LR-700

AC RESISTANCE BRIDGE

VERSION 1.3

USER'S MANUAL

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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-700 AC Resistance Bridge is an instrument that can measure resistance and reactance at 16 Hertz utilizing extremely low power. Resistances from 2 megaohm to 2 milliohms may be measured to better than 1 part in 200,000. Lower resistances can be measured down to nano ohms.

The amount of power used to measure a sensor can be varied by the operator by selecting full scale resistance voltages from 20 millivolts to 20 microvolts in factors of 1-3-10 steps. Each of these steps may be linearly varied from the 100% value down to approximately 5% in 1% 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 displays can be changed to show whatever 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 displays.

The LR-700 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, line printers 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 and/or ΔX. Alternatively, a recorder may be hooked up to the DAC analog output where the instrument decodes the display using the digital filtering and outputs a voltage to the strip chart recorder. Interfacing to printers is easily accomplished by connecting any centronics compatible printer to the printer output port on the back of the instrument. This output is compatible to a PC printer port.

The instrument can be interfaced with computers by either its RS-232 or 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 the sensor apparatus for a temperature control system by connecting a temperature controller, such as the Linear Research model LR-130, to the ΔR output of the rear panel. When using the LR-700 along with the LR-130, set points may be set with a resolution of 1 part in 200,000.

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-700.

The LR-700-TC Temperature Controller (TC) is driven directly by the LR-700's ΔR or ΔX analog signals, allowing resistance or mutual inductance sensors to control the temperature. The TC's all analog signal path drives a multirange current output circuit that delivers current to the heater resistor. The current output may also be used to DC bias sensor resistors when measuring non-linear sensors. Support of Temperature

Controller operation with one sensor while the LR-700 momentarily measures a second sensor is possible.
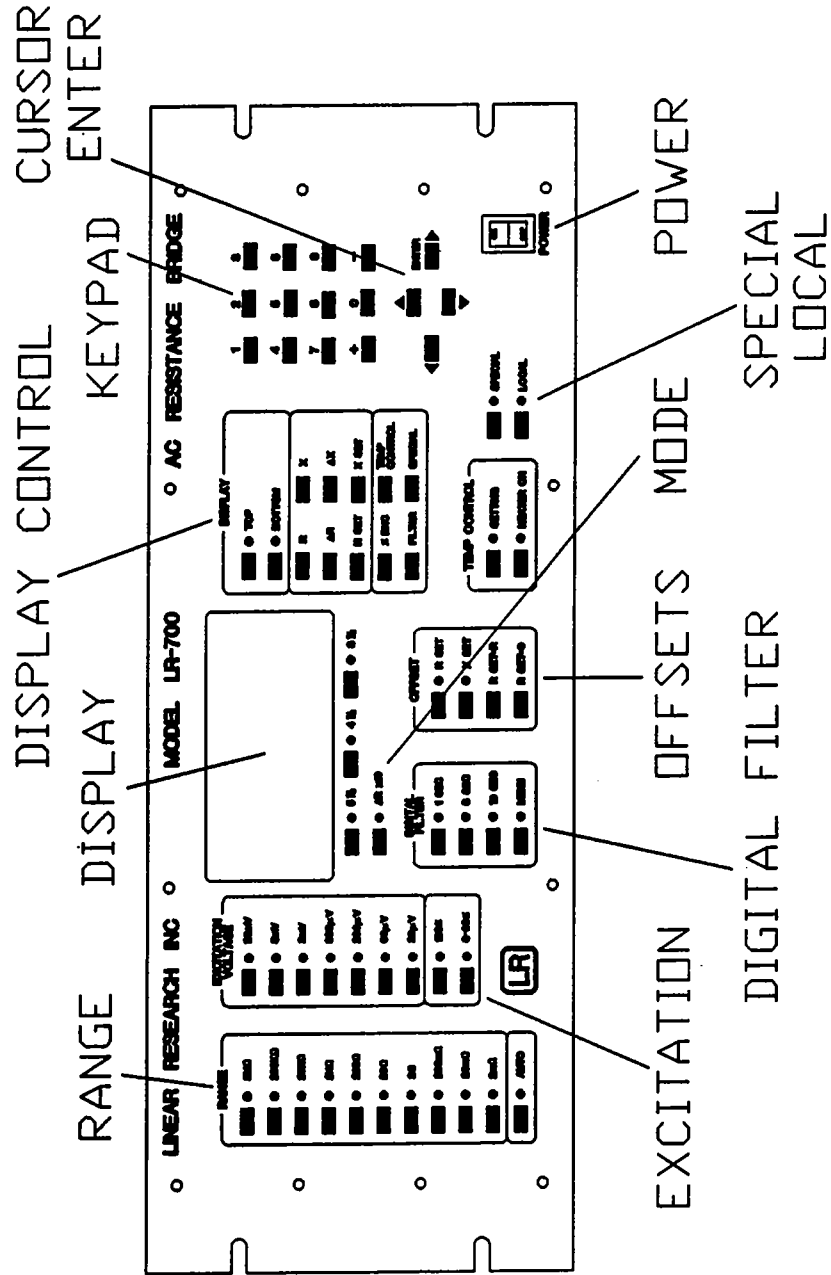
FRONT PANEL CONTROLS AND FEATURES

FIGURE 1.1

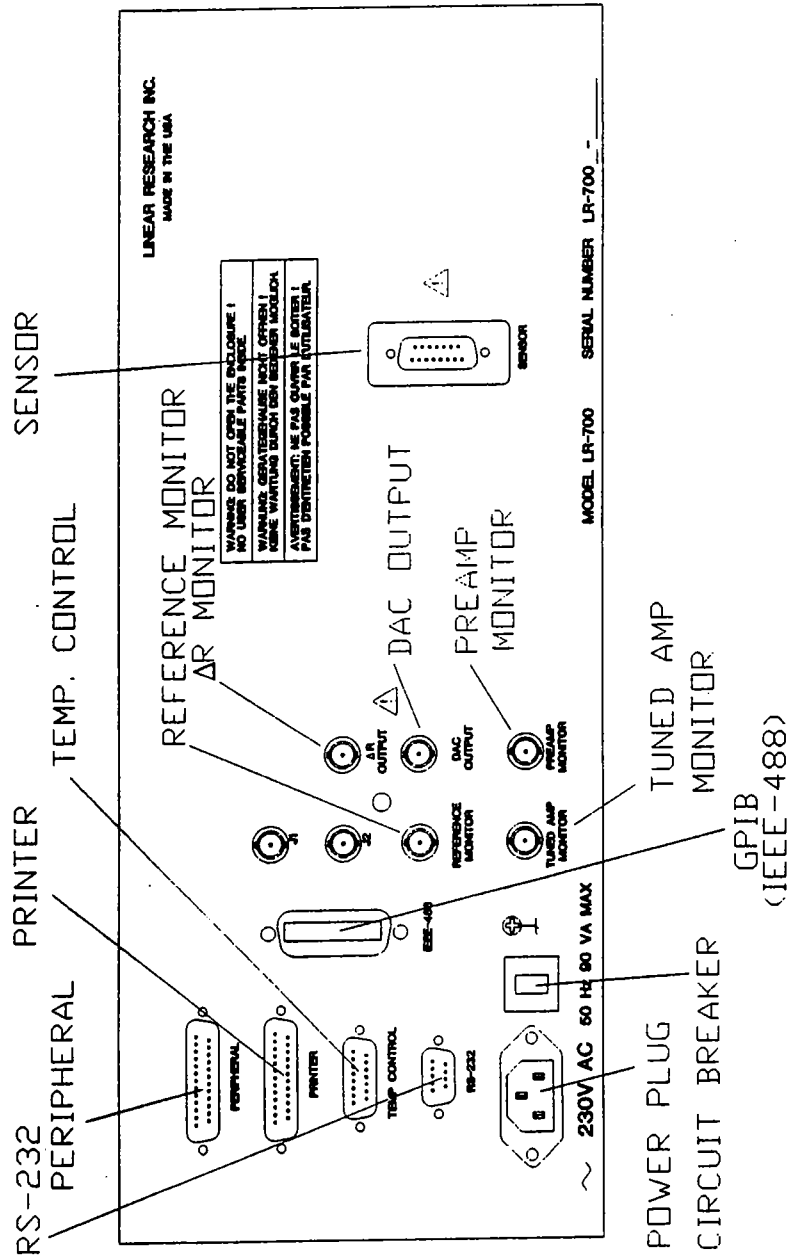**REAR PANEL FEATURES**

Figure 1.2

CHAPTER 2   OPERATING THE BRIDGE

This chapter deals with operating the LR-700. 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-700 main unit
   ☐ Power cord
   ☐ Sensor cable with attached resistor
   ☐ Spare sensor connector kit

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

2. **Verify The Power Cord and Plug.**

   Supplied with your LR-700 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-700 to make sure that it is configured for the correct voltage. Underneath the power plug you should find:

   > ☐100-120VAC
   > ☐220-240VAC
   >
   > 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 100Ω. It is a 1% metal film resistor.

(3) Select the 200Ω 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 20mV excitation.

(5) Select the 1 second digital filter.

(6) Press the RSET=0 button in the offset section.

(7) If the ΔRx10 LED is lit, press its button to go back to the ΔRx1 mode.

(8) To select the displayed information, press TOP, then R, then press BOTTOM then ΔR.

The bridge should now be measuring the 100Ω 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-700. 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 20KΩ, the bridge can measure up to 20KΩ 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

If the Autorange Option (LR-700-AR) is installed in your unit, you may enable the autorange function by pressing the AUTO button located below the range 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 located in the special feature section of this chapter.

If this option is not installed on your bridge, a temporary message, "NOT INSTALLED", will appear in the bottom display.

The Autorange Option performs in the following manner:

o 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.

o 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.

o The bridge will select the next lower range if the reading drops below 10,000 counts out of the 200,000 counts.

o 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.

o The software causes 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-700 needs to know which excitation to use for the range that it selects. There are basically 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.

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 define a custom trace that is "User Defined". This trace can have any allowable excitation to be used for any range.

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 labelled with a voltage. For example, 20mV 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 2KΩ range, if you select 20mV excitation, and you have a 2KΩ resistor, the excitation voltage will be 20mV. If the resistance you are measuring is ½ of the resistance range (in this example, 1KΩ), then the voltage across the sensor will be 10mV. This is because the bridge actually uses a fixed amplitude AC excitation current whose value depends on the resistance range, full scale excitation voltage, and % excitation voltage selected.

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 2mΩ range, you may not select any excitation greater than 60μV. 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.

VARIABLE EXCITATION OPTION

If the Variable Excitation Option (LR-700-VE) is ordered with your bridge, you have the ability to reduce the excitation current in 1% steps from 100% down to 5% of the currently selected excitation setting. To set the Variable Excitation, (sometimes referred to as "% EXC") press the 0-99% button. A value entry display will show up on the lower display and you may use the key pad and cursor controls to input the desired excitation current. As you reduce the variable excitation, you most likely will encounter some offsets and increased noise. The increased noise is due to the signal to noise ratio dropping throughout the entire system and the offset is due to the reduced reference voltage into the A&D converters. In general, it's best if you can use another entire excitation setting. For example, if you're on 6 millivolts and you wish to go down to 30% of that, it's better to go down to 2 millivolts excitation than to go to 30% variable excitation. Although, if you wish to make small changes in excitation and measure the change in resistance, you'll of course have to use variable excitation. Typical offsets near 10% excitation are 50 counts out of 100,000 counts.

DIGITAL FILTER

The following information will be useful in understanding and operating the digital filter controls. The LR-700 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-700 is a straight average giving equal weight to each of the readings in the time period. For example, in the 1 second filtering mode, 5 readings are averaged together and divided by 5.

You may select a digital filter to help noise rejection, quieting down the display. You may select 1 second, 3 seconds or 10 seconds. If you have the filter menu option, you may also select a fourth digital filter labeled "MENU" on the front panel that can be user selected from direct readings every 188 milliseconds to a maximum filtering of 30 minutes. Please note that these three, possibly four, digital filters are always available for display. When you select the desired digital filter, the bridge does not start to settle at that time. It has been continuously settling since the last range or other major bridge change such as RSET. Therefore, when you make a change in RSET, you may select the one second

digital filter to find the settled value very quickly. You may look at this value while the 3 and 10 second digital filters are settling. Once they have settled, you may shift over to the 3 second or 10 second digital filters without upsetting the bridge.

Note: The analog circuitry of the bridge settles in an exponential fashion with a time constant of less than ½ 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 10 second filter will ramp into the settled value in 10 seconds, plus 3 seconds fixed for the analog settling of the circuitry. Therefore, within 13 seconds, the 10 second filter has completely settled the display to 1 part in 200,000.

OFFSETS, RSET AND XSET

By using the offset controls, you may change the origin of the ΔR/ΔX measurements. For example, if you know your sensor is approximately 10KΩ, you can enter an offset of 10KΩ into RSET and by displaying the ΔR readings you can measure how your sensor differs from 10KΩ.

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

1) RSET or XSET allow an offset to be entered in a random fashion to any setting from -199999 to +199999. After pressing RSET or XSET, 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 and also the XSET will be set to 0, in effect turning the offsets off.

3) RSET=R will change the RSET value to the current R value which is taken from the currently selected digital filter. The XSET value will also be set to the current X value.

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 (unlike mutual inductance 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 (▲ and ▼) 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 ▦ 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 10KΩ when you're on the 20KΩ range, press RSET, the display will come up blinking. With RSET=+000000, you may press ▦ 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.

The XSET offset works in the same way as the RSET described above. As previously noted, the RSET=R and RSET=0 buttons will affect both the RSET and XSET. There is a method using these buttons to affect only one offset and not the other. For example, if both RSET and XSET are zero and you would like to make XSET equal to X while not changing RSET, press the

XSET button first. Instead of entering the XSET value from the keypad, press the RSET=R button. The RSET=R now acts as an "XSET=X" button only. The entry menu will now have the current value of X as the XSET and the blinking cursor will be at the far right of the window. Now you may press XSET or ENTER to accept the new value of XSET and finish the entry.

Note: No XSET value may be entered when on the 20KΩ, 200KΩ, or 2MΩ range. This is because the bridge balances the quadrature (90° component) through the current excitation channel on these ranges.

DISPLAY CONTROL

The display on the LR-700 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, for example XSET if there is no XSET capability 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

Directly below the displays are four buttons. Three of the buttons control how many digits of resolution are displayed on the front panel. The bridge always 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 pressing the 4½ or 3½ digits buttons. Of course, to return to 5½ digit mode press 5½.

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 and ΔX are 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 (and ΔX mode), or in the 10ΔR (and 10ΔX mode). Both modes, x1 or x10, do not co-exist at once in either the LR-700's analog circuitry or in the microcontroller's memory. For example, when the bridge's mode changes from ΔR to 10ΔR, any ΔR in the memory is redefined as 10ΔR data and any new data will come in as 10ΔR data.

TEMPERATURE CONTROL

There are two buttons on the front panel which control the Temperature Controller Option, the SETTING button and a HEATER ON button. These two buttons control most of the features used in the option in the Temperature Controller that are changed quite often. All other parameters associated with the Temperature Control Option are set via the special features (#20-29). Please see the following section on Special Features.

TEMPERATURE CONTROL SETTING KEY

After pushing the SETTING button, a selection menu will come up in the lower display. It will prompt you to select a Thermal Time Constant (TTC). After you set the TTC, the lower display will then prompt you to select the Gain. Once you've selected the Gain, you will be prompted to select the maximum current for the heater (Imax).

The TTC parameter may be set from 1,000 seconds down to 0.2 seconds in 1, 2, 5, 10 steps. One additional setting, USER DEFINED, may be selected where the operator may individually select the integration and derivative time constants. Please see Special 22 and Special 23, accordingly. Please note that when you select a Thermal Time Constant, this is equivalent to the integration that will be used and the derivative will be automatically selected by the internal software.

The gain is selectable from .1 to 5,000 in 1, 2, 5, 10 steps.

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 the setting.

TEMPERATURE 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-700 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 as follows:

CATEGORY	KEY SEQUENCE			DESCRIPTION
Printer	SPECIAL	1 1	ENTER	Immediate Print
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

SPECIAL FEATURE DETAILS

SPECIAL 11   Print immediate data

By activating this special feature, the LR-700 will send through its printer interface the current bridge settings along with all six of the measurements.

The printer should be connected before issuing this command.

The output on the printer will look like this:

```
SETTINGS:  2K OHMS,   20mV,   100%,   1 sec        996
R  =+1000.22     /\R  =+1000.22      RSET=+0000.00
X  =+0000.24     /\X  =+0000.24      XSET=+0000.00
```

See Chapter 3, Printer for more information.

SPECIAL 20   Temperature controller input

Allows the operator to select ΔR or ΔX as the temperature controller input signal. To use the external Temperature Controller Input select ΔX.

SPECIAL 21   Noise filter

Allows low pass filtering of the selected input ($\Delta R / \Delta X$) 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-700 where the ΔR is the input. Use inverted loop in case you are using positive temperature coefficient (PTC) sensors or if you're using a susceptibility sensor, such as CMN thermometry and using ΔX as the input to the temperature controller. 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	:	30μamps
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-700 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-700 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 50   DAC output

This special feature allows the operator to select the gain and the measurement parameter for the DAC output. Upon issuing this command, the top line will read "Recorder Output" and the bottom line will give you a current setting for what value will be decoded as a 10 volt output. You may change the number of digits that are converted to a 10 volt output. By using the up and down arrows, the following selections are possible:

```
+10V= +199999
+10V= +099999
+10v= +009999
+10V= +000999
+10V= +000099
+10V= +000009
```

When the desired mode is displayed press ENTER.

Please refer to the DAC Output section in Chapter 3 for more details.

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 and the min range to 2mΩ.

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

	TRACE		
RANGE	DEFAULT	MAX PWR	MIN PWR
2M	20mV	20mV	2mV
200K	6mV	20mV	600μV
20K	2mV	20mV	200mV
2K	600μV	20mV	60mV
200Ω	600mV	20mV	20mV
20Ω	600mV	20mV	20mV
2Ω	600mV	20mV	20mV
200mΩ	600mV	6mV	20mV
20mΩ	200mV	600μ	20mV
2mΩ	60μV	60μV	20mV

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-700 will light the 2mΩ 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 2MΩ and the minimum range at 2mΩ.

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 ΔX signal. Press **ENTER** to accept when you choice of ΔR or ΔX 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.

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:

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

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

ΔR±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 10ΔR 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 (10ΔR) display will read +200500 or -200500, its maximum value. This is the value input into the digital filter calculation.

ΔX±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.
- 10ΔX 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.

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

NOTE: These two overrange messages will only appear if there are no overload conditions also present. Any time 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* **ΔR±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=±CIT±X±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.

CHARACTER	DESCRIPTION AND POSSIBLE CAUSE
±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 $10K\Omega$-$1M\Omega$.

±X | ΔX OVERRANGE

This indicates ΔX is overrange.   In units without X DISPLAY, this will be the only indication of high reactance.

±R | ΔR OVERRANGE

This indicates ΔR is overrange.

MEASUREMENT TECHNIQUES

ΔR-10ΔR Modes

The bridge is either in the ΔR (and ΔX mode), or in the 10ΔR (and 10ΔX mode). Both modes, x1 or x10, do not co-exist at once in either the LR-700's analog circuitry or in the microcontroller's memory. For example, when the bridge's mode changes from ΔR to 10ΔR, any ΔR in the memory is redefined as 10ΔR data and any new data will come in as 10ΔR data.

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

Preferred Method For Measuring Small Sensor Changes

With the bridge settled, push RSET=R. This will bring ΔR (and ΔX) to ΔR = 0 ±20 counts, typically between ±1 and ±10 counts. If more resolution is required, you can now go to the 10ΔR 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, measurment 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-700 is under computer control, measuring a slowly changing single sensor, program the computer to update the LR-700 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.

MUTUAL INDUCTANCE MEASUREMENTS

The LR-700 allows mutual inductance measurements to be made only on the lower ranges of 2mΩ through 2KΩ. This is because high inductance values greater than 20 Henrys (2KΩ) in mutual inductance transformers are rare. Accordingly, the bridge doesn't allow XSET to be entered on the 20K, 200K, or 2MΩ ranges.

Since mutual inductance measurements are confined to the lower resistance ranges of the LR-700, lead reversal in mutual inductance measurements is not a problem (as described elsewhere) and leads may be reversed at will without locking up the bridge. Figure 3.2B shows the standard sensor cable hooked up for mutual inductance measurements. Only the standard sensor cable should be used for mutual inductance measurements. A DC ground return path must be made from the mutual inductance transformer secondary to the chassis of the LR-700 to give a DC return for the preamp input bias currents. This is shown in Figure 3.2B as a connection between V-SHIELD and V-LO. This connection may be made at the top of the cryostat.

When first testing a new setup with a mutual inductance transformer, check the I-HI and V-HI sensor lines for unwanted audio high frequency oscillations. Do this with a 1MΩ or 10MΩ oscilloscope probe. Be sure that the oscilloscope probe ground lead is connected to the LR-700 chassis or cryostat chassis and not to I-HI, I-LO, V-HI, or V-LO. If oscillations are present, eliminate these oscillations by placing a capacitor between the I-HI and I-LO lines preferably, or alternatively, place a capacitor across the V-HI and V-LO lines. Use a low leakage film capacitor. Do this test with the mutual inductance transformer both at room temperature and at the experimental low temperature. If the oscillation is present, first try to kill it with a small value capacitance (such as a 300pf), then work up with increasing capacitance values in steps until the oscillation stops. Pick a slightly larger value of capacitance for permanent installation. The

capacitor can be mounted at the head of the cryostat at room temperature where the sensor leads enter the cryostat.

Superconducting and other samples can be measured inside a user built mutual inductance transformer. The transformer should consist of a single primary and two secondary windings. The secondary windings are stacked one on top the other with modest space in between and well inside the longer primary. All windings share a common central axis. The LR-700's current excitation leads directly drive the primary. The secondaries, electrically connected in series opposition, directly drive the voltage input leads.

Placing a sample inside one of the secondaries will generate an in-phase and quadrature mutual inductance signal that can be measured by the LR-700.

Thus, the user measures samples in terms of χ' and χ'' allowing characterization of bulk and thin film superconductors.

The RSET=R (and XSET=X) features of the LR-700 allow for fast initialization of the set-up. Data can be then taken in the ΔR and ΔX or $10\Delta R$ and $10\Delta X$ modes.

EXTERNAL INTERFERING SIGNALS

External interfering signal sources that might cause an overload of the LR-700's amplifier chain or nonvalid LR-700 readings are:

1. Large 50, 60, 100, or 120 Hz powerline interferences are usually coupled in at the sensor, sensor leads, the LR-700 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 florescent lights, florescent 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-700'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-700 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-700 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-700'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-700 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-700 will filter out this "fast" 3.1 Hz beat note.

USING TWO OR MORE LR-700 BRIDGES

When the experiment calls for two or more 15.9 Hz AC bridges, either two LR-700s or an LR-700 plus an LR-400, 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.
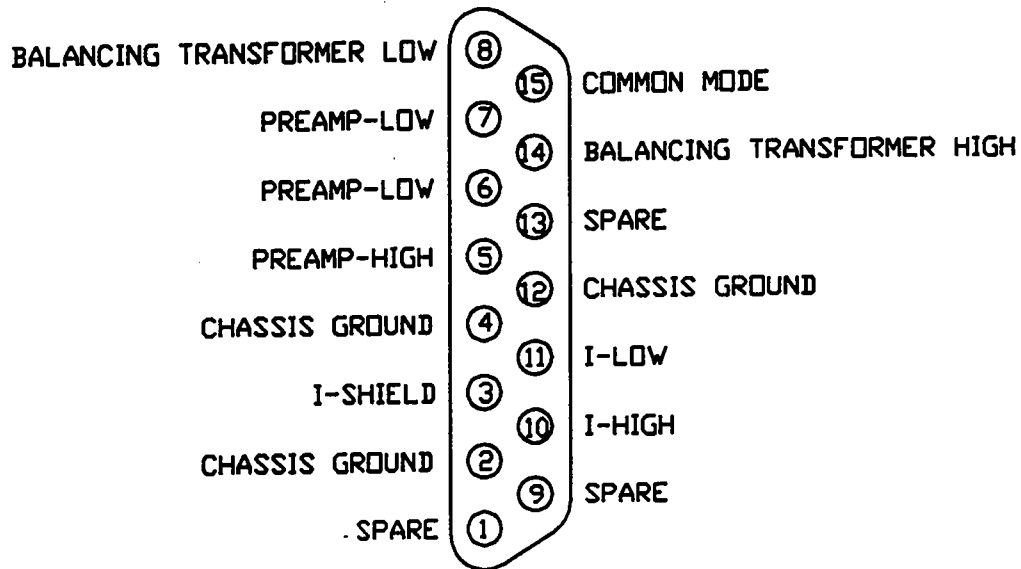
CHAPTER 3   INTERFACING

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-700 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-700 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.

```
BALANCING TRANSFORMER LOW   ⑧
                                ⑮   COMMON MODE
            PREAMP-LOW   ⑦
                                ⑭   BALANCING TRANSFORMER HIGH
            PREAMP-LOW   ⑥
                                ⑬   SPARE
           PREAMP-HIGH   ⑤
                                ⑫   CHASSIS GROUND
         CHASSIS GROUND   ④
                                ⑪   I-LOW
              I-SHIELD   ③
                                ⑩   I-HIGH
         CHASSIS GROUND   ②
                                ⑨   SPARE
                 SPARE   ①
```

3-1

The Standard Sensor Cable

The standard sensor cable is supplied with the LR-700 unit. Figure 3.2 shows a schematic of this cable connected to a resistance sensor. Figure 3.2B shows this cable connected to a mutual inductance 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 when measuring mutual inductance.

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-700 driven shields cable. Nonetheless, CMRR is still very good and equivalent to our LR-400 bridge with its grounded shield cable. The LR-700 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 = +100.000Ω 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 2mΩ through 2KΩ
ranges so quadrature balance lock-up due to reverse leads will
not occur. Reversed leads in this case are simply equivalent
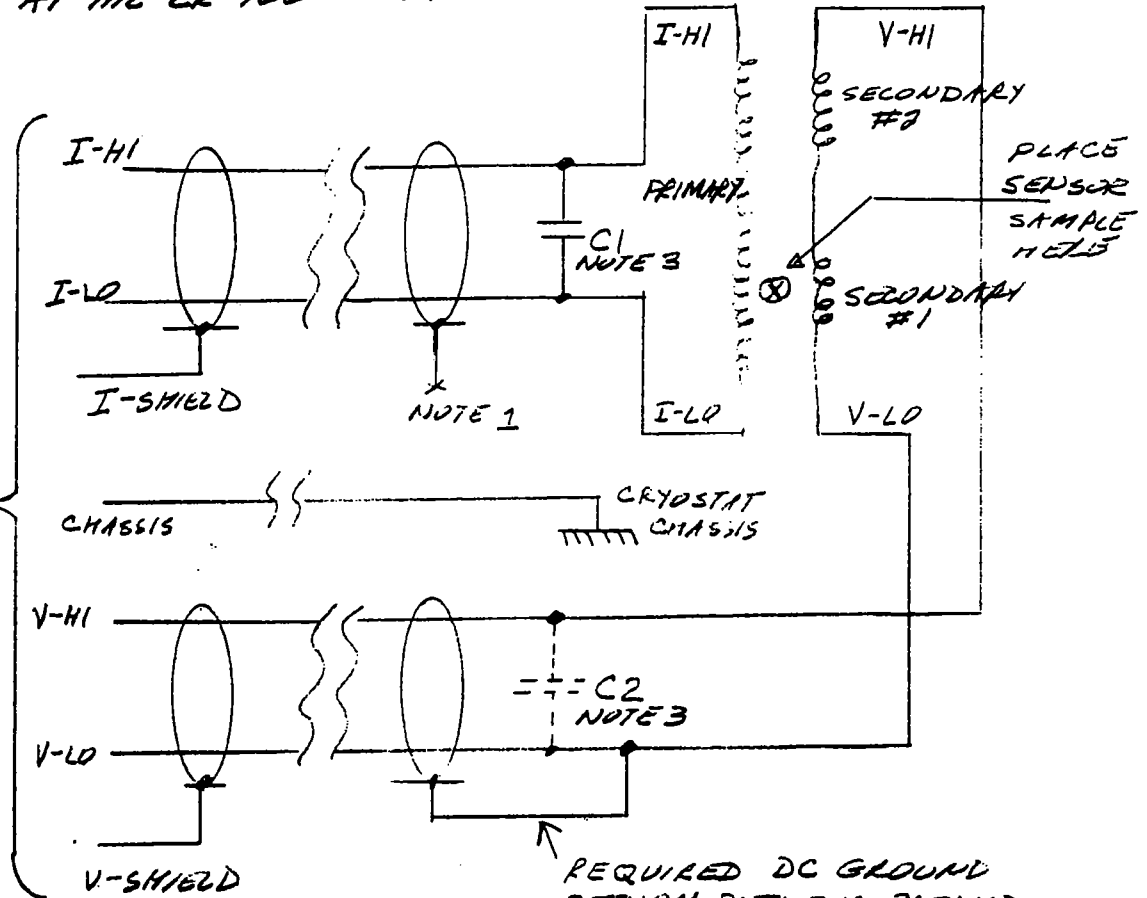to a reversed transformer secondary and thus is not a concern.
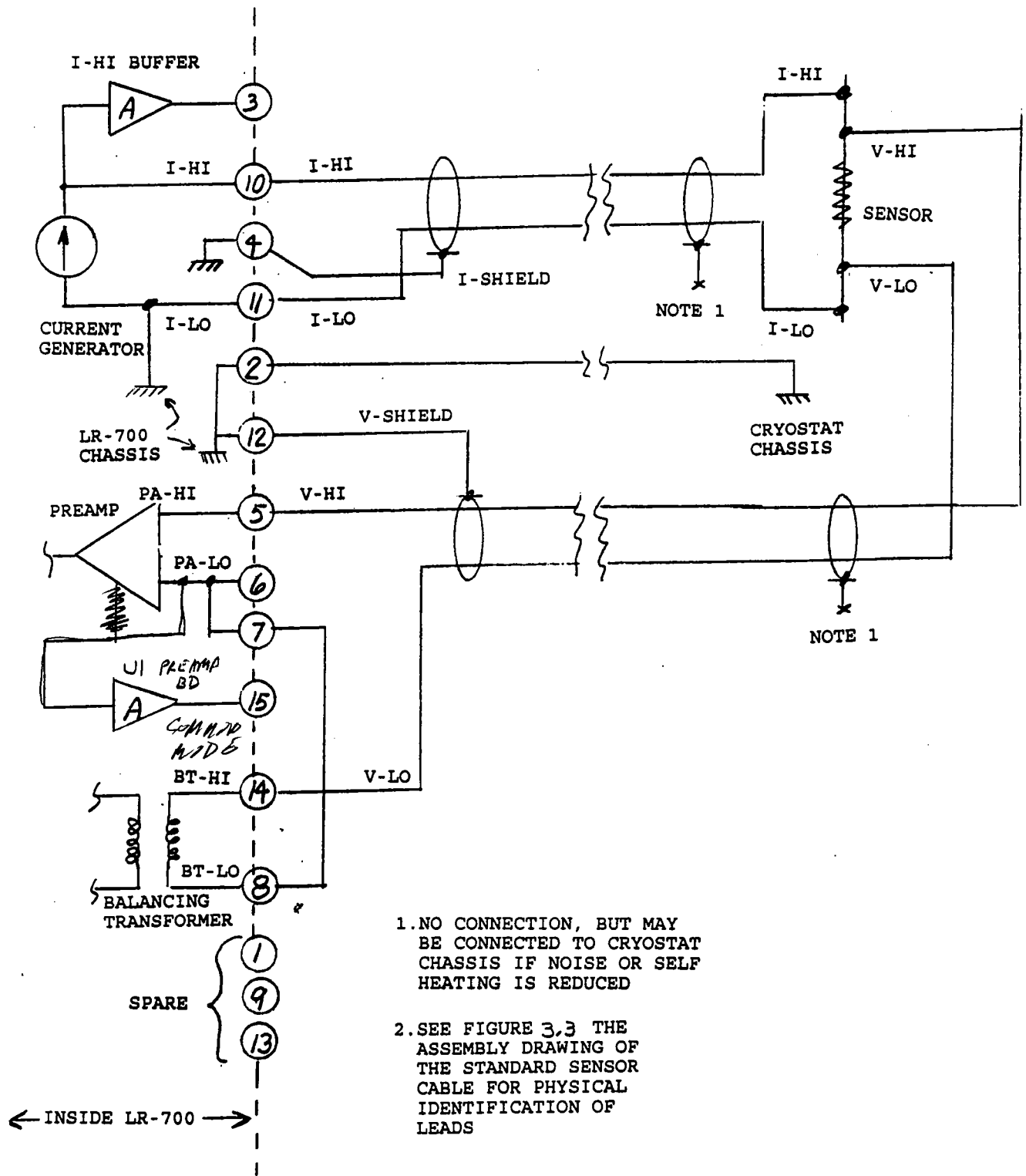
STANDARD
SENSOR CABLE

FIGURE 3.2

USE ONLY THE STANDARD
SENSOR CABLE WITH
GROUNDED SENSOR SHIELDS
AT THE LR-700 END.

SENSOR
MUTUAL INDUCTANCE
TRANSFORMER

SEE FIGURE 3.2 FOR LR-700 END

I-HI

I-LO

I-SHIELD

NOTE 1

C1
NOTE 3

I-HI

PRIMARY

I-LO

V-HI

SECONDARY
#2

SECONDARY
#1

V-LO

PLACE
SENSOR
SAMPLE
HERE

CHASSIS

CRYOSTAT
CHASSIS

V-HI

V-LO

V-SHIELD

C2
NOTE 3

REQUIRED DC GROUND
RETURN PATH FOR PREAMP
INPUT BIAS CURRENT
(V-SHIELD TO V-LO)

1. NO CONNECTION, BUT MAY
   BE CONNECTED TO CRYOSTAT
   CHASSIS IF NOISE OR SELF
   HEATING IS REDUCED

2. SEE FIGURE 3.3 THE
   ASSEMBLY DRAWING OF
   THE STANDARD SENSOR
   CABLE FOR PHYSICAL
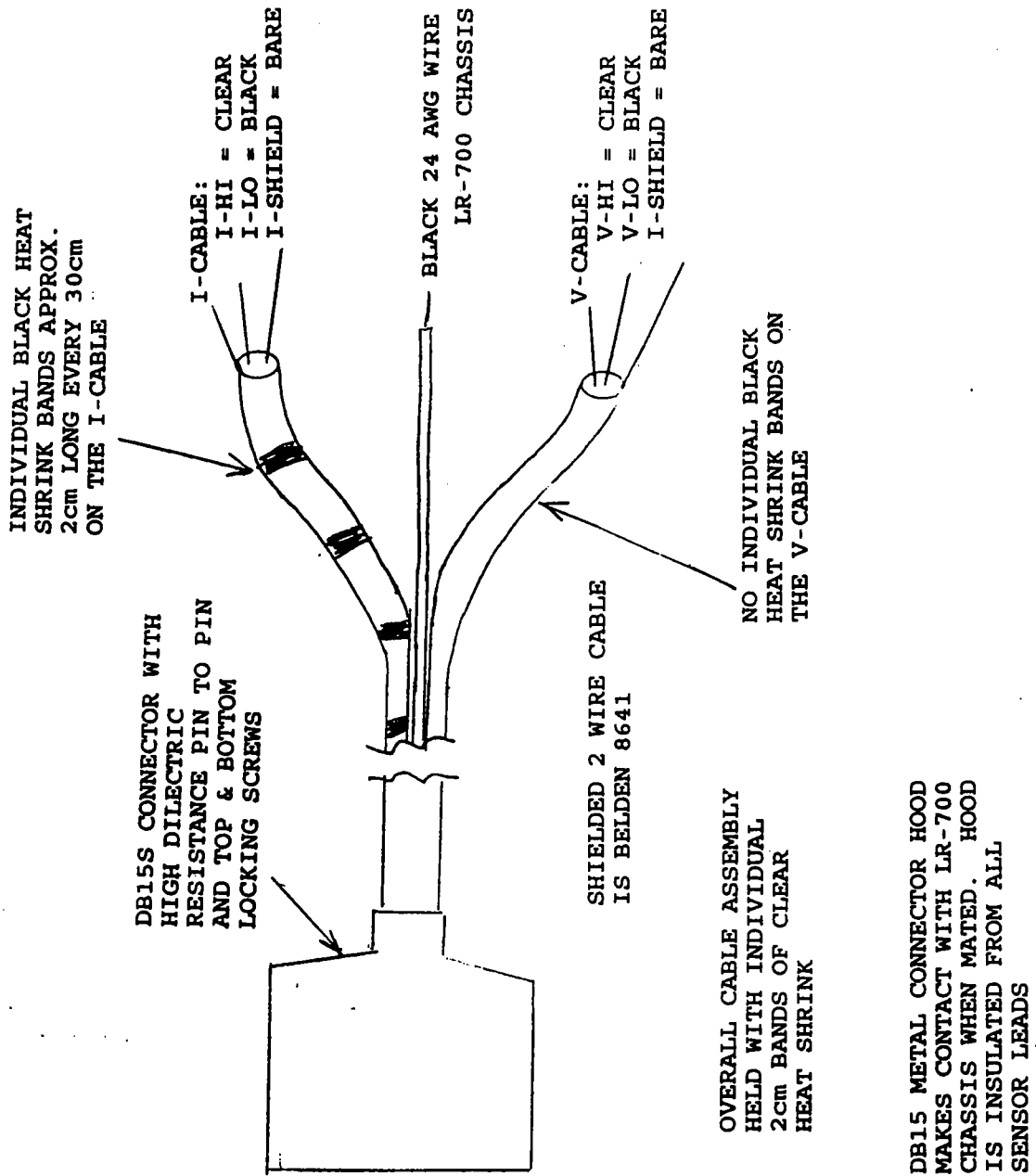   IDENTIFICATION OF
   LEADS

3. C1 OR C2 CAN BE
   ADDED TO KILL
   OSCILLATIONS IF
   PRESENT, SEE TEXT.

FIGURE 3.2B

MUTUAL INDUCTANCE
MEASUREMENTS

FIGURE 3.3

STANDARD SENSOR CABLE
ASSEMBLY DRAWING

INDIVIDUAL BLACK HEAT
SHRINK BANDS APPROX.
2cm LONG EVERY 30cm
ON THE I-CABLE

I-CABLE:
  I-HI = CLEAR
  I-LO = BLACK
  I-SHIELD = BARE

BLACK 24 AWG WIRE
LR-700 CHASSIS

V-CABLE:
  V-HI = CLEAR
  V-LO = BLACK
  I-SHIELD = BARE

DB15S CONNECTOR WITH
HIGH DILECTRIC
RESISTANCE PIN TO PIN
AND TOP & BOTTOM
LOCKING SCREWS

NO INDIVIDUAL BLACK
HEAT SHRINK BANDS ON
THE V-CABLE

SHIELDED 2 WIRE CABLE
IS BELDEN 8641

OVERALL CABLE ASSEMBLY
HELD WITH INDIVIDUAL
2cm BANDS OF CLEAR
HEAT SHRINK

DB15 METAL CONNECTOR HOOD
MAKES CONTACT WITH LR-700
CHASSIS WHEN MATED. HOOD
IS INSULATED FROM ALL
SENSOR LEADS

STANDARD CABLE LENGTH = 3 METERS

Driven Shields Sensor Cable

This cable is not supplied with the LR-700 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.
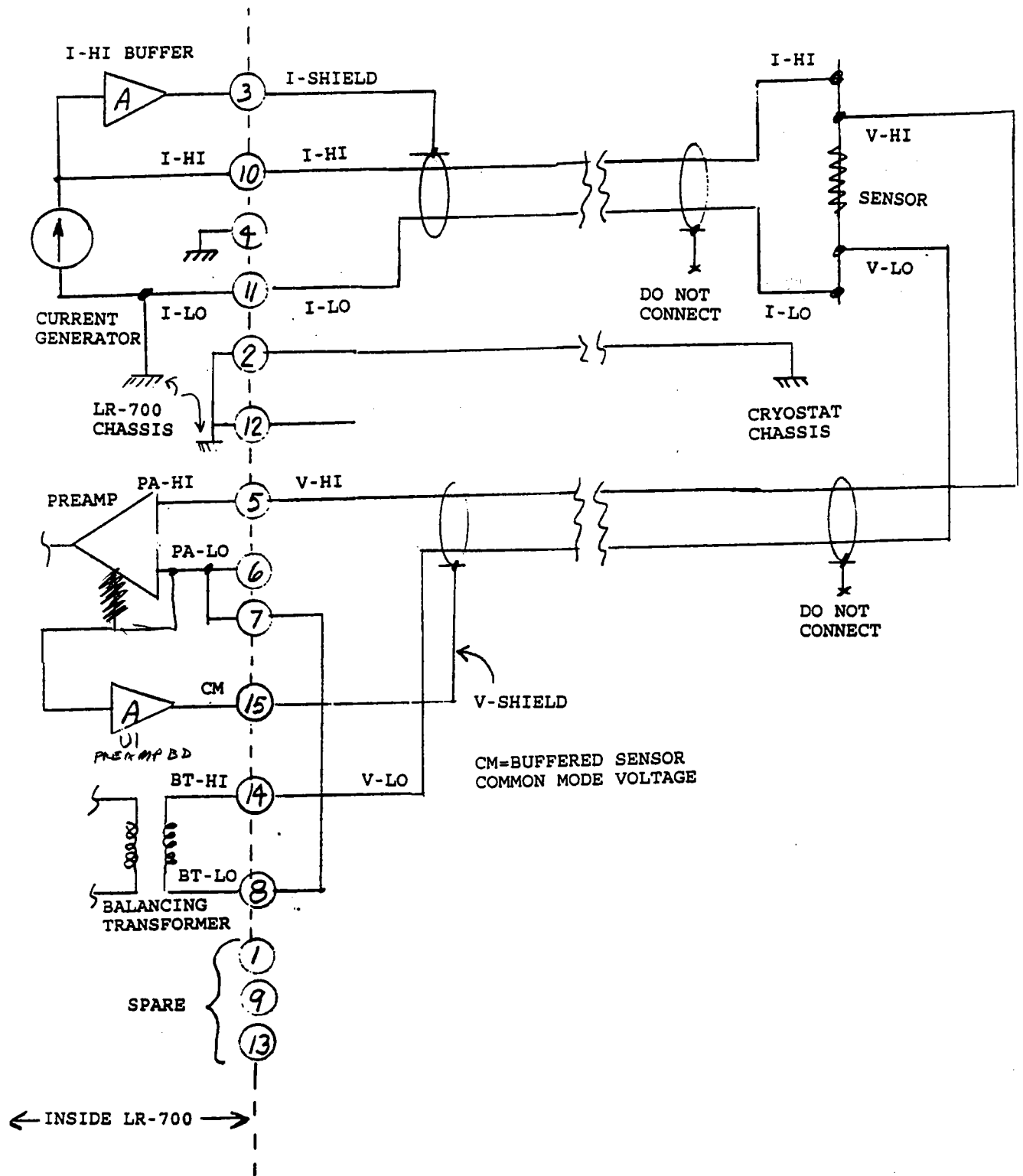
DRIVEN SHIELDS
SENSOR CABLE

FIGURE 3.4

DC Biasing Of The Sensor

Figure 3.5 shows a schematic of the technique for DC biasing the sensor. Figure 3.6 shows a simplified schematic. This technique will work with typical compliance voltages across the sensor of up to ±5VDC. However, the voltage across the sensor must not exceed the compliance voltage of the LR-700 AC current generator, which is slightly more than ±10VDC. Thus, if voltage in excess of ±10VDC in this configuration is applied to the sensor, the LR-700 current generator may be permanently damaged.

As shown in Figure 3.5, the inside of the shielded DC bias box, the R-return resistor must be large compared to the sensor resistance or the AC settling time of the bridge will be reduced. R-return allows a DC path for the small DC input current of the preamp to go to ground. The 100Ω resistor and two diodes protect the preamp's input from overvoltage should the sensor resistor be abruptly shorted. These components prevent the full capacitor voltage from being connected across the preamp input. The 100Ω resistor limits transient currents through the diodes. Its value must not be reduced.

The DC bias source shown in Figure 3.5 is the LRI infinite impedance current source (IICS) of the LR-700-TC Internal Temperature Controller Option. It delivers a negative DC output current. Accordingly, the polarity of the C-blocking capacitor must be as shown in Figure 3.5. Details of the IICS DC bias cable assembly are shown in Figure 3.18.

In Figure 3.6, note that neither the C-blocking capacitor nor the R-return resistor are directly in parallel or series with the AC measured portion of the sensor resistor. C-blocking and R-return are on the preamp side of the balancing transformer. The 100Ω resistor adds 1.4nV SRH of noise to the preamp. The AC current noise of the IICS will be larger than the 100Ω noise. The balancing transformer continues to balance the exact sensor voltage while C-blocking and R-return act only to isolate the DC voltage at the sensor from the preamp. This technique can be used because the LR-700 brings out the PA-LO node of the preamp to the sensor connector in order that the R-return resistor can be connected to this point. Our previous bridge, the model LR-400, did not have this PA-LO node available at its sensor connector, thus this technique could not be configured in the field for the LR-400 bridge.

Note: Applying a DC bias voltage to the sensor, in a manner different than that described above, can permanently damage the preamp.

Bridge Noise is Increased When Using DC Biasing

In designing the Internal LR-700-TC Temperature Controller Option, the primary goal was to design a controlled amplitude variable DC current source for heating the user's heater resistor. Extremely low values of 16Hz spectrum current noise were not a priority in the design requirements. At the time, there was more interest in designing a DC current generator with a built-in LR-700 100ma range with the capability of interfacing directly to the LR-730 external power boosters with currents of 0.3, 1, and 3 amps at a reasonable price. This was done successfully.

Later, after the design was completed, it was discovered that the DC generator feature could also be used to DC bias the sensor. It was found, however, that circuit design trade-offs in achieving the 3 amp range, with low internal LR-700 heat genereation on the DC current. Of course, when operating in the temperature controller mode, the 16Hz noise can be ignored as long as it is a small percentage of DC output, ai it is in this case.

This 16 Hz current noise degrades (overrides) the low noise preamp performance of the LR-700 bridge. Thus, the user will see more noise at the bridge's sensor resistance analog output and at the display than when using the bridge in its non-biased mode. The user must see if the added noise is acceptable for his measurements when using the DC bias mode.

So, until all PC boards are re-designed, sometime in the future, in a general LR-700 upgrade including reduction of the 16Hz noise current, the IICS noise can only be reduced by eliminating the temperature control feature (by changing components on thetemperature controller PC board), thus dedicating the TC option to DC bias operation only.

Note: Applying a DC bias voltage to the sensor, in a manner different than that described above, can permanently damage the preamp.

The table below shows the recommended values of the C-blocking and R-return components shown in Fig. 3.5 for various bridge resistance ranges. The R-C time constant for all values is 10 seconds. This will determine the settling time for a DC current step change overload at the diodes. The user may choose shorter or longer time constants (different C and R values) for his application, but the 100Ω resistor cannot be changed. Maximum direct sensor DC compliance voltage without the C-blocking and R-return technique is limited by the preamp. Lock-up or saturation of the preamp output will occur at about ±10 millivolts DC across the sensor.

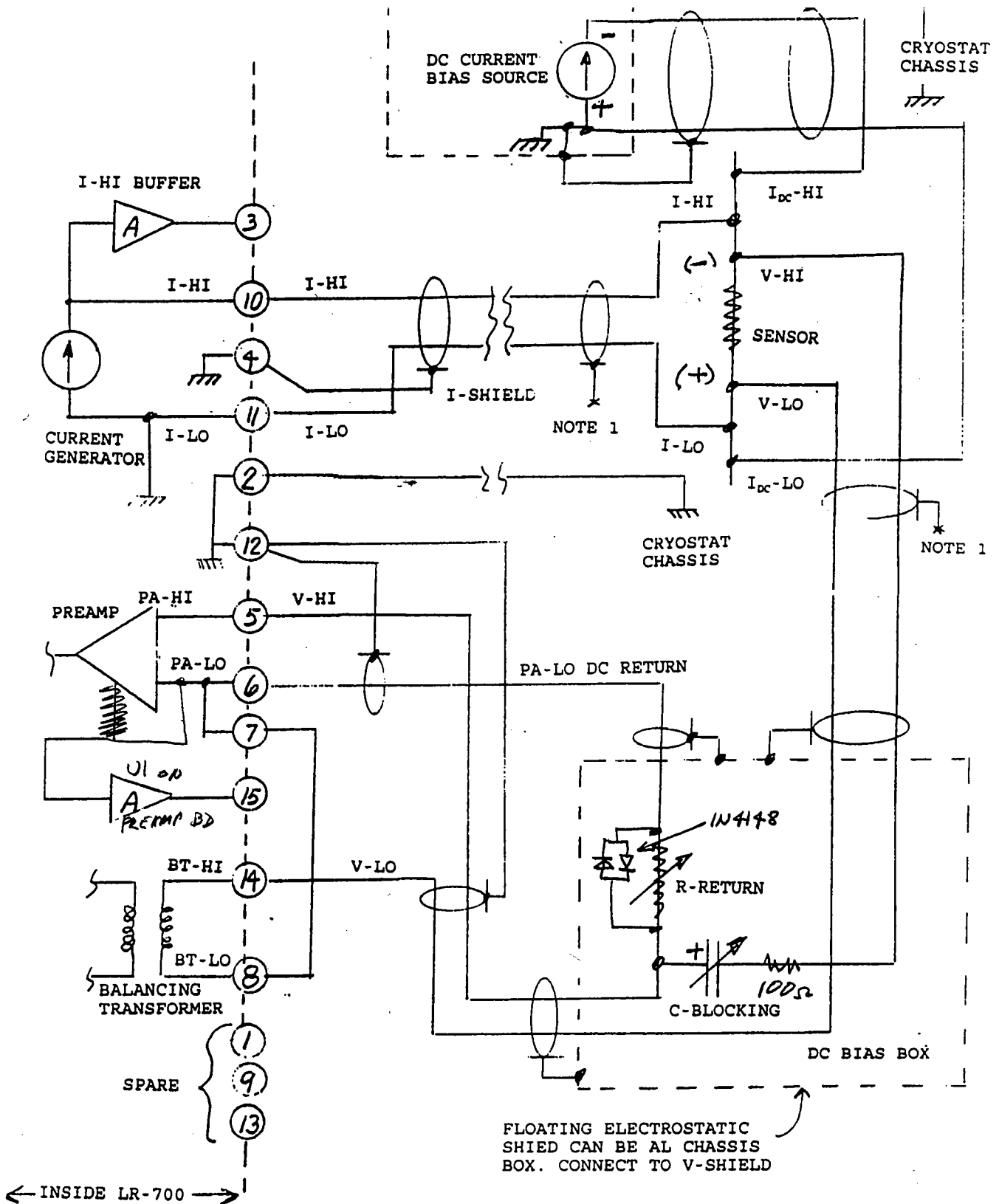| RANGE	C-BLOCKING	R-RETURN
2mΩ	1mf	10KΩ
20mΩ	1mf	10KΩ
200mΩ	1mf	10KΩ
2Ω	1mf	10KΩ
20Ω	1mf	10KΩ
200Ω	1mf	10KΩ
2KΩ	100μ	100KΩ
20KΩ	10μ	1MΩ
200KΩ	1μ FILM	10MΩ
2MΩ	0.1μ FILM	100MΩ
mf = millifarad, (1mf = 1,000μf)		
Resistors are ¼ watt		

FIGURE 3.5 (8/96)
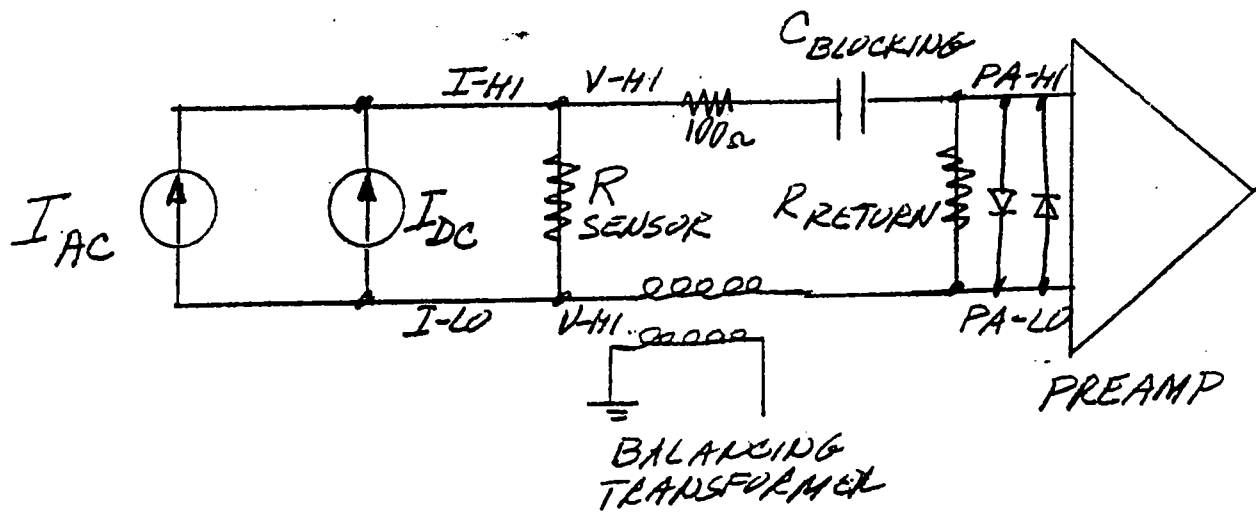
DC BIASING
OF THE SENSOR

FIGURE 3.6 (8/96)

SIMPLIFIED SCHEMATIC
DC BIASING OF THE SENSOR
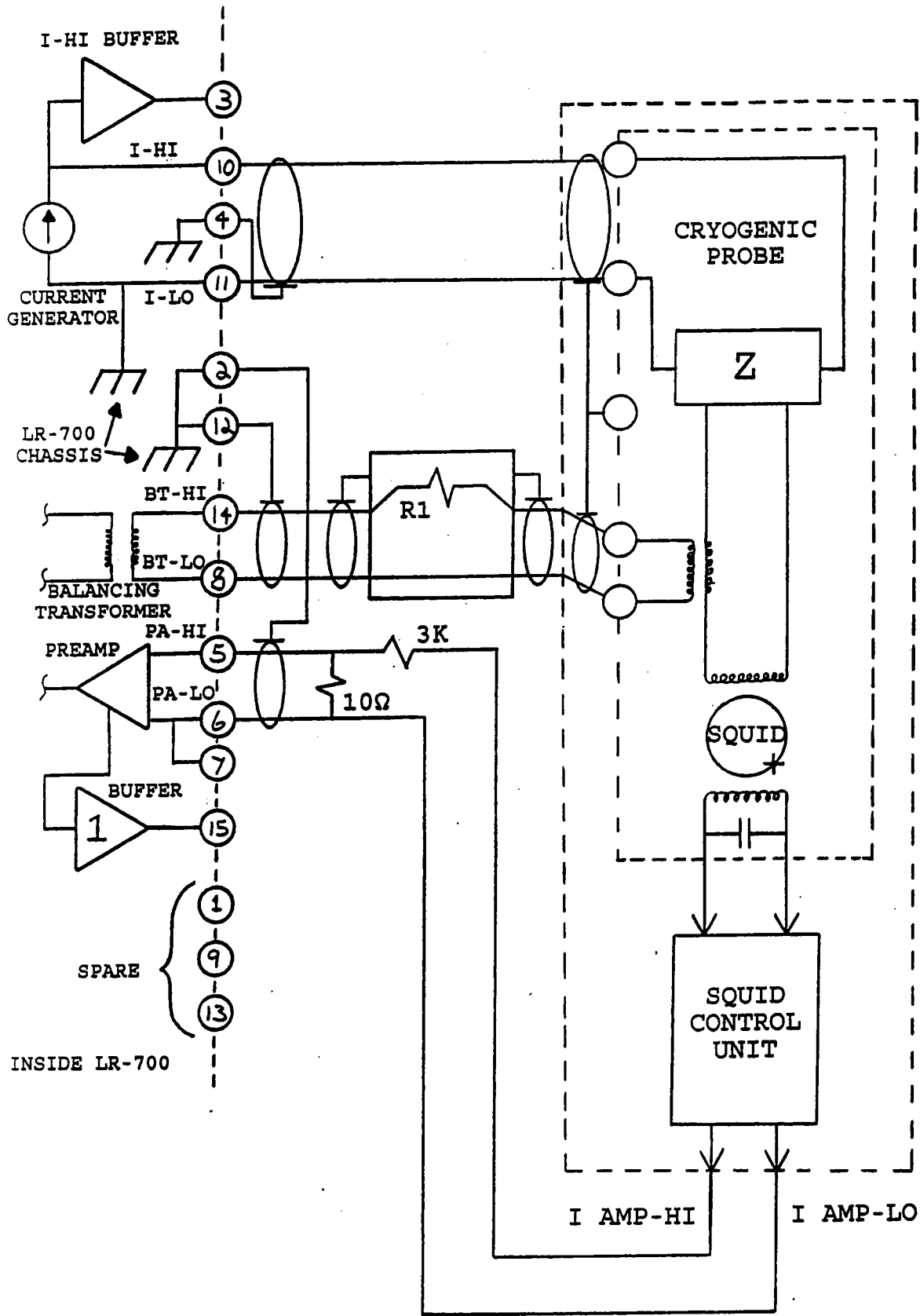
FIGURE____

SQUID INTERFACING

ANALOG OUTPUTS

The LR-700 has two types of analog voltage outputs.

1. Direct analog outputs.
   One BNC for ΔR(or $10\Delta R$).
   One BNC for ΔX(or $10\Delta X$). With X-Display Option.

2. DAC analog output.
   One individual BNC. The micro controller takes the measured data and drives a digital to analog converter which drives the BNC.

FEATURES OF DIRECT AND DAC ANALOG OUTPUTS	
Direct Analog Output	DAC Analog Output
Individual BNC connectors. One for ΔR($10\Delta R$) and one for ΔX($10\Delta X$).	One output BNC, but you may select R, ΔR, $10\Delta R$, X, ΔX or $10\Delta X$. Also RSET and XSET for direct span chart calibration.
Infinite monotonicity. Can be used as an input that drives the highest performance temperature controllers.	Monotonicity is 1 part in 19 to 1 part in 3,999 full span for driving lower 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.	Filtered time constant appears as a ramp and is set by the LR-700's digital filter. Can give very long filter times with random noise reduction.
Ultimate strip chart resolution is infinite but sensor or pre-amp random noise will usually limit performance. Can achieve up to 1 part in 5 million of full scale range resolution with a 10 second external analog filter in $10\Delta R$ mode. Recorder span sensitivity must approach 1mV.	Ultimate strip chart resolution in $10\Delta R$ with a DAC mode equal to 000999 is exactly 1 part in 1 million of full scale range.
Can drive external 6½ and 7½ digit digital volt meters with their own IEEE-488 interface for high resolution data logging.	Can drive strip chart recorders without the need for millivolt span amplifiers.

Direct Analog Outputs

The direct analog outputs are driven directly from the ΔR and the ΔX high gain DC amplifiers (see LR-700 Block Diagram Figure 4.1) via differential isolation amplifiers. These amplifiers reference the outputs to LR-700 chassis ground. For simplicity, the differential amplifiers are not shown in the Block Diagram. These isolation amplifiers give clean ΔR (or 10ΔR) and ΔX (or 10ΔX) DC output signals suitable for driving an external temperature controller, a 6½ or 7½ digital volt meter, or a high gain strip chart recorder.

DAC ANALOG OUTPUT

As shown on the Block Diagram (Figure 4.1), the microcontroller decodes selected digits of the LR-700's parameters and sends them to a digital to analog converter for conversion to an analog voltage that is available at the rear panel BNC connector labeled DAC OUT. This signal can be used to drive a strip chart recorder directly.

Parameters that can be selected for DAC analog outputs are: R, ΔR, 10ΔR, X, ΔX, 10ΔX and also Rset and Xset.

Rset or Xset can be selected to calibrate the strip chart recorder or check its operation. Typically the user would input in sequence -100, -50, 0, +50, and +100 % of full scale Rset values. Then noting the position of the recorder trace for each setting, the wholesomeness of the strip chart recorder can be checked. For example, if the selected DAC mode is 000999, input Rset values would be -000999, -000500, +000000, +000500, and +000999. In addition, the user could input a + or - overload of-100000 or +100000 to verify proper operation.

To select a measurement and enter a DAC output mode, do the following:

1. Be sure the LR-700 is in a normal operating mode (that is not already in the middle of a input sequence such as % excitation or RSET, etc.).

2. Put into the top display the measurement or parameter that you want to output into the DAC. For example, if you want to output 10ΔR, get into the 10ΔR mode by pressing the following keys: TOP, ΔR, ΔRx10.

Make sure that the 10ΔR display is not in a + or - overload condition.

3. Select the DAC analog mode output or range. The key sequence for selecting the DAC is "SPECIAL 50" as shown the special feature section, (thus, i.e., press the following keys in sequence: SPECIAL, 5, 0, ENTER).

4. This will bring up in the lower display the last selected DAC mode. For example this might be:

   "+10V=+099999 ↑↓".

5. Scroll through the DAC modes by pressing cursor up and down until you display the mode you want.

6. Now press the ENTER key.

The DAC is now, in this example, locked onto the 10ΔR parameter.

Make a note of the selected DAC mode because once you change the upper display (for example, from 10ΔR to R), the LR-700 will give no further indication as to where the DAC input is pointed.

Note: When recording in the ΔR or 10ΔR modes, be sure the LR-700 stays in the mode that you wish to record. If you are recording in the ΔR mode and then change to 10ΔR mode on the face of the LR-700, the recording will not continue as 10ΔR. The DAC output will stay at the last ΔR measurement before entering the 10ΔR mode. This is because the LR-700's memory manipulates one or the other of ΔR or 10ΔR, not both simultaneously. Of course, the LR-700 manipulates R and X always in memory irrespective of whether you're in the R, ΔR or 10ΔR mode.

For high resolution strip chart recording methods, a longer digital filter time constant can be conveniently used. The recording, Figure 3.7, was made with a digital filter time constant of 5 minutes. Compare this with (A) the direct analog output with no external analog filter (Figure 3.8) and (B) direct analog output with recording made with a 10 second external analog filter (Figure 3.9).

Figure 3.10 shows the transfer function of the DAC analog output in the 009999 mode.

Figure 3.11 shows the schematic of the output stage of the DAC
circuitry that drives the DAC analog output.

Figure 3.12 shows the technique for interfacing the DAC analog
output to strip chart recorders that have full scale spans
that are less than 10 volts.
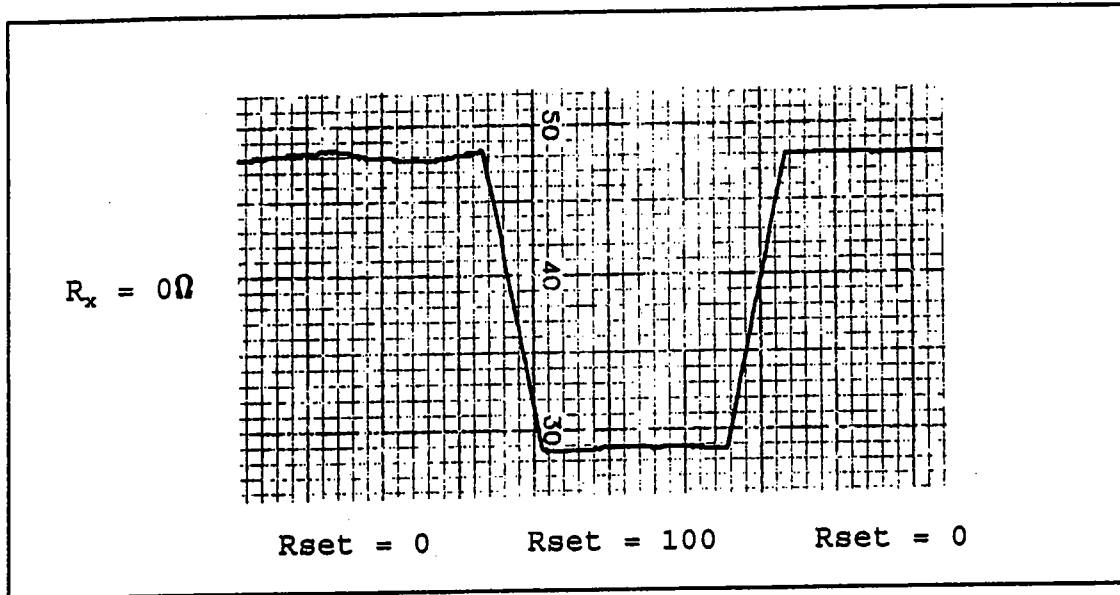
Figure 3.7 DAC ANALOG OUTPUT
DAC Filter = 5min
Strip Chart = 10cm/min, 50mV Full Span
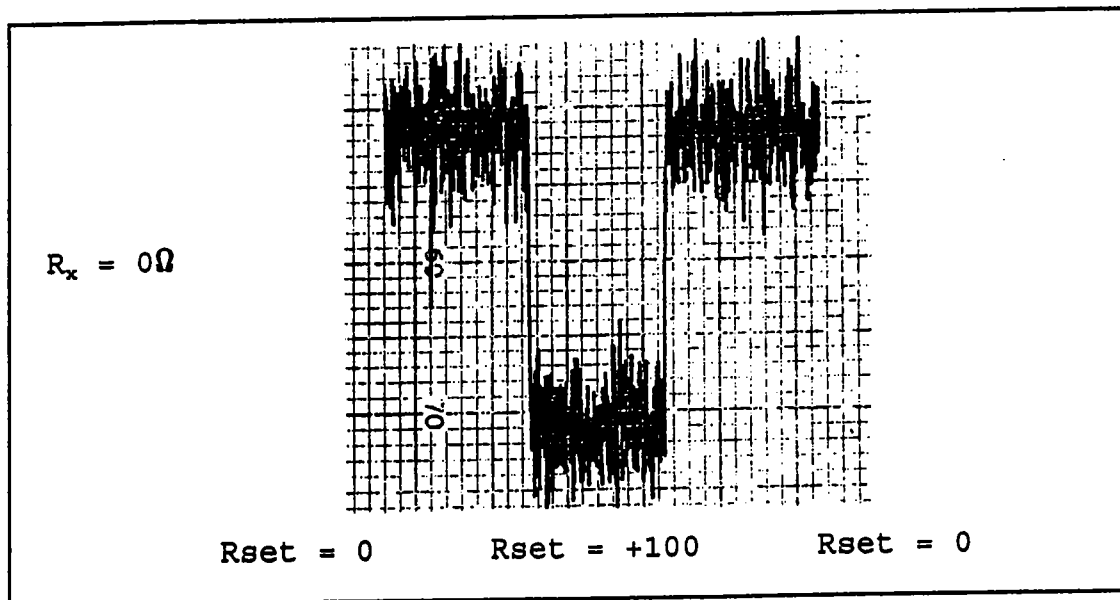
Figure 3.7A DAC ANALOG OUTPUT
DAC Filter = 1 sec
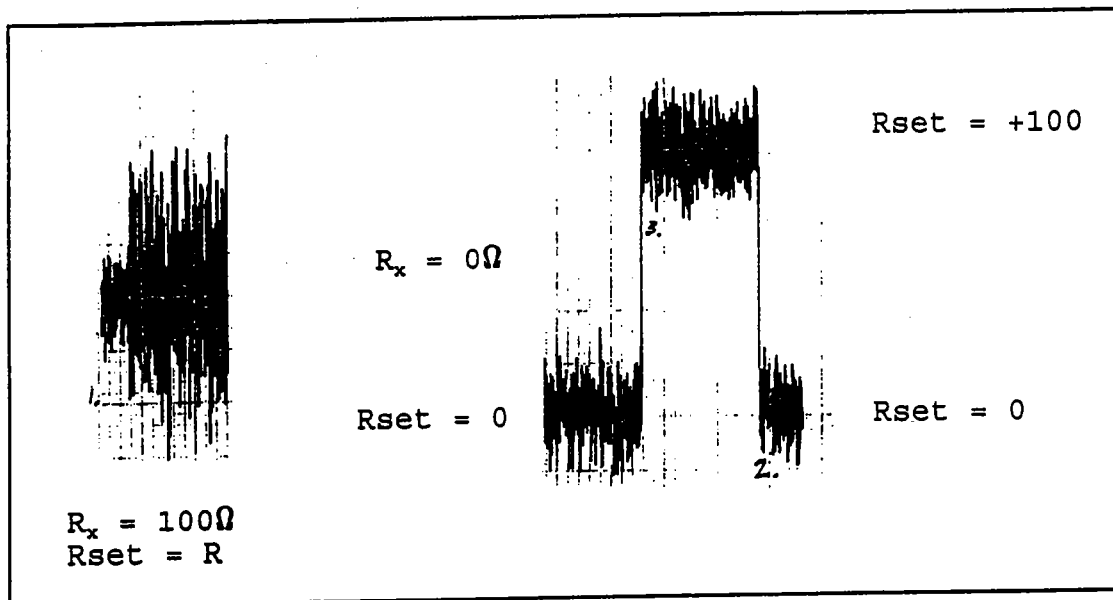
Figure 3.8   ΔR ANALOG OUTPUT
Range/Exc: 200Ω/20μV
Strip Chart Span = 1.0cm/min, 0.2V Full Span
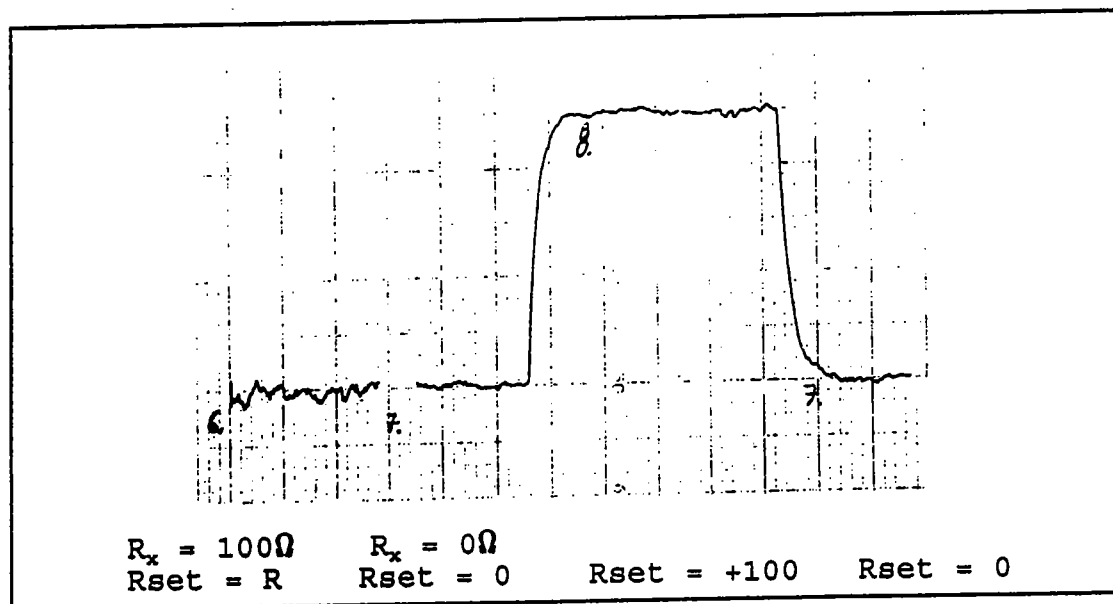
Figure 3.9   ΔR ANALOG OUTPUT WITH 10SEC EXTERNAL FILTER
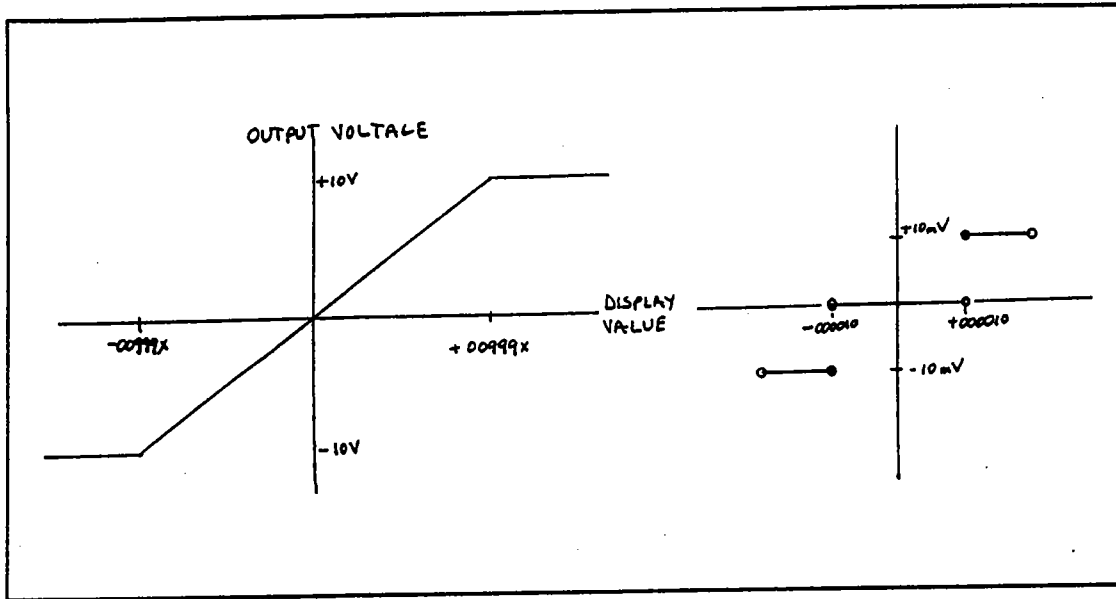
Figure 3.10
Typical DAC analog output transfer function shown for a DAC
mode of "+009999".
Total steps for -10VDC to +10VDC = 1999
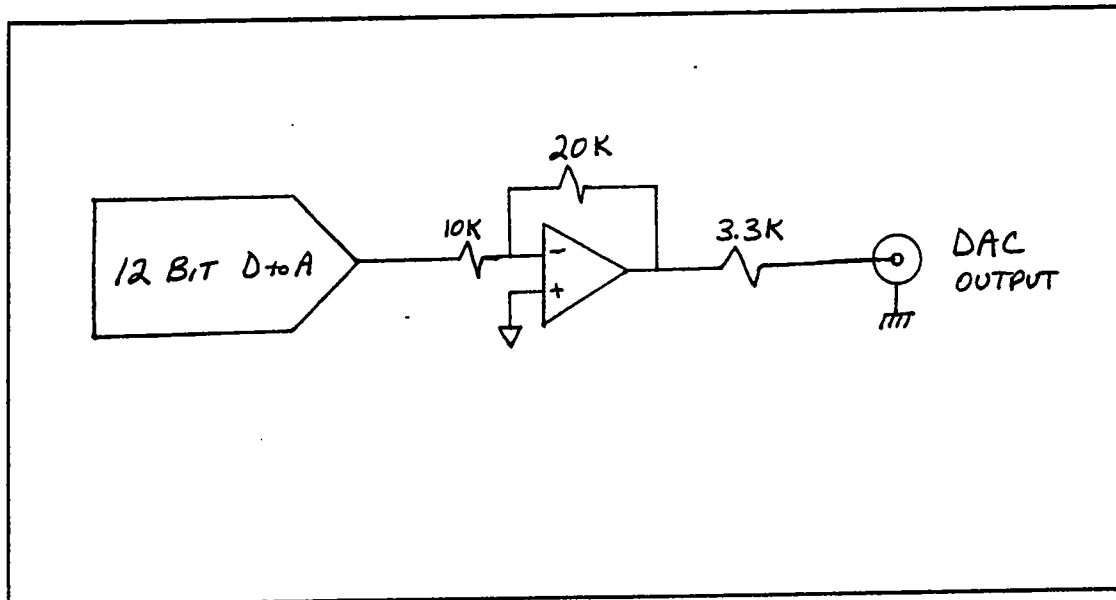
Figure 3.11   SCHEMATIC OF DAC OUTPUT STAGE
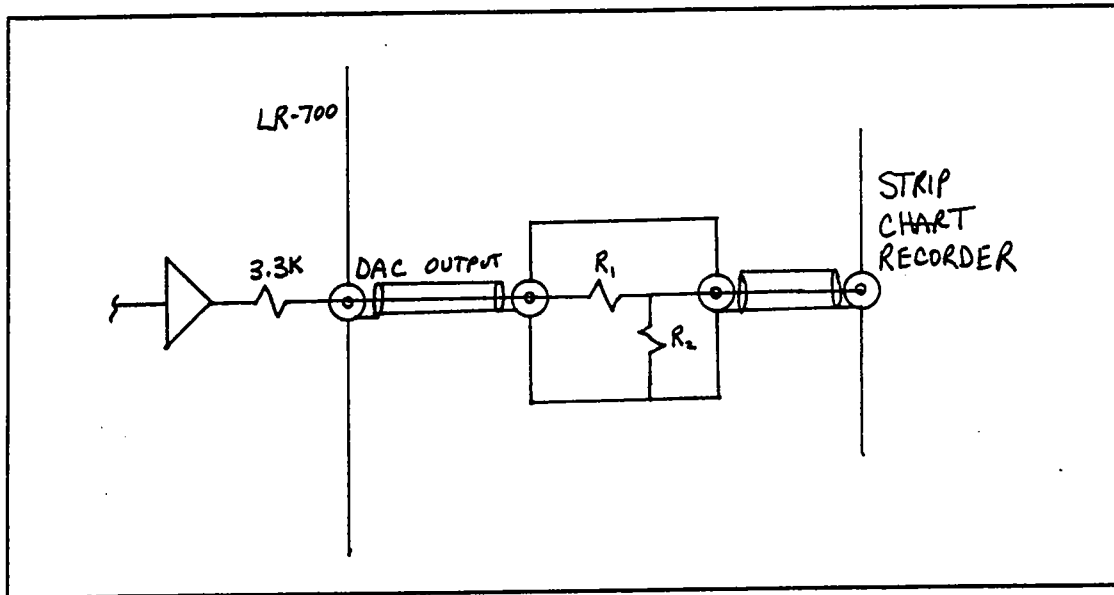
Figure 3.12   SCHEMATIC SHOWING ATTENUATOR USED TO INTERFACE
DAC OUTPUT TO STRIP CHART RECORDER

STRIP CHART RECORDER

ADAPTOR BOX R-VALUES		RECORDER SPAN	
R1	R2	Center to (FULL Right) (FULL Left)	Full Left to Full Right
ZERO*	NONE*	0± 10.00VDC	20.0V
3.24K	6.04K	0± 5.00VDC	10.0V
11.8K	4.99K	0± 2.50VDC	5.0V
10K	3.32K	0± 2.00VDC	4.0V
15K	2.0K	0± 1.00	2.0V
15.8K	1K	0± 0.50	1.0V
16.2K	499	0± 0.25	0.5V
13.0K	332	0± 0.20	0.4V
16.5K	200	0± 0.10	0.2V
16.9K	100	0± 0.05	0.1V
45.3K	49.9	0± 5.00mV	10.0mV
97.6K	10	0± 0.50mV	1.0mV

*Connect directly to recorder.

Table 3.12

Figure 3.13   DAC OUTPUT DECODING

DAC OPERATING MODE	OUTPUT	
Menu Display Selected	Actual Display Digits Decoded	Total Span* Resolution of Output Voltage
+199 999 ↓	±199 9AA	1 pp 3999
+099 999 ↑ ↓	±X99 9AA	1 pp 1999
+009 999 ↑ ↓	±XX9 99A	1 pp 1999
+000 999 ↑ ↓	±XXX 999	1 pp 1999
+000 099 ↑ ↓	±XXX X99	1 pp 199
+000 009 ↑ ↓	±XXX XX9	1 pp 19

*Total Span = Full left to full right of strip chart recorder. Zero is in center. Span voltage is 0±10VDC (20VDC peak to peak).

A = Digits ignored and not decoded. If these digits change value, DAC output will not change value.

X = Leading Digits. If these are a value other than zero, they will force the DAC output to: positive limit (≈ +10VDC) if polarity of display is positive or negative limit (≈ -10VDC) if polarity of display is negative.

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 3.3KΩ 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-700 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-700.

PREAMP MONITOR

This monitors the output of the preamp.
Source resistance is 3.3KΩ.

Tuned Amp Monitor

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

J1 AND J2

J1 Analog Filter Output option

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

J2 ΔX/10ΔX Direct Output Option

This BNC is the ΔX/10ΔX direct analog output. It operates in the same manner as the ΔR direct analog output except its signal is ΔX.

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-700'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-700. 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-700 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-700 power is off when connecting or disconnecting the cables. All power to the multiplexer is delivered by the LR-720 CONTROL BUS cable.

Figure 3.14 shows pictorially how to connect one or more LR-720 multiplexers to the LR-700 AC Resistance Bridge.

To connect the multiplexer:

o The cable labeled "LR-720 SENSOR BUS" connects from the LR-700's SENSOR connector to the multiplexer's SENSOR BUS connector. Either SENSOR BUS connector may be used.

o The cable labeled "LR-720 CONTROL BUS" connects from the LR-700'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.
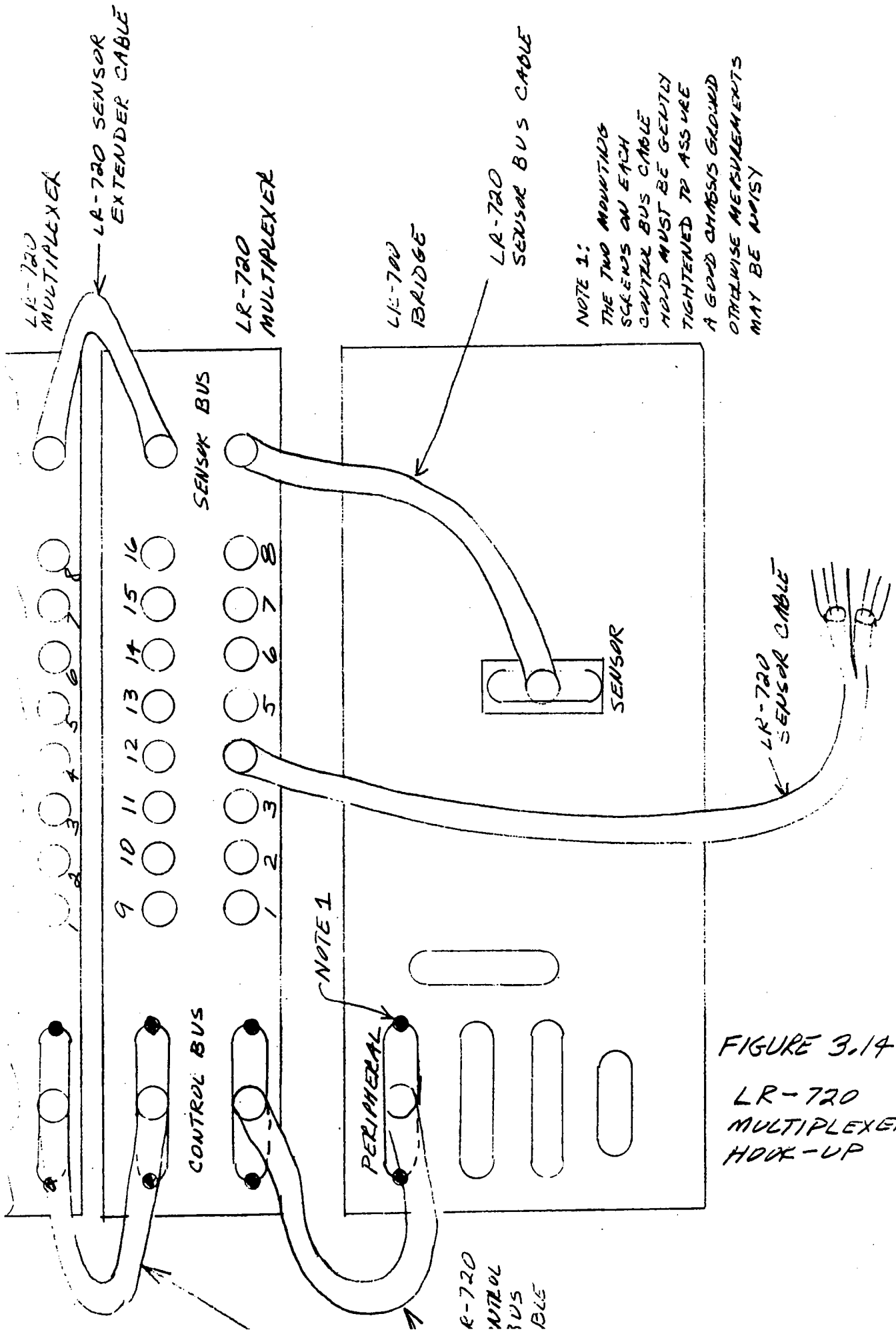
FIGURE 3.14

LR-720
MULTIPLEXER
HOOK-UP

NOTE 1:
THE TWO MOUNTINGS
SCREWS ON EACH
CONTROL BUS CABLE
HOOD MUST BE GENTLY
TIGHTENED TO ASSURE
A GOOD CHASSIS GROUND
OTHERWISE MEASUREMENTS
MAY BE NOISY

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 3.14 shows how to connect an additional multiplexer unit to another multiplexer unit.

To connect an additional multiplexer:

o   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.

o   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-700. Both of the shields are grounded and there is no provision for driven shields.

Figure 3.15 shows a detailed schematic of the LR-720 SENSOR CABLE.

For the highest common mode rejection of sensor line resistance, the LR-700 SENSOR CABLE with driven shields should be used and connected directly from the LR-700 to the sensor.

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

OUTSIDE VIEW
LR-720
SENSOR CABLE

SOLDER SIDE
VIEW LR-720
SENSOR CABLE

TO LR-700
I-HI ← ③ I-HI

I-HI

V-HI

TO LR-700
I-LO ← ⑤ I-LO

NOTE 1

SENSOR

I-SHIELD

CONNECTOR
SHELL

CHASSIS

MUX
CHASSIS

②

CRYOSTAT
CHASSIS

V-LO

I-LO

TO LR-700
CHASSIS ←

V-SHIELD

TO LR-700
V-HI ← ① V-HI

TO LR-700
V-LO ← ④ V-LO

NOTE 1

← LR-720 →
UNIT
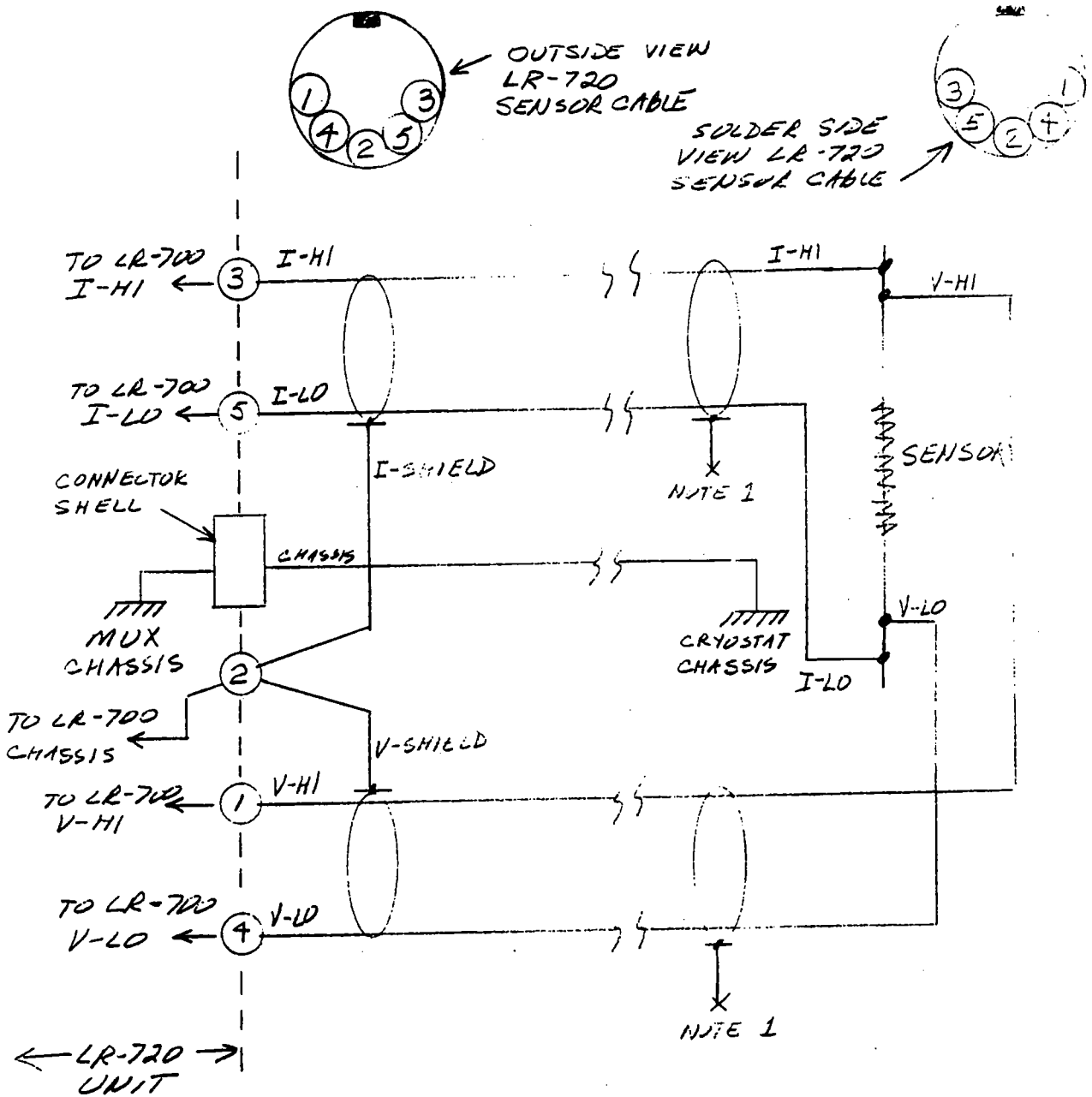
NOTES:

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 PRCH
   ELECTRONICS INDUSTRY INC
   TYPE 71430-050, 5PIN

4 SHIELDED 2 WIRE CABLE

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

PRINTER

You may connect a PC compatible printer (centronix compatible) up to the printer output on the rear panel of the bridge. This enables the bridge to print out all the measurement parameters as well as settings so that the operator need not hand write all the information.

CONNECTING THE PRINTER

Hooking a printer up to the LR-700 is identical to hooking a printer up to the LPT: Port of a PC compatible computer. You will need a normal PC compatible printer cable which you may obtain from any PC vendor that deals with PC type printers.

Caution: The power to the LR-700 as well as the power to the printer must be off when connecting the interface cable between the two. Failure to turn both instruments off may cause damage to either of the devices and any damage from such action would not be covered under the warranty.

Once the printer is connected to the LR-700 and the power for both instruments is on, you may obtain a print out by pressing the following key strokes:

SPECIAL 1 1 ENTER

Immediately the bridge will print out to the printer the following information:

```
SETTINGS: 2K OHMS,  20mV,  100%,  1 sec              996
R    =+1000.22        /\R   =+1000.22    RSET=+0000.00
X    =+0000.24        /\X   =+0000.24    XSET=+0000.00
```

The first line is the current bridge settings such as range, excitation, percent excitation, filter, overloads, and record number. This record number is a number between 0 and 999 which gets incremented every time the print function is issued. This is provided for reference in case you wish to reference any specific data sets. The second line and the third line, as can be seen, are the resistance values, the R values, the ΔR values, and the RSET values. If you have purchased the X display option, the X value, the ΔX value, and the XSET value will be printed in a third line.

COMPUTER INTERFACES

This chapter covers the command language used by the LR-700 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=<0-8><1-9>]
           [U=<0-6>₀,  <0-6>₁,.......<0-6>₉]
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>]
       [X=<±><000000-199999>]
Print <0-1>
Range <0-9>
Special S=<01-99>
Top <0-9>
Varexc [<0-1>] [=<05-99>]
```

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   [<0-1>] [L=<0-8><1-9>] [T=<0-4>]
            [U=<0-6>$_0$<0-6>$_1$.........<0-6>$_9$]
     Sets the Autorange settings

Autorange   0
     Turns Autorange Off

Autorange   1
     Turns Autorange On

Autorange   L=<0-8><1-9>
     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=<0-4>
     Selects which trace to use when autoranging

<0-4>	Trace Selected
0	Reset Autorange Features
1	Default
2	Minimum Excitation
3	Maximum Excitation
4	User Defined

Autorange U=<0-6><0-6><0-6><0-6><0-6><0-6><0-6><0-6><0-6><0-6>
     Sets the excitation to be used for each range when using
     the user defined trace

               First parameter is excitation for 2mΩ range
                Second parameter is excitation for 20mΩ range
          :   :   :   :   :   :   :
                    Ninth parameter is excitation for 200KΩ range
              Tenth parameter is excitation for 2MΩ range

NOTE: Parameters may be strung together or separated by spaces or tabs. All 10 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	X measurement	Bottom 1
2	$\Delta R/10\Delta R$ measurement	Bottom 2
3	$\Delta X/10\Delta R$ measurement	Bottom 3
4	RSET value	Bottom 4
5	XSET value	Bottom 5
6	% Excitation Setting	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:

<0-6>	EXCITATION SELECTED	PROGRAMMING EXAMPLES	
0	$20\mu V$	Excitation	0
1	$60\mu V$	Excitation	1
2	$200\mu V$	Excitation	2
3	$600\mu V$	Excitation	3
4	2mV	Excitation	4
5	6mV	Excitation	5
6	20mV	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 1 second Digital Filter.

Filter   1
    Selects the 3 second Digital Filter.

Filter   2
    Selects the 10 second Digital Filter.

Filter   3
    Selects the Variable Digital Filter.

Filter   =<00-24>
    Selects the length of the Variable Digital Filter where:

<00-24>	FILTER TIME
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.

<0-8>	RESPONSE MESSAGE	PROGRAMMING EXAMPLES
0	R measurement	GET 0
1	X measurement	GET 1
2	$\Delta R/10\Delta R$ measurement	GET 2
3	$\Delta X/10\Delta X$ measurement	GET 3
4	RSET setting	GET 4
5	XSET setting	GET 5
6	Bridge setting	GET 6
7	Bridge status	GET 7
8	Temperature Controller	GET 8

HEATER

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>]
       Temperature controller settings

Heater   0
    Turns the heater off

Heater   1
    Turns the heater on

Heater   C=<0-6>
    Selects the control type to be used

<0-6>	Control
0	D
1	DI
2	I
3	P
4	PD
5	PI
6	PID

Heater   D=<0-3>
    Selects the Temperature Controller Display to use for the
    front panel

<0-3>	Display
0	Heater voltage, numeric
1	Heater voltage, bar graph
2	% Heater current, numeric
3	% Heater current, bar graph

Heater   F=<0-7>
    Selects the low pass filter time constant for the input

<0-7>	Time Constant
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

<00-14>	Gain
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

<0-1>	Hold
0	Off
1	On

Heater **I=**<0-1>
     Selects the input to be used by the Temperature Controller

<0-1>	Input
0	ΔR
1	ΔX

Heater **L=**<0-2>
     Sets the loop control

<0-2>	Loop
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

	Cable Connected	
<00-10>	STD	LOW PWR
00	30μA	300nA
01	100μA	1μA
02	300μA	3μA
03	1mA	10μA
04	3mA	30μA
05	10mA	100μA
06	30mA	300μA
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 $\Delta R/\Delta X$ or measurement of $10\Delta R/10\Delta X$ where:

<0-1>	ΔR MODE	PROGRAMMING EXAMPLES	
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 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	ΔX

OFFSET

Offset   [=0] [=R] [R=<±><000000-199999>] [X=<±><000000-199999>]

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

Offset   =0

Sets both offsets R & X to zero (no offset). When the offsets are zero, ΔR=R and ΔX=X.

Offset   =R

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

Offset R=<±><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 1.00000Ω.

Offset X=<±><000000-199999>:

Sets the Xset in the same way as Offset R=<±><000000-199999> sets the Rset. See the above command.

PRINT

Print <0-1>

Print 1
    The bridge will print out the measurement and settings
    just as if **SPECIAL 1 1 ENTER** was entered on the front
panel. See Chapter 2 for more information.

RANGE

Range <0-9>
    Selects the full scale resistance range where:

<0-9>	RANGE SELECTED	PROGRAMMABLE EXAMPLES	
0	2 mΩ	Range	0
1	20 mΩ	Range	1
2	200 mΩ	Range	2
3	2 Ω	Range	3
4	20 Ω	Range	4
5	200 Ω	Range	5
6	2 kΩ	Range	6
7	20 kΩ	Range	7
8	200 kΩ	Range	8
9	2 MΩ	Range	9

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

Note – For example, to select sensor #7, do:

S_S=07
     ↖
       space

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.

VARIABLE EXCITATION

Varexc [<0-1>] [=<05-99>]
     Selects the percent of full excitation.

Varexc 0
     Selects 100% excitation.

Varexc 1
     Selects the previously set variable excitation percent.

Varexc =<05-99>
     Sets the percent of full excitation to be used when
     Varexc 1 is sent.

RESPONSE MESSAGES

After sending commands to the LR-700, 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-700 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-700 is on the 2mΩ range, 20mV excitation, variable excitation is at 100%, digital filter is 1 second and it is not in 10ΔR 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-700 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	$+\Delta X$ overrange	$\pm X$ overrange
2	$-\Delta X$ 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-700 may be connected to the GPIB Bus by using a standard GPIB cable and connecting it to the rear panel of the LR-700.

Caution: The power to the LR-700 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-700 or any other instrument.

Once the LR-700 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-700 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-700 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-700.

Caution: The power to the LR-700, 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-700 or your computer.

Once the LR-700 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-700 by issuing the following key strokes:

SPECIAL 4 2 ENTER

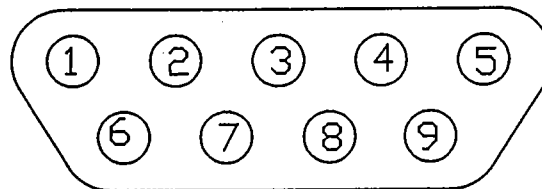This special function, 4 2, enables the LR-700 to respond to RS-232 Interface.

RS-232 CABLING

If you're connecting the LR-700 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-700. 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 3.16

RS-232 SIGNALS

The RS-232 cable should connect the following:

LR-700 SIGNALS			COMPUTER SIGNALS		
				DB9	DB25
NAME	PIN#		NAME	PIN#	PIN#
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-700, and connect the LR-700'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-700's DSR and CTS, and connect the LR-700's RTS to the computer's CTS.

RS-232 PROGRAMMING

When communicating with the LR-700 via the RS-232 interface, you must use the following procedures:

1. Each string sent to the LR-700 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-700, you must read the LR-700's response back from the instrument.
5. The serial port parameters for the LR-700 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-700 and acted upon, the LR-700 will send a response string back. The following table describes the responses:

| RESPONSE	DESCRIPTION
"OK"	The command was received properly and acted upon and the LR-700 has no information to send to the computer.
"?BADPARAM"	The LR-700 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-700.
"?SYNTAX"	The command was uninterpretable as a valid command by the LR-700. Either the computer sent an unrecognizable string or the string was improperly received by the LR-700.
RESPONSE MESSAGE	The command was received properly by the LR-700 and acted upon and the computer was requesting specific information from the LR-700. Please refer to the response messages sections in Chapter III, Command Language.

During certain portions of the LR-700's operating software, timing is absolutely critical for stable measurements. During these portions of the code, the LR-700 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-700 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-700. 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-700'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-700. Its pinout shown looking at the rear panel. This is also a view of the solder cups of the main connector.
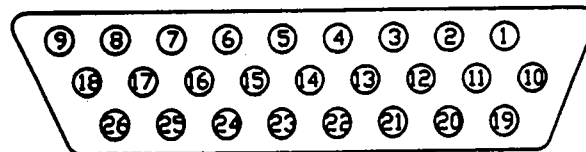
TEMPERATURE CONTROLLER SIGNALS

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

PRELIMINARY TUNING PROCEDURE FOR THE LR-700-TC

This is the preliminary tuning procedure for the LR-700 Internal Temperature Controller (TC). This procedure will be worded in a general manner and you may need to refer to the LR-700 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-700. 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.
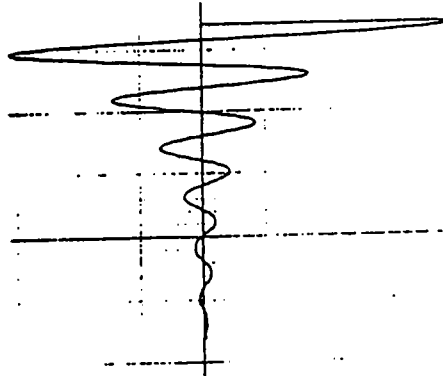
Note that one cycle of the ring is the same order of magnitude
in period as the oscillation measured previously. This is a
characteristic of your thermal system. Change the TTC up or
down one step and repeat the step change. Observe whether the
damped oscillation takes longer to dampen out or if it dampens
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:
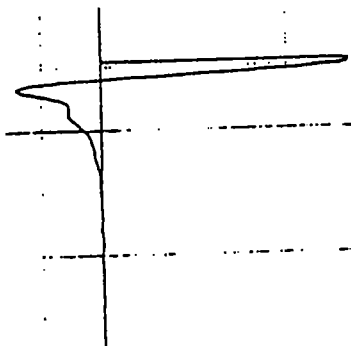
The Temperature Controller is now tuned.

Final Notes

Please keep in mind that you now have your settings for the tuned system. If you change range or go to a 10ΔR 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.
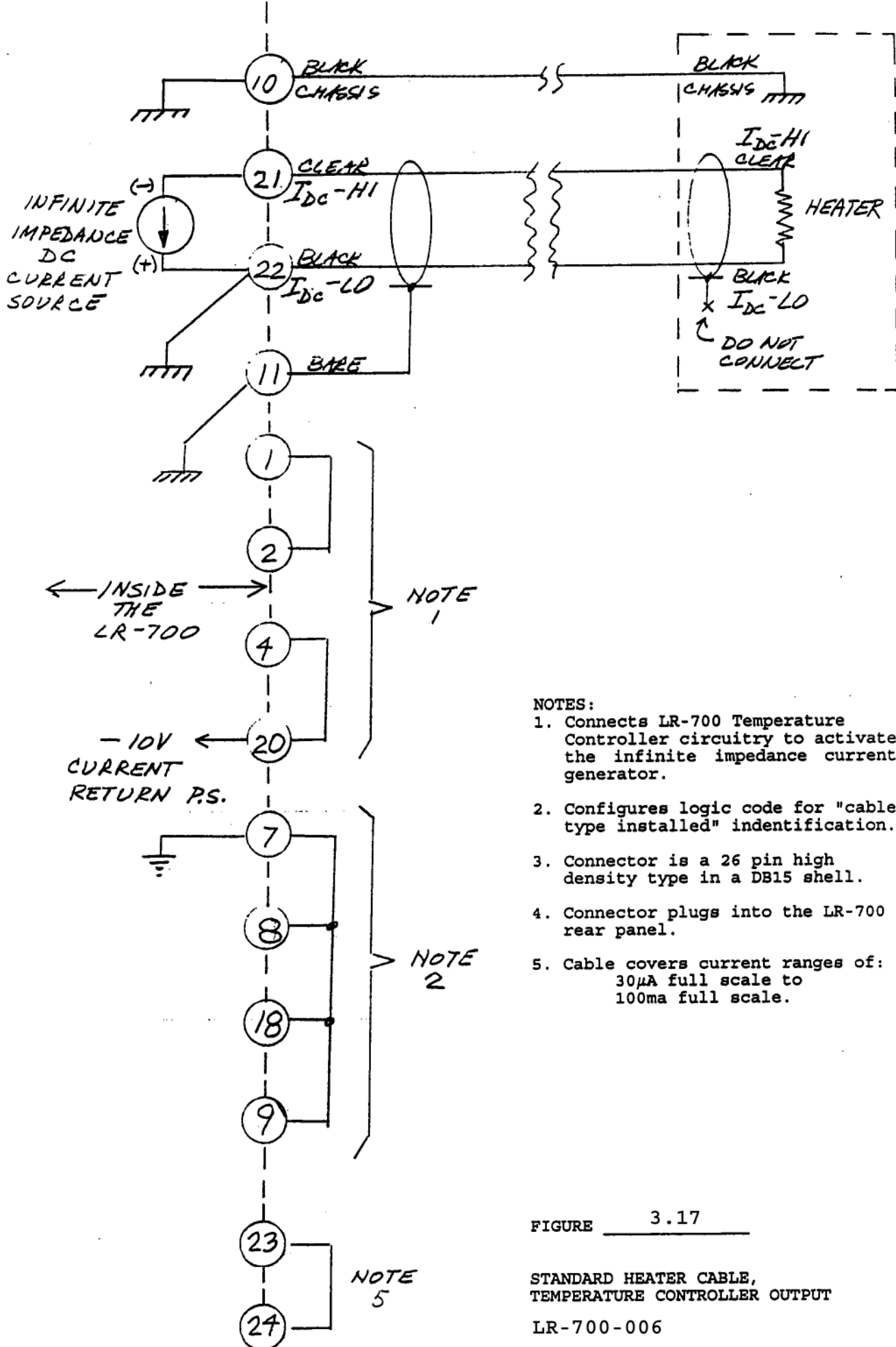
NOTES:
1. Connects LR-700 Temperature Controller circuitry to activate the infinite impedance current generator.

2. Configures logic code for "cable type installed" indentification.

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:
   30μA full scale to
   100ma full scale.

FIGURE ___3.17___

STANDARD HEATER CABLE, TEMPERATURE CONTROLLER OUTPUT

LR-700-006

NOTES:
1. Connects LR-700 Temperature
   Controller circuitry to activate
   the voltage-resistance (V-R)
   current generator.

2. Configures logic code for "cable
   type installed" indentification.

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:
       0.3µA full scale to
       300µa full scale.

FIGURE ___3.18___

LOW POWER HEATER CABLE,
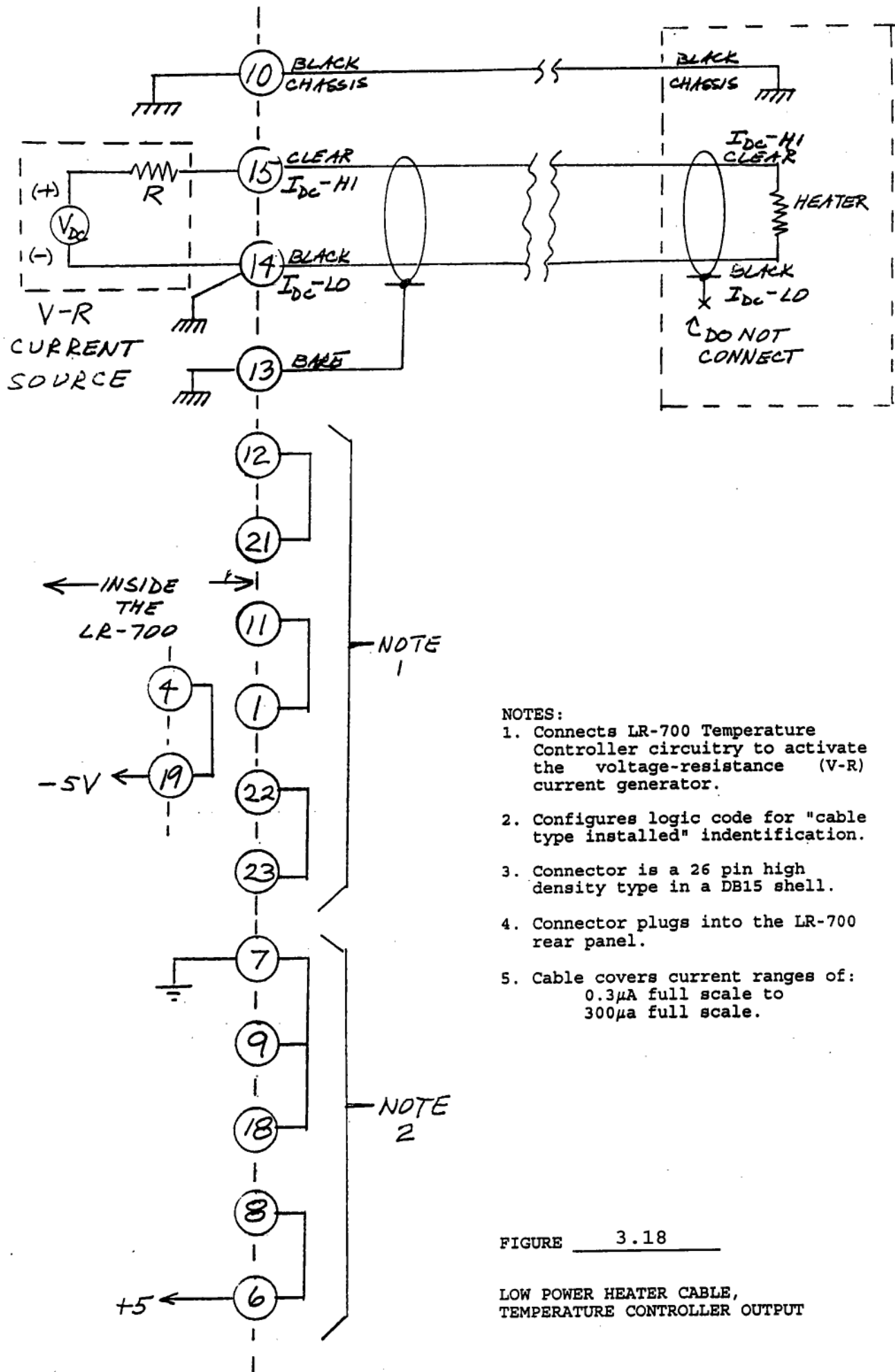TEMPERATURE CONTROLLER OUTPUT

NOTES:

1. Connects LR-700 Temperature Controller circuitry to activate the infinite impedance current generator.

2. Configures logic code for "cable type installed" indentification.

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: 30μA full scale to 100ma full scale.

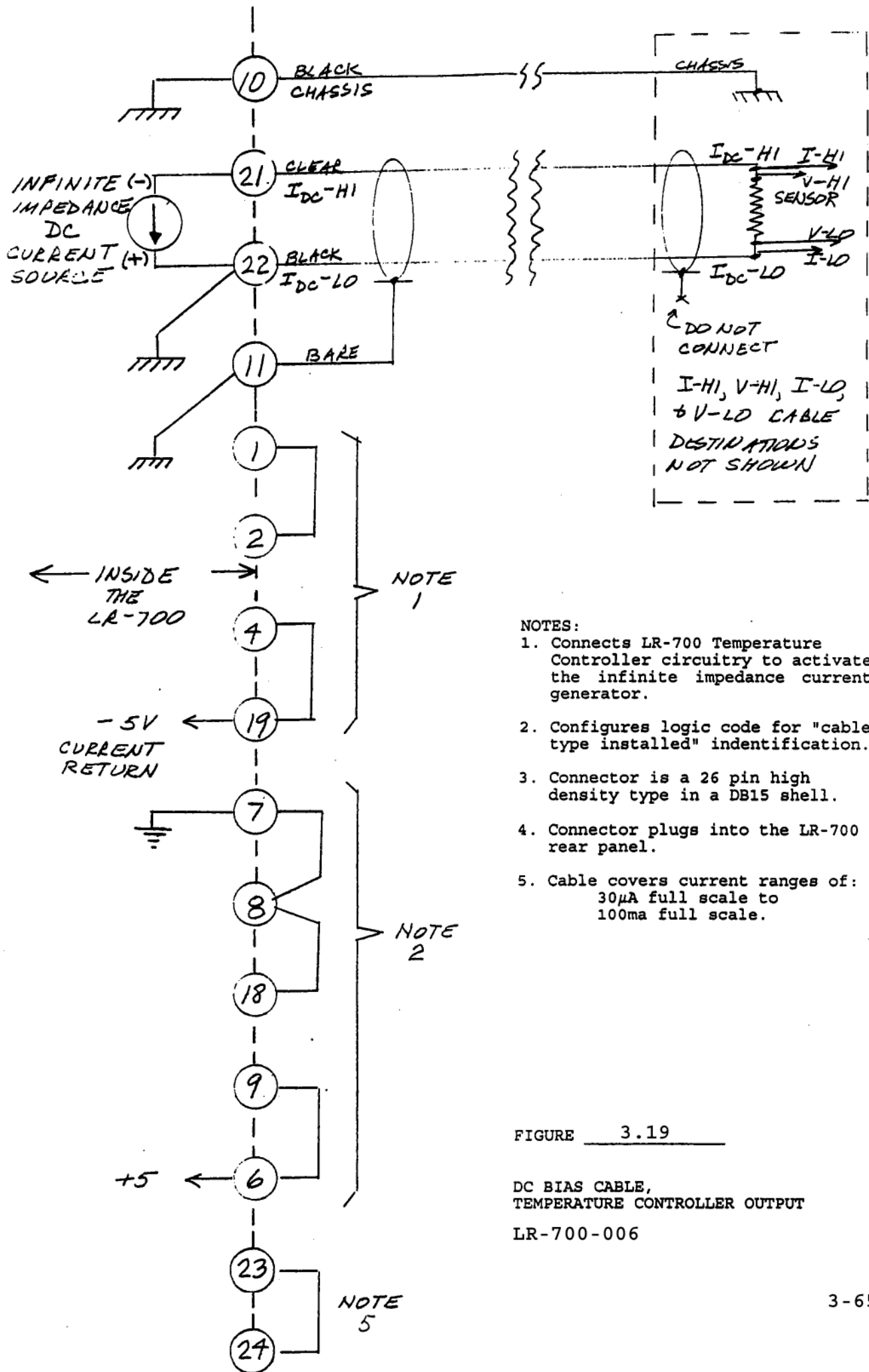FIGURE ___3.19___

DC BIAS CABLE, TEMPERATURE CONTROLLER OUTPUT

LR-700-006

OVERVIEW OF LR-730 FEATURES

The LR-730 series of Power Boosters are designed to be used with the LR-700 AC Resistance Bridge along with its Internal Temperature Controller Option (LR-700-TC). The LR-700-TC can deliver DC currents in the range of micro amps up to 100 milli amps 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 milli amps 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-700 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-700 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-700 Bridge. Therefore, any examples in this manual, or referred to in the LR-700 manual, are referring to setting of parameters in the LR-700 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-700 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 1
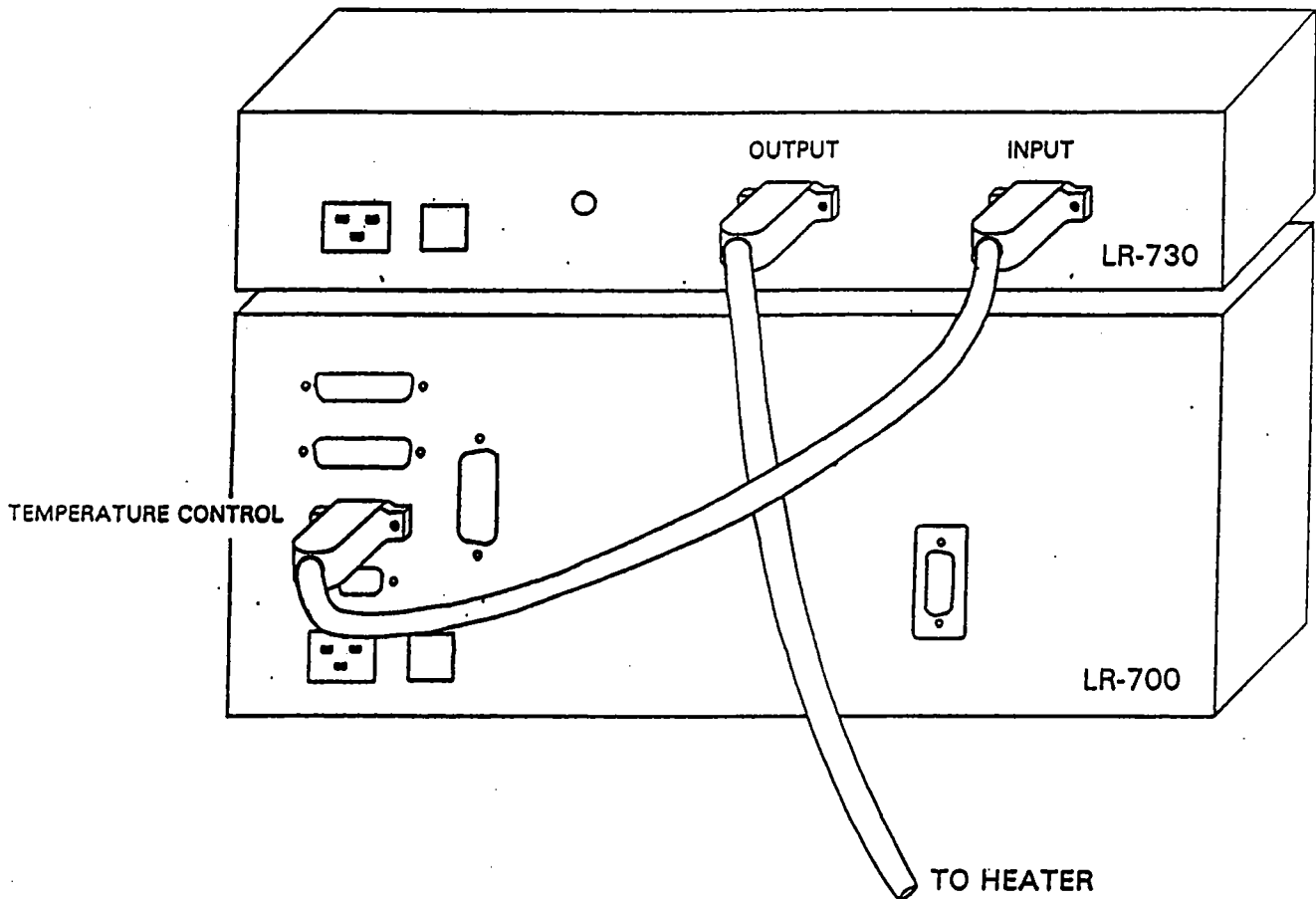
LR-730 HEATER CONNECTIONS

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 milli amps on the 15 watt version or even up to 3 amps full scale on the 150 watt version.

CONNECTOR TYPE: DB15S

50V POWER SUPPLY (+)

HEATER LOW

HEATER SHEILD

HEATER HOT

CURRENT GENERATOR

HIGH POWER ENABLE

HEATER 15W, 50W 150W
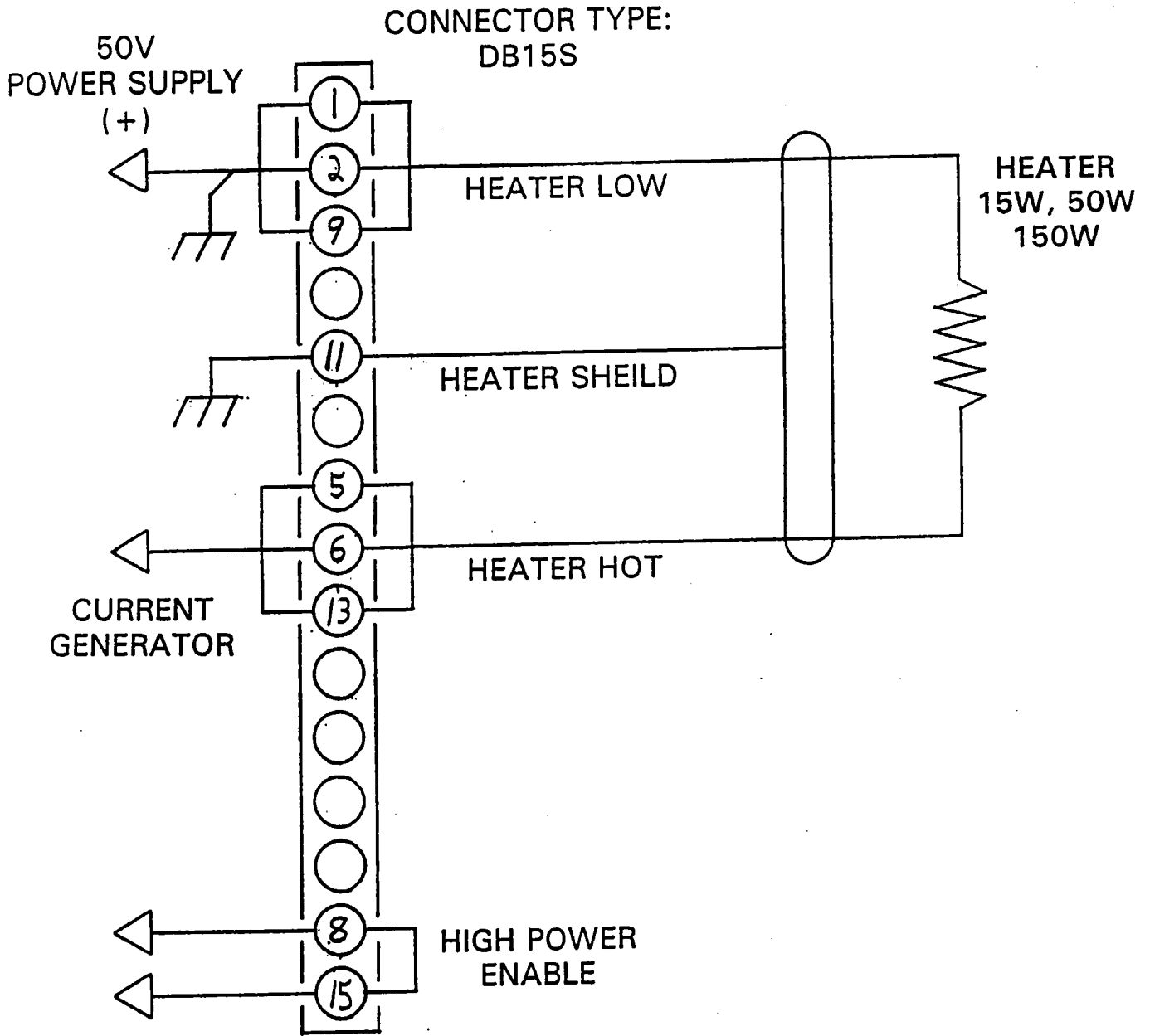
Notes:
1. Unnumbered pins have no connections.

2. Cable covers current ranges of:
   30μA full scale to
   300mA full scale(15W),
   1A full scale(50W),
   3A full scale(150W).

3. Heater hot compliance voltage from:
   0V to -50V.

Figure:

LR-730
High Power Heater Cable

CHAPTER 4 DEFINITIONS & SPECIFICATIONS

SYMBOL DEFINITIONS
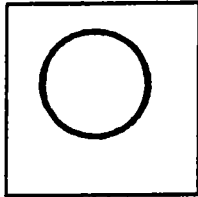
OFF (SUPPLY)
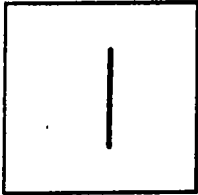
ON (SUPPLY)

CAUTION (Refer to the accompanying documents)
All inputs are ±5V, ±15V, or ±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

TERMINAL	MAXIMUM VOLTAGE TO CHASSIS
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-700 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-700 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 and ΔX DC-input-to-AC-output converters. These converters generate ΔR and ΔX AC signals 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 and XSET signals, 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, RSET, and XSET 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

4-2

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 and XSET values, then calculates $R = \Delta R + RSET$ and $X = \Delta X + XSET$ from the ΔR digital and ΔX digital signals 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 2MΩ 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 combined $\Delta X + XSET$ 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 3% of full scale) of these upper ranges.

FIG 4.1
LR-700
BLOCK DIAGRAM

RANGE 1na TO 30ma

I-HI

V-HI

PA-HI

PREAMP

C

SENSOR

C

AC NULL

BALANCING TRANSFORMER

PA-LO

I-LO

V-LO

RANGE CONTROL LOGIC

ADDITIONAL QUADRATURE-PHASE, VARIABLE AMPLITUDE CURRENT GENERATOR

AC=ΔR+RSET

AC

AC

REGULAR IN-PHASE FIXED AMPLITUDE CURRENT GENERATOR

AC

AC=ΔX+XSET

AC

ΔR

DC INPUT TO AC OUTPUT CONVERTER

DC REFERENCE

AC

ΔX

SUMMER

R (IN PHASE) REFERENCE

RANGE 20μv TO 20mV
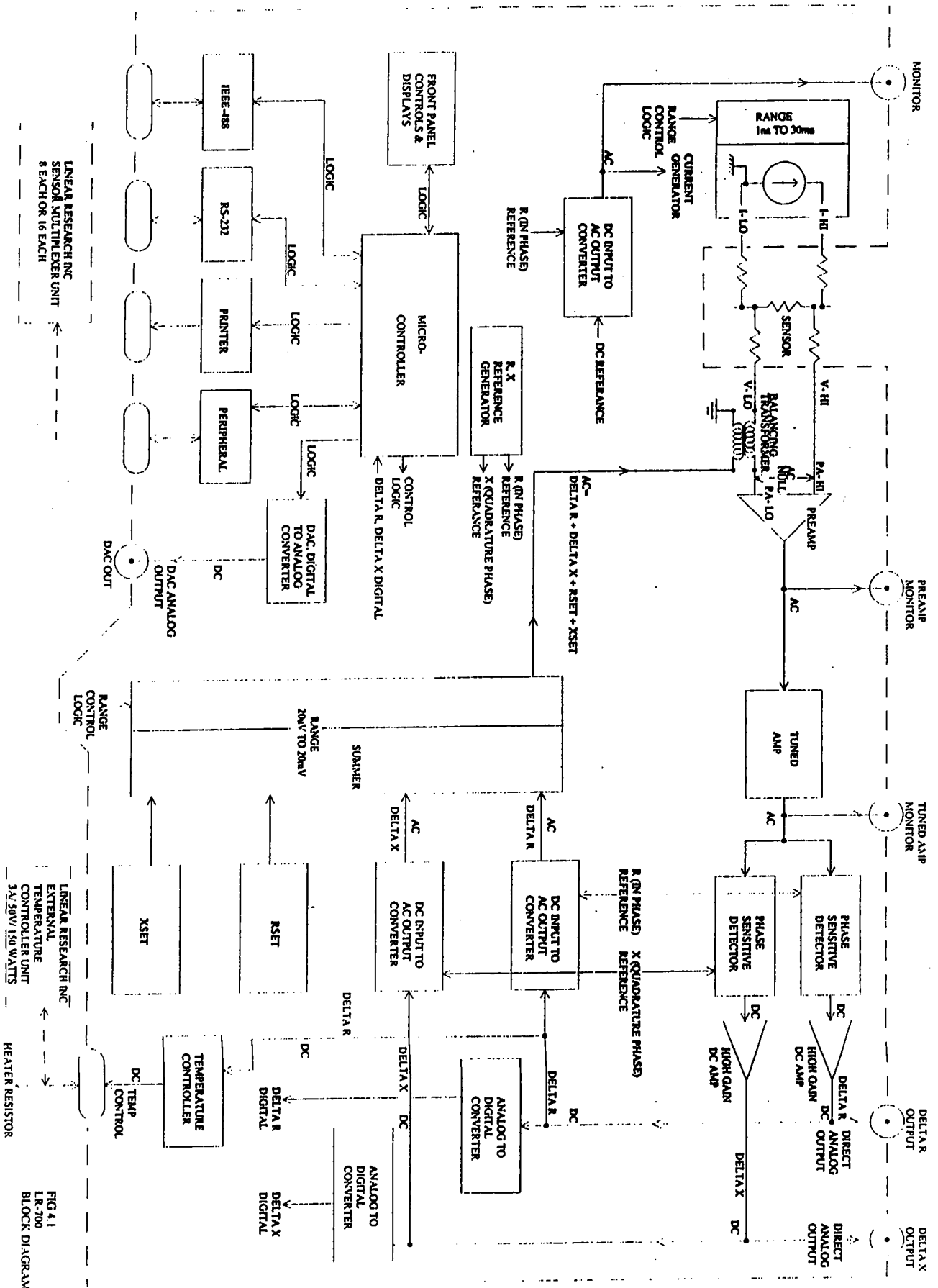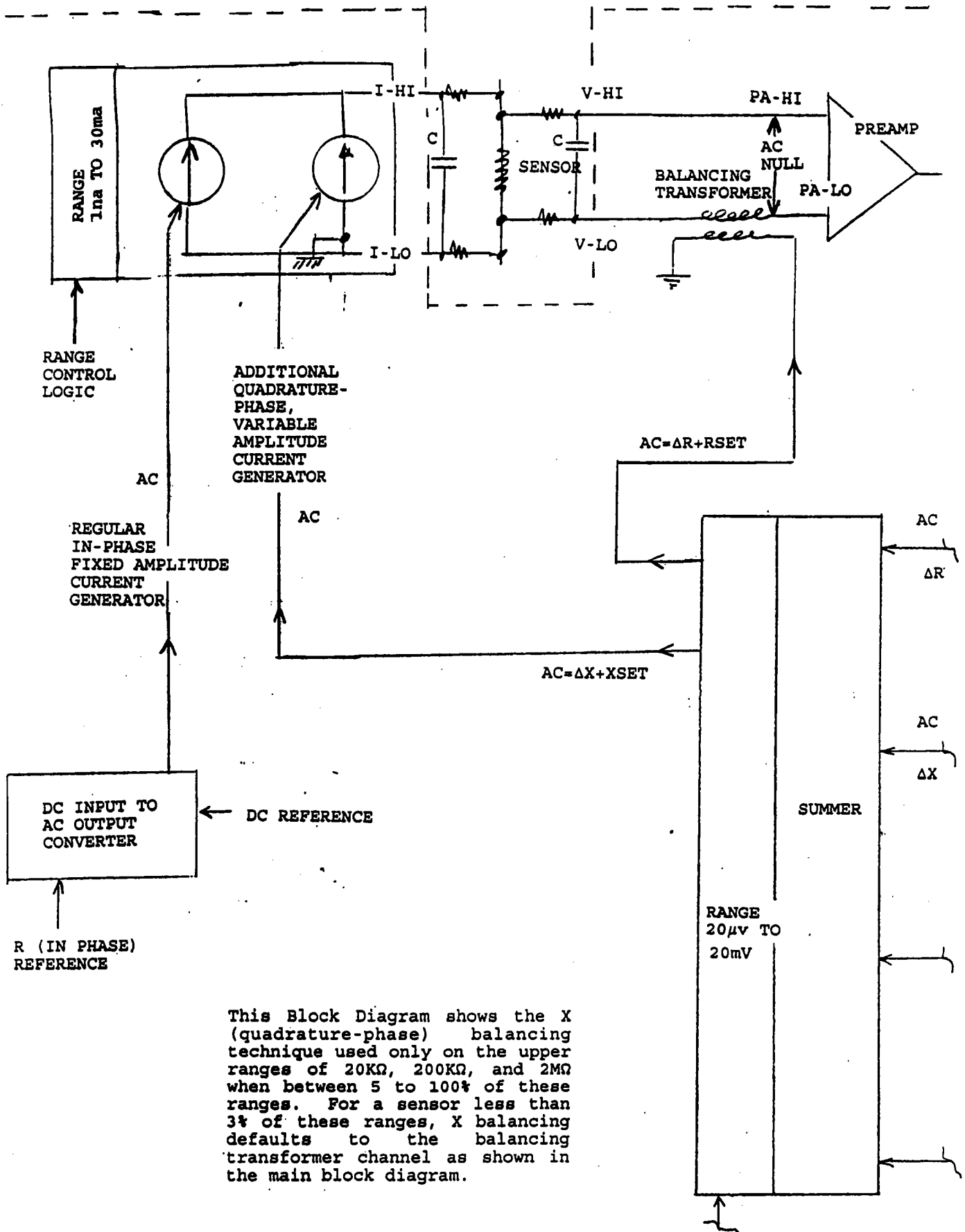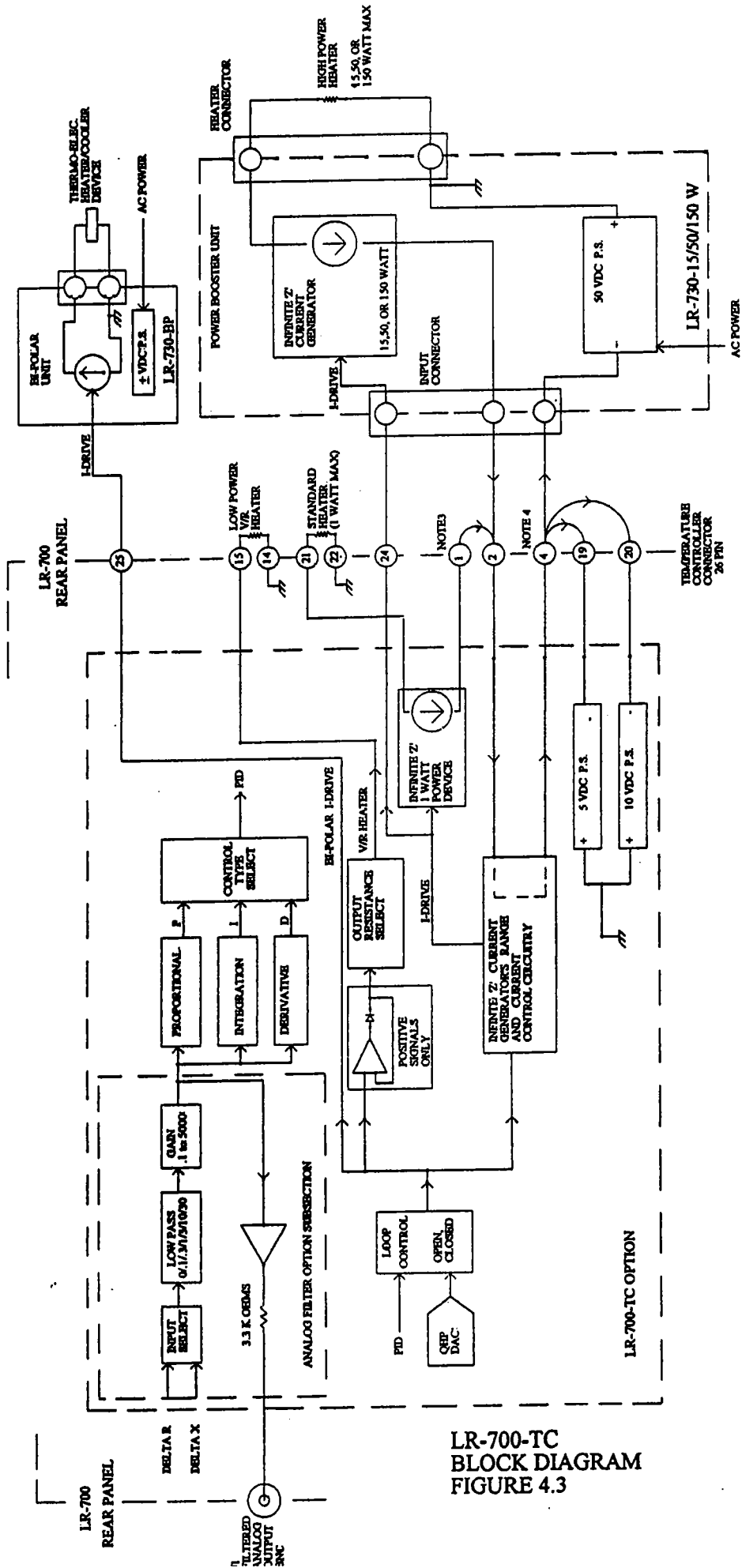
This Block Diagram shows the X (quadrature-phase) balancing technique used only on the upper ranges of 20KΩ, 200KΩ, and 2MΩ when between 5 to 100% of these ranges. For a sensor less than 3% of these ranges, X balancing defaults to the balancing transformer channel as shown in the main block diagram.

LR-700
BLOCK DIAGRAM
ADDENDUM 1

FIGURE 4.2

LR-700-TC
BLOCK DIAGRAM
FIGURE 4.3

SPECIFICATIONS

RANGE
2mΩ, 20mΩ, 200mΩ, 2Ω, 20Ω, 200Ω, 2KΩ, 20KΩ, 200KΩ, 2MΩ.
Resistance (R) in ohms. Mutual Inductance (X) in reactive ohms where 2mΩ = 20μHenry and 20mΩ = 200μHenry, etc.

EXCITATION VOLTAGE
20μV, 60μV, 200μV, 600μV, 2mV, 6mV, 20mV RMS at full scale resistance. Bridge delivers constant amplitude AC current to the sensor. Each excitation can be varied 0-100%

EXCITATION FREQUENCY
15.9 Hz sine wave. Crystal controlled frequency for high stability in mutual inductance mode.

DISPLAY
2 lines of 16 characters each. Displays any two of the following simultaneously: R, ΔR, 10ΔR, X, ΔX, 10ΔX, R-set, X-set, % Exc, Filter. Bright clear 5½ digit (±199999 counts) LED 5x7 dot matrix display. Kilohms, ohms, milliohms and micro-ohms are indicated in the display.

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

OFFSETS, RSET and XSET
User friendly, random entry of the 5½ digits in either R-set or X-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 ΔR=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-700'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 20,000. Most ranges when in ΔR mode with Rset = Rx.

ACCURACY
Typically, ± 0.02% (most ranges).

SUPPLY
100-115VAC		230VAC (±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 $0.6nV$ RMS/$\sqrt{Hz}$ (BW = 1 Hz) is equivalent to the thermal noise of a room temperature 20Ω resistor. For a filter of 3 sec, BW = 0.053 Hz with input noise of $0.138nV$ RMS or $0.69nV$ peak-peak.

For room temperature sensors greater than 20Ω at low level excitations, resolution is limited only by the thermal noise in the sensor. For sensors at low temperatures with values above 20Ω, resolution will improve due to lower sensor thermal noise since sensor noise drops by the square root of temperature.

A 10 milliohm resistor can be measured to within 150 nano-ohms RMS (15ppm) resistance resolution using only 1 milliamp of excitation current.

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

A $1M\Omega$ 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 15 ppm/°C in the ΔR mode where R-SET = Rx. 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 180 db. Thus, a 1 milliohm sensor ($2m\Omega$ range, 10ma excitation) with 100Ω of resistance in each of the four leads, yields typically less than $100n\Omega$ of induced offset error.

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.

TRUNCATION OF DISPLAYED DIGITS
Without upsetting the unit's internal readings or balancing, the displayed digits may be reduced by front panel selection from 5½, to 4½ or 3½ digits.

Useful for balancing out lower count continually unsteady digits or to achieve greater clarity for lower resolution "quick & dirty" measurements. Avoids errors in copying a long string of digits from the display when high resolution is not needed.

DRIFT (24 HOUR TEST)
Under typical laboratory ambient temperature conditions where RSET=R, 10ΔR drift is typically better than 1 part in 20,000 full scale for a 12 hour period.

DIGITAL FILTER

Front panel direct select either 1, 3, 10 seconds, or one filter time chosen from the menu. Filter function allows for fast output response/noise resolution trade offs. Menu selectable from .2 seconds to 30 minutes in 25 steps.

Every 200ms the filter computes an arithmetic average of the latest string of 200ms A/D conversions giving equal weight to each conversion. A 10 second filter setting has a string length of 50. Every 200ms the display is updated with the new arithmetic average on most filters.

RESOLUTION
ANALOG RESOLUTION

		SENSOR VOLTAGE (AT MID-SCALE)						
		$10\mu V$	$30\mu V$	$100\mu V$	$300\mu V$	1mV	3mV	10mV
R E S I S T A N C E Rx	1mΩ	15nΩ	5nΩ	X	X	X	X	X
	10mΩ	150nΩ	50nΩ	15nΩ	5nΩ	X	X	X
	100mΩ	1.5$\mu\Omega$	500nΩ	150nΩ	50nΩ	15nΩ	X	X
	1Ω	15$\mu\Omega$	5$\mu\Omega$	1.5$\mu\Omega$	500nΩ	200nΩ	150nΩ	100nΩ
	10Ω	150$\mu\Omega$	50$\mu\Omega$	15$\mu\Omega$	5$\mu\Omega$	1.5$\mu\Omega$	600nΩ	400nΩ
	100Ω	4.5mΩ	1.5mΩ	500$\mu\Omega$	150$\mu\Omega$	50$\mu\Omega$	15$\mu\Omega$	10$\mu\Omega$
	1KΩ	90mΩ	30mΩ	10mΩ	3mΩ	1mΩ	400$\mu\Omega$	200$\mu\Omega$
	10KΩ	3Ω	750mΩ	300mΩ	100mΩ	30mΩ	10mΩ	6mΩ
	100KΩ	X	* 30Ω	10Ω	3Ω	1Ω	0.3Ω	0.1Ω
	1MΩ	X	X	X	*100Ω	30Ω	10Ω	3Ω

* At 30% excitation.   X = nonvalid excitation.

Notes: RMS resistance resolution was derived from strip chart recording using the 10ΔR analog output voltage with midscale room temperature resistors and mid-scale R-SET values. The recording trace length was 120 seconds minimum. The strip chart recorder had better than 100 microvolts of span sensitivity. Values were normalized to a 3 second analog filter time constant.

We use the convention that peak to peak magnitude equals 5 times RMS noise magnitude. Noise decreases by the square root of filter time constant increase. nΩ = nano-ohms.

Resistance resolution values will:
 Improve by a factor of 1.7 for a 10 second filter time constant setting.
 Decrease by a factor of 1.7 for a 1 second filter time constant.
 Decrease by a factor of 5 for peak to peak resistance.

DIGITAL DISPLAY RESOLUTION

RANGE	DISPLAY MODE		READABLE DIGIT (1)	SENSOR EXCITATION
	R, ΔR, R-Set	10ΔR		
2mΩ	10nΩ	1nΩ	10nΩ	30μV
20MΩ	100nΩ	10nΩ	10nΩ	300μV
200mΩ	1μΩ	100nΩ	100nΩ	300μV
2Ω	10μΩ	1μΩ	1μΩ	300μV
20Ω	100μΩ	10μΩ	10μΩ	300μV
200Ω	1mΩ	100μΩ	(2) 100μΩ	10mV
2K	10mΩ	1mΩ	(2) 1mΩ	10mV
20K	100mΩ	10mΩ	(2) 10mΩ	10mV
200K	1Ω	100mΩ	(2) 1Ω	10mV
2MΩ	10Ω	1Ω	(2) 10Ω	10mV

Above measurements are for room temperature mid-scale resistor and 10 second filter time constant.
 (1) A readable digit is one that holds a fixed value ±1 count for one minute.
 (2) Sensor noise for room temperature sensors shown exceeds bridge preamp noise. Thus, better resolution will be achieved at low temperatures where sensor noise is lower.

SENSOR EXCITATION CURRENT

		100% EXCITATION VOLTAGE, RMS						
		20μV	60μV	200μV	600μV	2mV	6mV	20mV
	2mΩ	10ma	30ma	X	X	X	X	X
	20mΩ	1ma	3ma	10ma	30ma	X	X	X
R	200mΩ	100μa	300μa	1ma	3ma	10ma	30ma	X
A	2Ω	10μa	30μa	100μa	300μa	1ma	3ma	10ma
N	20Ω	1μa	3μa	10μa	30μa	100μa	300μa	1ma
G	200Ω	100na	300na	1μa	3μa	10μa	30μa	100μa
E	2KΩ	10na	30na	100na	300na	1μa	3μa	10μa
	20KΩ	1na	3na	10na	30na	100na	300na	1μa
	200KΩ	X	* 0.3na	1na	3na	10na	30na	100na
	2MΩ	X	X	X	* 0.3na	1na	3na	10na

X = nonvalid excitation current. * 30% excitation of next higher valid excitation current can be used.

Notes: For any particular range and excitation voltage selected, the actual value of excitation voltage appearing across the sensor resistor is directly proportional to the magnitude in ohms of the sensor resistor.

SENSOR CURRENT AND POWER

		SENSOR VOLTAGE (AT MID-SCALE)						
		10μV	30μV	100μV	200μV	1mV	3mV	10mV
E X C I T A T I O N C U R R E N T	1na	10kΩ -14		100KΩ -13		1MΩ -12		
	3na		10KΩ -13		100KΩ -12		1MΩ -11	
	10na	1KΩ -13		10KΩ -12		100KΩ -11		1MΩ -10
	30na		1KΩ -12		10KΩ -11		100KΩ -10	
	100na	100Ω -12		1KΩ -11		10KΩ -10		100KΩ -9
	300na		100Ω -11		1KΩ -10		10KΩ -9	
	1μa	10Ω -11		100Ω -10		1KΩ -9		10KΩ -8
	3μa		10Ω -10		100Ω -9		1KΩ -8	
	10μa	1Ω -10		10Ω -9		100Ω -8		1KΩ -7
	30μa		1Ω -9		10Ω -8		100Ω -7	
	100μa	100mΩ -9		1Ω -8		10Ω -7		100Ω -6
	300μa		100mΩ -8		1Ω -7		10Ω -6	
	1ma	10mΩ -8		100mΩ -7		1Ω -6		10Ω -5
	3ma		10mΩ -7		100mΩ -6		1Ω -5	
	10ma	1mΩ -7		10mΩ -6		100mΩ -5		1Ω -4
	30ma		1mΩ -6		10mΩ -5		100mΩ -4	

Sensor power above indicated by the power of 10 exponent (-7 = 10-7)
Reading Row 3, Column 3:
        Excitation Current = 10na
        Sensor Voltage = 100μV (Excitation = 200μV, Range = 20KΩ)
        Sensor Resistor = 10KΩ
        Sensor Power = 10-12 watts

DIRECT ANALOG OUTPUTS

A rear panel BNC ($\pm$10 VDC span) gives a voltage equal to ΔR or $10\Delta R$. This can be used to drive the model LR-130 temperature controller or a chart recorder.

A rear panel BNC gives a voltage ($\pm$10 VDC span) equal to the ΔX or $10\Delta X$ quadrature component of the sensor resistor impedance, or when in mutual inductance mode, the inductive reactance impedance.

DAC OUTPUT

A rear panel BNC ($\pm$10VDC span) gives a Digital to Analog converted voltage of user selected display digits.

TEMPERATURE CONTROL

When used with this unit's Internal Temperature Controller option or with the Model LR-130 Temperature Controller, the temperature control stability achievable is limited only by the transfer characteristics (R-T) of the sensor, the ultra-low-noise of the LR-700, and the thermal characteristics of the payload (heater, heater block, sensor, heat leaks through lead wires, etc). Refer to our LR-130 Temperature Controller spec sheet for more details.

LEAD RESISTANCE INDUCED ERRORS
ZERO OFFSET ERRORS:

EXCITATION SETTING	RANGE/ EXCITATION CURRENT	LEAD or CONTACT RESISTANCE (Each of the Four Leads)					
		33Ω	100Ω	330Ω	1KΩ	3.3KΩ	10KΩ
20μv	2mΩ/10ma	**	0.1$\mu\Omega$	1$\mu\Omega$	OL	OL	OL
	20mΩ/1ma	**	**	1$\mu\Omega$	10$\mu\Omega$	100$\mu\Omega$	1mΩ
	200mΩ/100μA	**	**	**	10$\mu\Omega$	100$\mu\Omega$	1mΩ
	2Ω/10μA	**	**	**	**	**	**
60μv	2mΩ/30ma	**	0.1$\mu\Omega$	OL	OL	OL	OL
	20mΩ/3ma	**	**	1$\mu\Omega$	10$\mu\Omega$	OL	OL
	200mΩ/300μa	**	**	**	10$\mu\Omega$	100$\mu\Omega$	1mΩ
	2Ω/30μA	**	**	**	**	100$\mu\Omega$	1mΩ
200μv	20mΩ/10ma	**	0.1$\mu\Omega$	1$\mu\Omega$	OL	OL	OL
	200mΩ/1ma	**	**	3.3$\mu\Omega$	10$\mu\Omega$	100$\mu\Omega$	OL
	2Ω/100μa	**	**	**	10$\mu\Omega$	100$\mu\Omega$	1mΩ

** = Effect buried in noise of the digital display with a 10 sec filter.

Notes:
(1) OL = Overload. I-high compliance voltage $\pm$10VDC limit exceeded.
(2) Decibel attenuation ratio of (R-line resistance)+(offset resistance error) is the common mode rejection ratio:

        100Ω: 0.1$\mu\Omega$ = 180 db   3.3K : 100$\mu\Omega$ = 150 db
        330Ω: 1$\mu\Omega$ = 170 db   1KΩ : 10$\mu\Omega$ = 160 db
        330Ω: 3.3$\mu\Omega$ = 160 db   3.3K : 100$\mu\Omega$ = 150 db
                                 10K : 1mΩ = 140 db

SPAN ERRORS:

		EXCITATION CURRENT, RMS	LEAD R EACH LEAD	TYPICAL ERROR (INCLUDES OFFSET)	
				Ohms	PPM of F.S.
S E N S O R R E S I S T A N C E	1mΩ	30ma	100Ω	100nΩ	50ppm
	10mΩ	10ma	100Ω	300nΩ	15ppm
	100mΩ	3ma	330Ω	10μΩ	50ppm
	1Ω	1ma	1KΩ	50μΩ	25ppm
	10Ω	1ma	1KΩ	**	-
	100Ω	100μa	1KΩ	**	-
	1KΩ	10μa	1KΩ	**	-
	10KΩ	100na	1KΩ	1Ω	50ppm
			10KΩ	2Ω	100ppm
	100KΩ	100na	10KΩ	2Ω	10ppm
			100KΩ	13Ω	60ppm
	1MΩ	10na	100KΩ	20Ω	10ppm
			330KΩ	150Ω	75ppm

** = Effect buried in noise of the display with a 10 sec filter.

Notes:
(1) Sensor resistance is at mid-scale of range.
(2) "Lead R each lead" means lead resistance or contact resistance in each of the four leads. Errors are reduced for lower lead resistance.
(3) 100Ω lead resistance in each of four lead means 200Ω total round trip lead resistance in V-High/V-Low leads, and 200Ω total round trip lead resistance in the I-High/I-Low leads.

MAXIMUM LEAD RESISTANCE

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

Limit is I-High compliance voltage clipping at approx ±10VDC. 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 SETTLING
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 10 second digital filter alone settles completely to 1 part in 200,000 counts in exactly 10 seconds, unlike an analog 10 second R-C filter which takes 13 time constants or 130 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 1 sec filter mode settles to 1p 200,000 FS in exactly (3 sec + 1 sec) = 4 seconds.

PRINTER OUTPUT
A PC type printer can be driven directly by the LR-700. No computer is needed. Typically the range, excitation, R, ΔR, and R-set data are printed a line at a time. A specific interval time may be selected or a line of data can immediately sent to the printer by pressing selected keys. This feature saves the user from hand copying all data.

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
$2m\Omega$-200Ω	$5\mu F$
$2K\Omega$	$.5\mu F$
$20K\Omega$	$.5\mu F$
$200K\Omega$	$.05\mu F$
$2M\Omega$	$.005\mu F$

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 $1000Xc$.
Xc = Capacitive reactance at 15.9 Hz.

For best performance keep line to chassis and line to line capacitance to less than $.01\mu f$ on the $2m\Omega$ through $200K\Omega$ ranges, and $.001\mu f$ on the $2M\Omega$ range.

SUPERCONDUCTING SAMPLE MUTUAL INDUCTANCE MEASUREMENTS

Superconducting and other samples can be measured inside a user built mutual inductance transformer. The transformer should consist of a single primary and two secondary windings. The secondary windings are stacked one on top the other with modest space in between and well inside the longer primary. All windings share a common central axis. The LR-700's current excitation leads directly drive the primary. The secondaries, electrically connected in series opposition, directly drive the voltage input leads.

Placing a sample inside one of the secondaries will generate an in-phase and quadrature mutual inductance signal that can be measured by the LR-700.

Thus the user measures samples in terms of χ' and χ'' allowing characterization of bulk and thin film superconductors.

The R-set = R (and X-set = X) features of the LR-700 allow for fast initialization of the set-up. Data can be then taken in the ΔR and ΔX or $10\Delta R$ and $10\Delta X$ modes.

PHYSICAL SIZES

Dimensions: 19 inch rack mountable.
7 inches (178mm) high, 17 inches (432mm) wide and 17 inches (432mm) deep.
Net weight: 30 lbs (14 kg).
Gross Weight: 36 lbs (17 kg).

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TEMPERATURE CONTROL ACHIEVABLE
Temperature control can approach the resolution and stability of the LR-700'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.

GROUNDED 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-700. 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 accidently 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-700 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-700'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 30μA 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-700-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
33KΩ to 33MΩ in 1-3-10 steps. For example, with this V-R current source with
10MΩ selected and a heater of 300Ω, full scale current is 1μA, 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-700-TC to "hold" the input voltage at zero, and thus
the heater output current constant, while the LR-700 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-700's AC current generator's compliance voltage is +10 VDC.

DC CURRENT SENSOR BIASING
This TC option may also deliver a semi-precision, stable, programmable DC current
output to DC bias a sensor resistor while the sensor's AC resistance is measured
by the LR-700. Use the TC's quiescent output current on any output current
range. The user supplies an external R-C coupling/blocking network to easily
implement this feature. Span resolution and monoticity of the DC current source
is 1pp4,096. Output is unipolar (i.e. zero to minus current range maximum
value). Output current determining resistors are mostly 1%, 100ppm/°C types,
hence current source performance is semi-precision.

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-700 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 1pp4096 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, 10ΔR, ΔX, or 10ΔX
signal from the LR-700 as the TC's input.

LOW PASS FILTERING/ANALOG OUTPUT

The LR-700-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-700'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-700-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 or ΔX changes. This is an improvement over the LR-700's regular direct ΔR or ΔX analog outputs which are unfiltered and can't be internally amplified.

OUTPUT HEATER POWER & CURRENT

The LR-700-TC option itself can deliver Picowatts to 1 watt full scale output power.

POWER OUTPUT TO 150 WATTS

LRI can supply power booster units driven by the LR-700-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-700 rear panel connector.

Booster units may be purchased separately at any time and simply connected to the LR-700 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-700-TC Option in the LR-700 main frame. The power generation, power supplies, and heat sink circuitry reside in the power booster units.

COOLING WITH LR-730-BP BOOSTER

When driving peltier or thermo-electric heating/cooling devices, the Model LR-730-BP should be used. This unit delivers bipolar output currents of up to $\pm$3 amps in selectable 1-3-10 steps. The unit is designed for controlling, for example, copper block payloads, etc. With care, payload block temperature stabilities as good as 100's of microKelvins can be achieved at room temperature.

THERMAL TIME CONSTANTS

The LR-700-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

MUTUAL INDUCTANCE
Allows measurement of sensor reactance (X). Reactance offset (X-SET) may be entered so that ΔX as well as $10\Delta X$ may be measured. X, ΔX and $10\Delta X$ are displayed with 5½ digits. X-SET resolution is one part in 200,000. Ideal for measuring Cerium Magnesium Nitrate samples in low temperature thermometry. May also be used where the sensor is a mutual inductance transformer to make susceptibility measurements.

X DISPLAY
Allows measurement of reactance (X). This option is ideally suited when you want to measure reactance of the sensor, and you have no need to input a reactance offset. Does not allow measurement of ΔX nor $10\Delta X$.

VARIABLE EXCITATION
Additional circuitry and software allow full scale excitation voltage to be linearly changed from 100% down to 5%. This allows measurement of sensors that are not linearly dependent on excitation current. Also allows a further reduction of the excitation power with the trade off being slightly more noise.

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.

DAC ANALOG OUTPUT
Additional hardware is added allowing the user to select certain digits of the front panel display to be converted to an analog voltage signal that can be sent to a strip chart recorder directly without needing to adjust the strip chart recorder for gain.

PRINTER OUTPUT
With this option, the LR-700 can be connected to a Centronix compatible printer via a normal personal computer type printer cable. Upon front panel command, or with an interface command, the current settings and measured values will be printed directly on the printer.

IEEE-488 INTERFACE
Control of the bridges features as well as reading the measurement parameters by the IEEE-488 interface with the use of simple commands.

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-700. Up to sixteen of these multiplexor units may be connected to one LR-700, therefore giving a total of 255 sensors. The sensor selected is controlled from the LR-700 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.

FUTURE OPTIONS

An internal temperature controller as well as an auto-range feature are in development and should become available in the third quarter of 1993. Consult factory for details.

LR-700 BASIC UNIT

Includes the following features: ranges of 2mΩ to 2MΩ, excitations of 20μV to 20mV, filter times of 1, 3 and 10 seconds and R-Set. Can measure and display R, ΔR, 10ΔR, R-Set and filter.

LR-700 STANDARD UNIT

Includes all Basic Unit features plus: variable excitation, DAC output, printer output, IEEE-488 interface and filter menu. Can display R, ΔR, 10ΔR, RSET, variable excitation and filter.

LR-700 PREMIUM UNIT

Includes all Standard Unit features plus mutual inductance package and RS-232 interface. This unit can display R, ΔR, 10ΔR, R-SET, X, ΔX, 10ΔX, X-SET variable excitation and filter.

ORDERING INFORMATION

Select a unit listed above and then list individually the additional options you wish to add to that unit. For example, if you wish an instrument that includes the Standard Unit features, but you would also like to display and measure X, you would order the LR-700 Standard Unit and the X Display Option.

Note that the Standard Unit, as well as the Premium Unit, offers significant price discounts over the Basic Unit with the options added individually.

No features may be deleted from the Standard or Premium Unit. If you wish to not include all the features that are listed in either of those units, you may start with the Basic Unit and add the options you wish.

DECLARATION OF CONFORMITY

Type of Equipment : AC Resistance Bridge

Model Name : LR-700 System

Model Number : LR-700P Premium Unit
        LR-720 Multiplexer
        LR-730-50W Power Booster

Year of Manufacture : 1996

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 : Dr. George V. Lecomte
        Cryoengineering
        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   Date
President
Linear Research Inc.
5231 Cushman Place, Suite 21
San Diego, CA 92110-3910 USA

CHAPTER 5 SAFETY AND SERVICE

SAFETY

EQUIPMENT INSTALLATION

- Mount the instrument in a standard electronic rack or place it on a sturdy laboratory type 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-700 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-700. By assembly design however, LRI has made every attempt to see that these power line voltages inside the LR-700 are covered and not exposed to direct human finger contact. There are no user serviceable components inside the LR-700, thus, there is no need to remove the LR-700 enclosure covers to gain access to the inside of the LR-700 for any reason.

   Therefore, never remove any cover of the LR-700 to gain access to the inside of the LR-700 or try to repair the LR-700. Repair of the LR-700 can only be done at the Linear Research Inc. factory or by an LRI 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-700 if the LR-700 is turned on. Damage to the LR-700 caused by mating connector hood shorting is not covered by the LR-700 warranty. Therefore, always turn off the LR-700 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-700 chassis before touching the sensor cable when first working with the LR-700 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-700 chassis, or unsoldering or disconnecting the leads to a mutual inductance transformer, primary or secondary, when the LR-700 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-700 has rows of air vent cooling holes along the left and right sides of the LR-700 enclosure. Be careful not to stick metal objects into these holes or allow loose wires, hook-up wires, LR-700 sensor cable ends, etc. to enter the LR-700 through those holes and possibly short out the circuitry. Permanent damage to the LR-700 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:

Occurrence	Characteristics
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
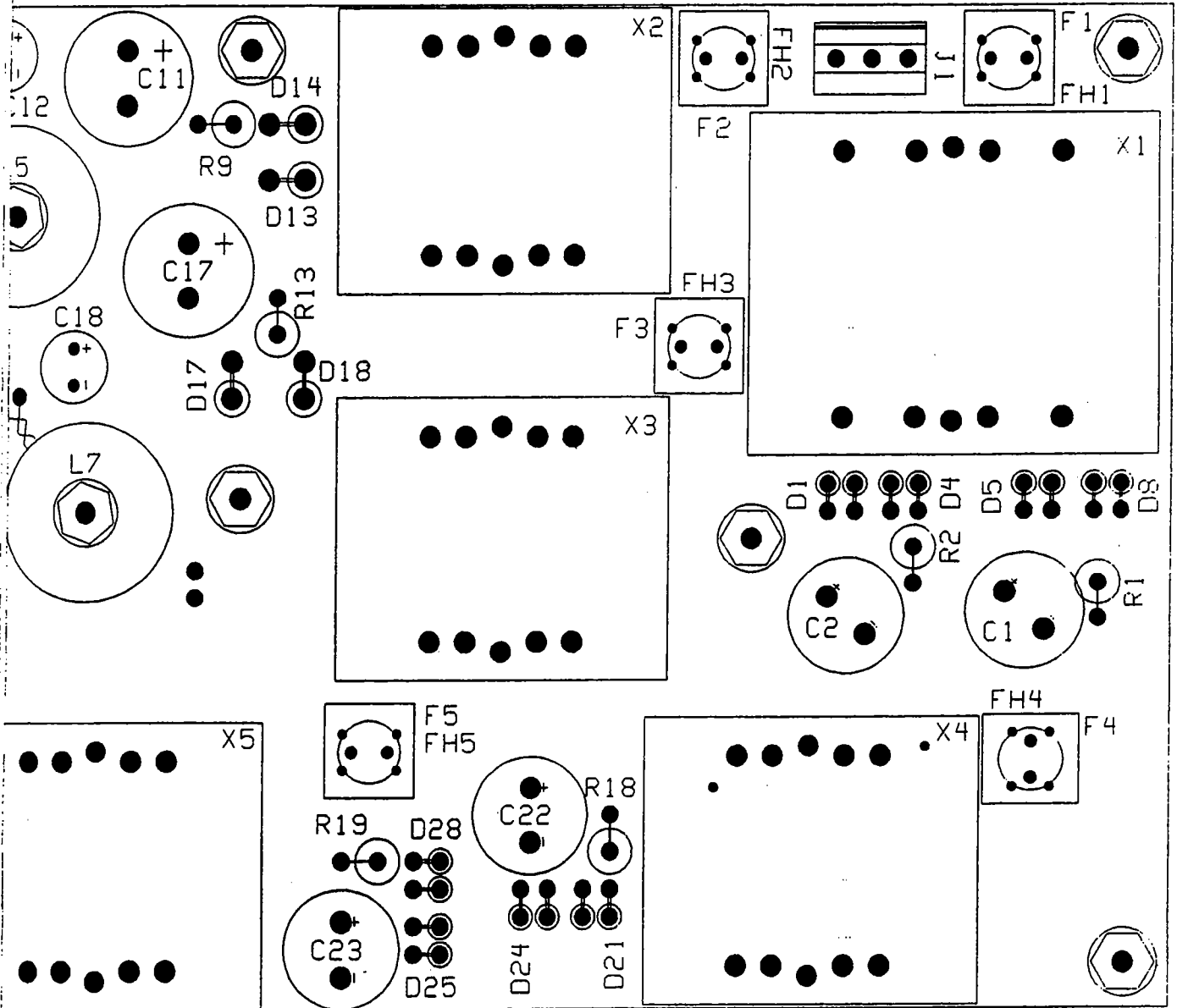Phone: 619-299-0719
Fax: 619-299-0129

FIGURE 5-1

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