GPIB operational mode currently selected

3. the current status of the audible indicator enable switch

8.2.7 DISPLAYING THE DATE CALIBRATION

It is possible to display the date of the last calibration change by entering diagnostics mode (see Section 8.2), then pressing the '7' key. The instrument will display the date of calibration in the format "YY/MM/DD hh.mm.ss".

8.2.8 SETTING THE INSTRUMENT SERIAL NUMBER

It is possible to set the instruments serial number by entering diagnostics mode (see Section 8.2), then pressing the '8' key. The instrument will prompt the user to enter the instruments serial number. The serial number can be entered by pressing the digit (0-9) keys, and the BACK SPACE key, when the correct serial number is displayed pressing the ENTER key will store the new serial number. The serial number can also be set from the GPIB interface.

8.3 PREVENTATIVE MAINTENANCE

Preventative maintenance consists of cleaning, visual inspection, etc. Preventative maintenance performed on a regular basis may prevent instrument breakdown and will improve the reliability of this instrument. The severity of the environment to which the 6560 is subjected determines the frequency of maintenance. A convenient time to perform preventative maintenance is preceding recalibration of the instrument.

The 6560 should be cleaned as often as operating conditions require. Accumulation of dirt in the instrument can cause overheating and component breakdown. Dirt on components acts as an insulating blanket and prevents efficient heat dissipation. It also provides an electrical conduction path which may result in instrument failure. The dress skins provide protection against dust in the interior of the instrument. Operation without these panels in place necessitates more frequent cleaning.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in this instrument. In particular, avoid chemicals which contain benzene, toluene, xylene, or similar solvents.

Periodically inspect the instrument for general cleanliness. Remove the cover and clean out any accumulated dust with a soft brush; at the same time check for discoloured or damaged wiring. Check all screws and hardware for tightness.

9 PARTS LISTS (can be ordered from Guildline)

Model 6560

PL18688.01.02	General Assembly
PL18722.01.02	Display pcb
PL18725.01.02	Resistor pcb
PL18726.01.02	6560 CPU pcb

10 DRAWINGS (can be ordered from Guildline)

18688.01.02	General Assembly
18722.01.02	Display pcb Assembly
18725.01.02	Resistor pcb Assembly
18726.01.02	CPU pcb Assembly
18688.01.04	Main Assembly Schematic
18722.01.04	Display pcb Schematic
18725.01.04	Resistor pcb Schematic
18726.01.04	CPU pcb Schematic