

# **LR-130**

## **TEMPERATURE CONTROLLER**

VERSION 1.2

### **USER'S MANUAL**

**LINEAR RESEARCH INC.**

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## CONTENTS

<b>OVERVIEW OF FEATURES</b>	1
Input DC Offset Control	
DC Gain Control	
Input Signal BNC Test Points	
Resolved Offset BNC Test Point	
Stability Amp Out BNC Test Point	
Output 1K-10M BNC Test Point	
Polarity Control	
Quiescent Heater Voltage	
Heater Output	
Heater Output Power	
<b>TUNING PROCEDURE</b>	4
Initial Control Settings	
Initial Optimization	
Final Optimization	
<b>DEFINITIONS AND DIAGRAMS</b>	8
Symbol Definitions	
Block Diagram	
<b>SPECIFICATIONS</b>	13
<b>ADDENDUM</b>	16
<b>SAFETY</b>	17
Equipment Installation	
Cautions	
<b>WARRANTY AND SERVICE</b>	18
Warranty	
Internal Fuses	
Factory Service	
Schematic	

## OVERVIEW OF 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. The LR-130 includes the following features:

### **Input DC Offset Control**

Covering ranges of -10, -1, OFF, +1, +10VDC. Allows input signals within these ranges to be converted to null signals. The "set temperature" is determined by the DC offset setting in this mode.

### **DC Gain Control**

Variable from .03 to 3,000 in 1-3-10 steps. This allows the LR-130 to be driven from instruments that do not have DC gain controls, such as, instruments that have their output voltage linearly proportional to a resistance sensor.

When the above features are not needed, as when driven by the LR-100 Picowatt Resistance Bridge that has a built in variable gain control, simply set Input Offset = Off and DC Gain = 1.

### **Input Signal BNC Test Points**

These front and rear panel input signal BNC's are connected in parallel. Either can be used as a test point to drive a digital voltmeter or strip chart recorder.

### **Resolved Offset BNC Test Point**

This test point monitors the input signal after undergoing DC offset from the DC offset control and after amplification by the DC gain control. This test point may be used to drive a strip chart recorder during the tuning procedure when the DC offset control is used as the set temperature control. This way the strip chart recorder always sees a null signal about zero volts D.C.

### **Stability Amp Out BNC Test Point**

This test point monitors the input signal after undergoing DC gain, integration (T1), and differentiation (T3), but prior to the power amplifier that drives the heater. Use this test point with an oscilloscope to look for 60 Hertz noise etc., and set T2 to minimize this noise if amplitude is excessive (greater than 1 volt peak to peak).

### **Output 1K-10M BNC Test Point**

Monitors heater voltage. (Actually the voltage across the series combination of the resistance selected by the output resistance control and the heater resistor).

### **Polarity Control**

Set this to yield negative DC feedback in the closed loop mode. If set wrong, the heater output voltage will lock-up at either +12VDC or 0VDC.

### **Quiescent Heater Voltage**

The quiescent heater voltage control, a 10 turn variable resistor, is used only in open loop mode to supply power to the heater.

In the closed loop mode the effect of the T1 integrator control automatically yields the required heater voltage for minimum temperature error. Accordingly, when operating in the closed loop mode, set to "000".

### **Heater Output**

As shown on the block diagram, the 0 to +15VDC voltmeter (M1) monitors the voltage applied to the series combination of the output resistance control and the heater. Heater power can easily be determined. For example: if output resistance = 10M ohms, heater = 1K ohms and M1 = 12VDC, then heater power =  $1.44 \times 10^{-7}$  watts. For a low resistance heater requiring a high output current, set output-resistance to zero ohms.

Always connect the heater to the three pin rear panel output connector. This connector has greater current handling capacity than the front panel output BNC. The front panel output BNC should be used as a monitor point only. It has a 1K ohm resistor in series with it since it cannot handle high current.

When in the "0" ohms mode, an external resistance in the range of 0 to 1K ohms, and of proper power handling capability, can be placed in series with the heater to limit the maximum heater power and assure mid-scale operation of the output voltmeter at the set temperature.

### **Heater Output Power**

Absolute maximum output power is approximately 18 watts. This maximum power is with a 5 ohm heater resistance, and the output voltage is 9.5 volts DC (the saturation output voltage for this 5 ohm load).

For typical operation in a closed loop system, the instantaneous power to the heater will vary about a quiescent value. Thus, the system should be designed for mid-range operation of the heater output voltage. For instance, a slightly upper mid-range of 7 VDC quiescent output voltage yields a quiescent output power of about 10 watts with a 5 ohm load. At the same time, the output maintains the ability to deliver a peak power of 18 watts to account for instantaneous thermal loading of the thermal system. Accordingly, the LR-130 should be used with systems that require typically quiescent heater powers of about 12 watts or less.

## TUNING PROCEDURE

This is the tuning procedure for the LR-130 Temperature Controller.

We show here the Linear Research Model LR-700 as the "front-end" electronics that drives the LR-130 Temperature Controller. In your set-up you may use a different bridge or other type of "front-end" signal conditioning unit. Nonetheless, you can still follow this procedure since this technique is of sufficient generality to be applicable to all types of thermal systems and configurations.

### LR-130 INITIAL CONTROL SETTINGS

Input Offset -	"OFF"
Input Offset 10 turn pot -	"000"
DC Gain -	"3K" to cause oscillations. Will probably be between 1 and 100 when optimized.
T1 -	"0.1" to cause oscillations. Will probably be between 1 and 300 seconds when optimized.
T3 -	"0". Set to 1/3 value of T1 when optimized.
T2 -	".03" seconds (initial and final value for operation with the LR-400).
Polarity -	Either "+" or "-" to cause oscillations. Fixed at that value thereafter. Wrong setting will give either zero power out continuously or maximum power out continuously.
Close Loop/Open Loop -	"Closed" (initial and final value).
Quiescent Heater Voltage -	"000" (initial and final value).
Output Resistance -	"0" or as required for mid-scale operation of the 15 VDC panel meter at temperature stabilization.
Heater On/Off -	"ON"

## LR-700 CONTROLS

Display Mode -  $\Delta R$

Filter, Seconds - "0.3"

Excitation Millivolts - 20 MV Reduce after thermal stabilization if this value causes sensor self heating.

Range, Ohms - As required for on scale reading of sensor resistor.

Set Resistance (R-Set) - As required for set temperature.

### INITIAL OPTIMIZATION

With the LR-130 controls set as described in the "initial setting" section, adjust the polarity switch to either + or - so that the system oscillates or hunts about the set temperature. In this mode the input signal to the LR-130 will greatly overshoot and undershoot the set temperature.

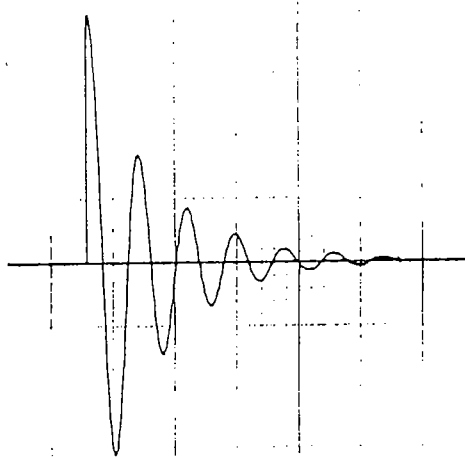
Connect a strip chart recorder in parallel with the LR-130's input signal, at the input signal BNC on the front panel (or connect to resolved offset BNC). Note the period in seconds of this oscillation. If a strip chart recorder is not available you may use an oscilloscope, but it does become more difficult for longer time constants to make measurements on the oscilloscope. Call this period T-OSC. Now set the T1 control (the integration time constant control) as close as possible to the measured T-OSC value. Set the T3 control to 1/3 the value of T1. (eg: If T-OSC=15 seconds, set T1=10 seconds and set T3=3 seconds).

Now reset the DC gain control. It was initially set at 3K to ensure oscillations. Reset this control for reduced gain, first to 1K, then to 300, then to 100, etc. Pause long enough at each setting (hold at least two or three times as long as the oscillation period T-OSC) to see if the system's oscillation will stop. If oscillations persist for all gain settings, repeat the above procedure with a one step increase or decrease in T1. Change T3 to be 1/3 the new value of T1. At some lower gain setting of the DC gain control, oscillations will stop completely. This will yield a steady and close to zero volts DC input signal at the LR-130.

### FINAL OPTIMIZATION

Make a small step change in the set resistance control on the LR-700. Make this change large enough to be seen at the strip chart recorder, but not large enough to exceed the dynamic range of the amplifier driving this test point, nor large enough to lock-up or pin full-off or full-on the heater output voltage (monitor the panel meter).

If the T1/DC gain controls are not at their optimum value the strip chart recorder will now show a damped ringing oscillation thus:

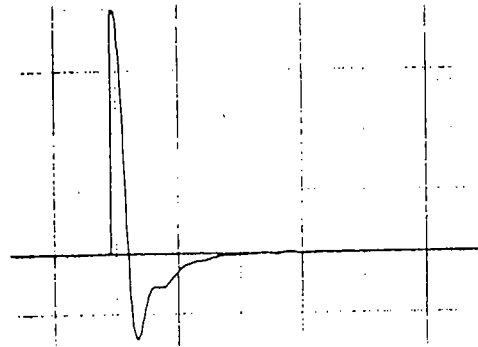


Note that one cycle of the ring is the same order of magnitude in period as the T-OSC previously measured.

Change the T1 (and with it T3,  $T3=1/3 T1$ ) one stop either way then make another small set resistance change. If the damped ringing oscillation is improved (ie: is more damped) hold this new T1 value. If the ringing increases or if it rings (oscillates) continuously, change T1 one step in the opposite direction. Similarly, change the DC gain control one step either way and note the effect on the damped ringing oscillation. Try to pick the highest value of DC gain and the smallest value of T1 that give the best strip chart recordings as shown below. This will assure the best long term temperature stability (smallest temperature variation with time), and fastest thermal settling time when going to a new set temperature.



When the T1/DC gain controls are finally optimized in their settings, the strip chart recording for a set resistance step change should be as follows:

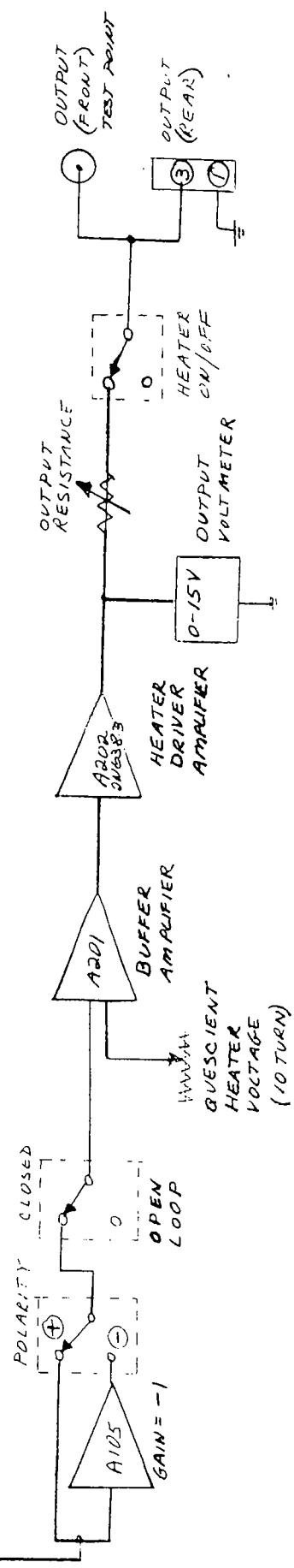
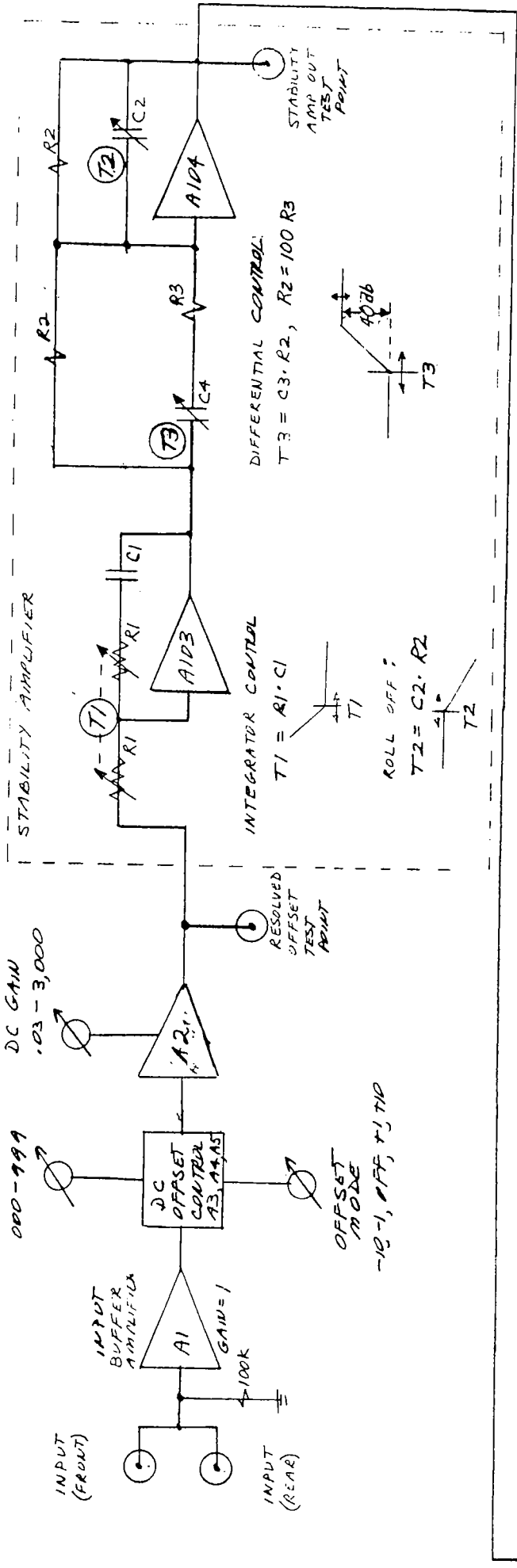


The LR-130 is now tuned.

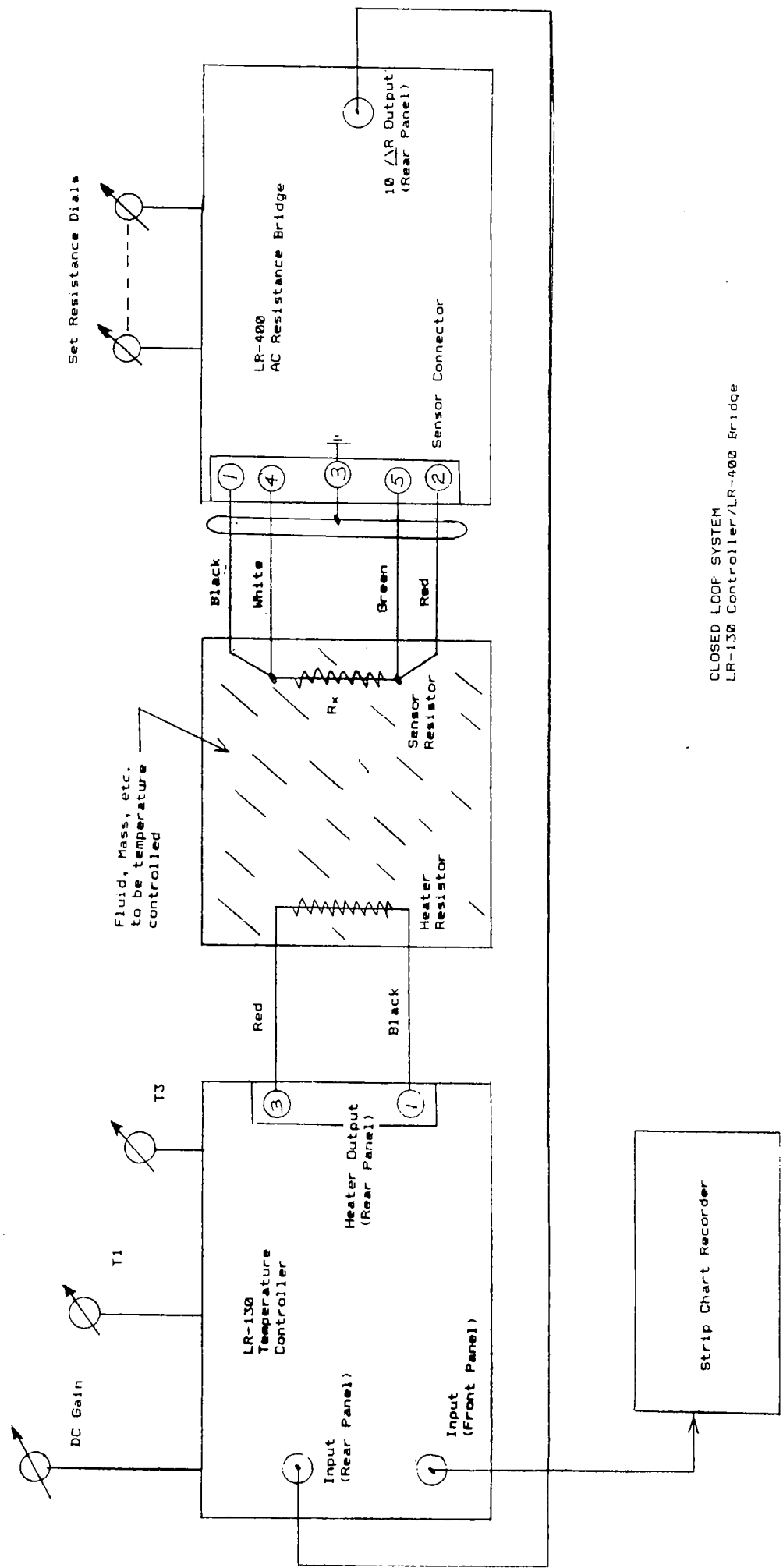
The LR-130 tuning is good for all excitation settings of the LR-700, from .06 to 20 millivolts. However, if the resistance range control is changed, for the same sensor resistor, there is then an effective change in loop gain. Thus, going to the next higher range with a fixed sensor resistor of the LR-700 reduces the loop gain by 10 requiring an increase of 10 in the LR-130's DC gain control.

BY \_\_\_\_\_ DATE \_\_\_\_\_ SUBJECT \_\_\_\_\_ SHEET NO. \_\_\_\_\_ OF \_\_\_\_\_  
 CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_ JOB NO. \_\_\_\_\_

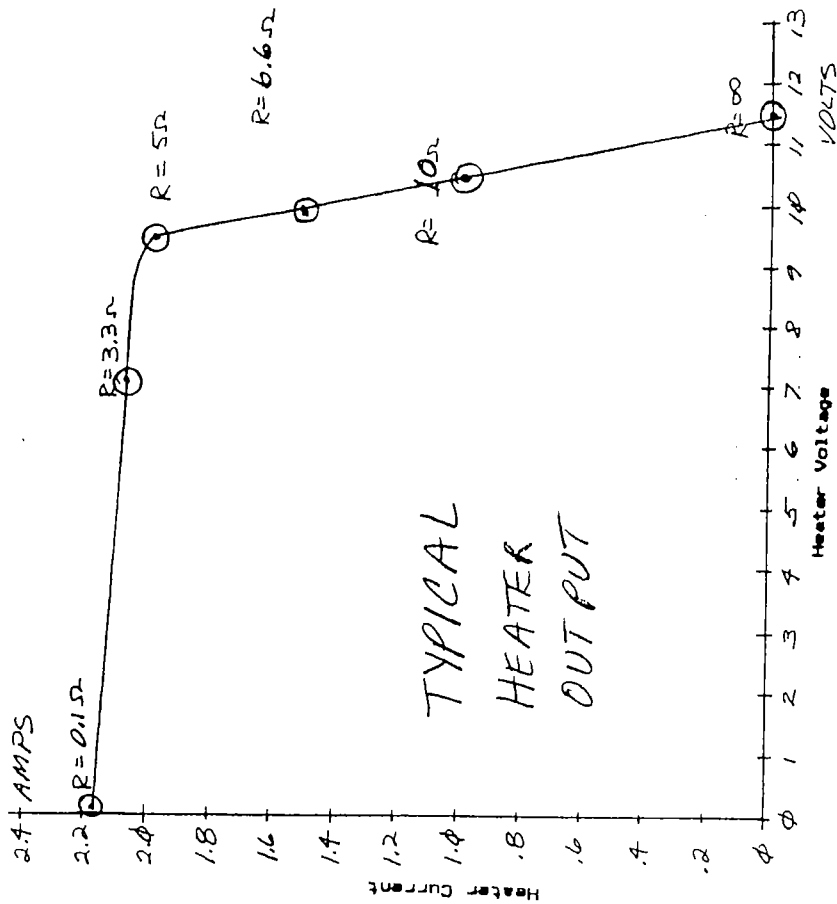
# LINEAR RESEARCH BLOCK DIAGRAM LR-130 TEMPERATURE CONTROLLER



BLOCK DIAGRAM  
 LR-130

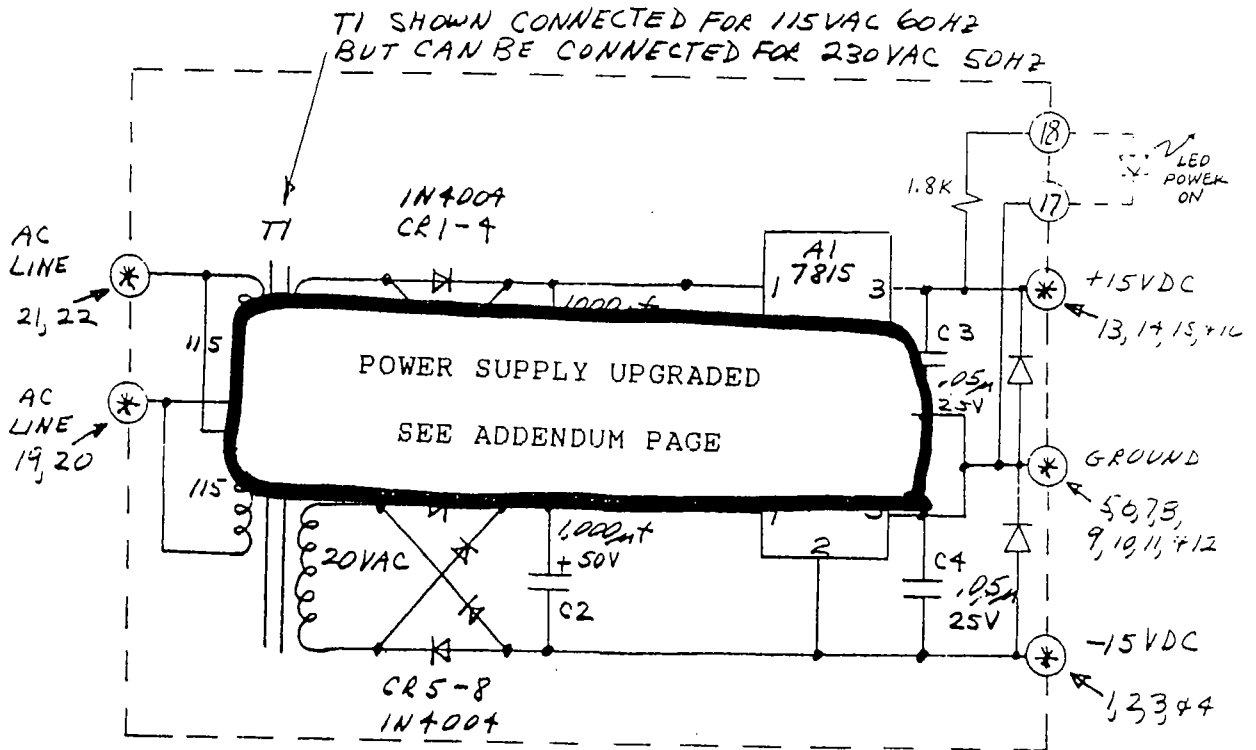


CLOSED LOOP SYSTEM  
 LR-130 Controller/LR-400 Bridge



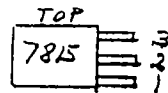
LR-130 HEATER OUTPUT V-I CHARACTERISTICS

1. Output Resistance Control = zero ohms.
2. Heater voltage measured directly at the rear panel output connector.
3. Maximum output power of 18 watts is obtained with a heater resistor of 5 ohms.



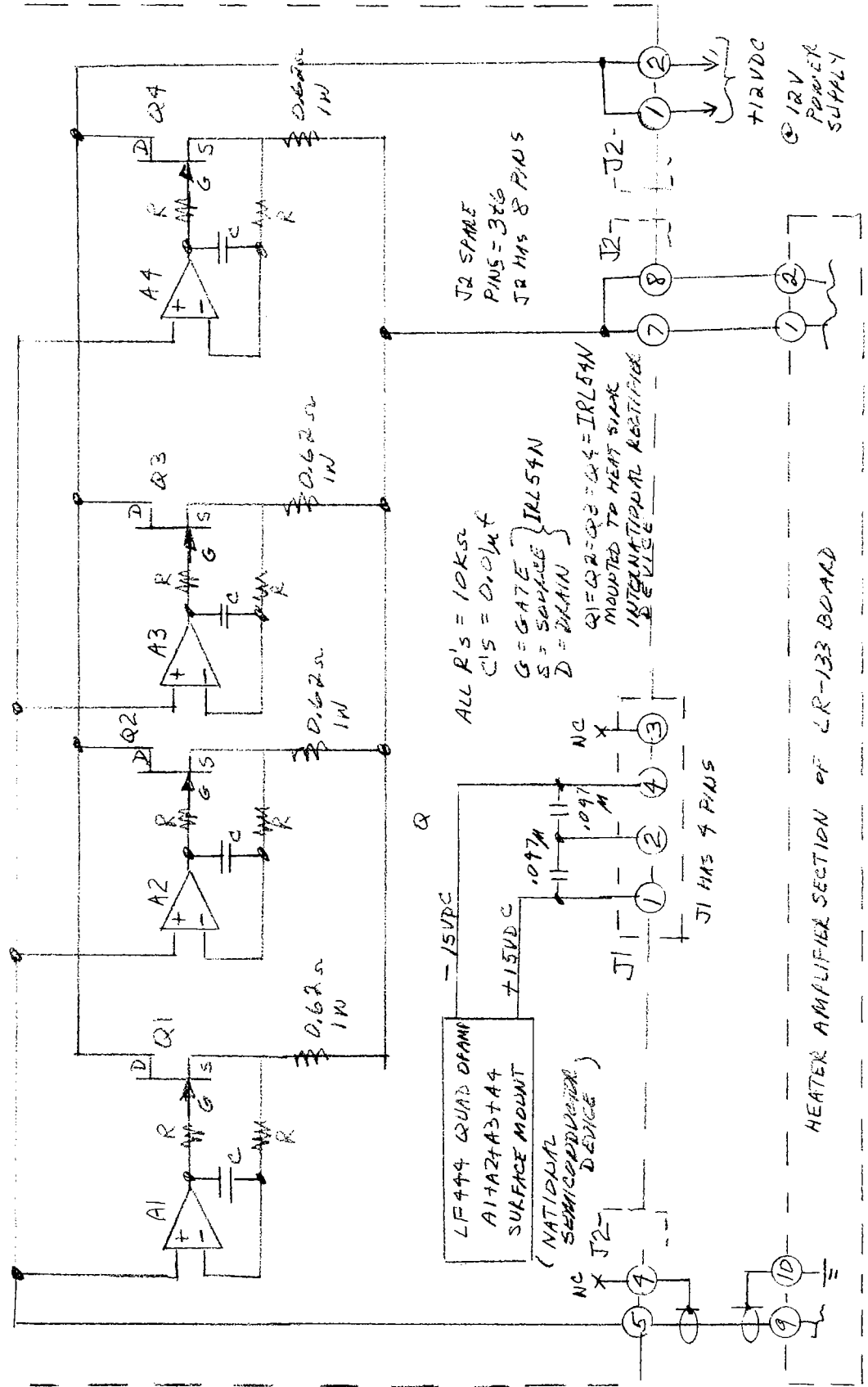
T1 = SIGNAL TRANSFORMER CO.  
DPC-40-250

A1 = A2 = 15VOLT REGULATOR



B500 POWER SUPPLY  
±15VDC  
LINEAR RESEARCH INC.

POWER OUTPUT BOARD ON HEAT SINK



ALL R'S = 10KΩ  
 C'S = 0.01μf  
 G = GATE  
 S = SOURCE  
 D = DRAIN  
 Q1 = Q2 = Q3 = Q4 = IRL54N  
 MOUNTED TO HEAT SINK  
 INTERNAL POINT RECTIFIER  
 2-85

LA-130 POWER OUTPUT STAGE  
 9-03 R. Entenmann (REPLACES 2N6283 POWER STAGE)  
 R. KRA 2-85

HEATER AMPLIFIER SECTION OF LR-133 BOARD

## **SPECIFICATIONS**

### **TEMPERATURE RANGE**

MilliKelvin to above 300 Kelvin.

### **TEMPERATURE CONTROL ACHIEVABLE**

Temperature control can approach the resolution and stability of the LR-700's ability to measure the sensor.

### **TIME CONSTANTS**

The LR-130 Temperature Controller will stabilize and control thermal systems having thermal time constants from 0.1 to 1000 seconds in 1-3-10 steps.

### **OUTPUT HEATER POWER**

Picowatts to 18 watts full scale.

A front panel switch enables the user to select resistance in series with the heater scaling the output power. Selected resistors range from zero to 10 M $\Omega$ .

LR-130 can deliver 1.9 amps at +9.5 volts into a 5 ohm heater resistor. Output current self-limits near 2 amps and can deliver full current indefinitely into a short circuit.

### **LOW HEATER NOISE**

Output power is generated by a linear amplifier with virtually nonexistent radio frequency noise.

### **DISPLAY**

An analog voltmeter monitors the voltage across the output resistance and heater load. This indicates power delivered to the heater.

### **UNDEDICATED CONTROLLER**

The LR-130 is an undedicated temperature controller. It has no built-in bridge or "front end" sensor measuring electronics. This is an advantage since it allows the LR-130 to accept input signals from any type of signal conditioning bridge or amplifier, thus isolated from digital noise sources.

The LR-130 can be driven by any bridge that delivers a DC signal in the region of 0 to  $\pm 10$ VDC. An ideal choice for a front end bridge is one of our bridges: LR-700, LR-400, or LR-110.

### **INPUTS**

The LR-130 incorporates precision low drift input offset controls that can accept two types of inputs.

Bipolar DC null signal where the "set temperature" function is determined by the resistance bridge through its own set resistance control.

Unipolar input voltage proportional to temperature. In this case the "set temperature" is controlled by the LR-130 Input/Offset control. Input voltage spans cover ranges of -1, +1, -10, and +10 VDC. This allows signals within these ranges to be converted to null signals. Allowing for operation with bridges or any "front end" that delivers a voltage proportional to sensor resistance.

### **QUIESCENT HEATER VOLTAGE**

Quiescent Heater Voltage control is used for setting heater power in the open-loop mode. During the closed-loop mode, this is set to zero and the integration circuitry delivers the required long term average heater voltage.

## OTHER FEATURES

Polarity Control for loop gain inversion or negative sensor coefficient.  
High Frequency Roll-off for elimination of 50/60 Hertz noise  
Open Loop/Closed Loop Control  
Heater On-Off Control  
Output Series Resistance  
Input Offset Controls

### LR-700

When used with the LR-700, with ranges of  $2m\Omega$  to  $2M\Omega$ , and excitations from  $20\mu V$  to  $20mV$ , and state of the art low noise, the LR-700 is the best choice to drive the LR-130. Set temperature can be set to 5½ digits manually or by the IEEE-488 or the RS-232 interfaces.

### LR-400

With its ranges from .02 ohms to 200K ohms, the LR-400 will work with most resistance sensors commercially available. These include platinum, germanium, carbon, and thermistor types. Set temperature can be set to 4½ digits.

## TYPICAL SYSTEM

A temperature control system consists of three major parts:

Payload. A Heater, Thermal Mass to be temperature regulated, and a Temperature Sensor, all in close thermal contact.

System components that determine stability are: sensor sensitivity (the higher the better); thermal coupling between the mass, the sensor, and the heater (the closer the coupling the better); thermal time constant of the system (the faster the better); performance of the "front end" with regard to stability of set resistance and noise level; heat leaks along the wires connecting to the outside environment; and thermal loading or interference from the surrounding environment.

A Bridge Amplifier or other "front end" that converts sensor temperature into a DC voltage.

The bridge usually includes a variable set resistance, which determines set temperature. It outputs a bipolar DC voltage (null signal) proportional to the difference between the sensor value and set resistance value. In some cases the bridge does not include a set resistance control and the output is simply proportional to the value of sensor resistance.

A Temperature Controller driven by the bridge.

It processes the signal in the gain-frequency domain selecting either the positive or negative portion of this signal. With an internal power amplifier delivers an output voltage that drives the heater. It ideally delivers to the heater the correct amount of instantaneous power necessary to hold the sensor, and hence the thermal mass, at exactly the set temperatures.

## THERMAL TUNING PROCEDURE

The LR-130's Instruction Manual includes a step by step tuning procedure enabling the user to achieve optimum performance for the thermal system.

#### CLOSED-LOOP OSCILLATIONS CAUSED BY HEAT FLOW EQUATION PHASE SHIFTS

The transfer equation for the payload portion of the system is governed by a heat flow equation. This partial differential equation relates "Voltage In" at the heater to "Voltage Out" at the sensor. It does not behave as would a simple resistor-capacitor R-C filter network. The R-C network gives a fixed 90 degrees phase shift and a fixed 20 decibels per frequency-decade amplitude attenuation at frequencies above its time constant. If the thermal system behaved this way, one could simply connect the output of the bridge to the heater via a wide bandwidth high gain power amplifier and the system would be stable.

The actual transfer function is such that for frequencies higher than the thermal time constant, both the phase shift and the amplitude attenuation continue to increase indefinitely with frequency. Thus, the phase shift quickly reaches 180 degrees for modest increases in frequency beyond the thermal time constant.

Unless corrected, this phase shift causes continuous oscillations with modest open-loop gain when the loop is closed. Reducing gain will, of course, stop oscillations but at the price of a temperature offset and poor regulation.

#### OSCILLATIONS ELIMINATED

Gain frequency controls are needed to compensate for the phase shift inherent in the heat flow equation. For optimum performance, all three controls must be adjusted to tune the thermal system.

The LR-130 incorporates variable:

- A. Proportional DC gain.
- B. Integration Time Constant.
- C. Derivative Time Constant.

The DC gain control is used to set the gain as high as possible. It is adjustable from .03 to 3,000 in 1-3-10 steps.

The Integration control gives near infinite gain at very low frequencies. This assures minimum long term temperature offset. It is adjustable from 0.1 to 1,000 seconds in 1-3-10 steps.

The Derivative control mitigates the effect of heat flow phase shift above the thermal time constant sufficiently allowing the DC gain control to be increased considerably without oscillations. This gives oscillation free operation with fast response. It is adjustable from 0.01 to 300 seconds in 1-3-10 steps.



## ADDENDUM

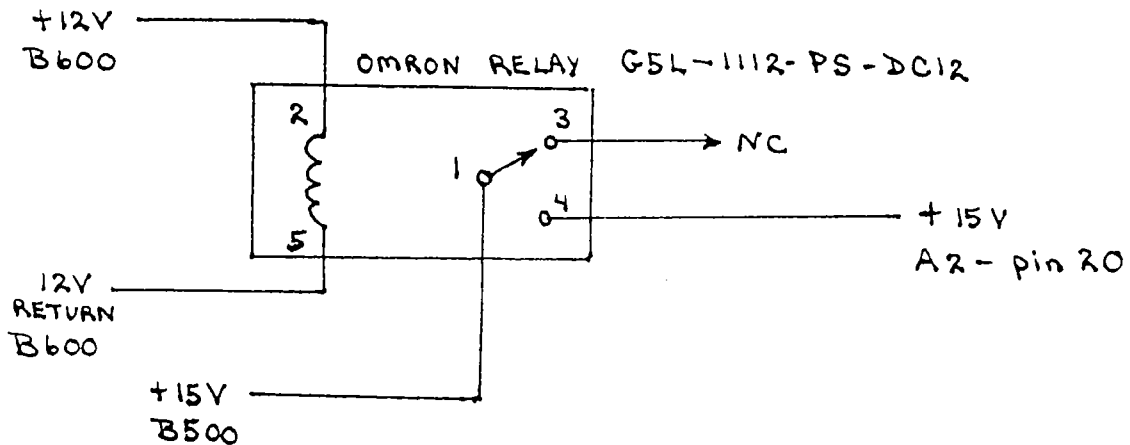
ADDENDUM MAY 1997

LR-130s shipped after April of 1997 have the following upgraded power supplies:

The B500 power supply has been upgraded to a  $\pm 15V$  DC power supply made by Condor Power Supplies Inc., model #HAD15-0.4-A+.

The B600 power supply has been upgraded to a  $\pm 12V$  DC/3.4amp power supply made by Condor Power Supplies Inc., model #HC12-3.4-A+.

Additionally, the following power sequencing additions have also been added to the instrument:



## SAFETY

### EQUIPMENT INSTALLATION

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

### CAUTIONS

#### 1. Do not open the LR-130 enclosure.

Any voltage of 100 volts or more is dangerous. Powerline voltages from 100 to 240 volts AC, 50/60 Hertz are present, inside the LR-130. By design however, LRI has made every attempt to see that these power line voltages are covered and not exposed to direct human contact. There are no user serviceable components inside the LR-130.

Therefore, never remove any cover of the LR-130 to gain access to the inside of the unit or try to repair the LR-130. Repair of the LR-130 can only be done at the Linear Research Inc factory or by an authorized representative.

#### 2. Do not allow objects to enter into vent holes.

The LR-130 may have air vent cooling holes along the sides of the enclosure. Be careful not to allow metal objects into these holes or allow loose wires, sensor cable ends, etc. to enter through these holes and possibly short out the circuitry. Permanent damage to the LR-130 may result. This damage is not covered by the warranty.

## **WARRANTY AND SERVICE**

### **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.

### **INTERNAL FUSES**

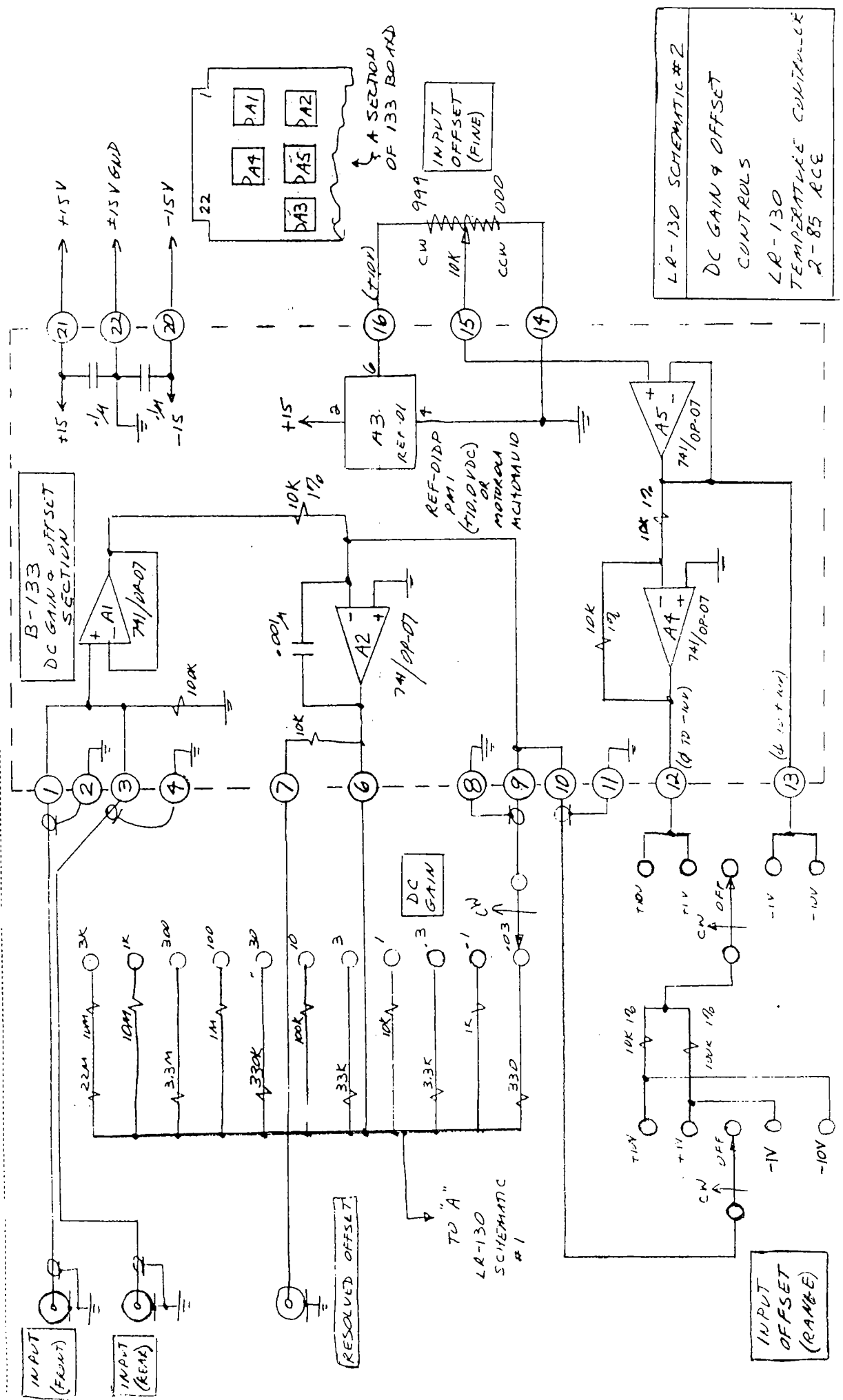
There are no internal fuses.

### **FACTORY SERVICE**

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

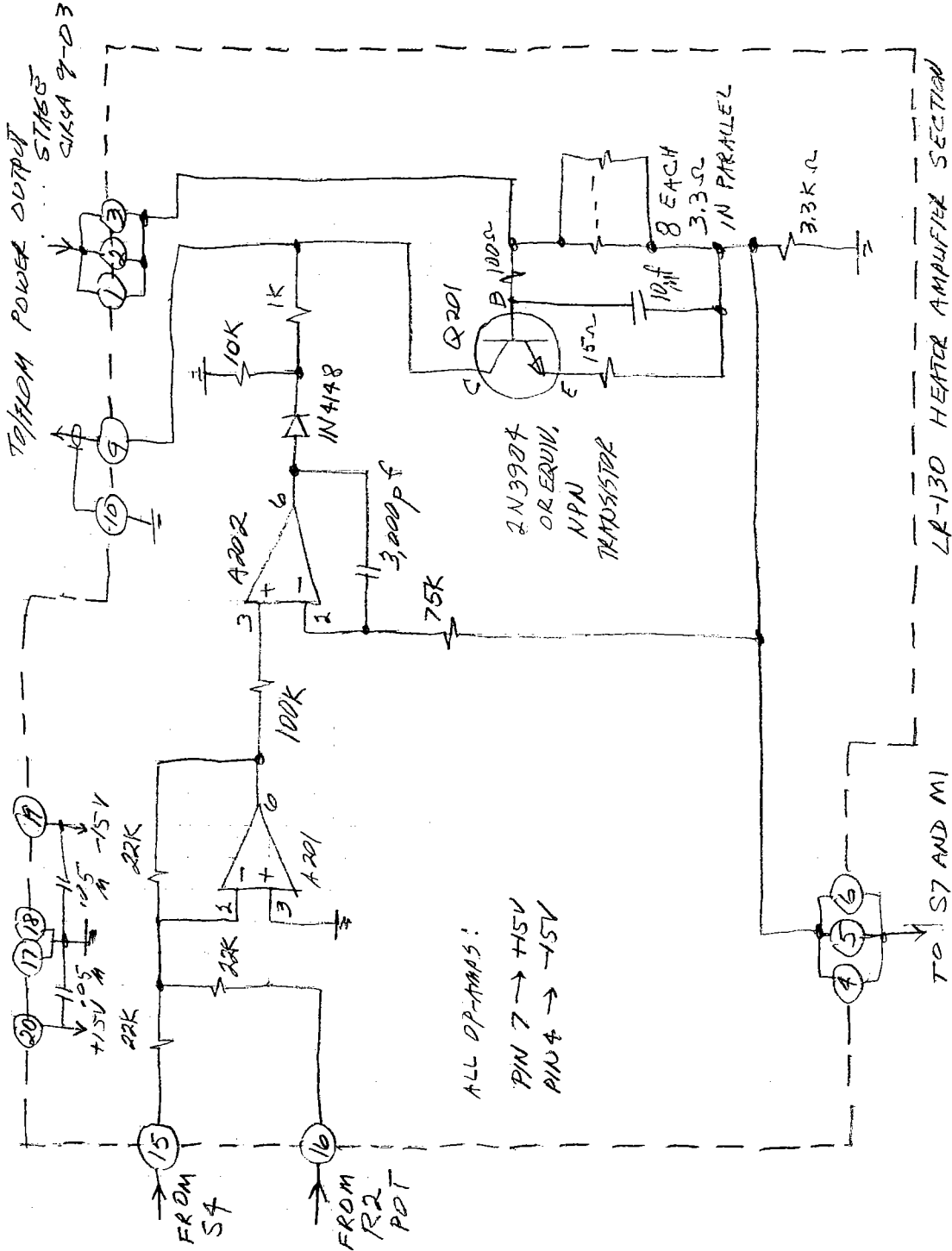
LINEAR RESEARCH INC.  
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San Diego, CA 92110-3910 USA  
Phone: 619-299-0719  
Fax: 619-299-0129

BY: ..... DATE: ..... SUBJECT: ..... SHEET NO. .... OF .....  
 CKD BY: ..... DATE: ..... JOB NO. ....



LR-130 SCHEMATIC #2  
 DC GAIN & OFFSET CONTROLS  
 LR-130 TEMPERATURE COMPENSATE  
 2-85 ACE

LINEAR RESEARCH INC.



TO/HOM POWER OUTPUT STAGE  
CIRCUIT 9-03

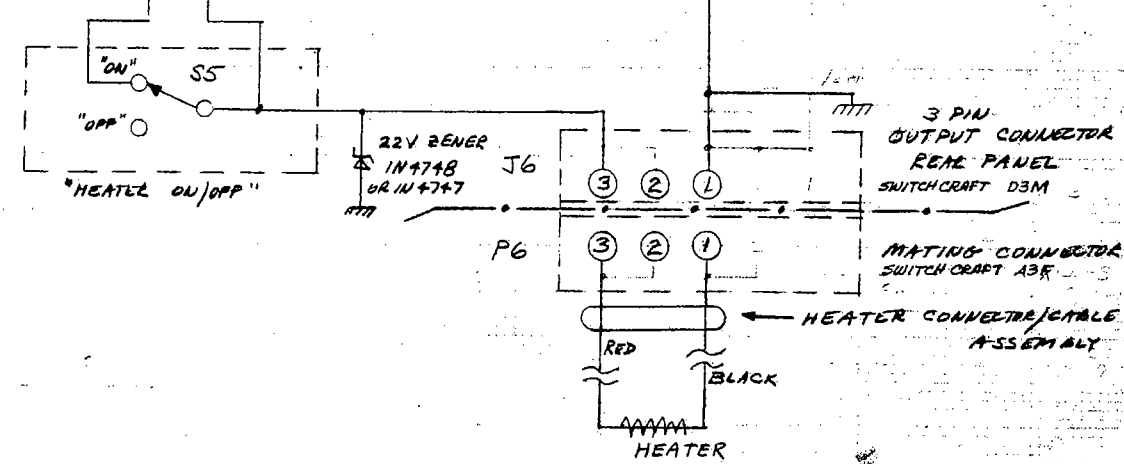
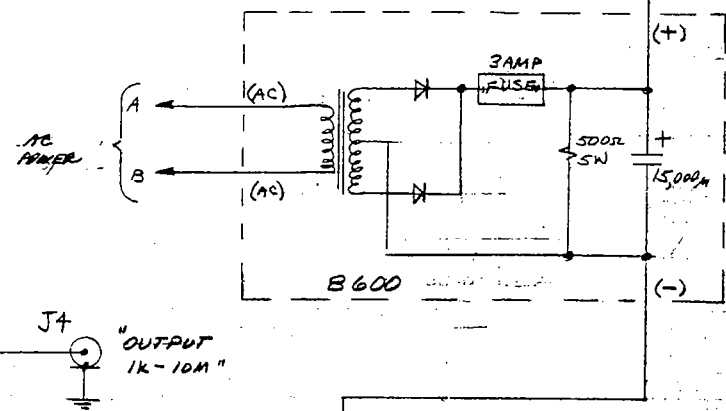
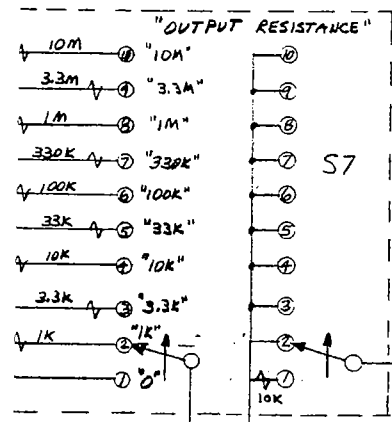
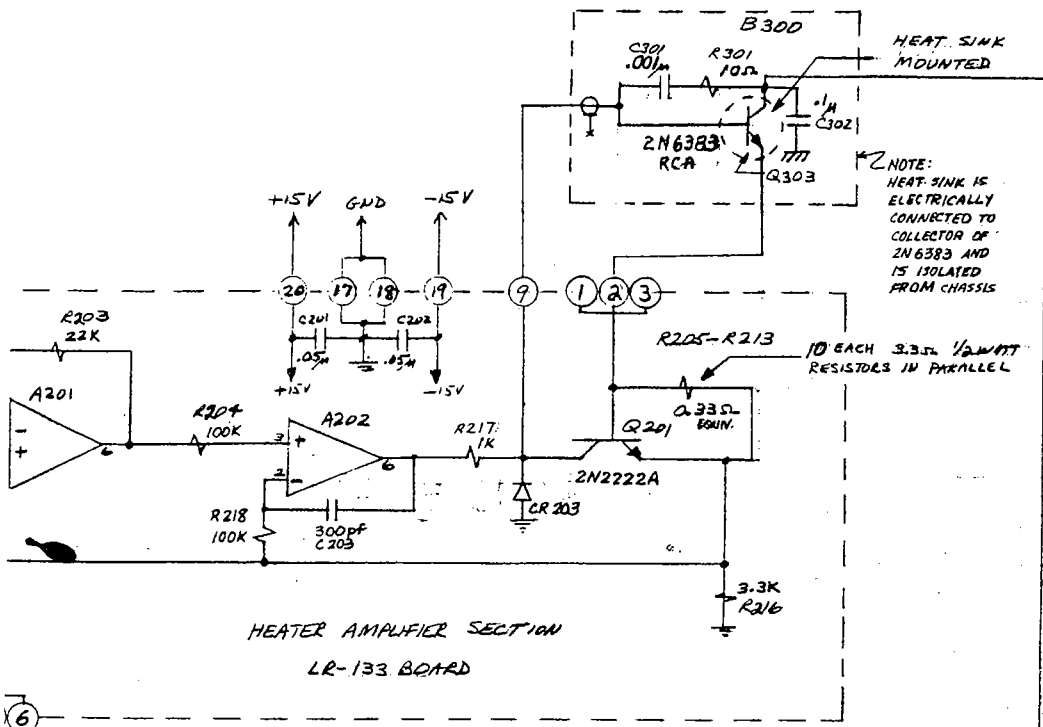
ALL OP-AMPS:  
PIN 7 → +15V  
PIN 4 → -15V

LR-130 HEATER AMPLIFIER SECTION

OR LR-133 P-C BOARD

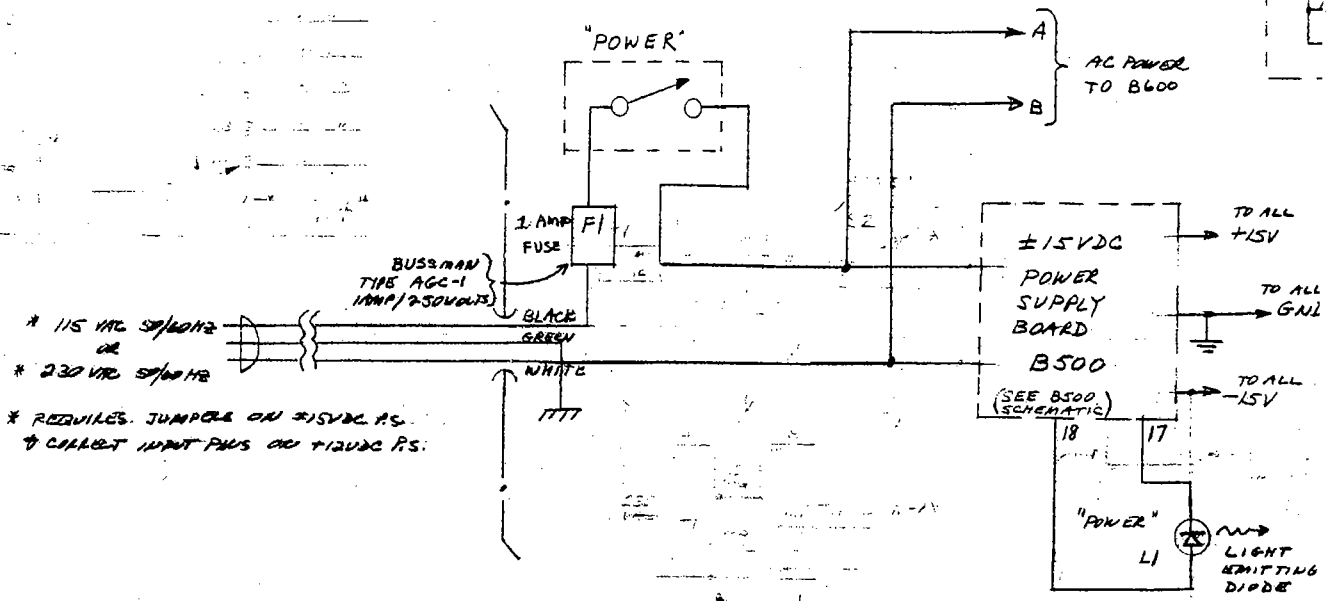
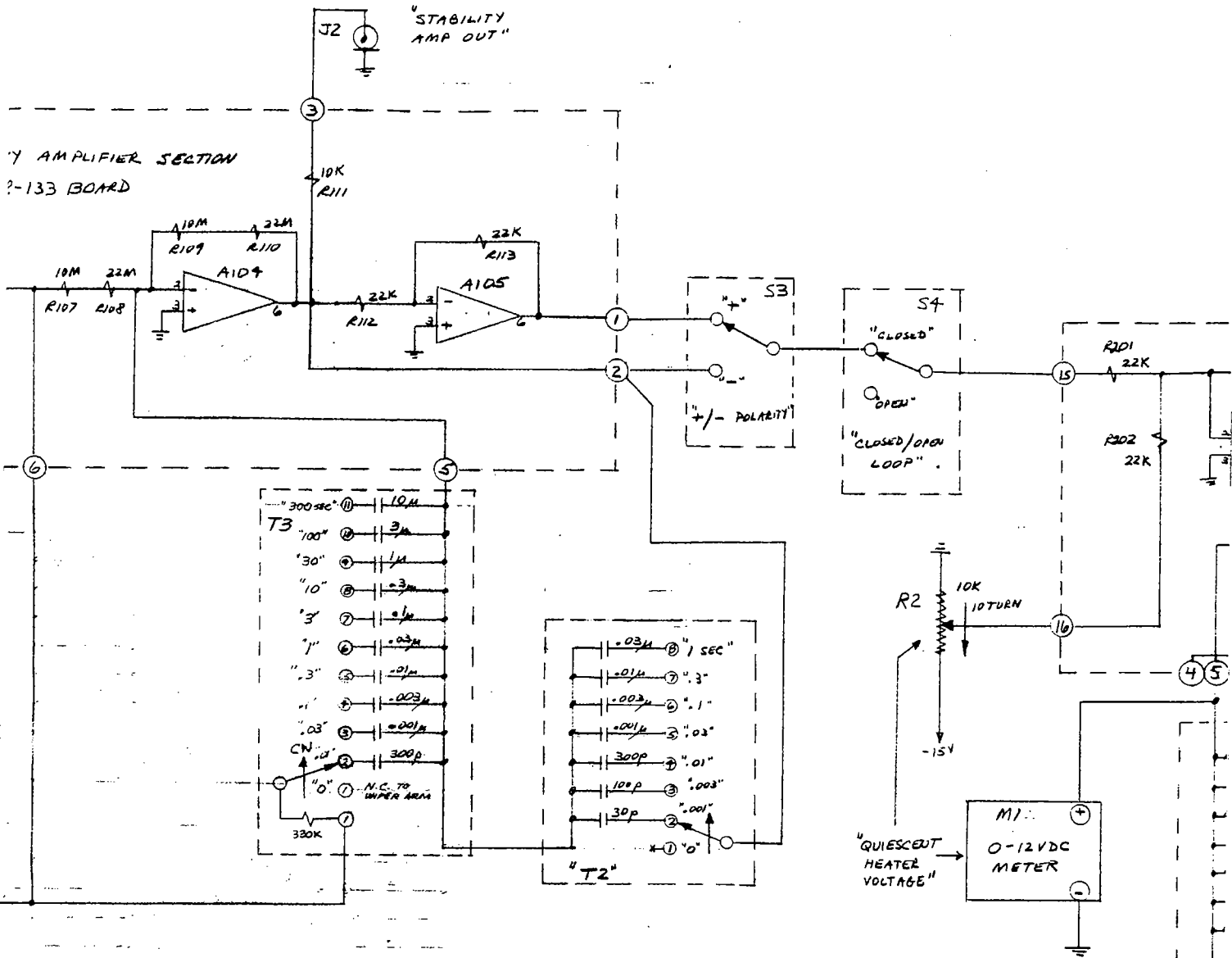
(REPLACES 2-85 SCHEMATIC)

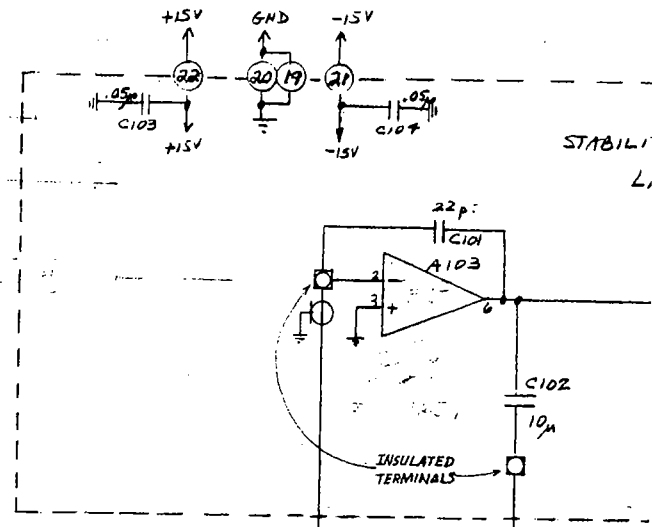
8-09 R. C. [unclear]



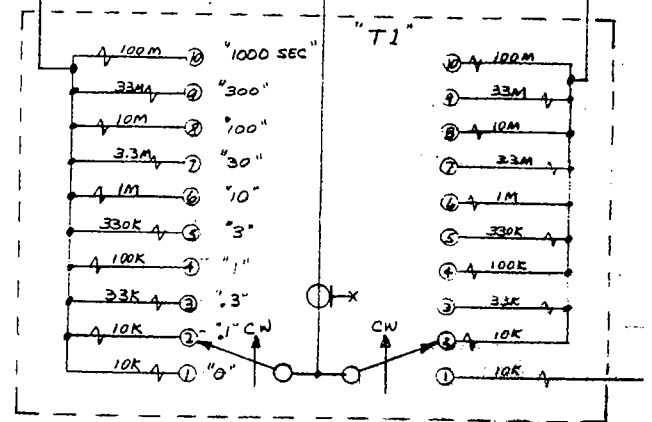
LINEAR RESEARCH INC.  
5231 CUSHMAN PLACE  
SAN DIEGO, CA 92118

REVISION 2-82  
LINEAR RESEARCH INC.  
SAN DIEGO, CA  
SCHEMATIC #1  
LR-130



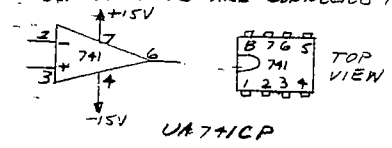


TO POINT "A" ←  
 SEE DC GAIN &  
 OFFSET CONTROLS →  
 LA-130 SCHEMATIC #2

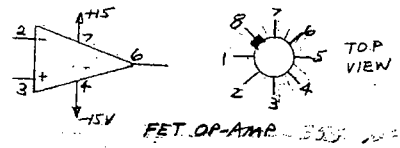


- NOTES:
1.  $33M \Rightarrow 22M \quad 10M$
  2.  $100M \Rightarrow 22M \quad 22M \quad 22M \quad 22M \quad 22M$

3. ALL DIP OP AMPS ARE CONNECTED THUS:



4. METAL CAN OP AMP IS CONNECTED THUS:



7. A103 = AD542JH  
 A104 = TI1071CP or LF411CN  
 A105 = 741  
 A201 = 741 OR OP-07  
 A202 = 741 OR OP-07

5. ALL RESISTORS ARE 1/4 WATT ALLEN BRADLEY  
 10% COMPOSITION (1K = 1,000Ω)  
 (1M = 1,000,000Ω)
6. ALL CAPACITORS ARE IN MICRO FARADS.