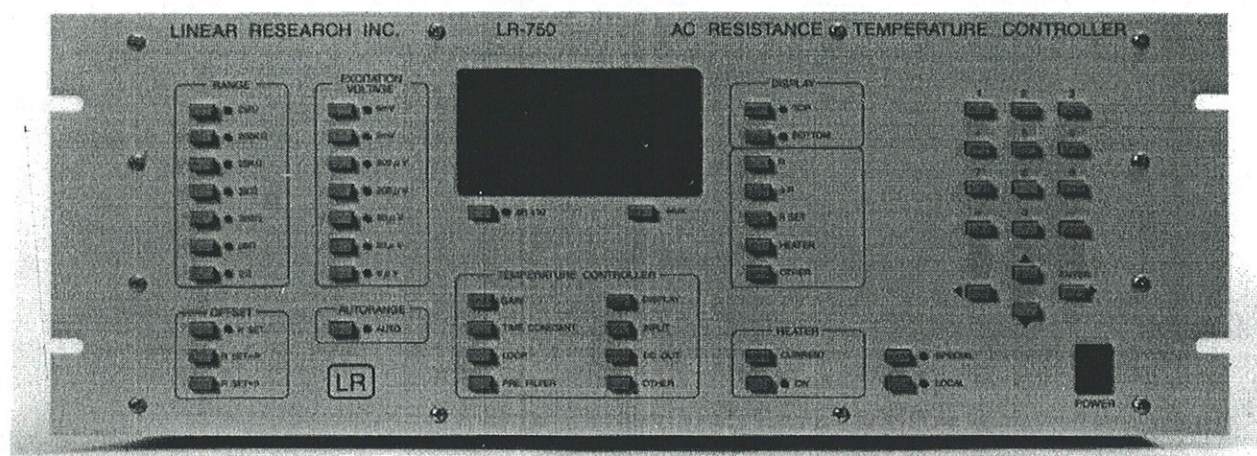


LR-750
AC RESISTANCE
BRIDGE

USER'S MANUAL

LR-750 SERIES

AC RESISTANCE TEMPERATURE CONTROLLER UNIT



LR-750 STANDARD UNIT

Internal temperature controller
7 Ranges 2Ω to $2M\Omega$
6 nanovolts RMS input noise
R, ΔR , $10\Delta R$ modes
 $6\mu V$ to $6mV$ excitation
0-100% variable each setting
IEEE-488 and/or RS-232
 $4\frac{1}{2}$ digit display
 $4\frac{1}{2}$ digit set resistance

Digital noise filtering of display
5 sec settling time to $1p$ $200,000$
Ultra low excitation 3 picoamps to 1ma
Heater power picowatts to 1 watt
15 & 50 watts with boosters
8 & 16 port multiplexer units available

Better noise resolution at picoamp
excitations than competition

LR-750R AC RESISTANCE BRIDGE

7 Ranges 2Ω to $2M\Omega$
6 nanovolts RMS input noise
 $4\frac{1}{2}$ digit display and set resistance
All Standard Unit bridge features
No Temperature Controller Features

LR-750 HIGH RESOLUTION OPTION

Add 2 nanovolts input noise
Add $5\frac{1}{2}$ digit display
Add $5\frac{1}{2}$ digit set resistance

LR-750

AC RESISTANCE BRIDGE

VERSION 1.0

USER'S MANUAL

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CONTENTS

CHAPTER 1 FEATURES

OVERVIEW OF FEATURES	1
FRONT PANEL CONTROLS AND FEATURES	3
REAR PANEL FEATURES	4

CHAPTER 2 OPERATING THE BRIDGE

QUICK START	1
CONTROLS	3
RANGE	3
EXCITATION	5
DIGITAL FILTER	5
OFFSETS	6
DISPLAY CONTROL	8
TEMPERATURE CONTROL	9
SPECIAL FEATURES	11
OVERLOAD MESSAGES	20
MEASUREMENT TECHNIQUES	23

CHAPTER 3 INTERFACING

SENSORS	1
ANALOG OUTPUTS	8
SENSOR MULTIPLEXER	11
COMPUTER INTERFACES	15
COMMAND LANGUAGE	15
COMMAND SUMMARY	16
DETAILED COMMAND REFERENCE	28
RESPONSE MESSAGE	33
IEEE-488 INTERFACING	35
RS-232 INTERFACING	36
TEMPERATURE CONTROLLER	40

CHAPTER 4 DEFINITIONS AND SPECIFICATIONS

SYMBOL DEFINITIONS	1
BLOCK DIAGRAM DESCRIPTION	2
SPECIFICATIONS	7

CHAPTER 5 SAFETY AND SERVICE

SAFETY	1
CAUTIONS	2
WARRANTY	4
SERVICE	5

INDEX

CHAPTER 1 FEATURES

This chapter covers the features of the bridge in general terms as well as illustrates the location of the controls and features of the instrument.

OVERVIEW OF FEATURES

The LR-750 AC Resistance Bridge is an instrument that can measure resistance at 16 Hertz utilizing extremely low power. Resistances from 2 megaohm to 2 ohms may be measured to better than 1 part in 200,000.

The amount of power used to measure a sensor can be varied by the operator by selecting full scale resistance voltages from 6 millivolts to 6 microvolts in factors of 1-3-10 steps.

The measured resistance may be displayed as the resistance value (R) or as a deviation from a set point (ΔR). The deviation measurement is made from a user input "offset" and is useful for measuring deviation from a standard or known value for comparisons.

The display can be changed to show a parameter the operator wishes to see in an easy and straight forward method. The operator picks either, "TOP" or "BOTTOM" and then chooses which parameter he wishes to show in that position, therefore eliminating the need to step successively through a menu of preset configurations.

The LR-750 uses a four-wire (four lead) AC Lock-Balance™ technique to measure the sensor. The four-wire technique eliminates errors that might be caused by lead resistance or sensor contact resistance. The AC technique eliminates thermal EMF DC voltage errors. It also allows for voltage resolution down to the sub-nanovolt region. This technique outperforms DC bridges by up to two orders of magnitude in voltage sensitivity.

Two leads are used to apply a fixed amplitude AC current to the sensor resistor. Two additional leads send the resultant sensor voltage back to the bridge to be balanced against an equal and opposite AC voltage. This gives a continuous null signal at the front end amplifier of the bridge's Lock-Balance™ circuitry. Knowing the value of the equal and opposite AC voltage gives the value of the sensor resistance.

The AC measurement method eliminates DC thermoelectric effects reducing the need to be careful selecting dissimilar metals or wires used for your contacts to the sensor.

The bridge is easily interfaced to external hard copy recorders such as strip chart recorders and computers. The bridge has BNC connectors on the rear panel to allow strip chart recorders to be hooked directly to the instrument recording the actual analog measurement of ΔR .

The instrument can be interfaced with computers by its IEEE-488 interface, allowing full control of the settings of the bridge as well as reading all of the measurements back from the bridge using a straight forward command language.

The bridge may be used as a temperature controller.

The Internal Temperature Controller Option incorporates functions similar to our industry standard LR-130 Temperature Controller, but is upgraded to include digital management of the analog signal path. This option is comprised of hardware and software installed inside the LR-750.

The 750 Temperature Controller (TC) is driven directly by the LR-750's ΔR analog signal, allowing resistance sensors to control the temperature. The TC's all analog signal path drives a multi-range current output circuit that delivers current to the heater resistor.

REAR PANEL FEATURES

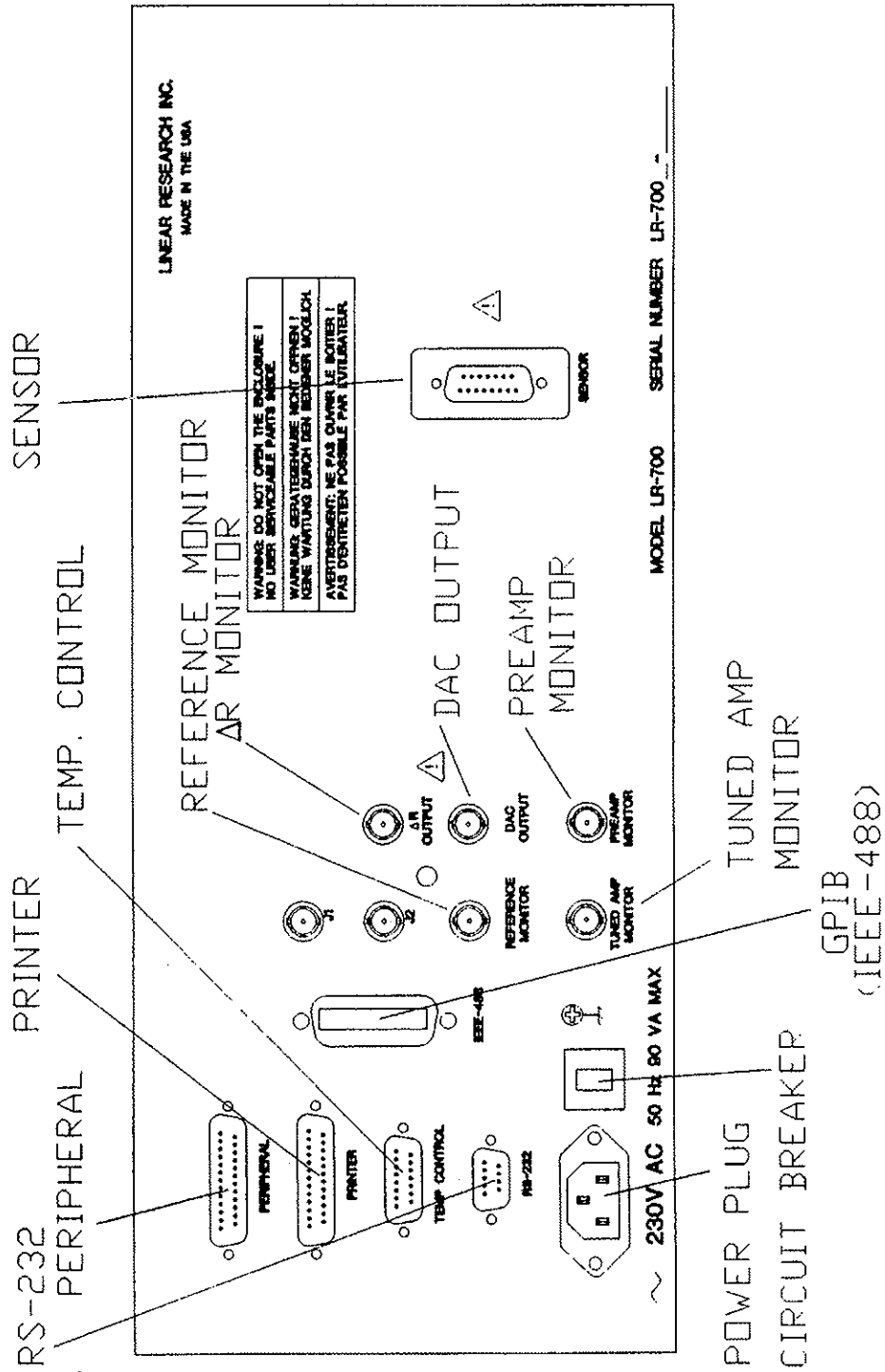


Figure 1-2

CHAPTER 2 OPERATING THE BRIDGE

This chapter deals with operating the LR-750. In this chapter you will find the quick start section as well as a section for each of the groups of controls along with explanations of messages the bridge may display on the front panel.

QUICK START

1. Check That All Items Are Received.

Before you operate the bridge for the first time, you should first check the list of supplied items to make sure that you have received everything. You should have the following:

- ☐ This User's Manual
- ☐ LR-750 main unit
- ☐ Power cord
- ☐ Sensor cable with attached resistor

If anything is missing, please contact us at Linear Research Inc.

2. Verify The Power Cord and Plug.

Supplied with your LR-750 is a power cord that should have the correct plug for your country. If this cord is not correct for your power outlets, please contact us immediately. Next, you should check on the rear panel of the LR-750 to make sure that it is configured for the correct voltage. Underneath the power plug you should find:

110VAC

or

230VAC

Please verify that the correct voltage is indicated. If not: 1) Please do not plug the instrument in; and 2) contact LRI immediately.

Note: This must be done before you plug the instrument in for the first time!

3. Getting Started.

- (1) Connect the power cord and turn on the bridge. The power switch is located on the front panel, in the lower right.
- (2) Connect the sensor cable with the attached resistor to the sensor connector on the rear panel. The resistor soldered on the end of the sensor cable is approximately 100 Ω .
- (3) Select the 200 Ω range on the front panel. The range that the bridge is on is indicated by an LED in the range section of the front panel. To change the range, push the button next to the LED of the range that you wish to select. The bridge should respond by lighting the LED next to the button you pressed.
- (4) Select the 6mV excitation.
- (5) Press the **RSET=0** button in the offset section.
- (6) If the $\Delta R \times 10$ LED is lit, press its button to go back to the $\Delta R \times 1$ mode.
- (8) To select the displayed information, press **TOP**, then **R**, then press **BOTTOM** then **ΔR** .

The bridge should now be measuring the 100 Ω resistor and displaying the value on the front panel. You should note that the R and ΔR measurements are the same value. This is because there is no offset set. If you wish to put an offset in, you can put a specific offset in directly by pressing the **RSET** button and entering a value, or you may "null" the ΔR measurement by pressing the **RSET=R** button.

CONTROLS

This section describes the various controls on the front panel of the LR-750. A number of individual controls are grouped together in each section and discussed as a group.

RANGE

By selecting the resistance range, you are selecting the maximum resistance that the bridge can measure. For example, if you pick 20K Ω , the bridge can measure up to 20K Ω or any resistance below that. Generally, it is most desirable to pick a range so that the reading will be between 25% and 75% of the full scale you've selected. If your resistance value changes an order of magnitude or more, it's best to select the range based on what the maximum sensor resistance will be.

To select the range, press the button just to the left of the range desired.

If the bridge does not respond by changing to the range selected, one of two situations could exist:

- (1) The bridge could be in a data entry mode where it is waiting for the operator to finish entering a value such as RSET, etc. In this case there should be a flashing cursor in a lower display.
- (2) The bridge is in local lockout mode due to the computer interface, where the computer has requested the operator not be allowed to make any changes. See the Locallockout section in Chapter 3.

AUTORANGE OPTION

The Autorange Option may be enabled by pressing the **AUTO** button located below the excitation buttons. Once in autorange, to turn autorange off, you can either press **AUTO** again or press any range or excitation button. More detailed control of the autorange can be accessed by the special functions #55-57 described in the special feature section of this chapter.

The Autorange Option performs in the following manner:

- The autorange will select a higher range when the current resistance or reactance reading exceeds 180,000 counts, for example, 180Ω on the 200Ω range.
- If an overload occurs, the bridge will immediately select the 2MΩ range (or the maximum range) and then move down ranges until it finds the correct range.
- The bridge will select the next lower range if the reading drops below 10,000 counts out of the 200,000 counts.
- If you start autorange in the 10ΔR mode, upon the first overrange or overload condition, the bridge will select the ΔRx1 mode. Autorange will not select 10ΔR mode at any time during its control.
- The software uses delays whenever a range is changed or if the user sets an Rset value. This prevents the bridge from spuriously changing range and prevents hunting back and forth between ranges.

When changing ranges, the LR-750 needs to know which excitation to use for the range that it selects. There are four choices you may choose from by using the special features. You may select one of three predefined excitation sets for the ranges. These are a maximum power, a medium power, and a minimum power set that we call traces. Additionally, the operator may define a custom trace that is "User Defined". This trace can have any allowable excitation to be used for any range.

When first activating autorange, you should see a temporary message in the lower display letting you know which trace is being used by the autorange.

Additionally, the operator may select a minimum and a maximum resistance range. This can reduce the time to settle upon the correct range in an overload condition or to absolutely limit the maximum heater power emitted to the sensor.

EXCITATION

The excitation settings are labeled with a voltage. For example, 6mV for the maximum excitation. This is the voltage that will appear across the sensor resistor if its resistance is equal to the full scale of resistance range selected. For example, on the 2K Ω range, if you select 6mV excitation, and you have a 2K Ω resistor, the excitation voltage will be 6mV. If the resistance you are measuring is $\frac{1}{2}$ of the resistance range (in this example, 1K Ω), then the voltage across the sensor will be 3mV. This is because the bridge uses a fixed amplitude AC excitation current whose value depends on the resistance range and full scale excitation voltage.

To select the excitation voltage, press the button to the left of the excitation desired.

If the bridge doesn't respond to pressing the excitation voltage, the following conditions could exist:

- (1) The excitation may not be allowed for the resistance range selected because it would require a current that the bridge cannot deliver. For example, on the 2 Ω range, you may not select any excitation greater than 2mV. In this case, there will be a temporary message in the bottom display letting you know that a minimum or maximum excitation current condition exists.
- (2) The bridge may be in a data entry procedure such as RSET entry or display entry, etc. Before you can change the excitation, you must complete the entry of the other information you were entering.
- (3) The bridge will not respond to these buttons if the locallockout condition has been selected by a computer through one of the digital interfaces. This condition can occur when the controlling computer requests local controls be locked out. Please see the locallockout section for more information.

DIGITAL FILTER

The following information will be useful in understanding and operating the digital filter controls. The LR-750 measures the sensor resistor approximately every 188 milliseconds. This is regardless of the digital filter that is selected. The filtering method used by the LR-750 is a straight average giving equal weight to each of the readings in the time period. For example, the 3 second filtering mode, 15 readings are averaged together and divided by 15.

Note: The analog circuitry of the bridge settles in an exponential fashion with a time constant of less than 1/2 second. The digital filters respond to a step change in RSET in a ramp function. When you make a large step change, say 50% of F.S., the 3 second filter will ramp into the settled value in 3 seconds, plus 3 seconds fixed for the analog settling of the circuitry. Therefore, within 6 seconds, the 3 second filter has completely settled the display to 1 part in 200,000.

OFFSET, RSET

By using the offset control, you may change the origin of the ΔR measurement. For example, if you know your sensor is approximately 10K Ω , you can enter an offset of 10K Ω into RSET and by displaying the ΔR readings you can measure how your sensor differs from 10K Ω .

The offsets may be entered in one of the following ways:

- 1) **RSET** allows an offset to be entered in a random fashion to any setting from -199999 to +199999. After pressing **RSET**, the value is entered at the keypad. For resistive sensors, the RSET polarity will always be positive (+).
- 2) **RSET=0** will set the RSET value to 0 in effect turning the offset off.
- 3) **RSET=R** will change the RSET value to the current R value which is taken from the currently selected digital filter.

If you wish to set the RSET to a specific value, or make a specific change in the RSET, you may do the following: Press **RSET** and a data entry display will come up in the lower display. This display will show RSET=+XXXXXX where XXXXXX is

the current value of the RSET at the time that **RSET** was pushed. If **RSET=0** had been previously pressed, or if the RSET value is 0, the display would read "RSET =+000000" with a decimal point in the correct position for the current selected range. Please note that the first digit will be flashing. This is the cursor position.

Note: When first entering the data entry mode, the cursor is not at the polarity position. This is because for resistive sensors the polarity is always positive (+). To select the polarity, + or -, you may at any time during the data entry section, press the + or - button on the key pad to change the polarity. Alternatively, you may use the cursor movement buttons at the bottom of the key pad by pressing the left arrow to get the cursor position into the polarity position. Then you may use the up and down arrows to select the polarity you wish.

To enter the first digit, you may use the up and down arrows ($\blacktriangle$ and $\blacktriangledown$) to raise or lower the value of this flashing digit. Or, you may directly enter the digit you wish to enter. When using the up and down arrows to change the digit, the digit will continue to flash. When you reach the desired value, you must press the right arrow cursor ($\blacktriangleright$) to accept that digit and move on to the next digit. When entering the digit directly by pressing the number of the digit, the cursor control is automatically shifted to the right. The bridge will automatically skip over the decimal point during the data entry mode. After the last digit has been entered, the value will be shown on the display with a right arrow on the right side of the value. If this is the value you wish to accept, you may press the enter key below the key pad. If not, use the cursor control keys to move the cursor to the digit you wish to change. At any point during the data entry, if the value in the data entry display is the value you wish, you may press **RSET** and the displayed value will be accepted.

For example, if you wish to enter an RSET of 10K Ω when you're on the 20K Ω range, press **RSET**, the display will come up blinking. With RSET=+000000, you may press 1 and then you may press **RSET** to accept the value. At this point, the bridge will settle in with the ΔR reading the difference from 10K. Later, if you wish to change the RSET to 11K for example, you may press **RSET** and use the cursor controls to get over to the 1Ks digit in the display and enter "1", then press **RSET** and it will accept the new value.

Since the RSET value is only valid for a particular range, it is always set to zero upon a range change. Keep in mind that during RSET entry, all keys other than the keypad are ignored.

DISPLAY CONTROL

The display on the LR-750 is 2 lines of 16 characters each. The operator may select what measurement or setting is displayed in the top or the bottom line independently.

Note: The bottom line will be used for data entry overlays when in a data entry mode, such as RSET or variable excitation. It is also used for temporary messages to the operator. The bottom line will be restored to show the selected parameter once the entry is finished or the temporary message times out. The top display may occasionally be overwritten by error messages. This is a temporary form of message and will go away after the condition that initiated the error is corrected.

To select what measurement or setting is displayed in the top or the bottom display, press either the **TOP** or **BOTTOM** button in the display section. In this case, the LED will light next to the button you press. Next, press one of the measurement or setting buttons in the display section and that will become the new parameter displayed in the selected display. If you select a setting or parameter that is not available in your bridge. The display will come back with a message indicating that parameter is not available because that option has not been installed in your bridge.

TRUNCATING DIGITS

The bridge operates internally in the 5½ digit mode for measurements. If you don't care what the last digit or two digits are, you may blank them from the display (making the display easier to read) by using the Special 73, 74, and 75 commands. Displays using the 5½ digits are only available with the High Resolution Option and its additional digital filters.

ΔR OR 10ΔR MODE

The **ΔRx10** button toggles the bridge between the x1 and x10 modes. When the LED is lit, the bridge is in the 10ΔR mode. In this case, the ΔR is magnified by a factor of 10 by the analog circuitry and then measured. This increases the ΔR resolution by a factor of 10 for the current range with the trade off that you can only view 10% of the range centered on the offset values selected.

The bridge is either in the ΔR or in the $10\Delta R$. Both modes, $x1$ or $x10$, do not co-exist at once in either the LR-750's analog circuitry or in the microcontroller's memory. For example, when the bridge's mode changes from ΔR to $10\Delta R$, any ΔR in the memory is redefined as $10\Delta R$ data and any new data will come in as $10\Delta R$ data.

TEMPERATURE CONTROL

There are eight buttons to allow control of the TC's parameters. All other TC parameters can be set using the Special Features described later in this chapter.

BUTTON	FUNCTION
GAIN	Sets the TC's loop gain. Use the $\blacktriangle$ and $\blacktriangledown$ buttons to select the TC gain from 0.1 to 5,00 in 1-2-3-10 steps. Press GAIN or ENTER to accept the displayed value.
TIME CONSTANT	Sets the thermal time constant of the TC's loop. Use $\blacktriangle$ and $\blacktriangledown$ to select a TTC of 0.2sec to 1000sec in 1-2-5-10 steps. Select "USER DEF" to individually select the integration and derivative time constants using the Special Features. Press TIME CONSTANT or ENTER to accept the displayed value.
LOOP	Sets the loop polarity. Selections are open, inverted or normal. Use the open loop setting to apply a DC current to the heater that is selected by the DC out parameter.
PRE FILTER	Sets the low pass noise or pre filter. This value should be less than the TTC selected. This filters the non temperature dependent fluctuations in the sensor resistor. Selections are "OFF" and 0.1 to 30 sec. In 1-3-10 steps.

DISPLAY	Select the type of display to use when showing the heater voltage or current. Select "HTR V" or "% IMAX". Then, select "Numeric" or "Graphic" format. "HTR V" will display the heater actual instantaneous voltage. "% IMAX" will display the TC's formatted output current. "Numeric" will display them in numeric format where "Graphic" will give a bar graph indication of the value.
INPUT	Select the analog signal to use for temperature control. Select "ΔR" or "EXTERN".
DC OUT	Select the DC output current value to use when open loop is selected.
OTHER	Select the optional digital filter from 0.2 sec. to 30 min. in 1-1.5-2-3-5-7-10 steps.

HEATER CONTROLS

There are two buttons on the front panel which control the heater, the **CURRENT** button and an **ON** button. All other parameters associated with the Temperature Control Option are set via the special features (#20-29) or the Temperature Controller buttons. Please see the following section on Special Features.

HEATER CURRENT KEY

After pushing the **CURRENT** button, a selection menu will come up in the lower display. It will prompt you to select the maximum current for the heater (Imax).

When inputting the heater maximum current, "Imax" parameter, the instrument will check the heater cable that is connected to the rear panel connector of the Temperature Control Option and determine which current ranges are available. Therefore, you must have an appropriate heater cable connected to the instrument before you set this parameter.

HEATER ON KEY

This button is an "on" or "off" switch for the heater current. When the LED is lit next to the button, the heater is "on" and can deliver power.

SPECIAL FEATURES

Some of the features for the LR-750 cannot be accessed with a single key press. This section explains how to use the **SPECIAL** button on the front panel to access special features of the bridge.

To access the special features, press **SPECIAL** in the lower right hand area of the front panel. The bottom display will come up with an entry window that will allow you to enter a two digit number specifying which special feature you wish to perform.

The special features available are shown on the next page.

CHAPTER 2 OPERATING THE BRIDGE
SPECIAL FEATURES

<u>CATEGORY</u>	<u>KEY SEQUENCE</u>	<u>DESCRIPTION</u>
INFORMATION	SPECIAL 0 1 ENTER	Serial number
	0 2	Options installed
	0 8	Telephone number
	0 9	Fax telephone number
TEMP CONTROL	SPECIAL 2 0 ENTER	T.C. Input
	2 1	Noise Filter
	2 2	Derivative
	2 3	Integration
	2 4	Control Type
	2 5	Loop Control
	2 6	Quiescent Heater
	2 7	Cable Type
	2 8	TC Display
	2 9	Reset TC
MULTIPLEXER	SPECIAL 3 0 ENTER	Select sensor
INTERFACE (IEEE/RS232)	SPECIAL 4 0 ENTER	Disable Interfaces
	4 1	Enable GPIB
	4 2	Enable RS-232
	4 3	Set the GPIB Dev #
	4 4	RS-232 Parameters
DAC	SPECIAL 5 0 ENTER	Setup DAC output
AUTO RANGE	SPECIAL 5 5 ENTER	AR Trace Select
	5 6	Program User Trace
	5 7	Set AR Limits
ANALOG FILTER	SPECIAL 6 0 ENTER	Analog Filter Settings
RESOLUTION	SPECIAL 7 3 ENTER	Selects 3½ digit mode
	7 4	Selects 4½ digit mode
	7 5	Selects 5½ digit mode
	SPECIAL 8 0 ENTER	Load MFR calibration

SPECIAL FEATURE DETAILS

SPECIAL 01 Serial number.

Displays the serial number of the unit.

SPECIAL 02 Options installed

Displays the options installed. The options are shown as a four digit hexadecimal number. The LR-750=1450, LR-750R=0450 other options will change these.

SPECIAL 08 Telephone number

Shows Linear Research's telephone number in the USA.

SPECIAL 09 Fax telephone number

Shows the telephone number of Linear Research to send a Fax.

SPECIAL 20 Temperature controller input

Allows the operator to select ΔR or external input as the temperature controller input signal.

SPECIAL 21 Noise filter

Allows low pass filtering of the selected input (ΔR or the external input) to prevent lock up of the derivative circuit due to noise fluctuations in the sensor.

The user may select one of the following time constants from the menu: noise filter off, .1s, .3s, 1s, 3s, 10s and 30 seconds.

SPECIAL 22 User defined derivative

This feature will allow the operator to select the user defined derivative that will be used when the Thermal Time Constant (TTC) is set to **USER DEFINED**. From the menu the operator may choose from the following selection of derivatives: .067s, .167s, .3s, .67s, 1.67s, 3s, 6.7s, 16.7s, 30s, 67s, 167s, and 300 seconds.

SPECIAL 23 User defined integration

This allows the operator to select the user defined integration time that will be used when the TCC is set to **USER DEFINED**.

The operator may choose one of the following selections: .2s, .5s, 1s, 2s, 5s, 10s, 20s, 50s, 100s, 200s, 500s, and 1000 seconds.

SPECIAL 24 Control type

This feature allows the user to select the type of control the temperature controller will utilize to stabilize the heater. Please note that for most applications, PID control is suggested. From the menu the user can select any of the combination of P, I, and D where any one or more are turned off. For example, if you need a PI controller you can select the PI selection.

SPECIAL 25 Loop control

This feature allows the operator to choose normal, inverted or open loop control. Use normal loop control for negative temperature coefficient (NTC) sensors when used with the LR-750 where the ΔR is the input. Use inverted loop in case you are using positive temperature coefficient (PTC) sensors. Choose open loop where the heater is no longer controlled by the PID controller but is driven from a digital to analog converter where the operator can set a known value of DC heater current. Please see **SPECIAL 26** for how to set the heater current.

SPECIAL 26 Quiescent heater

This feature allows the operator to control the quiescent heater current. Once you issue this command you will notice an entry display in the lower display that will allow you to enter a value of per cent of full scale heater current.

SPECIAL 27 Heater cable

This feature checks which cable is attached and displays the cable type.

SPECIAL 28 Temperature control display

This feature allows the operator to select the temperature controller display type. The unit can display heater output as a per cent of full scale or heater voltage. After selecting what to display, the operator is then prompted to select either a numeric or bar graph method of showing the value on the front panel.

SPECIAL 29 Reset temperature controller

This feature allows the operator to reset all the temperature controller features to a known starting point. The following features will be set to the indicated value:

TTC	:	10 sec
GAIN	:	1
IMAX	:	30 μ amps
INPUT	:	ΔR
NOISE FILTER	:	30sec
USER DERIVATIVE	:	300sec
USER INTEGRATION	:	1000sec
CONTROL	:	PID
LOOP	:	NORMAL
DISPLAY	:	HTR V, NUMERIC

SPECIAL 30 Select multiplexer sensor number

Allows the operator to select which sensor in the multiplexer will be selected.

Note: The sensor number will be remembered by the bridge and upon power up, the bridge will reset the sensor multiplexer to the last sensor selected. See Chapter 3, Sensor Multiplexer for more information.

SPECIAL 40 Disable GPIB and RS-232

After issuing the Special 40 command, the bridge will thereafter ignore communication with the GPIB and RS-232 interfaces. If the bridge is connected to an interface, it will ignore the interface completely to the point that any commands issued over the interface to this instrument will not be responded to and the controller should experience a time out error.

SPECIAL 41 Enable GPIB

This command turns on the GPIB interface. The LR-750 will listen to and respond to the GPIB BUS as its currently set GPIB device number.

SPECIAL 42 Enable RS-232

This command turns on the RS-232 interface. The LR-750 will receive and transmit using the RS-232 interface. See Chapter 3, RS-232 for more information.

SPECIAL 43 Set GPIB device number

This special function enables the operator to select the GPIB device number from the front panel. This should be done before the **Special 41** command is issued to turn on the GPIB. Valid device numbers are 01-31. The bridge will remember its device number and upon power up, re-initialize itself to that device number.

SPECIAL 44 Display RS-232 parameters

This command will display the RS-232 parameter in the bottom display.

SPECIAL 55 Autorange Trace Select

This special function allows the operator to select one of the available traces for the autorange software to use. A trace is a set of range excitation settings to be used when autoranging. By using the up and down arrows, the following traces are possible:

RESET AUTO
DEFAULT TRACE
MAX POWER TRACE
MIN POWER TRACE
USER DEFINED TRACE

The "RESET AUTO" selection selects the default trace and then sets the max range to 2M Ω and the min range to 2 Ω .

The following table shows which excitations are used for the defined traces.

RANGE	TRACE		
	DEFAULT	MAX PWR	MIN PWR
2M	200 μ V	6mV	6 μ V
200K	200 μ V	6mV	6 μ V
20K	200 μ V	6mV	6 μ V
2K	200 μ V	6mV	6 μ V
200 Ω	200 μ V	6mV	6 μ V
20 Ω	200 μ V	6mV	6 μ V
2 Ω	200 μ V	2mV	6 μ V

The user defined trace selection selects the user defined trace to program the user trace. See SPECIAL 56 function. The unit is shipped with the user trace equal to the default trace.

SPECIAL 56 USER TRACE PROGRAMMING

This special function allows the operator to select the excitations to be used for each range when autorange is using the user trace.

After issuing this command, the LR-750 will light the 2 Ω range and wait for a valid excitation button to be pressed. When a valid excitation has been selected, the next range LED will light and the unit will wait for the next excitation, etc.

*Note: To keep a previously selected excitation, just press **ENTER**. To escape from this routine, press **ENTER** until out of the routine.*

SPECIAL 57 SET AUTORANGE LIMITS

This special functions allows the operator to select a maximum range and a minimum range that the autorange software will use. This can be used to limit the time to find the sensor value or to limit the output current to acceptable limits.

After issuing this command, the bridge will wait for a minimum range. Press the range button. Then press **ENTER**. Next the bridge will wait for a maximum range to be selected. You must press **ENTER** to accept the selection.

*Note: By pressing **ENTER** without pressing a range, the previous limit will be accepted. To escape from this routine, press **ENTER** twice.*

The bridge is shipped with the maximum range at 2M Ω and the minimum range at 2 Ω .

SPECIAL 60 ANALOG FILTER SETTINGS

This special feature is used to set the analog filter option settings.

Note: The analog filter option is a subset of the temperature control circuitry, i.e., if you set the TC constant, it will change the analog filter setting, etc.

After entering **SPECIAL 60 ENTER**, you will be prompted to select the ΔR or EXTERN signal. Press **ENTER** to accept when your choice of ΔR or EXTERN is displayed. Next, you will be prompted to select the noise filter time constant. You may select OFF, .1, .3, 1, 3, 10 second filter.

Once the filter time has been sent, you will be prompted to select the gain.

SPECIAL 73 Select 3½ digit mode.

Reduces the number of display digits to 3½ digits. This mode is useful when monitoring noisy sensors, making it easier to read the displayed value.

SPECIAL 74 Select 4½ digit mode.

This special feature restores the normal 4½ digit display resolutions. This is the maximum useful resolution using the normal 3 second digital filter.

SPECIAL 75 Select 5½ digit mode.

This special feature increases the resolution to 5½ digits. The additional digit will most likely be buried in the noise unless longer digital filters are used. See the temperature control **OPTION** for more information.

SPECIAL 80 Local MFR Calibration

This feature reloads the manufacturer's calibration that is stored in non volatile ROM.

OVERLOAD MESSAGES

At certain times during the operation of the bridge, the bridge may respond with either temporary messages or error messages alerting the operator to conditions that prevent accurate measurements or uninterpretable keystrokes by the operator.

The bottom line of the display is used for temporary messages associated with entering information, such as entering RSET, variable excitation, or a sensor number. It is also overwritten temporarily for approximately 2 seconds whenever the operator presses a button that would cause the bridge to go into a non-operating condition. These non-operating conditions are normally associated with a request for an excitation that is not available on a specific resistance range. For example, the 2 milliohm range cannot have an excitation voltage greater than 60 microvolts due to a limit of 30 milliamps being able to be delivered by the bridge.

The top display will be overwritten by an overload message whenever an overload condition exists. The three overload messages are:

$\Delta R \pm \text{OVERRANGE}$
 $\Delta X \pm \text{OVERRANGE}$
 $\text{ERROR} = \pm \text{CIT} \pm X \pm R$

Once the condition causing the error message is corrected the top display will be restored to show the parameter selected.

$\Delta R \pm \text{OVERRANGE}$

This message indicates that the ΔR measurement has gone overrange. The polarity gives the polarity of the overrange signal. Possible causes of this overrange condition are:

- ☐ The sensor has opened.
- ☐ ΔR is greater than the resistance range selected.
- ☐ When in x10 mode, the $10\Delta R$ goes above 10% of the range.
- ☐ Too large of an offset entered that adds to, rather than nulls the ΔR reading.

When the bridge is in this overrange condition, the ΔR ($10\Delta R$) display will read +200500 or -200500, its maximum value. This is the value input into the digital filter calculation.

$\Delta X \pm \text{OVERRANGE}$

This overload condition indicates that the reactance or 90 degree component of the signal is greater than the full scale range selected. Conditions that can cause this are:

- ☐ The sensor has opened
- ☐ Too much capacitance across the sensor.
- ☐ ΔX is greater than the range selected.
- ☐ $10\Delta X$ is greater than 10% of the range.
- ☐ Too large of an offset being present and/or in a polarity opposite to the actual inductance or capacitance.

*NOTE: These two overrange messages will only appear if there are no overload conditions also present. Anytime there is an overload condition, the message, **ERROR=±CIT±X±R**, will be displayed. See next page for more information. Also note, that if ΔR and ΔX are both overrange then the **$\Delta R \pm \text{OVERRANGE}$** message has priority. To see if ΔX is overrange when ΔR is also overrange, view ΔX in the bottom display. The ΔX value will be ± 200500 when overrange.*

$ERROR = \pm CIT \pm X \pm R$

This message will appear whenever the common mode, I-High, or tuned amp overload conditions occur. Only the letters of the overloads that are present will be displayed.

<u>CHARACTER</u>	<u>DESCRIPTION AND POSSIBLE CAUSE</u>
$\pm C$	COMMON MODE VOLTAGE OVERLOAD This indicates that the common mode voltage of the sensor is too high. This is usually caused by large line resistance in the I-LOW lead.
I	I-HIGH VOLTAGE OVERLOAD This indicates that the I-HIGH voltage is too large exceeding the compliance voltage of the bridge. Usually caused by large round trip resistance in the I-HIGH, sensor, I-LOW loop.
T	TUNED AMP INPUT OVERLOAD This indicates an overload at the input to the tuned amp. This overload may occur along with the "C" or "I" overloads and by correcting them, it may be corrected. If this overload occurs on its own, it indicates a non-coherent pickup of nearby signals such as 50/60 Hertz line power or harmonics of them or coupling in of other non-coherent signals from lines near the sensor. This is most likely to occur with large sensor resistors such as 10KΩ-1MΩ.
$\pm X$	ΔX OVERRANGE This indicates ΔX is overrange. In units without X DISPLAY, this will be the only indication of high reactance.
$\pm R$	ΔR OVERRANGE This indicates ΔR is overrange.

MEASUREMENT TECHNIQUES

ΔR -10 ΔR Modes

The bridge is either in the ΔR (and ΔX mode), or in the 10 ΔR (and 10 ΔX mode). Both modes, x1 or x10, do not co-exist at once in either the LR-750's analog circuitry or in the microcontroller's memory. For example, when the bridge's mode changes from ΔR to 10 ΔR , any ΔR in the memory is redefined as 10 ΔR data and any new data will come in as 10 ΔR data.

Thus, concerning the Block Diagram, when in the 10 ΔR and 10 ΔX mode, assume that every ΔR and ΔX notation on the Block Diagram is relabelled to read 10 ΔR and 10 ΔX . This relabelling holds true also for the description of the Block Diagram when in the 10 ΔR mode.

Preferred Method For Measuring Small Sensor Changes

With the bridge settled, push **RSET=R**. This will bring ΔR to $\Delta R = 0 \pm 20$ counts, typically between ± 1 and ± 10 counts. If more resolution is required, you can now go to the 10 ΔR mode and again press **RSET=R**. The RSET and XSET generators are about one order of magnitude more stable than the DC-input-to-AC-output circuitry shown on the Block Diagram. Therefore, for most stable operation and lowest drift, set the RSET so that ΔR is close to zero.

Increased Multiplexer Speed Under Computer Control

When using the sensor multiplexer to sequentially measure a number of sensors, have the host computer remember the last resistance value of all the sensors. Then when a new sensor is selected, immediately send the "OFFSET R= +xxxxxx" command with the remembered value of resistance from the last measured value of the sensor selected. This allows the bridge to measure the difference between resistance last time and resistance this time. If resistance hasn't changed very much, the difference will be close to 0 and the bridge will settle quicker than if the bridge has to measure a random new (perhaps full scale) resistance. Using this method, measurement of multiple sensors can be increased by greater than a factor of two. Results for this technique holds true even when the sensors are on different ranges with different excitations.

Measuring A Slowly Changing Sensor Under Computer Control

When the LR-750 is under computer control, measuring a slowly changing single sensor, program the computer to update the LR-750 from time to time with RSET=R commands. This forces the bridge to keep ΔR or $10\Delta R$ close to zero for greatest stability.

EXTERNAL INTERFERING SIGNALS

External interfering signal sources that might cause an overload of the LR-750's amplifier chain or nonvalid LR-750 readings are:

1. Large 50, 60, 100, or 120 Hz powerline interferences are usually coupled in at the sensor, sensor leads, the LR-750 closed loop amplifier chain, or balancing transformer, etc. Usually these power line and harmonic signals are magnetic field type radiation, but can be coupled into the unshielded portion of the exposed sensor leads by electrostatic fields. Interfering sources can be overhead fluorescent lights, fluorescent light ballast transformers, electronic equipment with power transformers, soldering irons, or close by high current AC power cords, etc.
2. Other non-coherent (not at 15.9 Hz) electronic instruments that put out AC signals close to the LR-750's sensor's exposed leads in the cryostat. This interference can be caused by magnetic or electrostatic fields in the 1 Hz to 10 KHz region.
3. Very near by noisy personal computers and/or noisy computer display monitors etc.
4. Coherent (at or close to the same frequency) sources, such as other bridges with sensor leads in the same cryostat using 15.9 Hz sine wave excitation. Thus, another LR-750 or LR-400 AC Resistance Bridge can give rise to a beat note output signal at ΔR having a frequency of typically one cycle per 30 seconds to one cycle per 24 hours.

TESTING FOR INCOHERENT INTERFERING SIGNALS

A. Checking the preamp monitor output.

Check the output of the preamp to see if interfering signals are present. Use the oscilloscope X-Y Lissajous method or the Y-T method. In X-Y method, connect the reference output to the X (horizontal) scope input channel and the preamp output to the Y (vertical) scope input channel. With no interference, and the bridge balanced and settled, the scope will display a straight horizontal line with perhaps some amplified random amplifier or sensor Johnson noise. If there are incoherent signals present on the preamp output, they will be displayed on the scope as a moving or running, left to right, or right to left, vertical signal (this could be a sinewave, distorted sinewave, or a string of glitches, etc.). In the Y-T method, the reference is not used and the preamp output is connected to the Y (vertical) regular scope input channel with an internal scope time base X (horizontal) channel of about 5 millisecond per centimeter.

Interference signals, most likely 50/60 Hz or their harmonics, should be less than 2 volts peak to peak. The preamp output monitor has a wide bandwidth voltage gain referred to the sensor of 6,400. Interference signals greater than 5 volts peak to peak will cause lockups or distortions at some point in the tuned amp circuitry. With signals less than 1 volt peak to peak, it is hard to notice any effects. The best performance can be achieved if you can get the interference below 100 millivolts peak to peak.

B. Checking the tuned amp monitor output.

Check the output of the tuned amp to see if interfering signals are present. Use the oscilloscope test method as described in paragraph A above. The gain of the tuned amp varies with the LR-750 excitation voltage setting. The maximum allowable limit of interference signals is 2 volts peak to peak.

TESTING FOR COHERENT INTERFERENCE SIGNALS

A coherent interference signal (CIS) can not be seen inside the LR-750's balancing feedback loop since the bridge thinks it is a legitimate bridge signal and balances it to a null voltage at the preamp input. Thus, both the preamp and the tuned amp outputs will show a zero or null output signal for a coherent interference signal, and can not be used to show coherent interference.

Therefore, a CIS can only be seen at the bridge's ΔR or ΔX output as a very slowly varying DC offset signal (small magnitude long period sine wave beat note). With an approximate midscale stable sensor resistor on an appropriate resistance range, press **RSET=R**, yielding a $\Delta R = 0$ output. Connect a strip chart recorder to the ΔR direct analog output or the DAC output. Check for a beat note sine wave output signal imposed on the expected 0 volt straight line strip chart recorder trace.

If coherent interference is present, electrostatically shield the LR-750 sensor leads inside the cryostat, move the interfering source away, or change the frequency of the interfering source so that the interference becomes incoherent. For example, shift its frequency from 15.9 Hz to 19 Hz. In this case, there will then be a 3.1 Hz beat note present. If the interfering signal's amplitude is small and the digital filter is set to 3 seconds or more, the LR-750 will filter out this "fast" 3.1 Hz beat note.

USING TWO OR MORE LR-750 AND/OR LR-700 BRIDGES

When the experiment calls for two or more 15.9 Hz AC bridges, either two LR-750s or an LR-750 plus an LR-400 or LR-700, etc., with their sensor's located in the same environment or cryostat, sensor leads must be protected from cross talk between bridges or the bridge's frequency of excitation must be shifted by ± 3 Hz from each other. The bridges frequency can only be modified at the factory. See also paragraph C above, "Test For Coherent Interference Signals". Ordinarily, just having two bridges mounted next to each other, both operating at 15.9 Hz, will not cause cross talk through their enclosures. Cross talk coupling usually occurs only by the exposed sensor leads.

CHAPTER 3 INTERFACING

SENSORS

This section illustrates the sensor connector on the rear panel of the bridge for the operator's reference.

Caution: The power to the LR-750 should be off and none of the lines to the sensor energized by any other instrument when plugging or unplugging the sensor connector from the instrument. Plugging the sensor connector in while the power is on could lead to the operator shorting pins across the connector, in which case the LR-750 could be damaged or the sensor could be damaged.

SENSOR CONNECTOR PINOUT

Here is the pinout and signal names of the pins of the sensor connector. The sensor cable uses a DB15S connector.

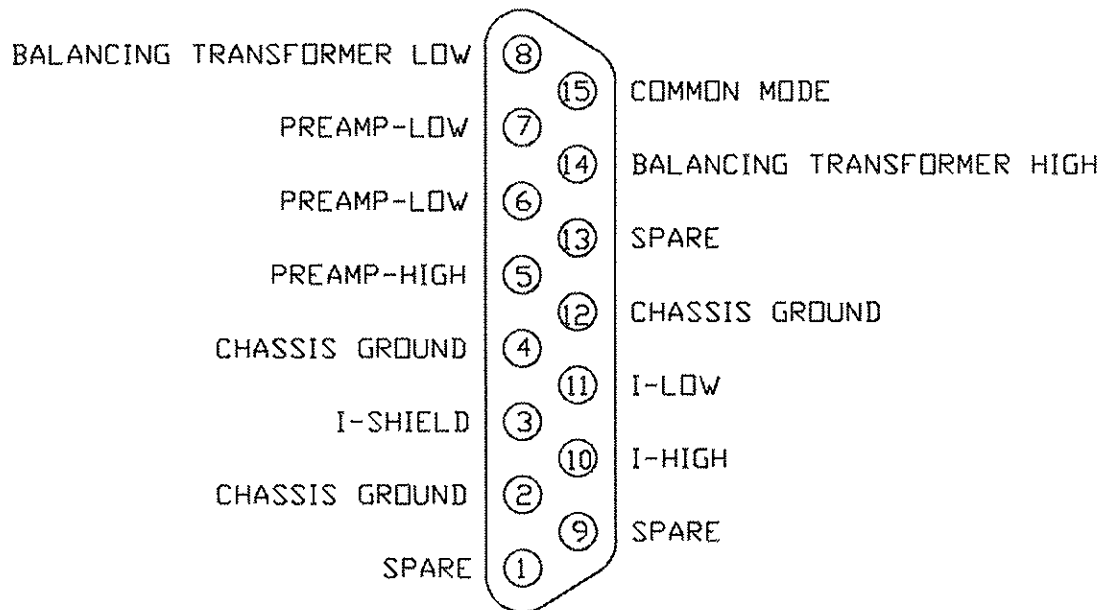


Figure 3.1

The Standard Sensor Cable

The standard sensor cable is supplied with the LR-750 unit. Figure 3.2 shows a schematic of this cable connected to a resistance sensor. Figure 3.3 is a physical assembly drawing of this cable allowing visual identification of each of the sensor leads without disassembling or electrically testing the cable. This cable connects both the I and V shields to ground. It is the simplest cable to hook up to the cryostat and one that is least prone to interference or cause oscillation.

The standard cable provided is the cable with grounded shields as illustrated in Figure 3.2. Other example sensor configurations are given to help the user configure the sensor for specific applications.

The standard sensor cable, although easy to use, does not have as good a common mode rejection ratio (CMRR) for line resistance as does the driven shields sensor cable. The common mode rejection for this cable is 20-30 DB lower than for the LR-750 driven shields cable. Nonetheless, CMRR is still very good and equivalent to our LR-400 bridge with its grounded shield cable. The LR-750 with its standard cable still outperforms all other competitor bridges.

For highest performance when measuring small sensors with large contact or line resistance, reconfigure (rewire) the standard cable connector to match the driven shield connector shown in Figure 3.4. Alternatively, the user can build up an entire driven shields sensor cable. The driven shields sensor cable can also be purchased directly from LRI.

Note: All LRI sensor cable assemblies are made from Belden Inc. type 8641 2-wire shielded cable. This type was chosen by LRI for its low induced electrical noise when mechanically flexed or shocked. In addition, all LRI sensor cable DB15S connectors use a specific manufacturer's type chosen for their extremely high pin to pin isolation resistance. Typical DB15S connectors will not perform as well.

Reversing Sensor Leads Gives Error Message

When the sensor leads are connected to a resistance sensor in reverse, like this:

V-HI to I-LO (wrong, reversed)
V-LO to I-HI (wrong, reversed)

Instead of the correct way, like this:

V-HI to I-HI (correct)
V-LO to I-LO (correct)

The following will happen:

1. All R , X , ΔR , ΔX values displayed will read out with a minus sign (-) instead of a plus sign (+). Small span errors may also result. Thus, an $R = +100.000\Omega$ correct reading may change to -100.020Ω with leads reversed.
2. On the bridge's three highest resistance ranges, when R is greater than 5% of range, the quadrature balance circuitry will saturate and the bridge will display an X overload error message. This is because the quadrature feedback loop, now passing through the sensor, is now inverted.

When the sensor leads are connected to a mutual inductance transformer, leads by user's choice may be reversed. Mutual inductance measurements are confined to the 2Ω through $2K\Omega$ ranges so quadrature balance lock-up due to reverse leads will not occur. Reversed leads in this case are simply equivalent to a reversed transformer secondary and thus is not a concern.

STANDARD SENSOR CABLE

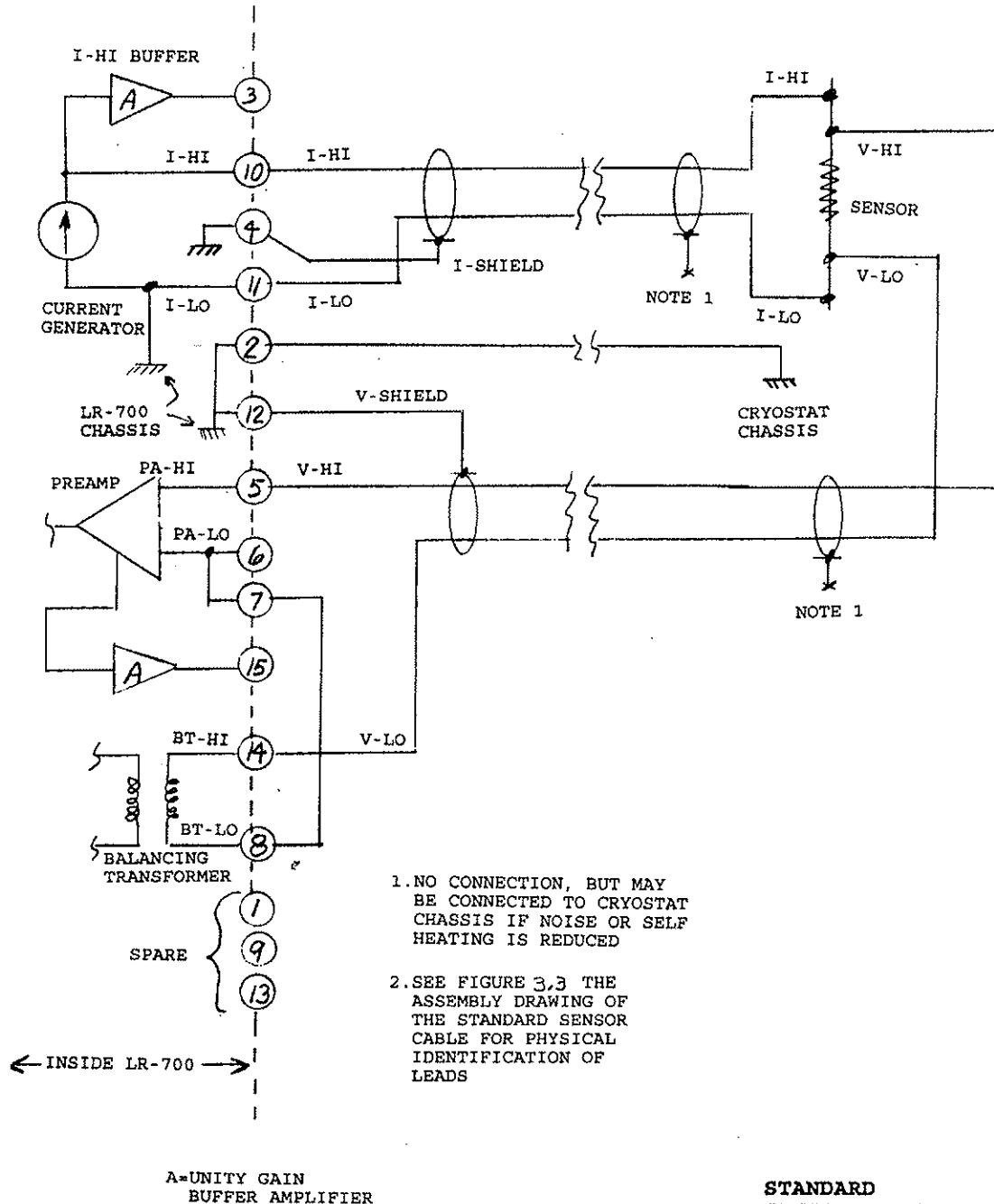


Figure 3.2

STANDARD SENSOR CABLE ASSEMBLY DRAWING

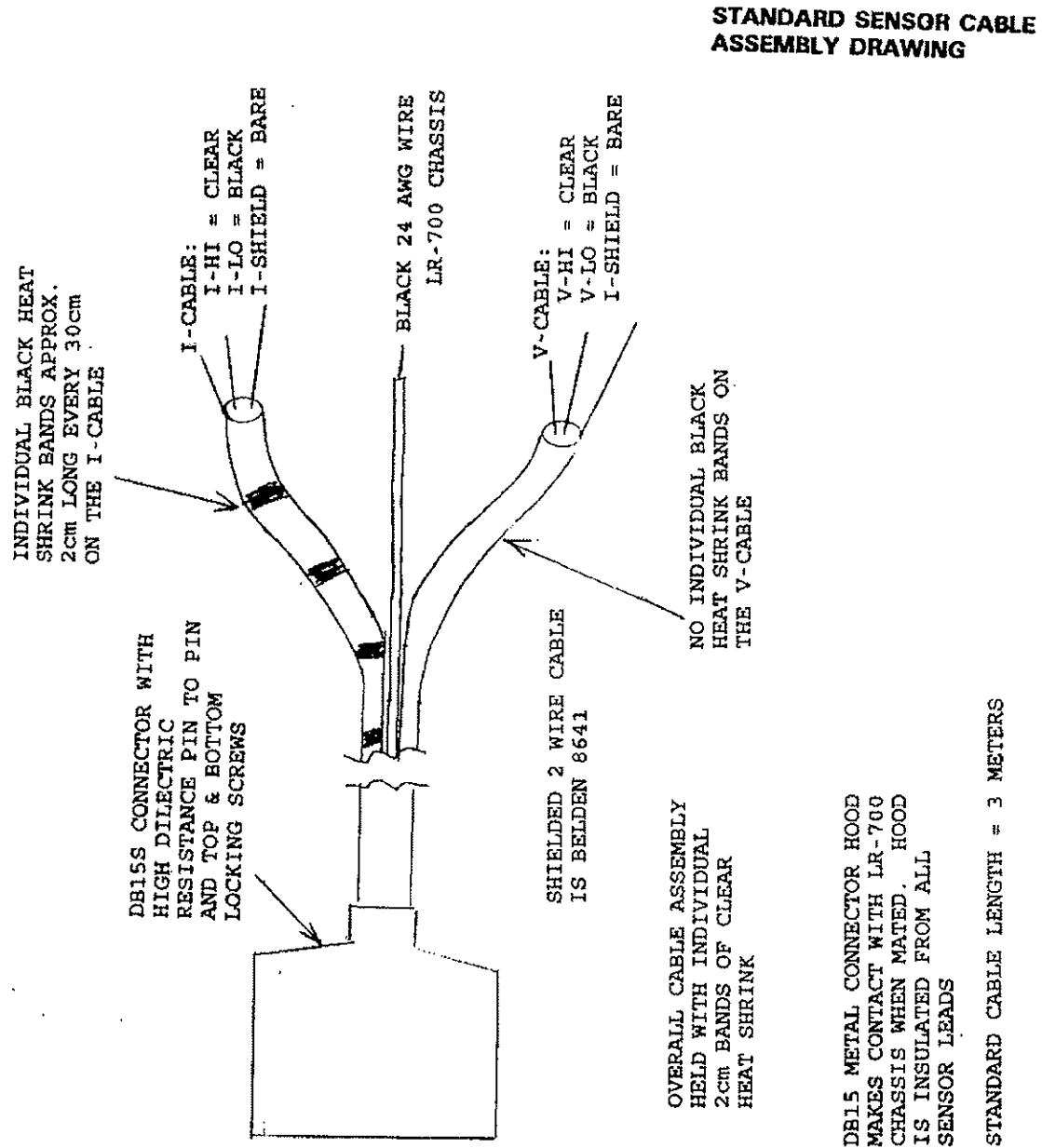


Figure 3.3

Driven Shields Sensor Cable

This cable is not supplied with the LR-750 as standard equipment. The standard sensor cable is supplied. However, the standard cable can be modified by the user, or this cable can be purchased from LRI. The driven shields sensor cable is shown in Figure 3.4. The I-Shield is driven by a buffered voltage equal to the I-High output voltage (pin 10). This neutralizes I-High to I-Shield capacitance.

The V-Shield is driven by a buffered voltage equal to the sensor common mode voltage to ground. This neutralizes V-High to shield and V-Low to shield capacitance.

This driven shield sensor cable must be used to achieve the high common mode rejection ratios shown in the Lead Resistance Induced Errors Chart in the specification section.

All sensor cable assemblies use Belden type 8641 2-wire shielded cable. See note in Standard Sensor section.

ANALOG OUTPUTS

ΔR Analog Output

The direct analog output is driven directly from the ΔR high gain DC amplifier (see LR-750 Block Diagram Figure 4.1) via a differential isolation amplifier. This amplifier references the output to the LR-750 chassis ground. For simplicity, the differential amplifier is not shown in the Block Diagram. This isolation amplifier gives a clean ΔR (or $10\Delta R$) DC output signal suitable for driving an external temperature controller, a 6½ digit digital volt meter, or a high gain strip chart recorder.

FEATURES OF ΔR OUTPUT

Individual BNC connector for $\Delta R(10\Delta R)$. Infinite monotonicity. Can be used as an input that drives the highest performance temperature controllers. Fixed filtered time constant 0.5 sec exponential. For strip chart trace random noise reduction an external 10 sec analog filter is recommended. Ultimate strip chart resolution is infinite but sensor or pre-amp random noise will usually limit performance. Can achieve up to 1 part in 1 million of full scale range resolution with a 10 second external analog filter in $10\Delta R$ mode. Recorder span sensitivity must approach 1mV. Can drive external 6½ digit digital volt meters with their own IEEE-488 interface for high resolution data logging.

J1 Analog Filter Output option

This BNC is the analog filter output. You may select either the ΔR or external signal and then select gain and filter. See **SPECIAL 60**.

ΔR ANALOG OUTPUT

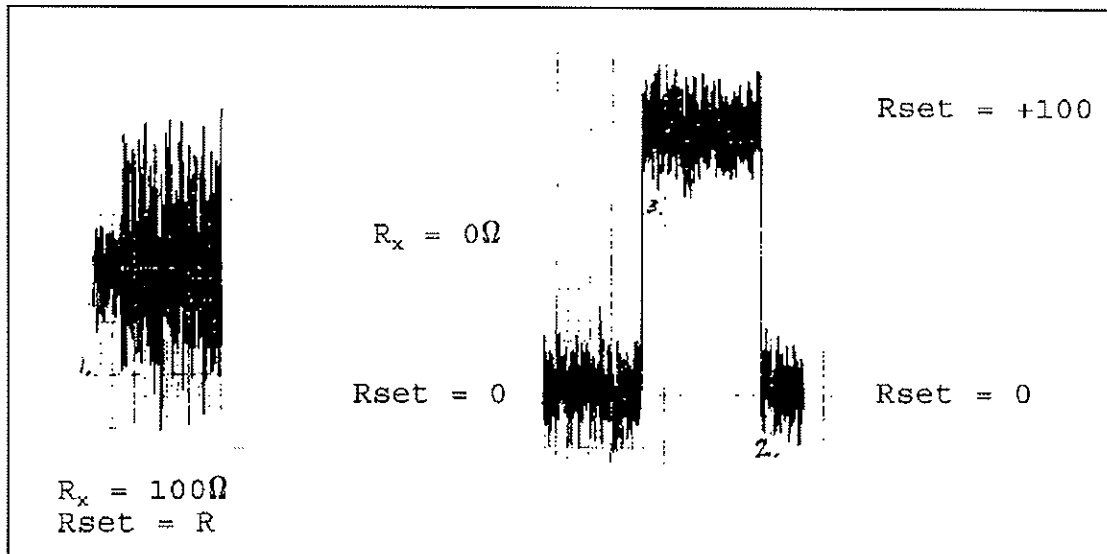


Figure 3.5

Range/Exc: $200\Omega/20\mu V$

Strip Chart Span = 1.0cm/min, 0.2V Full Span

ΔR ANALOG OUTPUT WITH 10SEC EXTERNAL FILTER

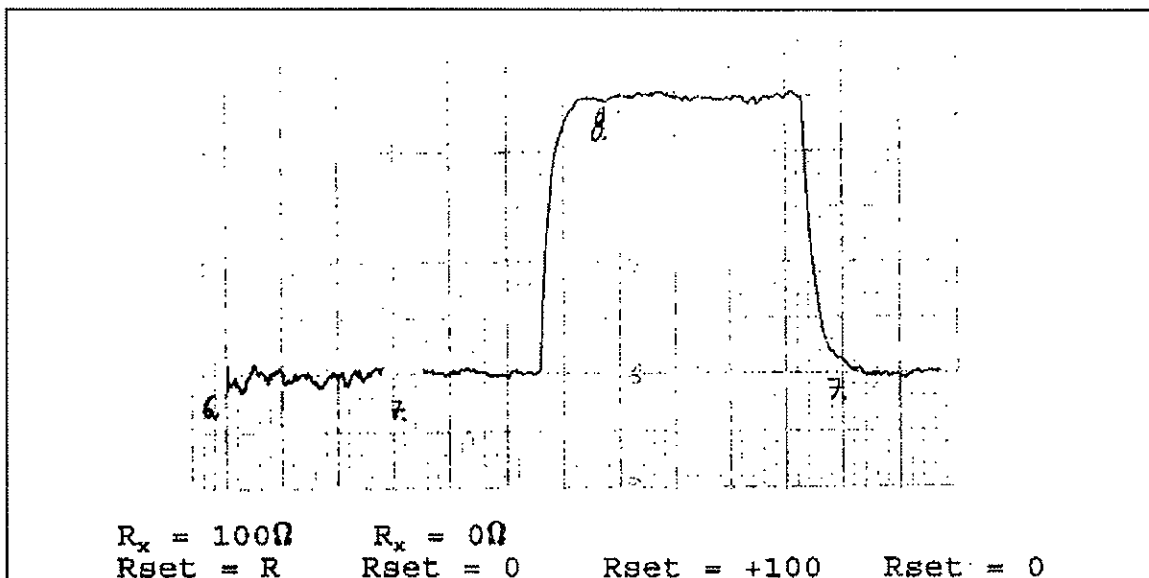


Figure 3.6

Rear Panel Monitor Outputs

REFERENCE MONITOR

The reference monitor output delivers a fixed amplitude, 16 Hz in-phase reference sine wave voltage. The amplitude is 3 volts RMS (8.5 Vp-p) centered about 0 volts DC. Source resistance is 3.3K Ω . This output is used to drive the X axis of an X-Y oscilloscope for making lissajous patterns when measuring or monitoring the preamp monitor or the tuned amp monitor. This fixed high level output can also be used when the LR-750 makes special measurements, such as measuring extremely high resistance greater than 1,000 megohms. For special measurements, see the section titled, "Other non-low temperature measurement applications of the LR-750."

PREAMP MONITOR

This monitors the output of the preamp.
Source resistance is 3.3K Ω .

Tuned Amp Monitor

This monitors the output of the tuned amplifier.
Source resistance is 3.3K Ω .

LR-720-8/16 SENSOR MULTIPLEXER

This section shows how to use the LR-720-8, 8 Sensor Multiplexer, and the LR-720-16, 16 Sensor Multiplexer.

The LR-720 switches all four sensor lines (I-HI, I-LO, V-HI, V-LO) with individual reed relays while the shields of all of the sensors are hard wired to the LR-750's chassis ground. Additionally, the LR-720's chassis ground is available as the individual black wires of the multiplexer sensor cables.

The sensors may be selected from the front panel or the computer interface of the LR-750. To select a sensor from the front panel, use the **SPECIAL 30** function. See Chapter 2 on how to use the **SPECIAL** key. See the section on COMMAND LANGUAGE for details of selecting sensors with a computer.

CONNECTING TO THE LR-750 BRIDGE

The multiplexer has two pairs of connectors, one labeled "CONTROL BUS" and the other "SENSOR BUS". When connecting to these points, either connector of the pair may be used. They are wired in parallel.

Make sure the LR-750 power is off when connecting or disconnecting the cables. All power to the multiplexer is delivered by the LR-720 CONTROL BUS cable.

Figure 3.7 shows pictorially how to connect one or more LR-720 multiplexers to the LR-750 AC Resistance Bridge.

To connect the multiplexer:

- The cable labeled "LR-720 SENSOR BUS" connects from the LR-750's SENSOR connector to the multiplexer's SENSOR BUS connector. Either SENSOR BUS connector may be used.
- The cable labeled "LR-720 CONTROL BUS" connects from the LR-750's PERIPHERAL connector to the multiplexer's CONTROL BUS connector. Again, either connector may be used.

The mounting screws on the CONTROL BUS cable must be used, gently tightened, to assure a good chassis ground connection. If they are not used, the measurements may be noisier.

LR-720 MULTIPLEXER HOOKUP

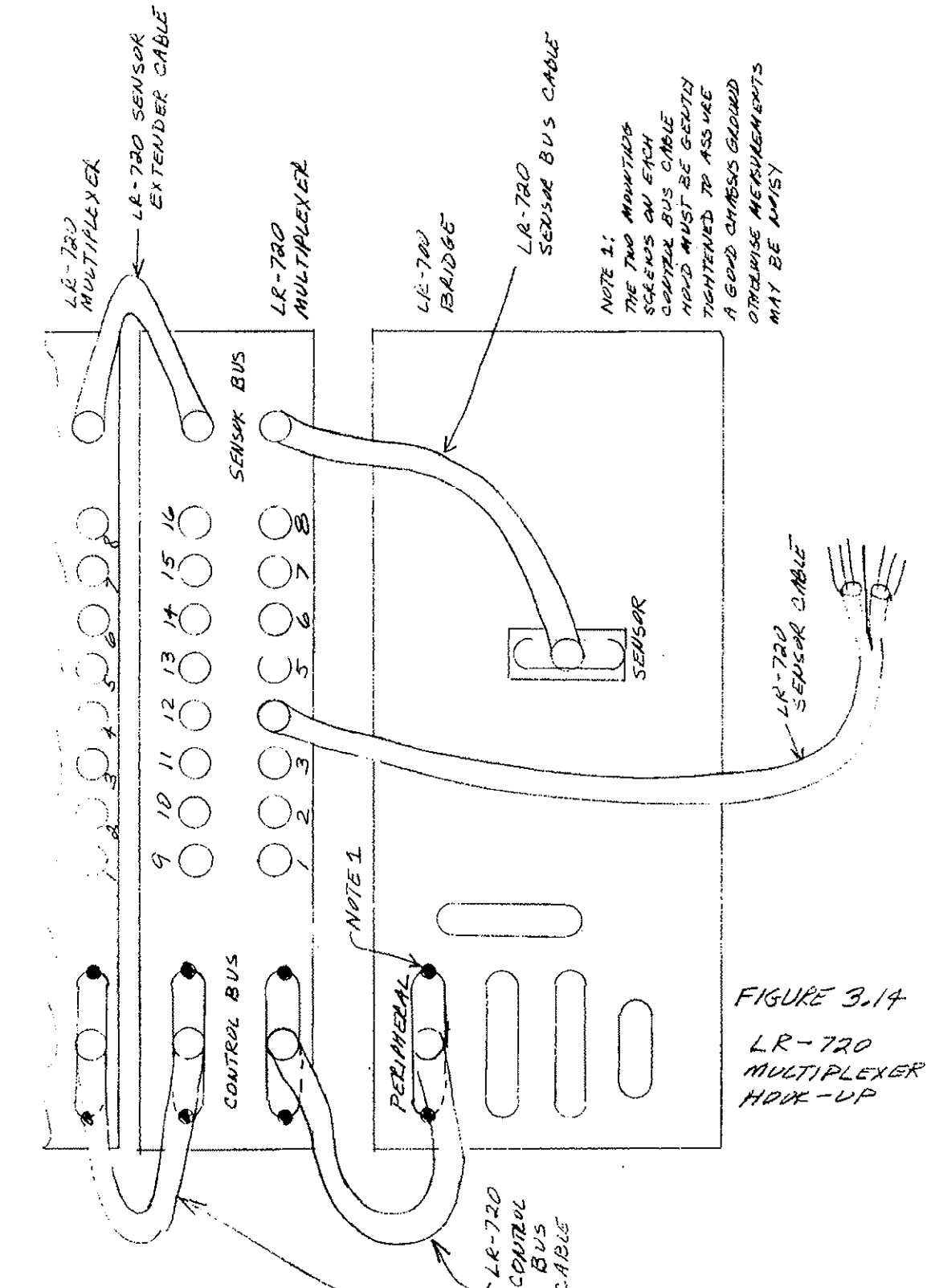


Figure 3.7

CONNECTING ADDITIONAL MULTIPLEXERS

Additional multiplexers may be connected together to increase the total number of sensors that may be selected. Up to 6 LR-720 units may be used in any combination of 8 sensor or 16 sensor versions. This can yield a maximum of 96 sensors if all 6 units are 16 sensor versions.

Figure 3.7 shows how to connect an additional multiplexer unit to another multiplexer unit.

To connect an additional multiplexer:

- The cable labeled "LR-720 SENSOR EXT" connects from the last LR-720's unused SENSOR BUS connector to the new multiplexer's SENSOR BUS connector. Either SENSOR BUS connector may be used.
- The cable labeled "LR-720 CONTROL BUS" connects from the last LR-720's unused CONTROL BUS connector to the new multiplexer's CONTROL BUS connector. Again, either connector may be used.

The mounting screws on the CONTROL BUS cable hood must be used, tightened gently, to assure a good chassis ground connection. If they are not used, the measurements may be noisy.

CONNECTING THE MULTIPLEXER TO THE SENSORS

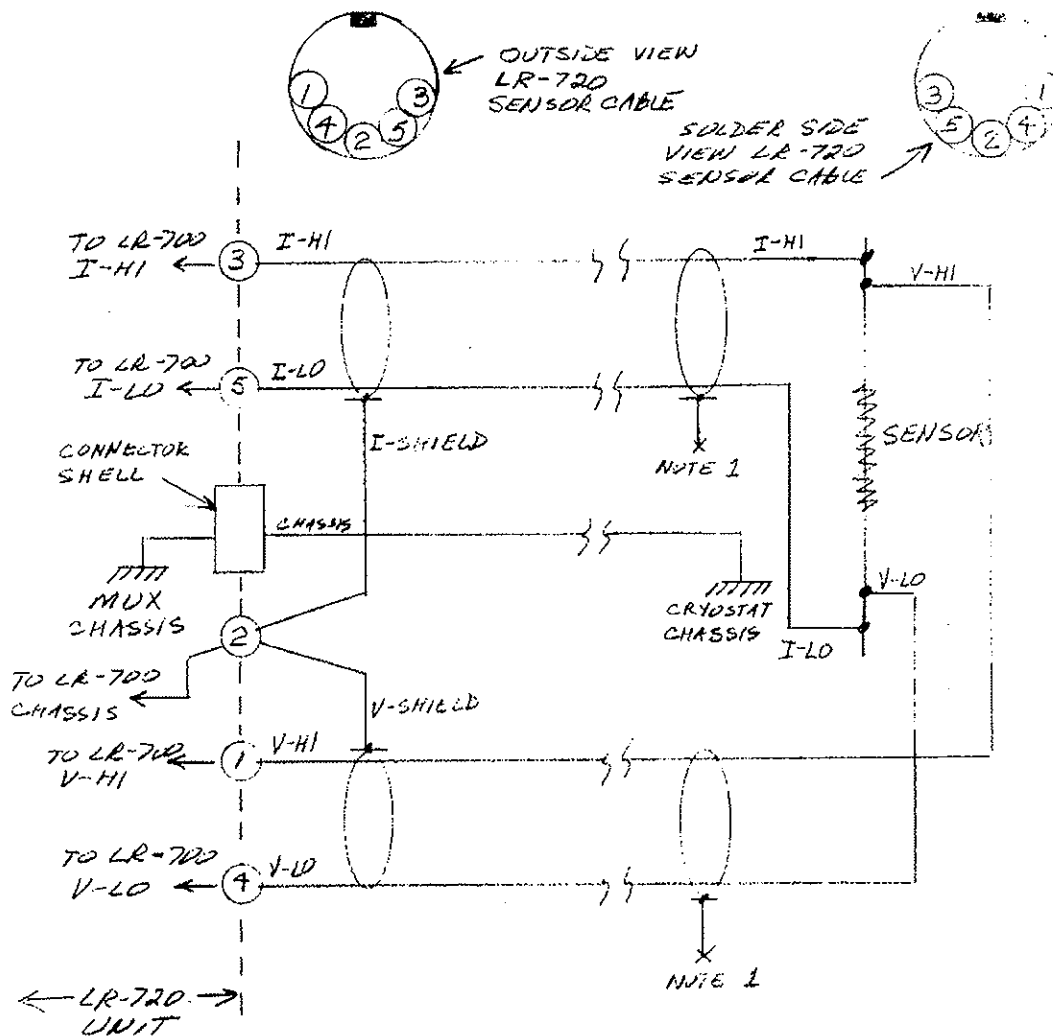
The cables labeled "LR-720 SENSOR CABLE" connect from the multiplexer's SENSOR connectors to the sensors. These sensor cables use a 5 pin connector (PREH# 71430-050) instead of a DB15S connector like the LR-750. Both of the shields are grounded and there is no provision for driven shields.

Figure 3.8 shows a detailed schematic of the LR-720 SENSOR CABLE.

For the highest common mode rejection of sensor line resistance, the LR-750 SENSOR CABLE with driven shields should be used and connected directly from the LR-750 to the sensor.

CAUTION: *Sensor terminal maximum voltage is ± 5 volts to chassis.*

LR-720 Sensor Cable



NOTES :

1. NO CONNECTION, BUT MAY BE CONNECTED TO CRYOSTAT CHASSIS IF NOISE OR SELF HEATING IS REDUCED
2. PHYSICAL IDENTIFICATION OF I-CABLE, V-CABLE, AND CHASSIS LINE SUBSECTIONS ARE THE SAME AS SHOWN IN THE STANDARD SENSOR CABLE ASSEMBLY DRAWING, FIGURE 3.3
3. CONNECTOR TYPE IS PRSH ELECTRONICS INDUSTRIES INC. TYPE 71430-050, 5PIN
4. SHIELDED 2 WIRE CABLE IS BELDEN 8641

FIGURE 3.15
LR-720 SENSOR
CABLE
(MULTIPLEXER
SENSOR CABLE)

Figure 3.8

COMPUTER INTERFACES

This chapter covers the command language used by the LR-750 as well as procedures for interfacing to the IEEE-488 BUS.

COMMAND LANGUAGE

This section provides information to help you control the bridge over either of the remote interfaces.

COMMAND SUMMARY

Here is a summary of all of the commands available to control the instrument over the interface in a summary form. Please refer to later sections for a detailed operation of each of the commands.

COMMANDS

Autorange [<0-1>] [T=<0-4>] [L=<0-5><1-6>]
 [U=<0-6>₀, <0-6>₁,<0-6>₆]
Bottom <0-9>
Excitation <0-6>
Filter [<0-3>] [M<00-24>]
Get <0-8>
Heater [<0-1>] [C=<0-6>] [D=<0-3>] [F=<0-6>] [G=<00-14>]
 [H=<0-1>] [I=<0-1>] [L=<0-2>] [Q=<±><000-999>]
 [R=<00-10>] [T=<00-12>] [U=<00-11><00-11>]
Locallockout <0-1>
Mode <0-1>
Noise Filter [F=<0-7>] [G=<00-14>]
Offset [=0] [=R] [R=<±><000000-199999>]
Range <0-6>
Special S=<01-99>
Top <0-9>

DETAILED COMMAND REFERENCE

This section illustrates in detail the exact syntax that must be used to select each of the features of the bridge.

Throughout this section the following convention should be used. All of the characters in bold type must be present for the command to operate properly. All of the letters in lower case can be omitted or in fact changed. They will be ignored by the command interpreter. Triangle brackets (<>) indicate that you must substitute a character or a number of characters as a parameter for the command. Square brackets ([]) indicate one choice of multiple choices. You must include one of the formats in one of the square brackets to accompany the command. The new line character <nl>, must be sent to end each line. The new line character is ASCII character #10 or 0A in Hex.

The exact syntax for each of the commands in this language is not sensitive to lower case or upper case characters. You may use either. When you separate the command word from the parameter, you may use a space, a number of spaces, a tab, or a number of tabs. You must end each command line with either a new line character or a carriage return character. Shown below are some examples that all accomplish the same task which is to set the bridge into the 2mΩ range.

PROGRAMMING EXAMPLES:

```
RANGE 0
Range 0
RANGE    0
Range    0
Range 0
Range [tab]0
R [tab]  0
R 0
```

All the above examples are equivalent to: RANGE 0

AUTORANGE

Autorange [$\langle 0-1 \rangle$] [$L=\langle 0-5 \rangle \langle 1-6 \rangle$] [$T=\langle 0-4 \rangle$]
[$U=\langle 0-6 \rangle_0 \langle 0-6 \rangle_1 \dots \dots \dots \langle 0-6 \rangle_6$]

Sets the Autorange settings

Autorange 0

Turns Autorange Off

Autorange 1

Turns Autorange On

Autorange $L=\langle 0-5 \rangle \langle 1-6 \rangle$

Sets the upper and lower limits on range

First parameter sets the lowest range

Second parameter sets the highest range

NOTE: Parameters may be strung together or separated by spaces or tabs. Both parameters must be present or the bridge won't accept the input and will give a ?BADPARAM message. The upper range must be larger than the lower range.

Autorange $T=\langle 0-4 \rangle$

Selects which trace to use when autoranging

$\langle 0-4 \rangle$	Trace Selected
0	Reset Autorange Features
1	Default
2	Minimum Excitation
3	Maximum Excitation
4	User Defined

Autorange $U=\langle 0-6 \rangle \langle 0-6 \rangle \langle 0-6 \rangle \langle 0-6 \rangle \langle 0-6 \rangle \langle 0-6 \rangle \langle 0-6 \rangle$

Sets the excitation to be used for each range when using the user defined trace

First parameter is excitation for 2Ω range

Second parameter is excitation for 20Ω range

: : : : : :

Sixth parameter is excitation for $200K\Omega$ range

Seventh parameter is excitation for $2M\Omega$ range

NOTE: Parameters may be strung together or separated by spaces or tabs. All 7 parameters must be present or the bridge won't accept the input and will give a ?BADPARAM message.

BOTTOM

Bottom <0-9>

Selects what measurement or Bridge Setting to Display in the lower half of the front panel Display where:

<u><0-9></u>	<u>DISPLAY</u>	<u>PROGRAMMING EXAMPLES</u>	
0	R measurement	Bottom	0
1	Not available	Bottom	1
2	$\Delta R/10\Delta R$ measurement	Bottom	2
3	Not available	Bottom	3
4	RSET value	Bottom	4
5	Not available	Bottom	5
6	Not available	Bottom	6
7	Filter Setting	Bottom	7
8	Temperature Controller	Bottom	8
9	Special Function	Bottom	9

EXCITATION

Excitation <0-6>

Selects the full scale excitation voltage where:

<u><0-6></u>	<u>EXCITATION SELECTED</u>	<u>PROGRAMMING EXAMPLES</u>
0	6 μ V	Excitation 0
1	20 μ V	Excitation 1
2	60 μ V	Excitation 2
3	200 μ V	Excitation 3
4	600 μ V	Excitation 4
5	2mV	Excitation 5
6	6mV	Excitation 6

FILTER

Filter [$<0-3>$] [$=00-24>$]

Selects which Digital Filter to use when displaying ΔR , ΔX , Rx, and X.

Filter 0

Selects the 3 second Digital Filter.

Filter 1

Selects the 3 second Digital Filter.

Filter 2

Selects the 3 second Digital Filter.

Filter 3

Selects the Variable Digital Filter.

Filter $=<00-24>$

Selects the length of the Variable Digital Filter where:

<u>$<00-24>$</u>	<u>FILTER TIME</u>
00	0.2 seconds
01	0.4 seconds
02	0.6 seconds
03	0.8 seconds
04	1.0 seconds
05	1.6 seconds
06	2.0 seconds
07	3.0 seconds
08	5.0 seconds
09	7.0 seconds
10	10.0 seconds
11	15.0 seconds
12	20.0 seconds
13	30.0 seconds
14	45.0 seconds
15	1.0 minutes
16	1.5 minutes
17	2.0 minutes
18	3.0 minutes
19	5.0 minutes
20	7.0 minutes
21	10.0 minutes
22	15.0 minutes
23	20.0 minutes
24	30.0 minutes

GET

Get <0-8>

Instructs the bridge to send a response message back to the computer.

Refer to the section "Response Messages" for details of the response message format.

<u><0-8></u>	<u>RESPONSE MESSAGE</u>	<u>PROGRAMMING EXAMPLES</u>	
0	R measurement	GET	0
1	Not available	GET	1
2	$\Delta R/10\Delta R$ measurement	GET	2
3	Not available	GET	3
4	RSET setting	GET	4
5	Not available	GET	5
6	Bridge setting	GET	6
7	Bridge status	GET	7
8	Temperature Controller	GET	8

HEATER

Heater [$\langle 0-1 \rangle$] [$C=\langle 0-6 \rangle$] [$D=\langle 0-3 \rangle$] [$F=\langle 0-6 \rangle$] [$G=\langle 00-14 \rangle$]
 [$H=\langle 0-1 \rangle$] [$I=\langle 0-1 \rangle$] [$L=\langle 0-2 \rangle$] [$Q=\langle \pm \rangle \langle 000-999 \rangle$]
 [$R=\langle 00-10 \rangle$] [$T=\langle 00-12 \rangle$] [$U=\langle 00-11 \rangle \langle 00-11 \rangle$]
 Temperature controller settings

Heater 0
 Turns the heater off

Heater 1
 Turns the heater on

Heater $C=\langle 0-6 \rangle$
 Selects the control type to be used

<u>$\langle 0-6 \rangle$</u>	<u>Control</u>
0	D
1	DI
2	I
3	P
4	PD
5	PI
6	PID

Heater $D=\langle 0-3 \rangle$
 Selects the Temperature Controller Display to use for the front panel

<u>$\langle 0-3 \rangle$</u>	<u>Display</u>
0	Heater voltage, numeric
1	Heater voltage, bar graph
2	% Heater current, numeric
3	% Heater current, bar graph

Heater $F=\langle 0-7 \rangle$
 Selects the low pass filter time constant for the input

<u>$\langle 0-7 \rangle$</u>	<u>Time Constant</u>
0	.01 sec
1	.1 "
2	.3 "
3	1 "
4	3 "
5	10 "
6	30 "

HEATER cont.

Heater G=<00-14>

Selects the amount of gain to apply to the input

<u><00-14></u>	<u>Gain</u>
00	.1
01	.2
02	.5
03	1
04	2
05	5
06	10
07	20
08	50
09	100
10	200
11	500
12	1000
13	2000
14	5000

Heater H=<0-1>

Turns the hold feature on or off

<u><0-1></u>	<u>Hold</u>
0	Off
1	On

Heater I=<0-1>

Selects the input to be used by the Temperature Controller

<u><0-1></u>	<u>Input</u>
0	ΔR
1	External

Heater L=<0-2>

Sets the loop control

<u><0-2></u>	<u>Loop</u>
0	Normal
1	Inverted
2	Open

HEATER cont.

Heater Q=<+><000-999>

Sets the quiescent heater current to be used in the open loop mode. A decimal point can be included. It will be ignored by the software. "H Q=+999" sets QHC to 99.9%.

Heater R=<00-10>

Selects the maximum current/voltage for the heater

<00-10>	Cable Connected	
	STD	LOW PWR
00	30 μ A	300nA
01	100 μ A	1 μ A
02	300 μ A	3 μ A
03	1mA	10 μ A
04	3mA	30 μ A
05	10mA	100 μ A
06	30mA	300 μ A
07	100mA	-
08	300mA*	-
09	1A*	-
10	3A*	-

*Requires external power booster

Heater T=<00-12>

Selects the Thermal Time Constant (TTC)

<00-12>	TTC sec.
00	.2
01	.5
02	1
03	2
04	5
05	10
06	20
07	50
08	100
09	200
10	500
11	1000
12	User Defined

HEATER cont.

Heater U=<00-11><00-11>

Sets the user defined TTC. The first parameter is the integration time constant. The second parameter is the derivative time constant.

<u><00-11></u>	<u>Integrations</u>	<u>Derivative</u>
00	.2	.067
01	.5	.167
02	1	.33
03	2	.67
04	5	1.67
05	10	3.33
06	20	6.7
07	50	16.7
08	100	33
09	200	67
10	500	167
11	1000	300

LOCAL LOCKOUT

Locallockout <0-1>

Instructs the bridge to respond to or ignore Front Panel Commands.

Locallockout 0

Allows Front Panel control simultaneous with remote control.

Locallockout 1

The Bridge will ignore all Front Panel commands except the local button.

MODE

Mode <0-1>

Sets the x1 or x10 mode to allow measurement of ΔR or $10\Delta R$ where:

<u><0-1></u>	<u>ΔR MODE</u>	<u>PROGRAMMING EXAMPLES</u>	
0	x1 (ΔR)	Mode	0
1	x10 ($10\Delta R$)	Mode	1

NOISE

Noise [F=<0-6>] [G=<00-14>] [I=<0-1>]

Sets the filter time constant or gain for the analog filter option. Can be used if you have either the temperature controller option or the analog filter option.

Noise F=<0-6>

Selects the analog filters low pass filter time constant

<u><0-7></u>	<u>Filter Time Constant</u>
0	.01 sec
1	.1 "
2	.3 "
3	1 "
4	3 "
5	10 "
6	30 "

Noise G=<00-14>

Selects the analog filter gain

<u><00-14></u>	<u>Gain</u>
00	.1 second
01	.2 "
02	.5 "
03	1 "
04	2 "
05	5 "
06	10 "
07	20 "
08	50 "
09	100 "
10	200 "
11	500 "
12	1000 "
13	2000 "
14	5000 "

Noise I=<0-1>

Selects the input for the analog filter

<u><0-1></u>	<u>Input</u>
0	ΔR
1	External

OFFSET

Offset [=0] [=R] [R=< $\pm$ ><000000-199999>]

Sets the offsets for ΔR measurements. The offset is the origin of the ΔR or 10Δ measurements.

Offset =0

Sets offset R to zero (no offset). When the offsets is zero, $\Delta R=R$.

Offset =R

Sets offset to the currently measured R (RSET=R). This command is used as a "NULL" for ΔR . Note: The R value is the value from the currently selected Digital Filter.

Offset R=< $\pm$ ><000000-199999>:

Sets the Rset to the parameter listed. This allows the Rset to be set to any value from -199,999 to +199,999. Note: +200,000 is full scale therefore setting Offset-R=100,000 when on the 2 ohm range sets or Rset equal to 1.00000 Ω .

RANGE

Range <0-9>

Selects the full scale resistance range where:

<u><0-9></u>	<u>RANGE SELECTED</u>	<u>PROGRAMMABLE EXAMPLES</u>	
0	2 Ω	Range	0
1	20 Ω	Range	1
2	200 Ω	Range	2
3	2 K Ω	Range	3
4	20 K Ω	Range	4
5	200 K Ω	Range	5
6	2 M Ω	Range	6

SELECT SENSOR

Select S=<01-99>

Selects the multiplexer sensor. Where <00-99> is the sensor number selected.

Select S=01

Selects sensor number 1

TOP

Top <0-9>

Selects what measurement or setting is displayed in the top half of the front panel Display. See **Bottom** <0-9> for details.

RESPONSE MESSAGES

After sending commands to the LR-750, in many cases you will not get a message to be sent back. If you try to read the response, you will get an empty string due to the fact that the LR-750 sends a line feed and an end of message terminator. If you send a command that is unrecognizable by the bridge, you will get a response message of "ERROR". If you read back from the instrument and get this response, the bridge didn't understand the previous command. The bridge will respond in the following manner for legitimate requests for information from the bridge through the GET command.

GET 0, Get 1, Get 2, Get 3, Get 4, Get 5

The bridge will respond with:

```
"<±><#####><MULT> OHM<PARA>",
```

where:

<#####> is the display value for the parameter.

Each # is either a digit or a decimal point.

<MULT> is K, M, U or a space.

<PARA> is the parameter: R, X, ΔR , ΔX , RSET or XSET.

GET 6

The bridge responds to this command with:

```
"#R,#E,###%,#F(string),#M,#L,##S"
```

Where # represents a number digit.

This line can be decoded in the following manner: The parameters in order are range, excitation, percent variable excitation, filter, mode, locallockout and sensor number. Each parameter is separated by a ",".

For example, if the LR-750 is on the 2m Ω range, 20mV excitation, variable excitation is at 100%, digital filter is 1 second and it is not in 10 ΔR mode, locallockout has not been sent to the bridge by the computer and the sensor is either unused or selecting the first sensor for the multiplexer. The GET 6 command would respond with "9R,6E,100%,0F,0M,0L,00S".

Note: If the filter menu has been selected, the response will be 3F string for the filter with the (string) explaining which user selectable filter has been selected.

GET 7

The LR-750 responds with any overloads or overranges that are detected by the bridge which would normally be displayed on the front panel of the instrument. The bridge will respond with the following:

"### OVERLOADS"

where each # is a digit.

The three digits are a number between 000-255. To decode this number, use the following table which shows the binary weight of each of the overloads.

WEIGHT	OVERLOAD INDICATED	WITH X DISPLAY
1	+ ΔX overrange	$\pm X$ overrange
2	- ΔX overrange	ΔX overrange
4	Common mode overload voltage +	
8	Common mode overload voltage -	
16	I-HIGH voltage overload	
32	Tuned amp input overload	
64	$\pm R$ overrange	
128	$\pm \Delta R$ overrange	

Get 8

The bridge responds with the temperature controller numeric display. An example is shown below.

"03.90 V HtrV"

IEEE-488 INTERFACING

The LR-750 may be connected to the GPIB Bus by using a standard GPIB cable and connecting it to the rear panel of the LR-750.

Caution: The power to the LR-750 as well as the power to all the instruments on the GPIB Bus must be off when connecting or disconnecting this plug to prevent the possibility of damage to the LR-750 or any other instrument.

Once the LR-750 has been connected to the GPIB BUS, it is not yet ready to accept information or respond to the BUS. The operator must enable the GPIB BUS by issuing the following keystrokes:

SPECIAL 4 1 ENTER

This special function, SPECIAL 4 1, enables the LR-750 to respond to the BUS.

Note: The factory setting of the GPIB device number is number 18. You may change this device number using the SPECIAL 43 command. Please refer to Chapter 2, Operating The Bridge, Special Function section, for more information.

RS-232 INTERFACING

The LR-750 may be connected to a PC compatible computer's serial port by using a 9 pin null modem cable. The cable should have a DB9 connector with sockets on both ends. The null modem cable connects directly to the rear panel of the LR-750.

Caution: The power to the LR-750, as well as the power to the computer on the other end of the RS-232, must be off when connecting or disconnecting the plug to prevent the possibility of damage to the LR-750 or your computer.

Once the LR-750 has been connected to your computer's RS-232, it is not yet ready to accept information or respond to the computer. The operator must enable the RS-232 interface on the LR-750 by issuing the following key strokes:

SPECIAL 4 2 ENTER

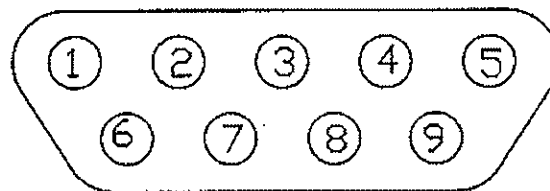
This special function, 4 2, enables the LR-750 to respond to RS-232 Interface.

RS-232 CABLING

If you're connecting the LR-750 to another RS-232 device, the following information may be helpful.

CONNECTOR PINOUT

The RS-232 connector is on the rear panel of the LR-750. Its pinout is shown looking at the rear panel. This is also a view of the solder cups of the mating connector.



RS-232

Figure 3.9

RS-232 SIGNALS

The RS-232 cable should connect the following:

LR-750 SIGNALS			COMPUTER SIGNALS		
<u>NAME</u>	<u>PIN#</u>		<u>NAME</u>	<u>DB9 PIN#</u>	<u>DB25 PIN#</u>
NC	1		NC	-	-
RXD	2	<----->	TXD	3	2
TXD	3	<----->	RXD	2	3
DTR	4	<----->	DSR	6	6
GND	5	<----->	GND	5	7
DSR	6	<----->	DTR	4	20
RTS	7	<----->	CTS	8	5
CTS	8	<----->	RTS	7	4
NC	9		NC	-	-

This cable connects the following signal at each device to the other:

```

RXD  to  TXD
RTS  to  CTS
DTR  to  DSR
GND  to  GND

```

If your computer uses RXD, TXD, DTR, DSR, and GND, connect DTR from the computer to DSR and CTS of the LR-750, and connect the LR-750's DTR to the computer's DSR.

If your computer uses RXD, TXD, RTS, CTS, and GND, connect the computer's RTS to the LR-750's DSR and CTS, and connect the LR-750's RTS to the computer's CTS.

RS-232 PROGRAMMING

When communicating with the LR-750 via the RS-232 interface, you must use the following procedures:

1. Each string sent to the LR-750 must end with a carriage return.
2. Upper case or lower case letters may be used for any letter.
3. To separate commands from their parameters, you may use either space(s) or tab(s).
4. After each command is sent to the LR-750, you must read the LR-750's response back from the instrument.
5. The serial port parameters for the LR-750 communication are as follows:

Baud rate = 9600
Parity is none
Number of bits is 8
Number of stop bits is 1

After each command is received by the LR-750 and acted upon, the LR-750 will send a response string back. The following table describes the responses:

<u>RESPONSE</u>	<u>DESCRIPTION</u>
"OK"	The command was received properly and acted upon and the LR-750 has no information to send to the computer.
"?BADPARAM"	The LR-750 could not determine a correct parameter from the parameter listed. Either the string was sent wrong or the string was not received properly by the LR-750.
"?SYNTAX"	The command was uninterpretable as a valid command by the LR-750. Either the computer sent an unrecognizable string or the string was improperly received by the LR-750.

RESPONSE MESSAGE The command was received properly by the LR-750 and acted upon and the computer was requesting specific information from the LR-750. Please refer to the response messages sections in Chapter III, Command Language.

During certain portions of the LR-750's operating software, timing is absolutely critical for stable measurements. During these portions of the code, the LR-750 will not respond to characters received by the IEEE-488 or the RS-232 interface. The IEEE interface suffers no degradation due to the fact that each byte is handshaked as received, whereas the RS-232 sends its bytes over and has no individual character hand shaking. Because of this, from time to time, that may seem like a random event, the LR-750 will not receive a character properly, (usually one character out of the string may be dropped). This is due to the fact the RS-232 interface circuitry receives a byte or a character and there is a limited amount of time, (the amount of time it takes to shift in the next character over the interface) to read that character out of the interface chip. As mentioned previously, this critical timing section of the code can cause a byte to be skipped from time to time. Therefore, it is recommended after each command you send, you read back the response from the LR-750. By reading back the response and checking for an "OK", or a normal response string, you will know if the command was received properly. It is a matter of writing a simple loop into your program to check for the two cases of "?BADPARAM" or "?SYNTAX" responses and resend the command if they occur.

TEMPERATURE CONTROLLER INTERFACING

This section describes how to interface the LR-750's Temperature Controller Option. The Temperature Controller can be used to control temperature or DC bias sensor resistors using its internal 1 watt power supply. Higher wattage can be obtained by using Linear Research power boosters (available separately).

CONNECTOR PINOUT

The Temperature Controller connector is located on the rear panel of the LR-750. Its pinout shown looking at the rear panel. This is also a view of the solder cups of the main connector.

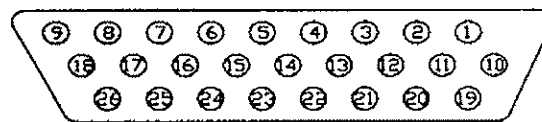


Figure 3.10

TEMPERATURE CONTROLLER SIGNALS

<u>Pin #</u>	<u>Signal Name</u>	<u>Pin #</u>	<u>Signal Name</u>
1	STD-FB (output)	14	VR-Low (chassis)
2	sample FB (input)	15	VR-High
3	sample FB (input)	16	02 (output)
4	V _{ps} -Low	17	01 (output)
5	V _{ps} -Low	18	I2 (input)
6	+5V (Logic High)	19	-5V ps
7	GND (Logic GND)	20	-10V ps
8	I0 (input)	21	STD-Hot
9	I1 (input)	22	STD-Low (chassis)
10	chassis	23	STD-Drive (input)
11	STD shield (chassis)	24	IGEN-Drive (output)
12	IGEN shield (chassis)	25	Bipolar Drive
13	VR-shield (chassis)	26	Spare (NC)

PRELIMINARY TUNING PROCEDURE FOR THE LR-750-TC

This is the preliminary tuning procedure for the LR-750 Internal Temperature Controller (TC). This procedure will be worded in a general manner and you may need to refer to the LR-750 Instruction Manual to learn specifically how to set the controls.

This procedure should be followed only after the connections to the thermal system have been made. It will be impossible to tune the system without the sensor and heater "live" and ready to control temperature.

Initial Settings

The bridge should be on a range suitable for the sensor resistor, i.e., if the sensor resistor is 10K thermistor it should be on the 20K range. The excitation should be set to a sufficiently high setting so that noise is low.

The Temperature Controller input should be set to ΔR or ΔX according to whether you have a resistance or mutual inductance sensor.

The noise filter should be off.

You may ignore the derivative and the integration time constants.

Control type should be PID.

Loop control should be normal or inverted. Normal is used mostly with negative temperature co-efficient sensors.

Quiescent heater should be off.

The TC display should be the per cent heater current in the graphics mode.

Using the Temperature Controller's button, the TTC (Thermal Time Constant) should be set to .2 sec, and the gain to 5,000. Set the maximum heater current to a value that should bring your temperature stabilized at approximately 50% for the current range selected. Be careful that you don't blow out your sample by selecting too high a current.

Use the heater "ON" key to turn the heater on.

RSET must be set to a reasonable set point that the thermal system can achieve using the heater current selected. For example, on a 20K range using a 10K thermistor, you might pick 5K or 6K. This is for a negative temperature co-efficient sensor.

Coarse Tuning

Set the bottom display to the TC so that you can see the bar graph and any oscillations in the heater power. Preferably, you can hook a strip chart recorder up to the ΔR output on the rear panel of the LR-750. With the heater on, the heater should go into a sustained oscillation. If there isn't any oscillation in the heater power, most likely your loop control is incorrect. If it is normal, select inverted. If it is inverted, select normal.

The next step is to measure the period of oscillations of the over-shoot. This is most easily done on a strip chart recorder, but you can measure the time in seconds on the front panel of the bar graph. Once you measure this period of oscillation, you can then set the TTC as close as possible to this setting.

Now reset the gain control by using the TC settings key. Initially it was at 5,000 to insure oscillations. Now, step down from 5,000 to 2,000 to 1,000 etc., pausing at least two or three times the oscillation period measured previously. If the oscillations persist all the way down through the gains, then you will need to change the TTC either up or down one setting. Then, repeat this step.

At some lower gain setting, the oscillations will stop completely. Most likely this will be on the TTC first chosen. This will yield a steady state and close to zero DC signal on the bar graph or the ΔR output.

Fine Tuning

Make a small step change in the RSET making sure that it is a large enough step change so that the recorder or bar graph makes a significant initial step change without overloading. What we are trying to achieve is making a step change without having anything in the bridge overload or lock-up. If the TTC and gain controls are not set at their optimum value, the strip chart recorder will now show a damped ringing oscillation as shown below.

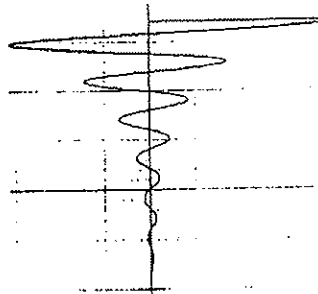


Figure 3.11

Note that one cycle of the ring is the same order of magnitude in period as the oscillation measured previously. This is a characteristic of your thermal system. Change the TTC up or down one step and repeat the step change. Observe whether the damped oscillation takes longer to dampen out or if it dampens out quicker. Similarly, you can change the gain setting one step up or down and see what effect it has on the damped oscillation. The goal is to select the highest value of DC gain and smallest value of TTC that give the best strip chart recording, as shown below. This will assure the best long term stability and fastest settling thermal time when going to a new set temperature.

When the TTC and gain controls are finally optimized in their settings, the strip chart recording for a set resistance step change should look somewhat as follows:

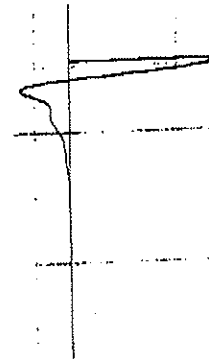


Figure 3.12

The Temperature Controller is now tuned.

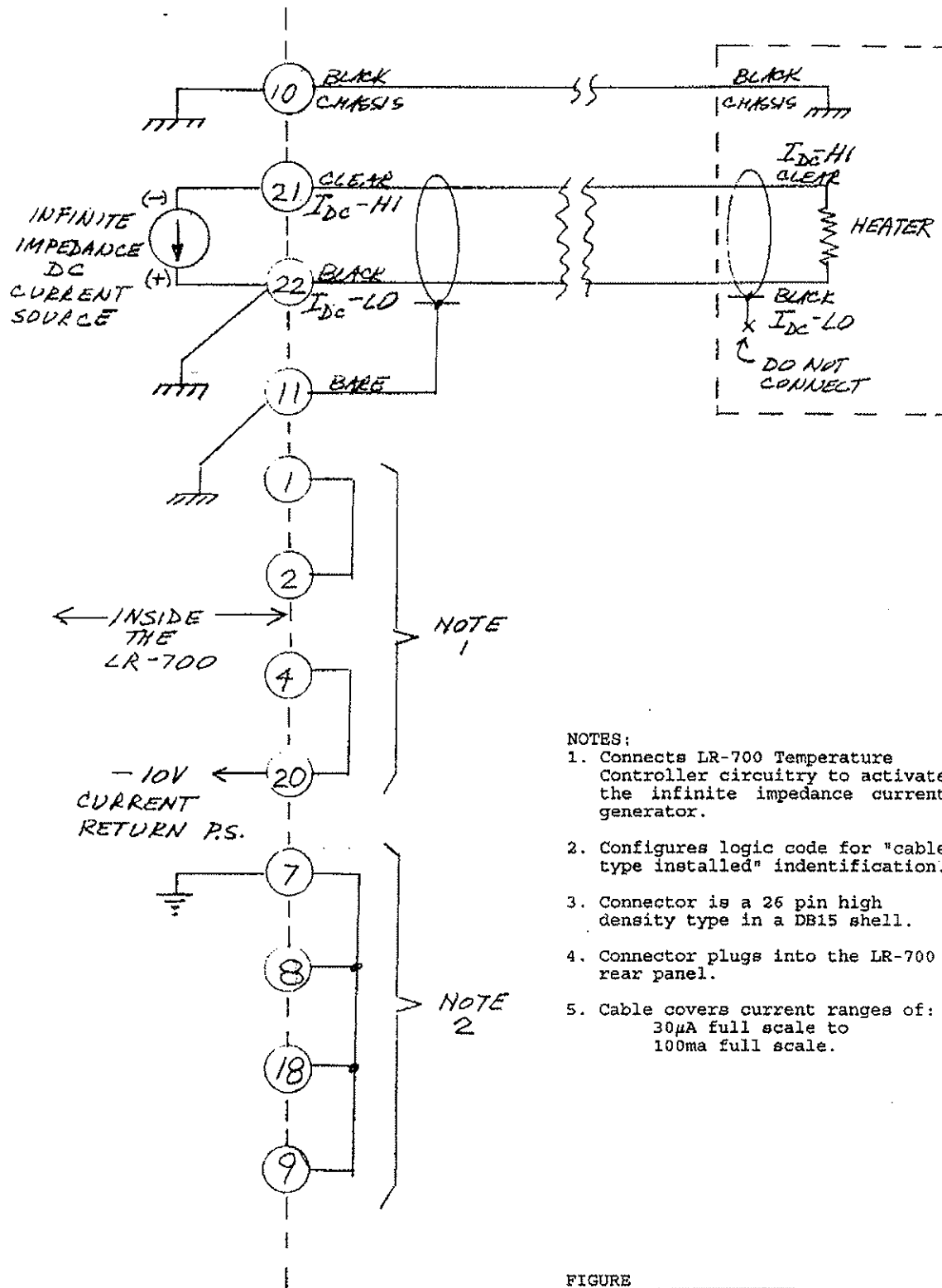
Final Notes

Please keep in mind that you now have your settings for the tuned system. If you change range or go to a $10\Delta R$ mode, you will, in effect, change the gain by a factor of 10 and you should adjust your gain setting accordingly. Changing excitation settings from 20mV down to 2mV does not change any gains and you need not adjust the gain setting.

At lower and lower excitations or at high sensor resistors, you may get Johnson noise in the sensor. You need to roll off this effect in a low pass filter because it is not actual temperature fluctuations. You can use the noise filter setting to reduce the effect of these and Johnson noise fluctuations.

Please note: You must make sure that the noise filter setting is quicker than the TTC setting. For example, if the TTC setting is set to 2 sec, the noise filter should be well below 2 sec, i.e., or .3 sec, or .1 sec.

STANDARD HEATER CABLE



- NOTES:
1. Connects LR-700 Temperature Controller circuitry to activate the infinite impedance current generator.
 2. Configures logic code for "cable type installed" identification.
 3. Connector is a 26 pin high density type in a DB15 shell.
 4. Connector plugs into the LR-700 rear panel.
 5. Cable covers current ranges of:
30 μ A full scale to
100ma full scale.

FIGURE _____

STANDARD HEATER CABLE,
TEMPERATURE CONTROLLER OUTPUT

Figure 3.13

LOW POWER CABLE

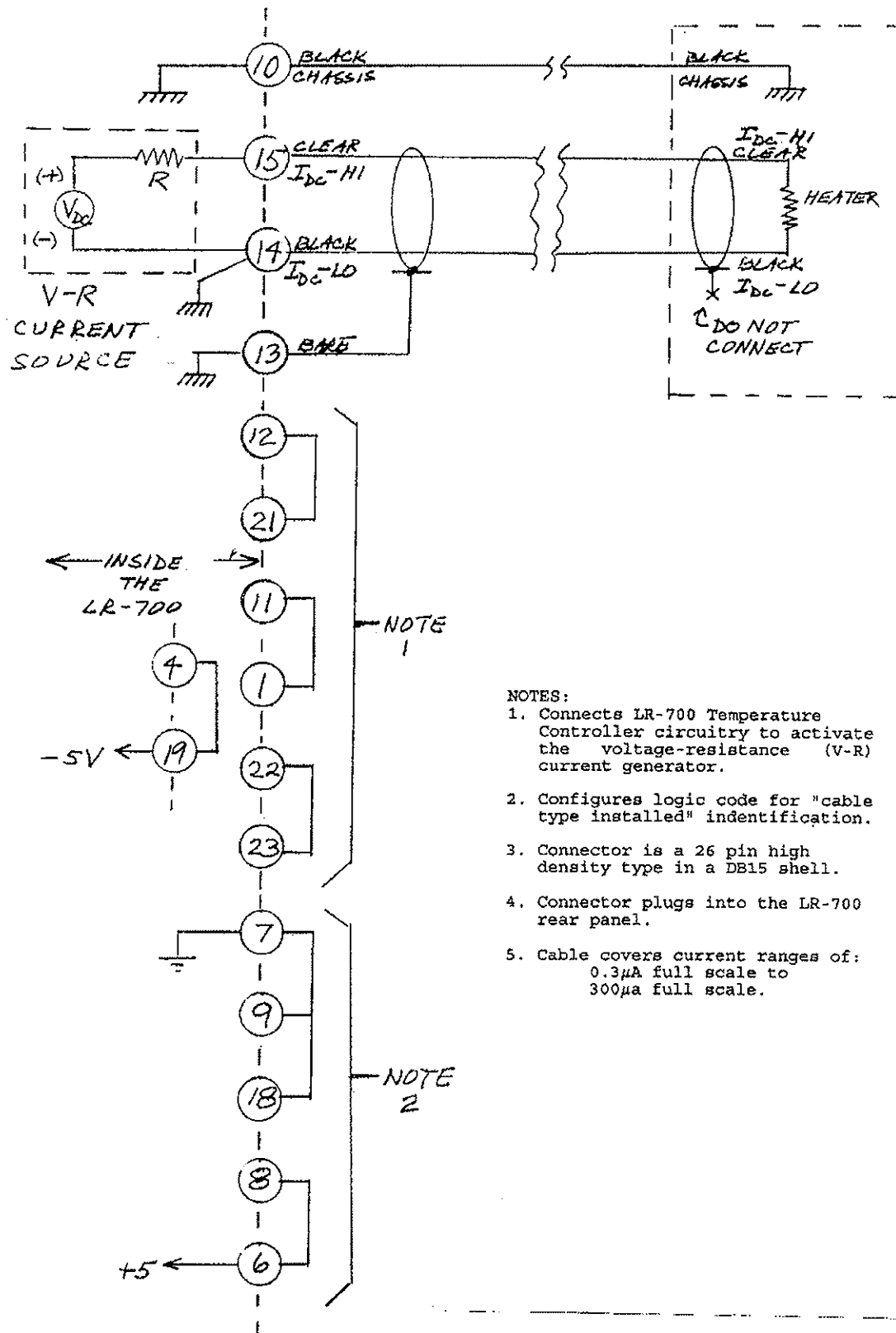


Figure 3.14

OVERVIEW OF LR-730 FEATURES

The LR-730 series of Power Boosters are designed to be used with the LR-750 AC Resistance Bridge along with its Internal Temperature Controller Option (LR-750-TC). The LR-750-TC can deliver DC currents in the range of micro amps up to 100 milliamps full scale with a compliance voltage of -10 volts DC maximum. With the LR-730 Power Boosters, the heater power deliverable by the Internal Temperature Controller is extended to 300 milliamps for the 15 watt version, 1 amp for the 50 watt version and to 3 amps for the 150 watt version. The compliance voltage for the LR-730 series is increased to -50 volts DC.

The LR-730 unit is supplied in its own enclosure and has its own switch mode power supply in the enclosure. The power supply can accept line voltages in the range of 85 to 264 volts AC 47-63 Hertz.

Cables provided with the instrument are a power cable suitable for the country of destination, an interconnect cable that connects the LR-730 Unit to the Temperature Controller connector of the LR-750 Bridge, and a high power heater cable that connects the LR-730 Unit to the heater resistor.

The unit has one control, a switch on the front panel, that turns on the power supply inside the LR-730 unit. The LR-730 is safety interlocked allowing it only to deliver power when it is connected to an LR-750 Bridge and a valid heater cable, which activate an internal relay that makes power available to the power drivers in the unit. All current ranges for the temperature control when using the LR-730 are controlled by the LR-750 Bridge. Therefore, any examples in this manual, or referred to in the LR-750 manual, are referring to setting of parameters in the LR-750 Unit. This includes setting parameters over the IEEE-488 or the RS-232 Interface of the bridge as well as the front panel keyboard.

CONNECTING THE LR-730 UNIT

Figure 1 shows a diagram of the connections made from the LR-730 Unit to the unit to the LR-750 Bridge. These connections should be made while both units have their power switches turned off, and even more preferably with the AC power cords disconnected. The connectors have small screws to firmly attach connectors so that they can not come out during normal operation. These should be employed so that the connections do not get broken while heavy currents are flowing between the instruments. And, so for the same reason, the

high power heater connector should also be attached with its screws so that, that connector can not inadvertently disconnect during operation.

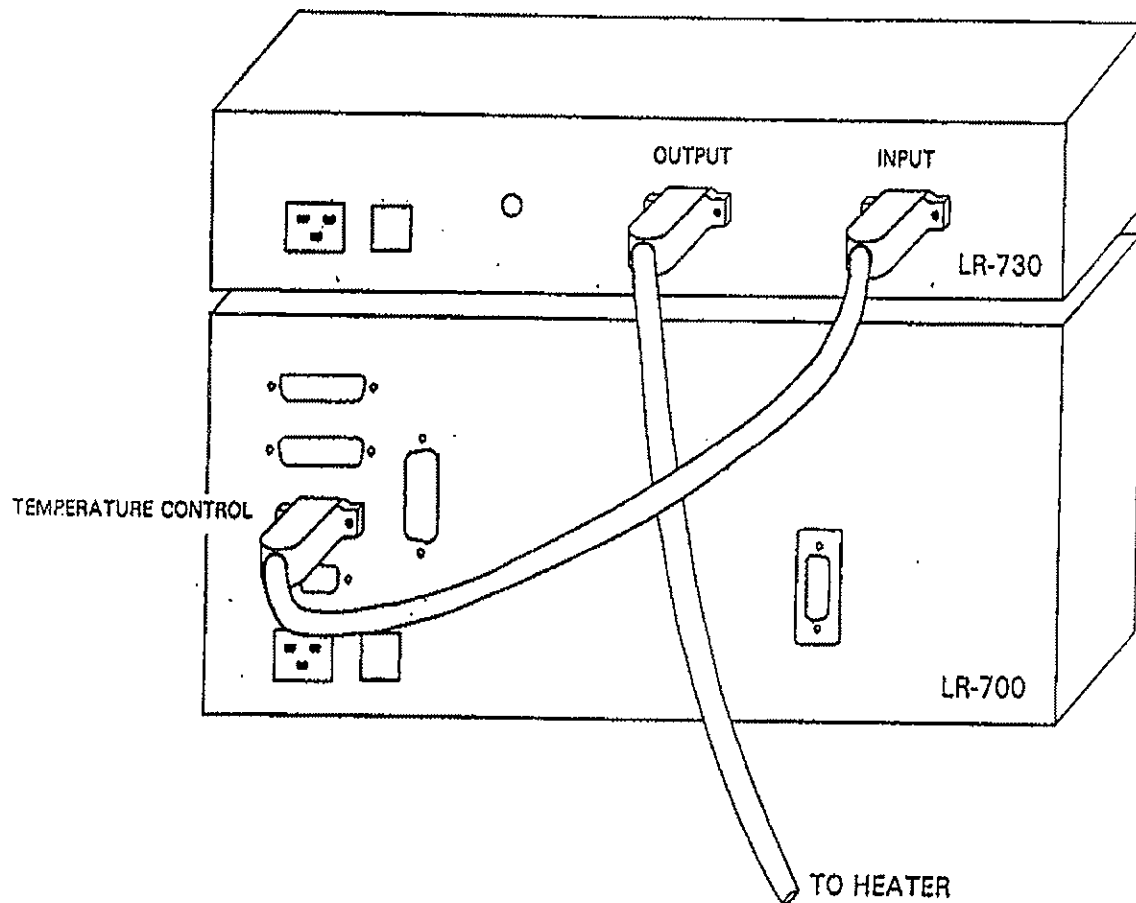


Figure 3.15

LR-730 HEATER CONNECTIONS

Figure 2 shows the high power heater cable output from the LR-730 connecting to the high power heater. Please note that the internal power supply will be inhibited if the heater connector is not connected with this high power enable short between pins number 8 and 15. An important note: The heater hot line (pins number 5, 6 and 13) has a compliance voltage between 0 and -50 volts DC. It is important that this line does not short out to other signals or lines in your cryostat, due to the 50 volt differential it could have to ground. Note that no damage will be done to the LR-730 unit itself if this line is shorted continuously to ground and the unit continuously delivers its full rated output. For example, the 300 milliamps on the 15 watt version or even up to 3 amps full scale on the 150 watt version.

LR-730 HIGH POWER HEATER CABLE

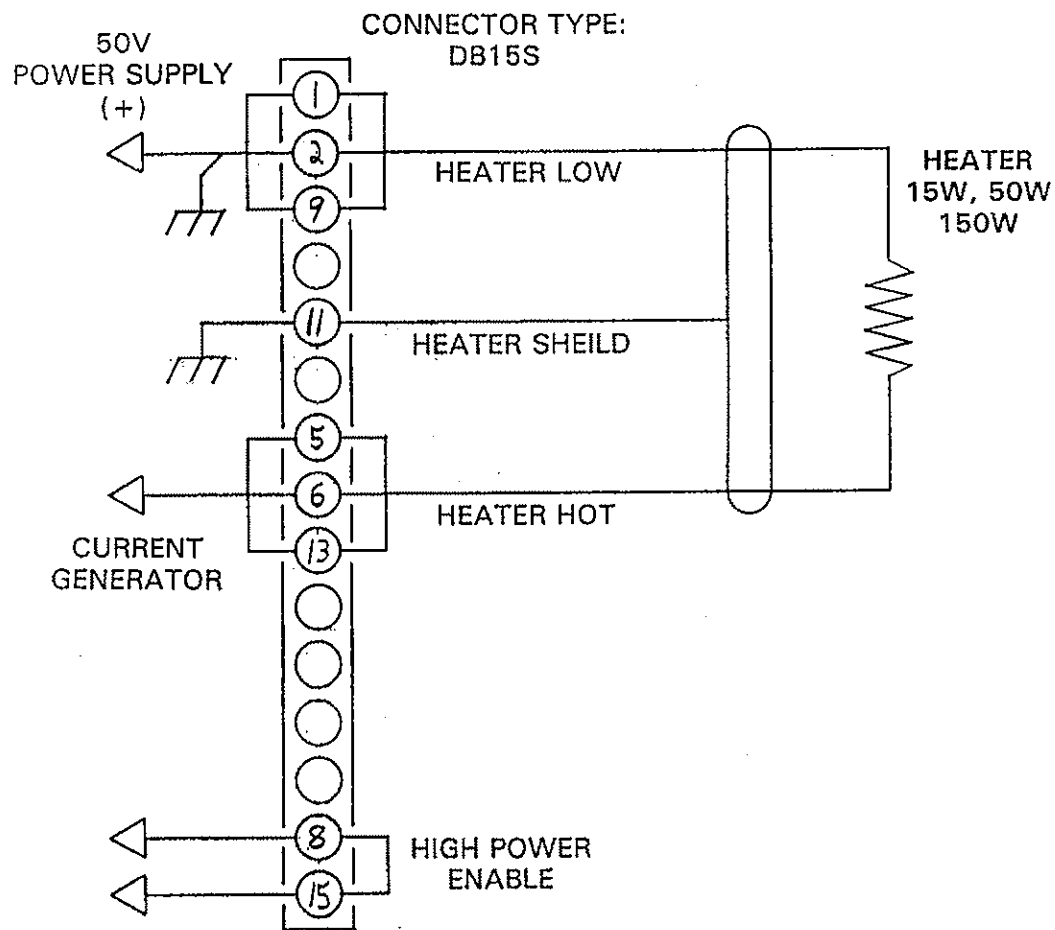


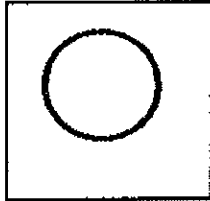
Figure 3.16

Notes:

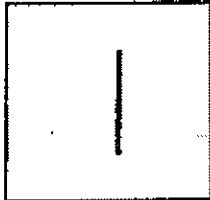
1. Unnumbered pins have no connections.
2. Cable covers current ranges of:
 - 30 μ A full scale to
 - 300mA full scale (15W),
 - 1A full scale (50W),
 - 3A full scale (150W).
3. Heater hot compliance voltage from:
 - 0V to -50V

CHAPTER 4 DEFINITIONS & SPECIFICATIONS

SYMBOL DEFINITIONS



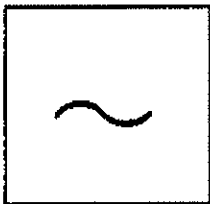
OFF (SUPPLY)



ON (SUPPLY)



CAUTION (Refer to the accompanying documents)
All inputs are $\pm 5V$, $\pm 15V$, or $\pm 50V$ to chassis.
Please refer to Table 4-1 below.



ALTERNATING CURRENT
100-115VAC 230VAC
50/60Hz or 50Hz
90VA MAX 90VA MAX

TABLE 4-1

<u>TERMINAL</u>	<u>MAXIMUM VOLTAGE TO CHASSIS</u>
PREAMP MONITOR	± 15 VOLTS
TUNED AMP MONITOR	± 15 VOLTS
ΔR MONITOR	± 15 VOLTS
J1	± 15 VOLTS
J2	± 15 VOLTS
REFERENCE MONITOR	± 15 VOLTS
SENSOR	± 5 VOLTS
TEMPERATURE CONTROLLER	± 50 VOLTS
RS 232	± 15 VOLTS
IEEE-488	± 15 VOLTS
PRINTER	+ 5 VOLTS
PERIPHERAL	+ 5 VOLTS

BLOCK DIAGRAM DESCRIPTION

GENERAL DESCRIPTION

The LR-750 uses a four-wire (four lead) AC technique to measure the sensor. The four-wire technique eliminates errors that might be caused by lead resistance or sensor contact resistance. The AC technique eliminates thermal EMF DC voltage errors. AC technique allows for voltage resolution down to the sub-nanovolt region. This technique outperforms DC bridges by up to two orders of magnitude in voltage sensitivity.

Two leads are used to apply a fixed amplitude AC current to the sensor resistor. Two additional leads send the resultant sensor voltage back to the bridge to be balanced against an equal and opposite AC voltage. This gives a continuous null signal at the front end amplifier of the bridge's Lock-Balance™ circuitry. Knowing the value of the equal and opposite AC voltage gives the value of the sensor resistance.

DETAILED DESCRIPTION

As shown in Figure 4.1, the LR-750 Block Diagram, a fixed magnitude in-phase 16 Hertz sinewave AC current is applied to the sensor resistor. The resultant AC in-phase and quadrature-phase voltage across the sensor impedance (sensor resistor + unwanted parallel capacitance + unwanted series inductance) is balanced against an equal and opposite voltage generated by the balancing transformer secondary. The resultant AC null signal is applied to the input of the preamp.

This null signal is amplified by the preamp and then by the tuned amp and delivered to the ΔR (in-phase) and ΔX (quadrature-phase) phase sensitive detectors (PSD). The resultant individual ΔR and ΔX null PSD DC output voltages are applied to high gain ΔR and ΔX DC amplifiers. These DC amplifiers, gain $>10^6$, output DC voltages that drive the ΔR DC-input-to-AC-output converter. This converter generates ΔR AC signal exactly proportional in magnitude to their input DC voltages.

Then the ΔR and ΔX AC high level signals, combined with fixed input high level RSET signal, are applied to the primary of the balancing transformer. The transformer's stepped down secondary yields a combined low level AC signal with components of ΔR , ΔX , and RSET that is equal and opposite in magnitude to the sensor impedance voltage mentioned above. This yields ideally an exactly zero AC null signal at the input of the preamp, thus closing and balancing the feedback loop.

The output of the ΔR and ΔX DC amplifiers mentioned above are DC voltages directly proportional to ΔR in-phase and ΔX quadrature phase values associated with the sensor. The microcontroller, already knowing the fixed RSET value, then calculates $R = \Delta R + RSET$ from the ΔR digital signal received from the DC amplifier driven analog to digital converters.

Sensor parallel capacitance might be a problem with large sensor resistors so the quadrature signal for the 20K, 200K, and 2M Ω ranges is balanced differently than on the other lower ranges. Figure 4.2, Block Diagram Addendum 1, shows the method of applying this quadrature feedback. Instead of applying quadrature through the balancing transformer, the ΔX signal is applied to the sensor impedance from a variable magnitude AC current generator in parallel with the fixed amplitude current generator mentioned above. This technique compensates for large capacitance (low ohmic value capacitive reactance) paralleling the sensor resistance. Sensor cable capacitance is found in both the current excitation cable and the voltage sensing cable.

Quadrature signal current feedback mode occurs when the sensor resistor value is between 5% and 100% of the bridges' three upper ranges. Quadrature current feedback defaults to the balancing transformer feedback regular method shown in the main block diagram when the sensor resistor value is at the low end (between 0% and 5% of full scale) of these upper ranges.

LR-750 BLOCK DIAGRAM

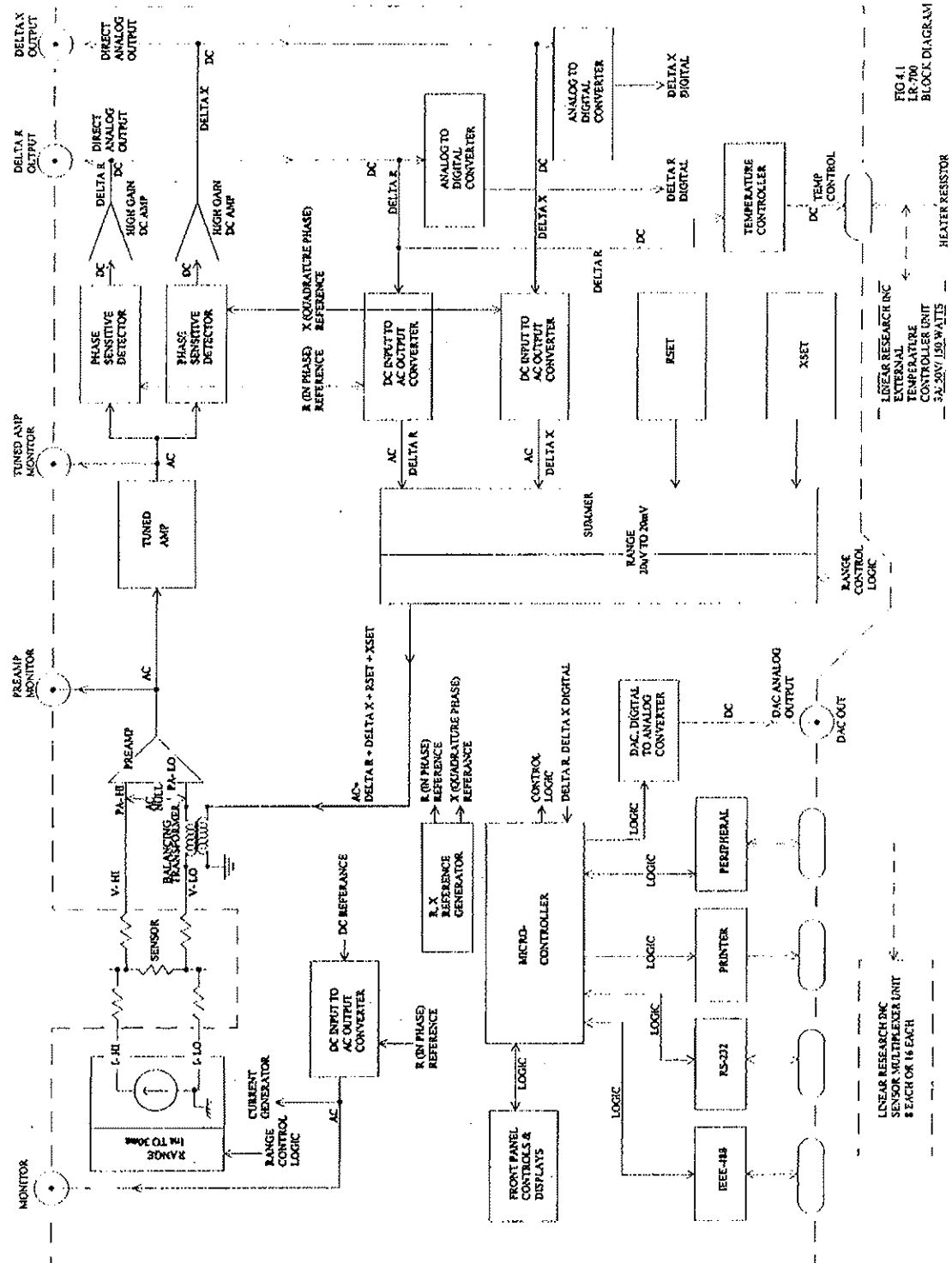


Figure 4.1

CHAPTER 4 DEFINITIONS AND SPECIFICATIONS
BLOCK DIAGRAM

LR-750 BLOCK DIAGRAM ADDENDUM 1

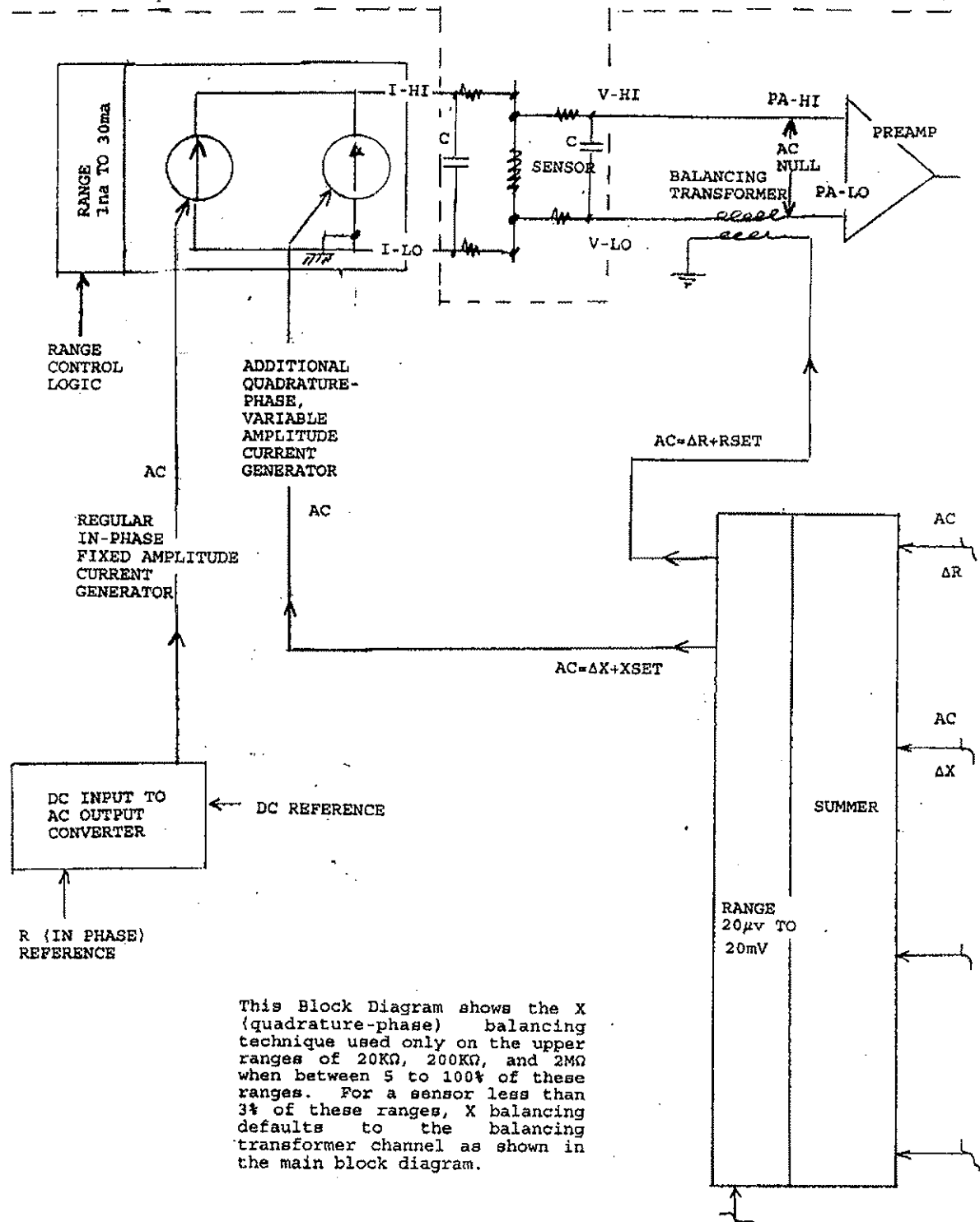
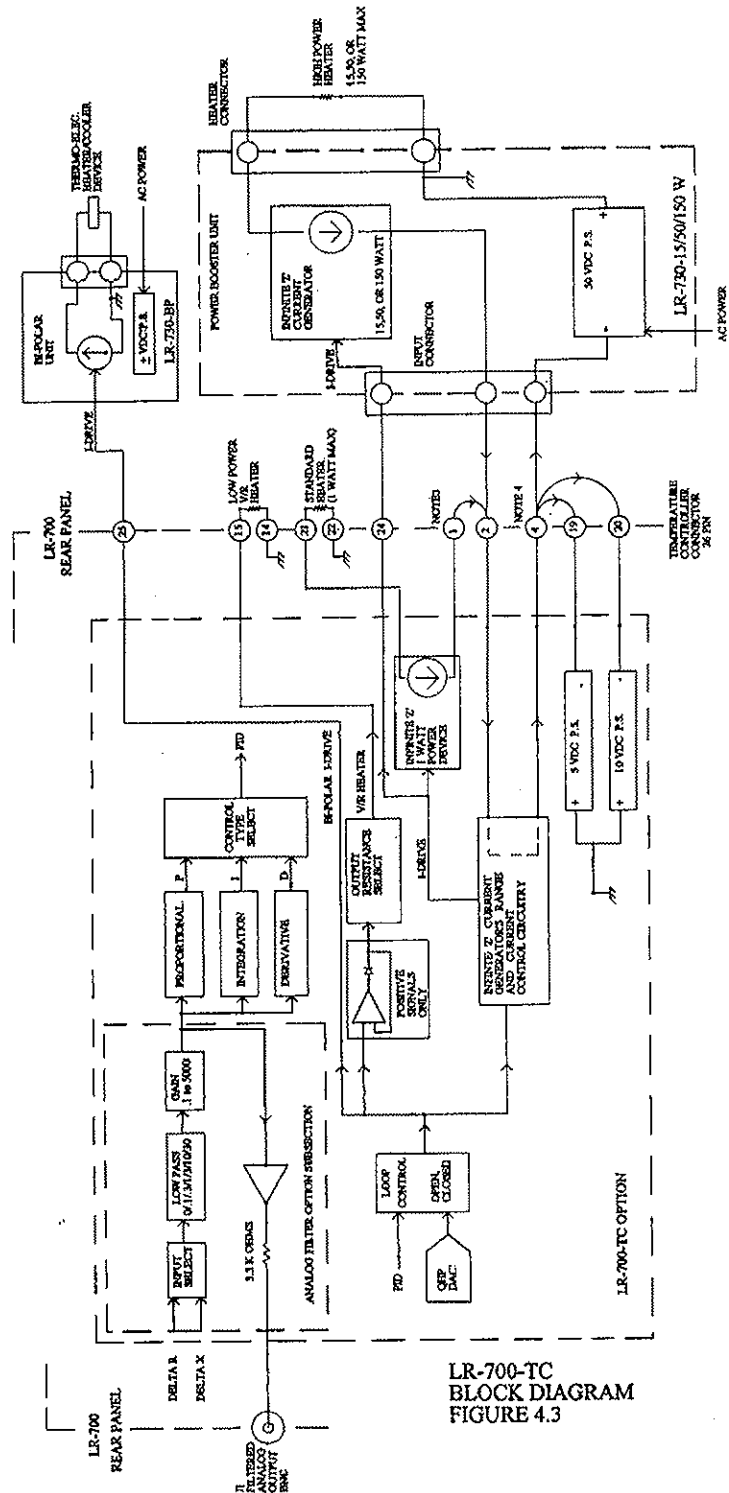


Figure 4.2

LR-750-TC BLOCK DIAGRAM



LR-700-TC
BLOCK DIAGRAM
FIGURE 4.3

Figure 4.3

SPECIFICATIONS

RANGE

2 Ω , 20 Ω , 200 Ω , 2K Ω , 20K Ω , 200K Ω , 2M Ω .
Resistance (R) in ohms.

EXCITATION VOLTAGE

6 μ V, 20 μ V, 60 μ V, 200 μ V, 600 μ V, 2mV, 6mV RMS at full scale resistance. Bridge delivers constant amplitude AC current to the sensor.

EXCITATION FREQUENCY

15.9 Hz sine wave. Crystal controlled frequency for high stability.

DISPLAY

2 lines of 16 characters each. Displays any two of the following simultaneously: R, Δ R, 10 Δ R, R-set. Bright clear 5 $\frac{1}{2}$ digit ($\pm$ 199999 counts) LED 5x7 dot matrix display. Kiloohms, ohms, and milliohms are indicated in the display.

READING RATE

Analog-digital conversion made every 200ms. Display is updated every 200m sec for most filter settings.

OFFSET, RSET

User friendly, random entry of the 5 $\frac{1}{2}$ digits in either R-set may be made at the front panel or by the computer interface. Can be set to 1 part in 200,000. R-set may also be directly set to zero or to Rx. When set to Rx this yields a Δ R=0 display reading.

LOCK-BALANCE™ AND MICROCONTROLLER

Uses Linear Research Inc.'s proprietary analog Lock-Balance™ lock-in circuitry with front end balancing of the sensor's in-phase and quadrature AC signals.

Lock-Balance™ circuitry assures the highest resolution, lowest noise, and greatest common mode rejection of any commercially available AC resistance measuring bridge or instrument.

The LR-750's careful design incorporates both nano-volt analog circuitry and the latest microcontroller based circuitry.

COMPUTER INTERFACES AVAILABLE

IEEE-488, RS-232, printer output.

LINEARITY

1 part in 10,000. Most ranges when in Δ R mode with Rset = Rx.

ACCURACY

Typically, $\pm 0.02\%$ (most ranges).

SUPPLY

100-115VAC	230VAC ($\pm 10\%$)
50/60Hz	or 50Hz
90VA MAX	90VA MAX

LOW NOISE & SENSOR POWER

Superior low noise performance is achieved by careful preamp design. The bridge preamp input noise of $4.7\text{nV RMS}/\sqrt{\text{Hz}}$ (BW = 1 Hz).

For room temperature sensors greater than 100Ω at low level excitations, resolution is limited only by the thermal noise in the sensor. For sensors at low temperatures with values above xxx, resolution will improve due to lower sensor thermal noise since sensor noise drops by the square root of temperature.

A $1\text{k}\Omega$ room temperature sensor can be measured to within $30\text{m}\Omega$ RMS(30ppm) resistance resolution using only 10-12 watts of excitation power (with better resolution at lower sensor temperatures).

A $1\text{M}\Omega$ room temperature sensor can be measured to within 100Ω RMS(100ppm) resistance resolution using only 10-14 watts of excitation power (with better resolution at lower sensor temperatures).

The above three examples were measured at the analog output.

TEMPERATURE STABILITY

Less than $30\text{ppm}/^\circ\text{C}$ in the ΔR mode where $R\text{-SET} = R_x$. This low temperature coefficient is useful when the bridge drives a temperature controller holding a constant payload temperature.

COMMON MODE REJECTION RATIO

On the lower resistance ranges, common mode line or contact resistance rejection is 160 db.

SENSOR CONNECTOR & CABLE

Signals are: I-High, I-Low, driven I-Shield,
V-High, V-Low, driven V-Shield.

Split V-I cable minimizes crosstalk between V and I lines. Extra connector pins and jumpers allow for external DC current biasing of the sensor or use of a remote balancing transformer for SQUID applications.

DRIFT (24 HOUR TEST)

Under typical laboratory ambient temperature conditions where $R_{SET}=R$, $10\Delta R$ drift is typically better than 1 part in 20,000 full scale for a 12 hour period.

DIGITAL FILTER

Every 200ms the filter computes an arithmetic average of the latest string of 200ms A/D conversions giving equal weight to each conversion. A 3 second filter setting has a string length of 15. Every 200ms the display is updated with the new arithmetic average on most filters.

RESOLUTION

ANALOG RESOLUTION TABLE, Ohms RMS								
		SENSOR VOLTAGE						
		3 μ V	10 μ V	30 μ V	100 μ V	300 μ V	1mV	3mV
R E S I S T A N C E ohms	1	480 μ	160 μ	48 μ	16 μ	4.8 μ	1.6 μ	na
	10	4.8m	1.6m	480 μ	160 μ	48 μ	16 μ	4.8 μ
	100	49m*	16m	4.8m	1.6m	480 μ	160 μ	48 μ
	1K	600m*	200m*	48m	16m	4.8m	1.6m	480 μ
	10K	16*	4.8*	1.6*	480m*	160m*	48m*	16m*
	100K	480*	160*	48*	16*	4.8*	1.6*	480m*
	1M	16K*	4.8K*	1.6K*	480*	160*	48*	16*
Value are in ohms where: μ = micro ohms m = milli ohms K = kilo ohms M = mega ohms Value followed by "*" are limited by the Johnson noise of the sensor at room temperature and will improve when measuring at low temperatures. These measurements were taken at the display using the 3 second digital filtering setting with the sensor at room temperature.								

CHAPTER 4 DEFINITIONS AND SPECIFICATIONS
SPECIFICATIONS

ANALOG RESOLUTION TABLE, ppm RMS								
		SENSOR VOLTAGE						
		3 μ V	10 μ V	30 μ V	100 μ V	300 μ V	1mV	3mV
R E S I S T A N C E ohms	1	480	160	48	16	5	2	na
	10	480	160	48	16	5	2	1
	100	490*	160	48	16	5	2	1
	1K	600*	200*	48	16	5	2	1
	10K	1600*	480*	160*	48*	16*	5*	1*
	100K	4800*	1600*	480*	160*	48*	16*	5*
	1M	16000*	4800*	1600*	480*	160*	48*	16*
Value are in ppm RMS where: ppm = μ = micro ohms m = milli ohms K = kilo ohms M = mega ohms Value followed by "*" are limited by the Johnson noise of the sensor at room temperature and will improve when measuring at low temperatures. These measurements were taken at the display using the 3 second digital filtering setting with the sensor at room temperature.								

CHAPTER 4 DEFINITIONS AND SPECIFICATIONS
SPECIFICATIONS

SENSOR EXCITATION CURRENT TABLE

		100% EXCITATION VOLTAGE, RMS						
		6	20V	60V	200V	600V	2mV	6mV
R A N G E ohms	2	3a	10a	30a	100a	300a	1ma	**
	20	300na	1a	3a	10a	30a	100a	300a
	200	30na	100na	300na	1a	3a	10a	30a
	2K	3na	10na	30na	100na	300na	1a	3a
	20K	300pa	1na	3na	10na	30na	100na	300na
	200K	30pa	100pa	300pa	1na	3na	10na	30na
	2M	3pa	10pa	30pa	100pa	300pa	1na	3na
Notes: For any particular range and excitation voltage selected, the actual value of excitation voltage appearing across the sensor is directly proportional to the magnitude in ohms of the sensor resistor. **Indicates an unavailable excitation current.								

SENSOR CURRENT AND POWER

		SENSOR VOLTAGE (AT MID-SCALE)						
		3 μ V	10 μ V	30 μ V	100 μ V	200 μ V	1mV	3mV
E X C I T A T I O N C U R R E N T	3pA	1M Ω -17						
	10pA		1M Ω -16					
	30pA	100K Ω -16		1M Ω -15				
	100pA		100K Ω -15		1M Ω -14			
	300pA	10K Ω -15		100K Ω -14		1M Ω -13		
	1na		10K Ω -14		100K Ω -13		1M Ω -12	
	3na	1K Ω -14		10K Ω -13		100K Ω -12		1M Ω -11
	10na		1K Ω -13		1K Ω -12		100K Ω -11	
	30na	100 Ω -13		1K Ω -12		10K Ω -11		100K Ω -10
	100na		100 Ω -12		1K Ω -11		10K Ω -10	
	300na	10 Ω -12		100 Ω -11		1K Ω -10		1K Ω -9
	1 μ A		10 Ω -11		100 Ω -10		1K Ω -9	
	3 μ A	1 Ω -11		10 Ω -10		100 Ω -9		1K Ω -8
	10 μ A		1 Ω -10		10 Ω -9		100 Ω -8	
	30 μ A			1 Ω -9		10 Ω -8		100 Ω -7
	100 μ A				1 Ω -8		10 Ω -7	
	300 μ A					1 Ω -7		10 Ω -6
	1mA						1 Ω -6	
Sensor power above indicated by the power of 10 exponent (-7 = 10 ⁻⁷) Reading Row 3, Column 3: Excitation Current = 10na Sensor Voltage = 100 μ V (Excitation = 200 μ V, Range = 20K Ω) Sensor Resistor = 10K Ω Sensor Power = 10 ⁻¹² watts								

DIRECT ANALOG OUTPUTS

A rear panel BNC (± 10 VDC span) gives a voltage equal to ΔR or $10\Delta R$. This can be used to drive a chart recorder.

TEMPERATURE CONTROL

When used with this unit's Internal Temperature Controller option, the temperature control stability achievable is limited only by the transfer characteristics (R-T) of the sensor, the low-noise of the LR-750, and the thermal characteristics of the payload (heater, heater block, sensor, heat leaks through lead wires, etc).

LEAD RESISTANCE INDUCED ERRORS

MAXIMUM LEAD RESISTANCE

RANGE	MAXIMUM LEAD RESISTANCE (Each of the Four Leads) LISTED EXCITATION CURRENT	
2m Ω	100 Ω /30ma	300 Ω /10ma
20m Ω	300 Ω /10ma	1K Ω /3ma
0.2 Ω	300 Ω /10ma	1K Ω /3ma
2 Ω	330 Ω /10ma	1K Ω /3ma
20 Ω	3K Ω /1ma	10K Ω /.3ma
200 Ω	10K Ω /1ma	

Limit is I-High compliance voltage clipping at approx ± 10 VDC. Above values are for linear operation but with possible higher errors than are listed in the lead resistance induced error chart.

SPEED OF BALANCE, SETTLING TIME

For sensor or R-set step changes, the direct analog output settling time is independent of the digital filter setting.

DIRECT ANALOG SETTling

For 100% full scale step changes:

1p 200,000 - 5 sec

1p 20,000 - 4 sec

1p 2,000 - 3.3 sec

For 50% full scale step changes:

1p 200,000 - 3 sec

DIGITAL FILTER SETTTLING

The digital filter responds in a ramp function to step changes of its input. The filter ramp time is equal to the digital filter time selected. A 3 second digital filter alone settles completely to 1 part in 200,000 counts in exactly 3 seconds, unlike an analog 3 second R-C filter which takes 13 time constants or 42 seconds for similar settling.

Since the digital filter is driven by the direct analog output, the display settling time is the sum of the analog and digital filter settling times. Thus, a 50% FS step change in the 3 sec filter mode settles to 1p 200,000 FS in exactly (3 sec + 3 sec) = 6 seconds.

LEAD CAPACITANCE

The units sine wave excitation current allows for tolerance of large lead capacitance across the sensor or to ground.

MAXIMUM SENSOR CAPACITANCE FOR LINEAR OPERATION

RANGE	MAXIMUM CAPACITANCE
2Ω-200Ω	5μF
2KΩ	.5μF
20KΩ	.5μF
200KΩ	.05μF
2MΩ	.005μF

Resistance errors will occur at these large capacitance values due to the capacitive dissipation constant paralleling the sensor resistor. Typically film capacitors have parallel resistance of from $100X_c$ to $1000X_c$.

X_c = Capacitive reactance at 15.9 Hz.

For best performance keep line to chassis and line to line capacitance to less than .01μf on the 2mΩ through 200KΩ ranges, and .001μf on the 2MΩ range.

PHYSICAL SIZES

Dimensions: 19 inch rack mountable.

7 in (178mm) high, 17 in (432mm) wide and 17 in (432mm) deep.

Net weight: 30 lbs (14 kg).

Gross Weight: 36 lbs (17 kg).

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

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TEMPERATURE CONTROL ACHIEVABLE

Temperature control can approach the resolution and stability of the LR-750's ability to measure the sensor.

TEMPERATURE RANGE

MilliKelvin to above 4 Kelvin with the included 1 watt output power. To 300 Kelvin with 15 or 50 watt booster units. Greater than 300 Kelvin with 150 watt booster unit. Room temperature control of thermo-electric modules with the bipolar booster unit.

ANALOG CIRCUITRY

Digital management of a completely analog signal path is used giving almost infinite resolution and elimination of least count digital hunting or digital noise as found in completely digital systems. The digital management only occurs when settings are changed, not in normal continuous operation.

LOW HEATER NOISE

Output power is generated by a linear current source designed to minimize or eliminate radio frequency and digital noise.

GROUNDING HEATER DRIVE

One side of the heater is driven by the current source. The other side of the heater is returned to chassis ground inside the LR-750. This eliminates power supply noise and ripple voltages from being coupled into the cryostat and heater area. Ungrounded heater temperature controllers have disadvantages such as: requiring a power supply filter unit to eliminate power supply ripple and noise, and/or running the risk of having the power supply output voltage accidentally short to chassis or other components with resultant permanent component failures.

EASY INPUT OF PARAMETERS

The unit implements Proportional Integral, and Derivative (PID) functions where the LR-750 software intelligence selects the required P and D settings from a user inputted Thermal Time Constant (TTC) value. Thus the user has only to program a Set Resistance (set temperature), then enter a TTC value, a proportional Gain value, and an output current range to stabilize the thermal system. Alternatively the P & D parameters may be directly and independently selected.

COMPUTER OPERATION

All settings can be made through either the LR-750's front panel controls or the IEEE-488 and RS-232 interfaces.

TWO CURRENT GENERATOR TYPES

Two output current sources are included.

FOR VERSATILITY AND HIGH POWER:

An analog circuit driven infinite impedance (infinite Z) current source with full scale outputs from $30\mu\text{A}$ to 100mA DC in 1-3-10 steps. Outputs of 300mA , 1A , and 3A DC with compliance voltages of 50 volts are available from the LRI external Power Booster Units. With this infinite Z current source, the LR-750-TC can deliver 0.1 amps at -10 volts into a 100Ω heater resistor for 1 watt maximum power.

FOR ULTRA LOW POWER AND NOISE

A voltage resistance (V-R) current source comprising an analog voltage op-amp with selectable series output resistors. Resistance can be selected from $33\text{K}\Omega$ to $33\text{M}\Omega$ in 1-3-10 steps. For example, with this V-R current source with $10\text{M}\Omega$ selected and a heater of 300Ω , full scale current is $1\mu\text{A}$, and power is 300 picowatts full scale, ideal for milliKelvin work.

With both types of current sources, output current self-limits and can be delivered indefinitely into a short circuit load.

CONTROL WHILE MEASURING

A hold feature allows the LR-750-TC to "hold" the input voltage at zero, and thus the heater output current constant, while the LR-750 momentarily switches, via an LRI Multiplexer, to another sensor to make a measurement. LRI makes 8 sensor and 16 sensor Multiplexers, see LRI's LR-720 Multiplexer series spec sheet.

COMPLIANCE VOLTAGES

Infinite Z current generator's compliance voltage is -10 VDC when driving heater loads. It is -5 VDC when driving sensor loads to protect the LR-750's AC current generator's compliance voltage is +10 VDC.

DISPLAY

An 8 bit analog to digital converter monitors the unit's output current. This indicates power delivered to the heater. The instantaneous output current can be displayed using the entire lower display of the LR-750 as a horizontal bar graph. Using this display, the user can quickly see if more filtering is needed to reduce noise induced output current source lock-up.

QUIESCENT HEATER CURRENT

This QHC feature uses a lpp4096 digital to analog converter to generate a quiescent heater current. Quiescent output current is used in the open-loop mode to force a fixed amount of power into the heater or for semi-precision DC biasing of a sensor. During the closed-loop mode, QHC is normally set to zero and the integral (I) circuitry delivers the required long term average heater current.

SELECTION OF TC INPUT SIGNALS

The temperature may be controlled by selecting either the ΔR or $10\Delta R$ signal from the LR-750 as the TC's input.

LOW PASS FILTERING/ANALOG OUTPUT

The LR-750-TC option includes low pass analog filter circuitry to reduce amplified Johnson noise present in the ΔR input signal. Especially helpful when sensor resistors are measured on the LR-750's very low excitation ranges of 20 and 60 microvolts. This stops the PID circuitry and the output current source from locking-up on sensor Johnson noise. Low pass filter values up to 10 seconds, in 1-2-5-10 steps may be selected. The LR-750-TC option incorporates an additional rear panel BNC output, driven directly after the low pass filter and proportional gain circuits, to give an analog output signal for non-TC applications. Use this analog output with its up to 10 second analog filter time constant to drive a strip chart recorder for measuring very small ΔR changes. This is an improvement over the LR-750's regular direct ΔR analog output which is unfiltered and can't be internally amplified.

OUTPUT HEATER POWER & CURRENT

The LR-750-TC option itself can deliver Picowatts to 1 watt full scale output power.

POWER OUTPUT TO 50 WATTS

LRI can supply power booster units driven by the LR-750-TC. Output power can be 15, 50, or 150 Watts, or 3 amps bi-polar. These are designed to directly connect to the TC option via a single dedicated LR-750 rear panel connector. Booster units may be purchased separately at any time and simply connected to the LR-750 in the field. The TC option, however, must be installed for these units to work. Thus, the user need only purchase what he/she needs now and can upgrade later for more power. Consult the LR-730 Power Booster spec sheets for more details.

POWER BOOSTER FUNCTION ALLOCATION

The output current range selection and PID circuitry reside in the LR-750-TC Option in the LR-750 main frame. The power generation, power supplies, and heat sink circuitry reside in the power booster units.

THERMAL TIME CONSTANTS

The LR-750-TC Temperature Controller will stabilize thermal systems with thermal time constants from 0.2 to 1000 seconds in 1-2-5-10 steps.

PROPORTIONAL (GAIN) FEATURE

The gain feature is adjustable from 0.1 to 5,000 in 1-2-5-10 steps.

INTEGRAL TIME CONSTANT FEATURE

The Integral (I) Feature gives near infinite gain at very low frequencies. This assures minimum long term temperature offset from the set temperature. I is settable from 0.2 to 1,000 seconds in 1-2-5-10 steps. Normally the software selects the required I value automatically from the user's inputted thermal time constant.

DERIVATIVE TIME CONSTANT FEATURE

The Derivative (D) feature mitigates the effect of continuously increasing "heat flow phase shift" for frequencies above the thermal time constant. It does this sufficiently to allow the proportional gain control to be increased considerably without oscillations. This gives oscillation free operation with fast response. D is settable from 0.067 to 300 seconds in 1-2-5-10 steps. Normally, the software selects the required D value automatically from the user's inputted Thermal Time Constant (TTC) value.

OTHER FEATURES

Polarity Control (+/-) to account for a loop gain inversion for a negative temperature coefficient sensor, etc.

Open Loop/Closed Loop Control

Heater On-Off Control

OPTIONAL FEATURES

FILTER MENU .2 SEC TO 30 MIN

Additional software allows the user to select any of twenty five different filter times varying from .2 sec to 30 min.

RS-232 INTERFACE

Control of the instrument as well as ability to read of the measurement parameters can be accomplished with simple string commands using a standard RS-232 interface.

SENSOR MULTIPLEXERS

Eight or sixteen sensor multiplexor units are available that can be used with the LR-750. Up to sixteen of these multiplexor units may be connected to one LR-750, therefore giving a total of 256 sensors. The sensor selected is controlled from the LR-750 and may be selected from the front panel or either computer interfaces. Multiplexers switch all four of the sensor lines, I-High, I-Low, V-High and V-Low.

DECLARATION OF CONFORMITY

Type of Equipment : AC Resistance Bridge

Model Name : LR-750 System

Model Number : LR-750 Unit
LR-720 Multiplexer
LR-730-50W Power Booster

Year of Manufacture : 2000

EC Directives to which
conformity is declared : Low Voltage Directive 73/23/EEC
EMC Directive 89/336/EEC

Standards to which
conformity is declared : LVD EN 61010-1: 1993 +A2: 1995
EMC EN 55011 : 1991
EN 50082-2: 1995

Manufacturer's Name : LINEAR RESEARCH INC.

Manufacturer's Address : 5231 CUSHMAN PLACE, SUITE 21
SAN DIEGO, CA 92110-3910 USA

Importer's Name : GVL Cryoengineering
Dr. George V. Lecomte GmbH
Aachener Strasse 89
D-52223 Stolberg
Federal Republic of Germany

We hereby declare that the products above conform to
the above mentioned Directives and Standards.

Richard C. Entenmann
President
Linear Research Inc.
5231 Cushman Place, Suite 21
San Diego, CA 92110-3910 USA

Date

CHAPTER 5 SAFETY AND SERVICE

SAFETY

EQUIPMENT INSTALLATION

- Mount the instrument in a standard electronic rack or place it on a sturdy laboratory bench.
- The room should be stable in humidity and temperature.
Ranges: Temperature range 0°C - 45°C
Humidity range 0% - 80%
- Place the instrument in a location that allows ventilation space of 2" on both sides and rear. No ventilation is required on top or bottom.
- The instrument should be connected to the mains by an approved power cord with protective earth conductor. Do not permanently attach the cord to the unit. The detachable rear panel inlet should be considered the main disconnect.
- The chassis is connected to the protective earth terminal. Therefore, the protective earth conductor must be used to make the connection to the mains protective earth terminal.
- If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

CAUTIONS**1. Do not open the LR-750 enclosure.**

Any voltage of 100 volts or more is dangerous. Powerline voltages from 100 to 240 volts AC, 50/60 Hertz are present, of course, inside the LR-750. By assembly design however, LRI has made every attempt to see that these power line voltages inside the LR-750 are covered and not exposed to direct human finger contact. There are no user serviceable components inside the LR-750, thus, there is no need to remove the LR-750 enclosure covers to gain access to the inside of the LR-750 for any reason.

Therefore, never remove any cover of the LR-750 to gain access to the inside of the LR-750 or try to repair the LR-750. Repair of the LR-750 can only be done at the Linear Research Inc. factory or by an authorized representative.

2. Do not short rear panel connector pins.

Rear panel multiple pin connectors labeled "SENSOR" and "PERIPHERAL", have accessible exposed male contact pins. These contact pins can be inadvertently shorted to each other or to chassis, by short circuiting through the metal hood, if the user is not careful when he tries to mate the connectors.

This shorting might result in permanent damage to the LR-750 if the LR-750 is turned on. Damage to the LR-750 caused by mating connector hood shorting is not covered by the LR-750 warranty. Therefore, always turn off the LR-750 front panel power switch before connecting or disconnecting the sensor connector or the peripheral connector.

3. Do not blow out the preamp.

Permanent damage to the preamp might result if the sensor cable (V-HI, V-LO) or driven shields (I-Shield, V-Shield) are subject to a momentary voltage greater than ± 10 volts DC differential (lead to lead or lead to chassis). This could be caused by brushing the sensor leads against an electrically charged object (a human body can hold a large electrostatic charge). Be sure to touch the LR-750 chassis before touching the sensor cable when first working with the LR-750 sensor cable assembly to discharge your electrostatic body charge to chassis.

Inadvertently connecting the sensor leads to an external voltage source such as an ungrounded chassis switch box that might have a large voltage potential different than the LR-750 chassis. or unsoldering or disconnecting the leads to a mutual inductance transformer, primary or secondary, when the LR-750 is turned on, or, applying a DC bias voltage to the sensor in a manner different than that described in the sensor section and shown in figure 3.5, could permanently damage the preamp.

4. Do not allow objects to enter into vent holes.

The LR-750 has rows of air vent cooling holes along the left and right sides of the LR-750 enclosure. Be careful not to stick metal objects into these holes or allow loose wires, hook-up wires, LR-750 sensor cable ends, etc. to enter the LR-750 through those holes and possibly short out the circuitry. Permanent damage to the LR-750 may result. This damage is not covered by the warranty.

WARRANTY

Goods are made in the U.S.A. Goods are warranted against defective material and workmanship for one year. You pay return shipping to Linear Research Inc. in San Diego, CA. The repair, parts, labor and return shipping to you is free.

SERVICE**INTERNAL FUSES**

The internal fuses are not to be replaced by the operator. If any of these fuses have opened, the instrument will need repair before replacement of the fuse.

The fuse is located on the power supply as shown in Figure 5.1 below. The fuse characteristics and values are:

<u>Occurrence</u>	<u>Characteristics</u>
FH1	T80mA250V
FH2	T50mA250V
FH3	T50mA250V
FH4	T50mA250V
FH5	T50mA250V

FACTORY SERVICE

If this product needs service, please contact Linear Research before sending your instrument back for repair.

LINEAR RESEARCH INC.
5231 Cushman Place, Suite 21
San Diego, CA 92110-3910 USA
Phone: 619-299-0719
Fax: 619-299-0129

INTERNAL FUSES

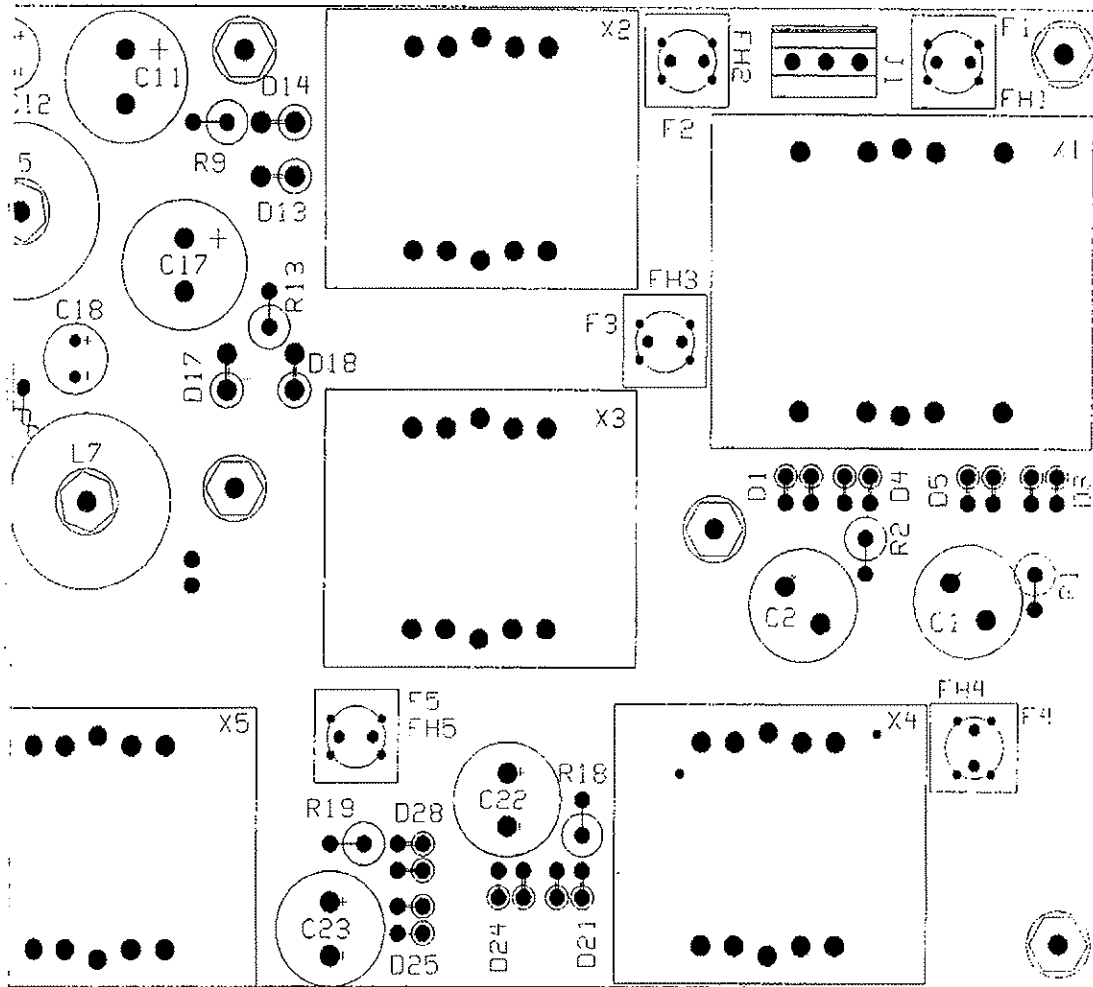


Figure 5.1

INDEX