NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WEST VIRGINIA

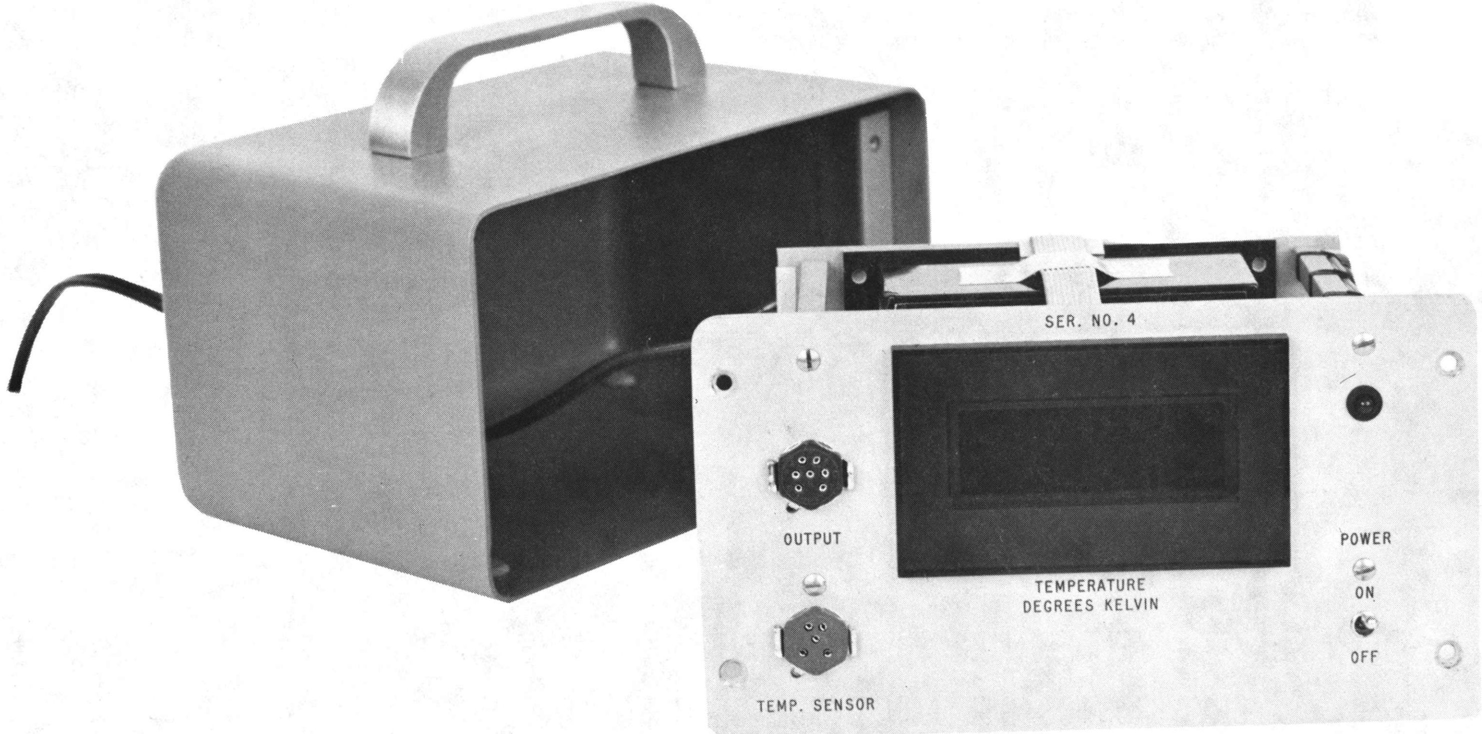
ELECTRONICS DIVISION INTERNAL REPORT No. 204

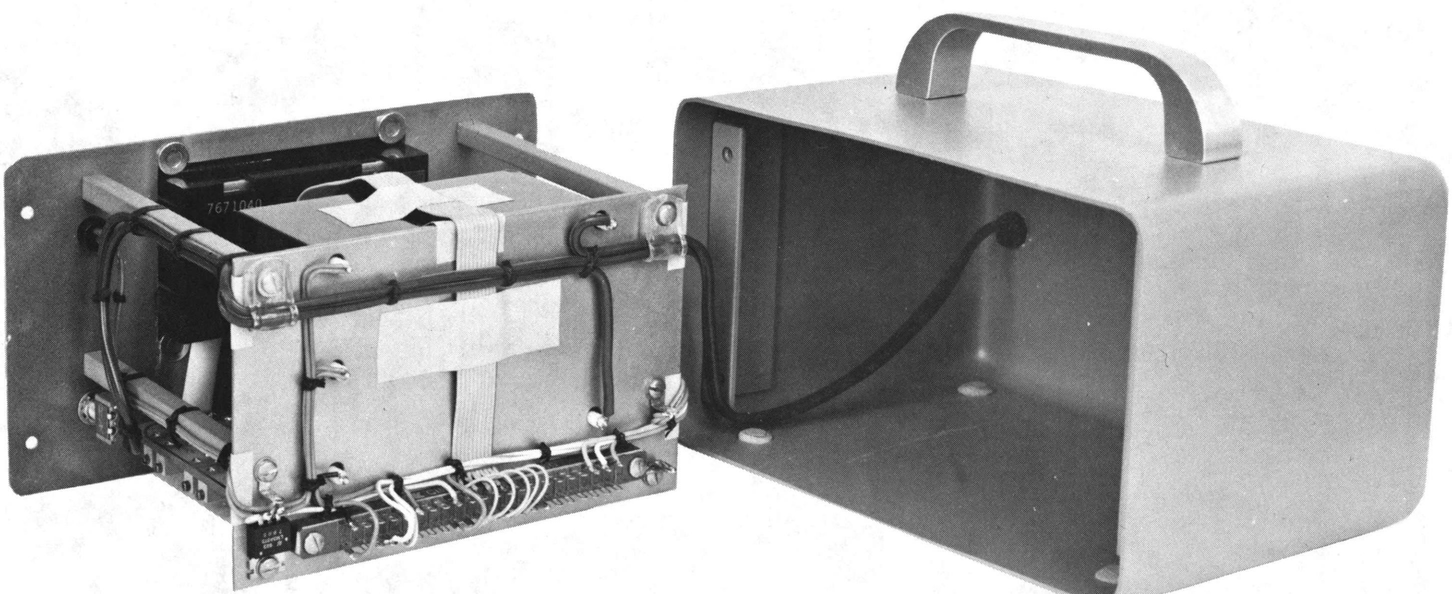
TEMPERATURE READOUT UNIT FOR LAKE SHORE YOTRONICS SILICON DIODE SENSORS (DT-500 SERIES)

MICHAEL BALISTER

MAY 1980

NUMBER OF COPIES: 150


SER. NO. 4
OUTPUT
POWER
ON
OFF
TEMPERATURE
DEGREES KELVIN
TEMP. SENSOR



TEMPERATURE READOUT UNIT FOR LAKE SHORE CRYOTRONICS SILICON DIODE SENSORS (DT-500 SERIES)

Michael Balister

Introduction

This report describes a Temperature Readout Unit for Lake Shore Cryotronics Silicon Diode Sensors (DT-500 series). After an initial calibration procedure, the unit can be used with any of the DT-500 series diodes without further calibration over the temperature range 2 K to 380 K. The unit measures the forward voltage drop across the sensor diode when biased at a constant current 10 μA. The sensor temperature is determined from the voltage using a two-straight-line calibration curve. The slopes are set by adjusting the unit to give the correct temperature readout at 4, 25, 80 and 300 K using the manufacturer's calibration data at these temperatures. Since there is a large change in slope at about 26 K, the unit is scaled to read temperature in degrees above 26 K and tenths of degrees below this temperature. The total temperature error due to sensor and readout unit is less than ± 2 K over most of the temperature range. The maximum errors resulting from the approximation to the calibration curve are up to 4 K and are around indicated temperatures of 30 K and 370 K.

The Temperature Sensor

The DT-500 series silicon diode temperature sensors can be used over the range 1-400 K. The forward voltage drop versus temperature is shown in Figure 1. Table 1 is the manufacturer's mean calibration data for this diode. NRAO uses the TO5 stud package and CU disc package (has central mounting hole) for all temperature monitoring applications.

Circuit Description

Figure 2 is a block diagram of the unit and Figure 3 gives the circuit diagram of the components mounted on the printed circuit board. An LM 334 adjustable current source is used to bias the diode to 10 μA. The addition of a resistor and diode results in current stability over the normal operating temperature range of better than 1%. Since the dynamic resistance of the sensor is about 1 kΩ, better current stability is not required.

The sensor forward voltage drop is measured with an instrumentation amplifier AD521K with gain set to 4 times. The high input impedance of 3×10^9 Ω ensures that no error occurs due to resistive loading of the diode due to the amplifier.

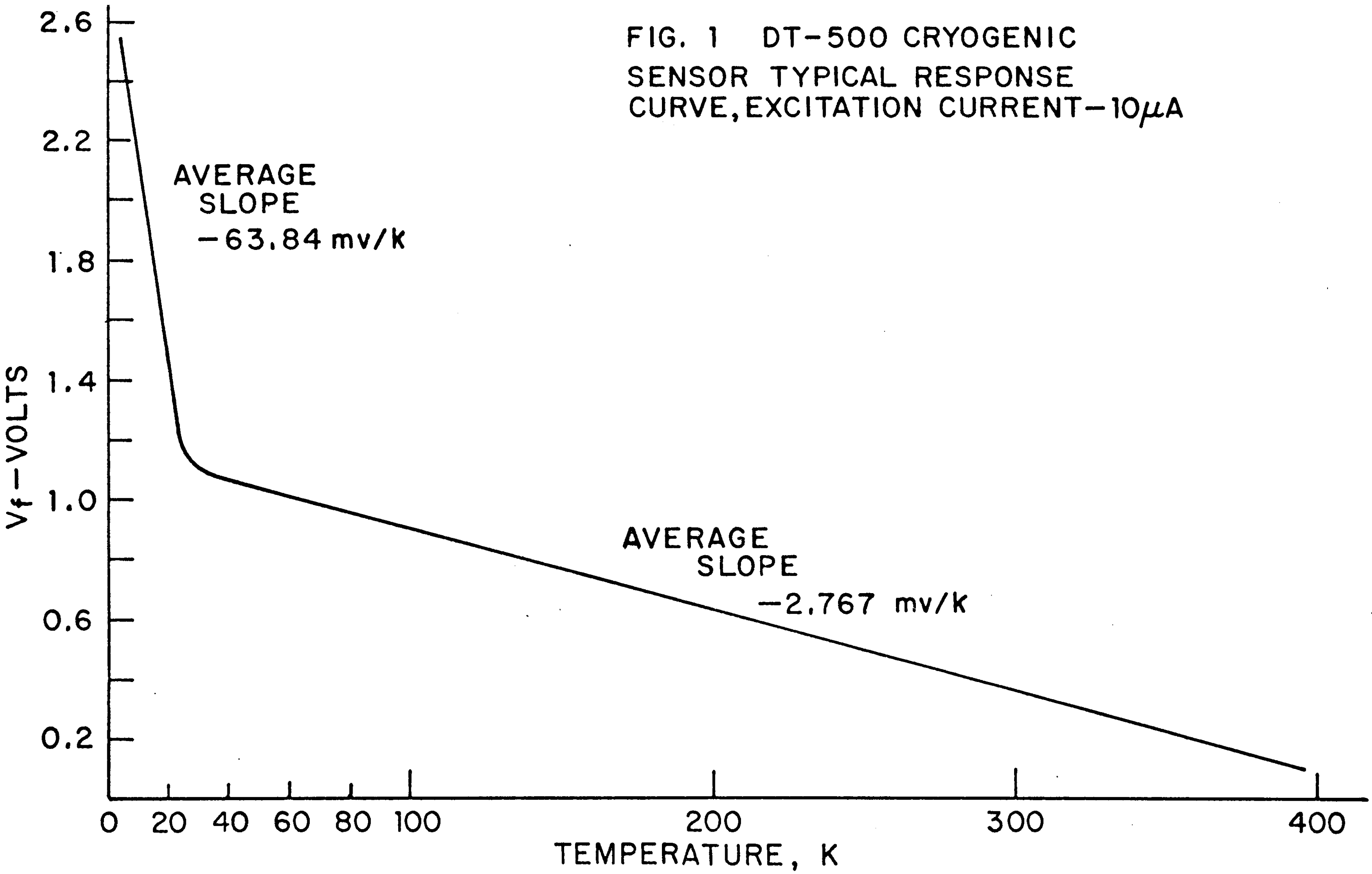


FIG. 1 DT-500 CRYOGENIC SENSOR TYPICAL RESPONSE CURVE, EXCITATION CURRENT—10μA

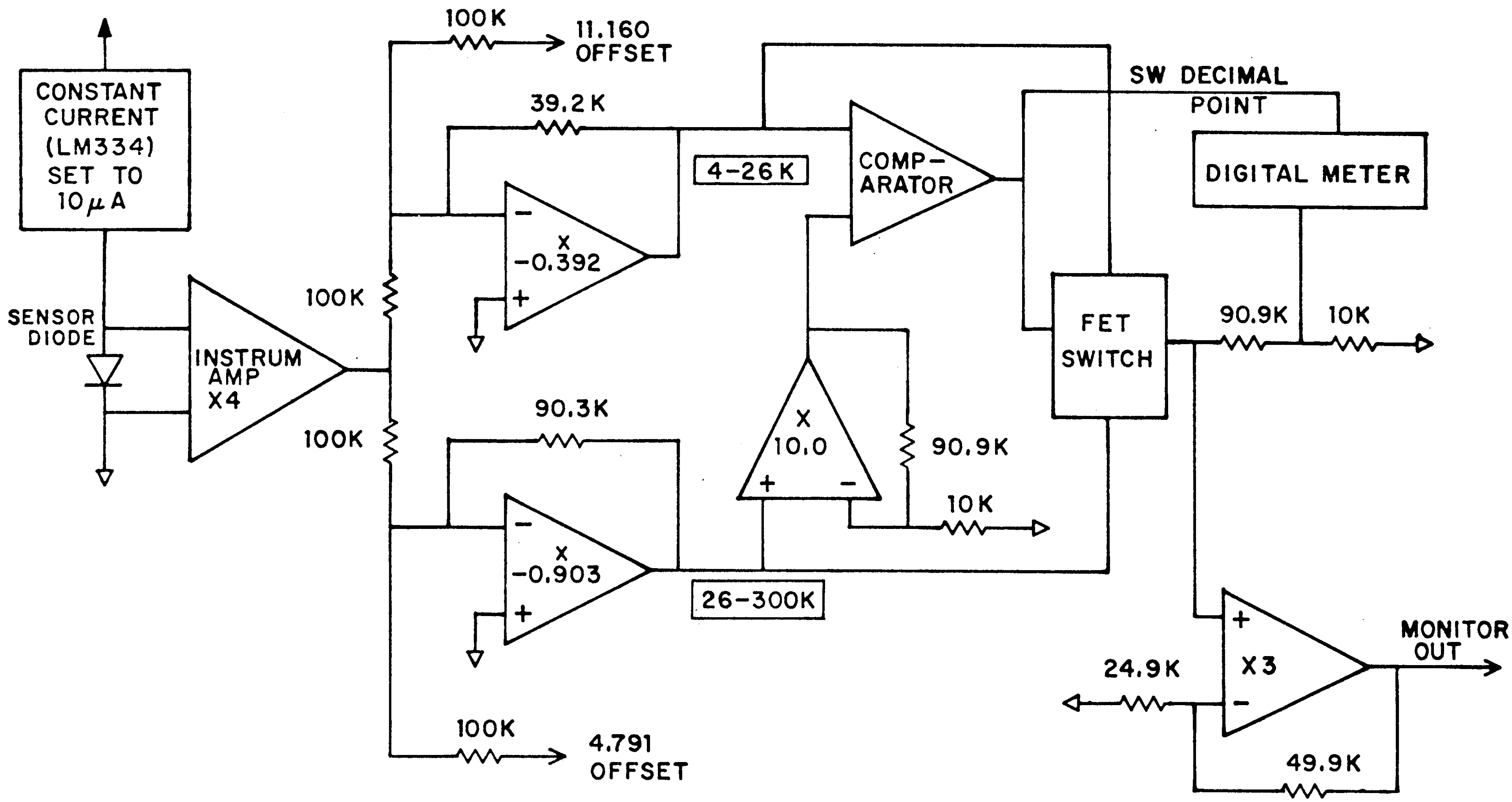
Manufactured By: LAKE SHORE CRYOTRONICS
64 E. WALNUT ST.
WESTERVILLE, OHIO 43081

TABLE 1

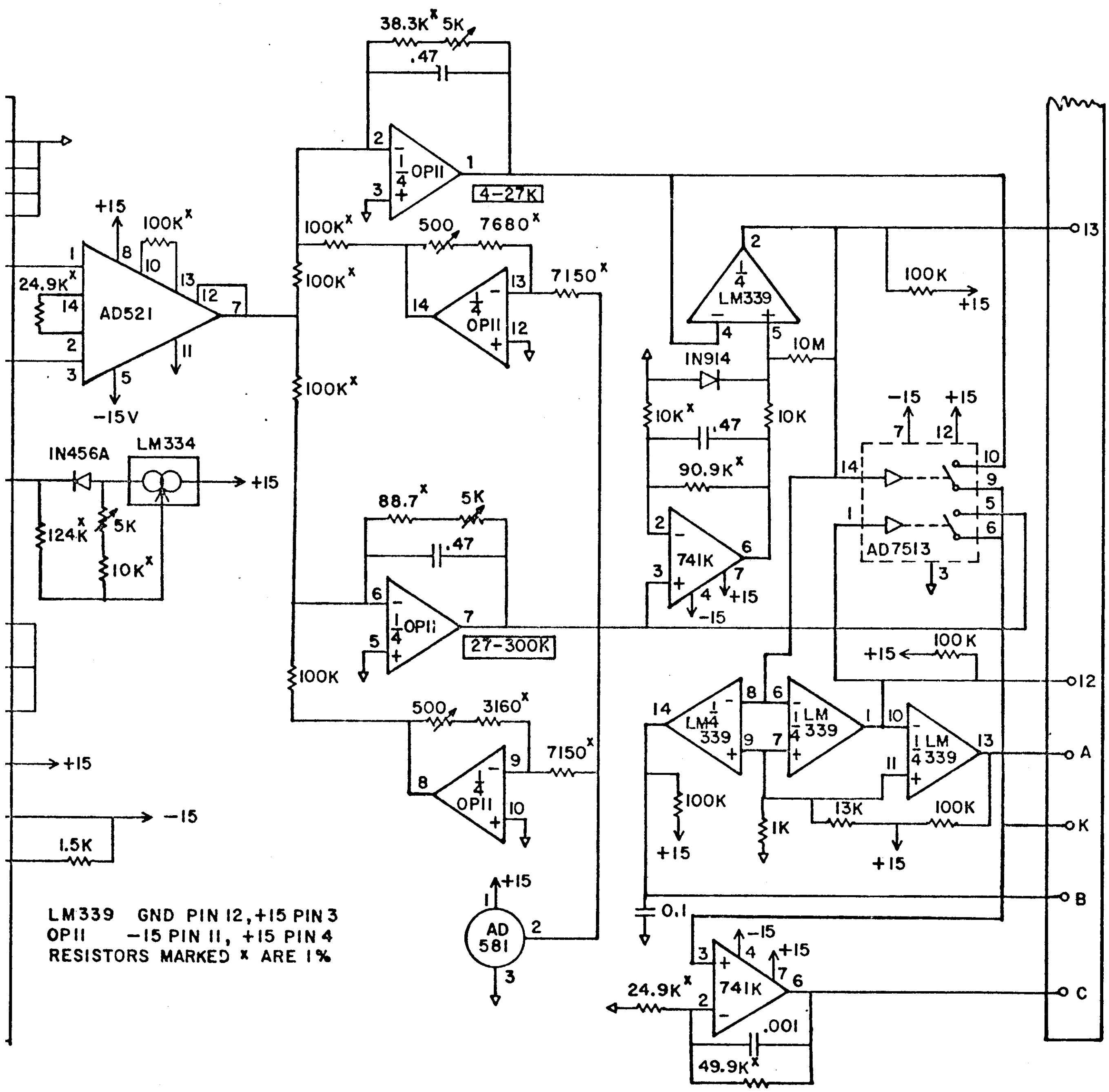
DT-500-DRC (B) Voltage - Temperature Characteristic

T, Kelvin	Sensor Voltage	T, Kelvin	Sensor Voltage	T, Kelvin	Sensor Voltage
1.0	--	19.0	1.5944	160.0	0.75680
1.5	2.6647	20.0	1.5159	165.0	0.74276
1.6	2.6622	21.0	1.4389	170.0	0.72868
1.7	2.6593	22.0	1.3575	175.0	0.71457
1.8	2.6562	23.0	1.2895	180.0	0.70041
1.9	2.6528	24.0	1.2378	185.0	0.68622
2.0	2.6491	25.0	1.1955	190.0	0.67201
2.2	2.6410	26.0	1.1645	195.0	0.65777
2.4	2.6321	27.0	1.1434	200.0	0.64353
2.6	2.6223	28.0	1.1293	205.0	0.62928
2.8	2.6117	29.0	1.1192	210.0	0.61504
3.0	2.6005	30.0	1.1115	215.0	0.60084
3.2	2.5886	32.0	1.1003	220.0	0.58672
3.4	2.5762	34.0	1.0923	225.0	0.57268
3.6	2.5633	36.0	1.0859	230.0	0.55880
3.8	2.5499	38.0	1.0804	235.0	0.54508
4.0	2.5361	40.0	1.0752	240.0	0.53152
4.2	2.5220	45.0	1.0632	245.0	0.51810
4.4	2.5075	50.0	1.0515	250.0	0.50479
4.6	2.4928	55.0	1.0397	255.0	0.49151
4.8	2.4780	60.0	1.0276	260.0	0.47818
5.0	2.4631	65.0	1.0151	265.0	0.46483
5.5	2.4254	70.0	1.0024	270.0	0.45137
6.0	2.3877	75.0	0.98933	275.0	0.43773
6.5	2.3505	80.0	0.97610	280.0	0.42388
7.0	2.3142	85.0	0.96277	285.0	0.40988
7.5	2.2790	90.0	0.94939	290.0	0.39574
8.0	2.2452	95.0	0.93591	295.0	0.38155
8.5	2.2127	100.0	0.92238	300.0	0.36729
9.0	2.1818	105.0	0.90881	305.0	0.35294
9.5	2.1524	110.0	0.89520	310.0	0.33843
10.0	2.1246	115.0	0.88156	315.0	0.32375
11.0	2.0731	120.0	0.86788	320.0	0.30893
12.0	2.0236	125.0	0.85412	325.0	0.29407
13.0	1.9730	130.0	0.84035	330.0	0.27919
14.0	1.9186	135.0	0.82652	335.0	0.26432
15.0	1.8561	140.0	0.81265	340.0	0.24943
16.0	1.7942	145.0	0.79873	345.0	0.23458
17.0	1.7325	150.0	0.78478	350.0	0.21974
18.0	1.6651	155.0	0.77081	355.0	0.20500
				360.0	0.19037
				365.0	0.17596
				370.0	0.16192
				375.0	0.14846
				380.0	0.13597

FIG. 2 BLOCK DIAGRAM OF TEMPERATURE READOUT UNIT



IG. 3 TEMP. SENSOR READOUT CIRCUIT BOARD



LM339 GND PIN 12, +15 PIN 3
OP11 −15 PIN 11, +15 PIN 4
RESISTORS MARKED x ARE 1%

The following table lists the nominal voltages at various points in the circuit for the four calibration points.

Temperature K	Voltage Across Sensor at 10 μA	Voltage at AD521 Output V	Input to Meter Divider V	Panel Meter mV
300	0.36729	1.46916	3.000	300
80	0.97610	3.9044	0.800	80
25	1.1955	4.7820	2.500	250
4	2.5361	10.1444	0.400	40

The change in slope of the temperature/voltage characteristic of the sensor occurs at 26 K. The output voltage from the AD521 instrumentation amplifier is split into separate paths for processing such that above 26 K the meter reads 26-300 K in degree steps, and below 26 K the meter reads 2 to 26 K in 0.1 degree steps. Both channels use inverting amplifiers with input offset to give the correct voltages for the display. A simple calculation gives the following requirements.

Temperature Range K	Gain	Offset
360-26	-0.903	+4.791
26-2	-0.392	+11.160

The intersection of the two straight line calibration curves is sensed by an LM 339 comparator with a x 10 gain amplifier in the higher temperature path. This comparator controls an AD7513 FET switch which connects the digital panel meter to the correct path for the temperature being measured. The AD2026 3-digit panel meter displays input -99 mV to +999 mV. An input attenuator divides the circuit output voltage by 10 and the meter then reads temperature directly. The comparator also moves the decimal point up one digit when the scale changes at about 26 K.

Provision is made for an external meter to be attached remotely. The output voltage is boosted by a factor of 3 to minimize any pickup problems. Two extra digital outputs are also provided for control of the decimal points. The table lists the remote meter or recorder output voltage at the calibration temperatures.

Temperature K	Voltage V
300	9.000
80	2.400
25	7.500
4	1.200

Calibration Procedure

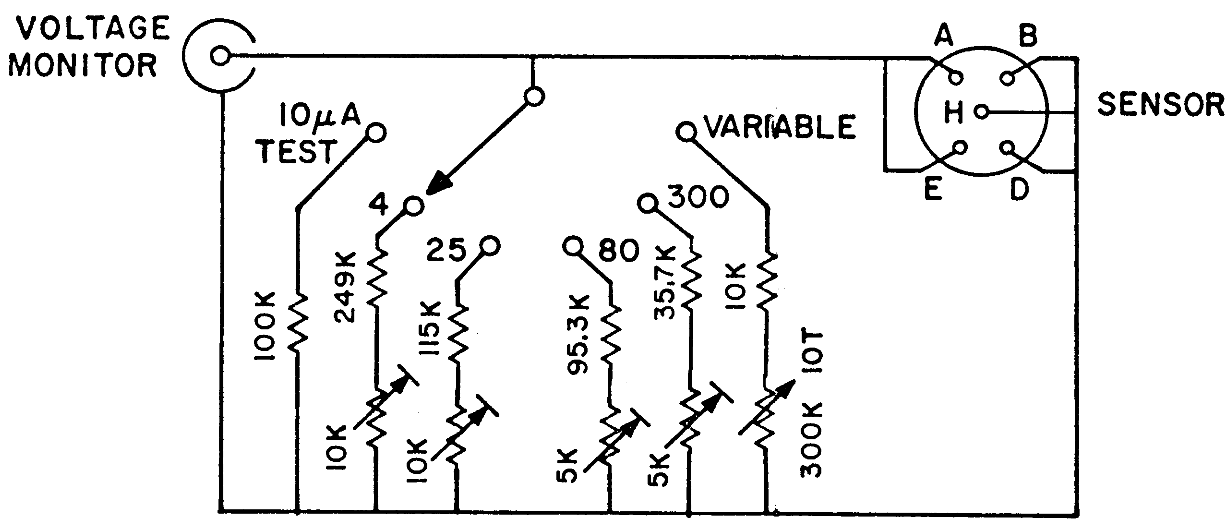
The calibration points used to set up this circuit were chosen to minimize the errors that occur due to the straight line fitting to the calibration characteristic. These are listed below.

Temperature K	Voltage V
300	0.36729
80	0.97610
25	1.1955
4	2.5361

These voltages are given by Lake Shore Cryotronics for their B sensor. Measurements confirm that these points are close for the sensors received from them during 1979. The company does not expect to radically change their sensors in the near future.

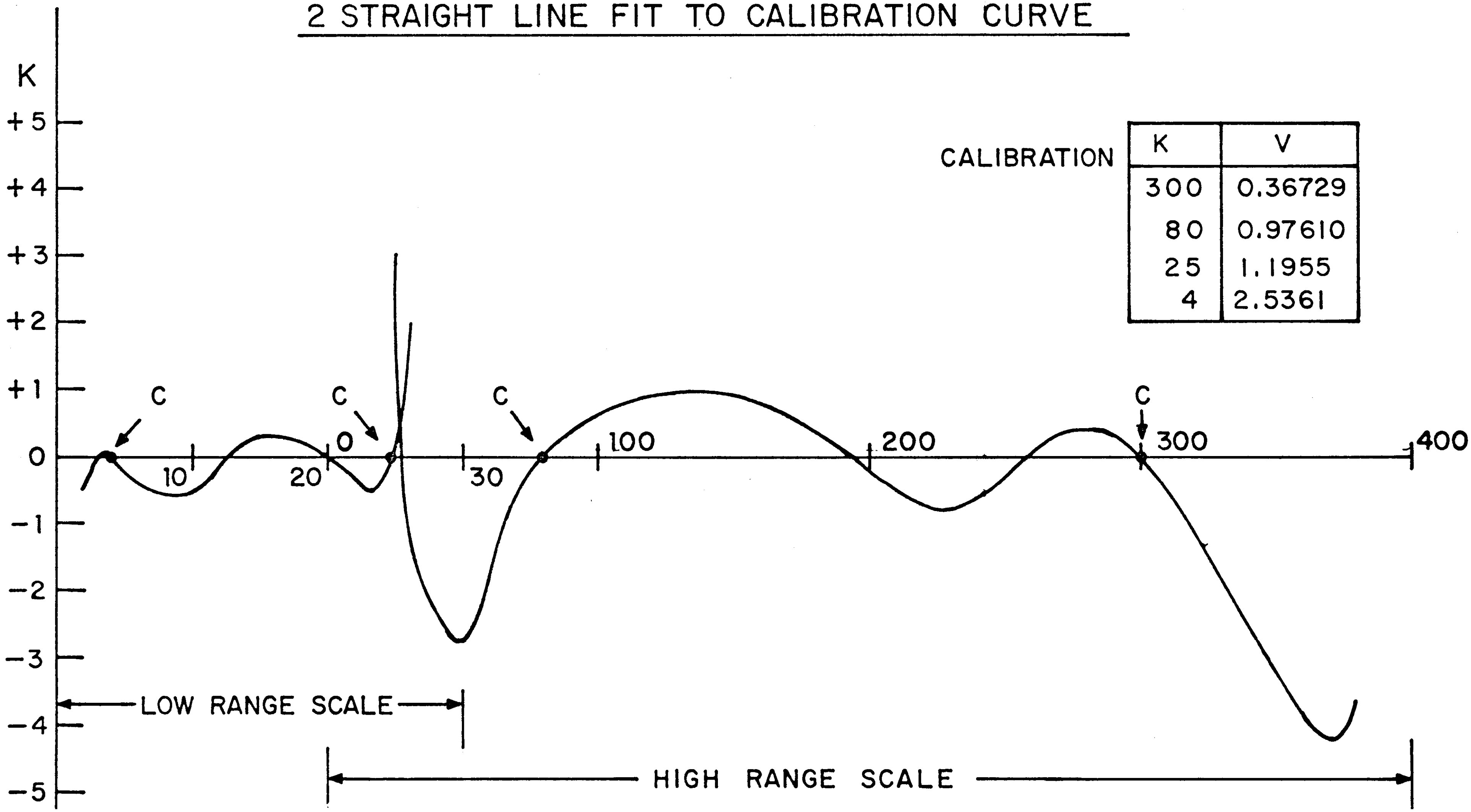
The calibration procedure is simplified by the use of a test box which is used to simulate the sensor at the four calibration temperatures (Figure 4). The resistors are adjusted, using a high input impedance precision DVM, to give the correct voltage at the calibration temperatures. A 100 kΩ selected 1% resistor is used to enable the constant voltage source to be set to 10 μA by adjusting the 5 K resistor to give 1.000 volt across the selected resistor The high temperature range is set by adjusting the gain and offset pots to give the correct temperature readout at 300 and 80 K. The low range is adjusted at 25 and 4 K. The transition between ranges should occur at about 26 K.

FIG. 4 TEST BOX FOR TEMPERATURE INDICATOR



ALL FIXED RESISTORS ARE 1%

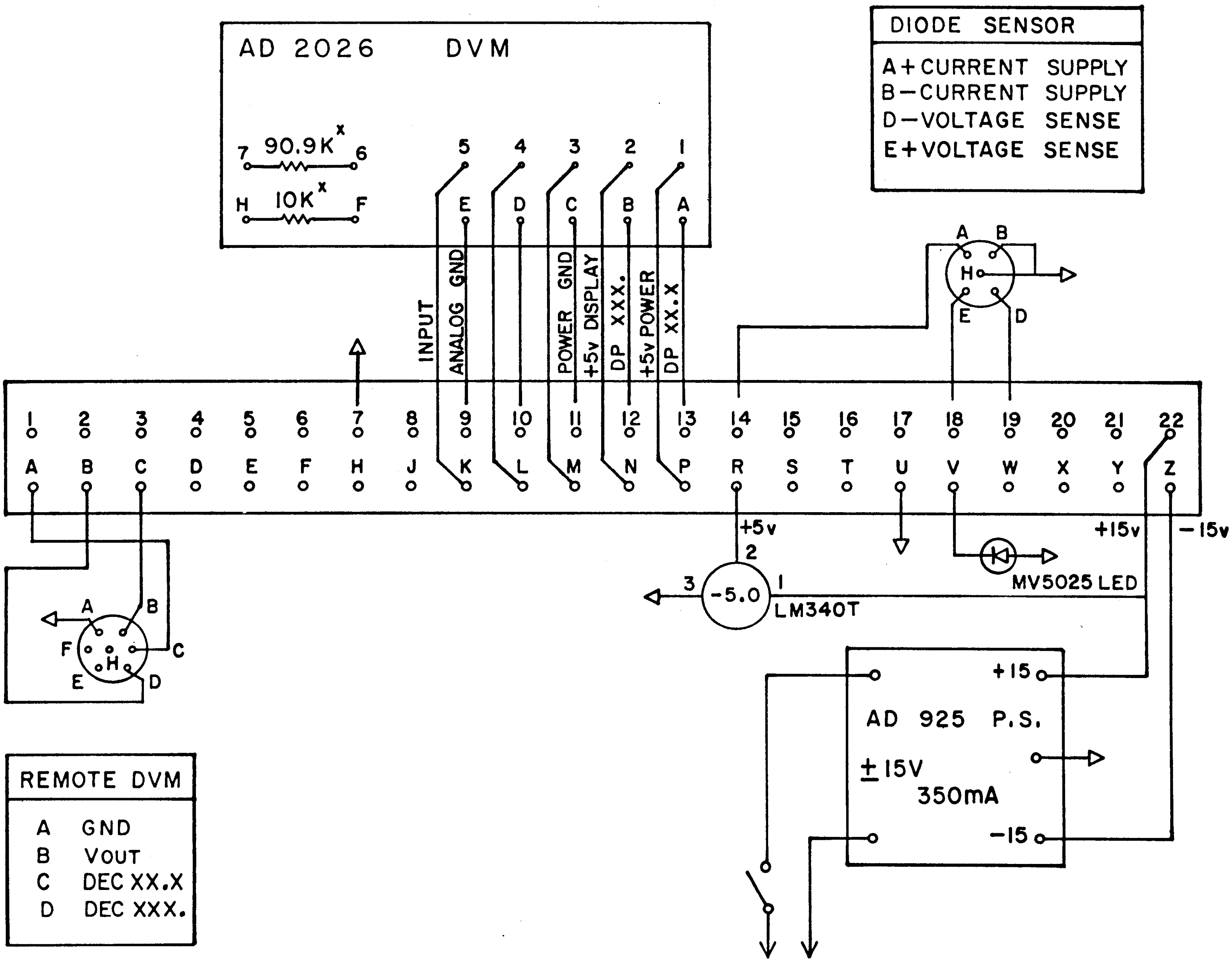
FIG.5 T_{IND} CORRECTION FOR DT-500DRC (B) SENSOR WHEN USING 2 STRAIGHT LINE FIT TO CALIBRATION CURVE



CALIBRATION

K	V
300	0.36729
80	0.97610
25	1.1955
4	2.5361

FIG. 6 WIRING DIAGRAM FOR LAKE SHORE CRYOTRONICS DIODE SENSOR READOUT CIRCUIT



Using the calibration data above, we can determine the indicated temperature T_{IND} as a function of input voltage V_{IN}:

$$T_{IND} = \frac{0.36720 - V_{IN}}{.002767} + 300 \quad \text{for 26-360 K temperature range.}$$

$$T_{IND} = \frac{1.1955 - V_{IN}}{.06384} + 25 \quad \text{for 2-26 K temperature range.}$$

If the input is shorted ($V_{IN} = 0$), the indicated temperature will be 433 K. (Sensor only gives correct readings to ∿ 400 K.)

A comparison of the Lake Shore calibration data with the indicated temperature is shown in Figure 5. It can be seen that over most of the temperature range that the agreement is better than ± 1 K. The greatest error occurs around 30 K and 370 K where the indicated temperature is high by 3-4 K.

It is fortunate that the main temperatures of interest are at:

300 K ...... room temperature

77 K ...... LN_2

20 K ...... CTI refrigerator cold station

4 K ...... LH_4

since these temperatures are at or very close to calibration points. Even the uncalibrated DT-500 sensors used at NRAO are within 1 K of each other, so the indicated temperature should generally be within ± 2 K of the corrected value.

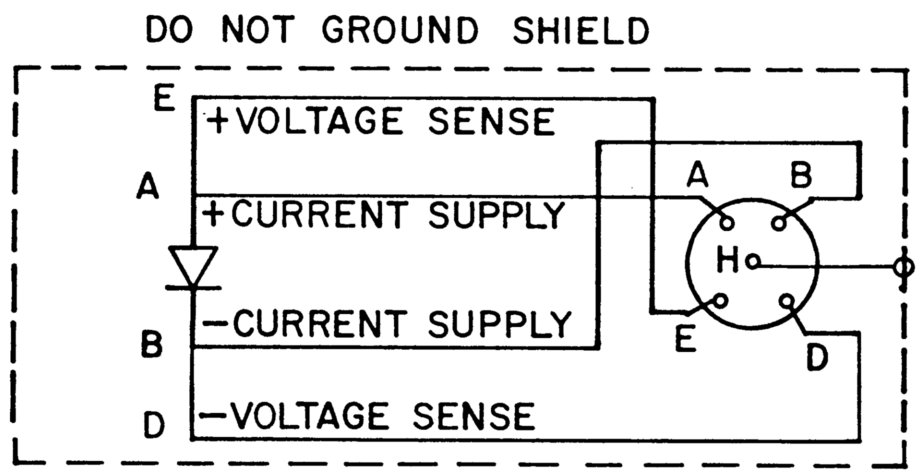
Construction

The unit is continued in a Zero Manufacturing box (model ZIC 407). An AD925 power supply gives +15 V ± at 350 mA; 5 volts for the digital panel meter is derived from the +15 V line using an LM340T 5 V regulator. Figure 6 shows the interconnections between the circuit board, power supplies, etc. The sensor input connector and wiring are identical (Figure 7) to that used by Lake Shore Cryotronics on their microprocessor curve fitting temperature indicator units (DR7C).

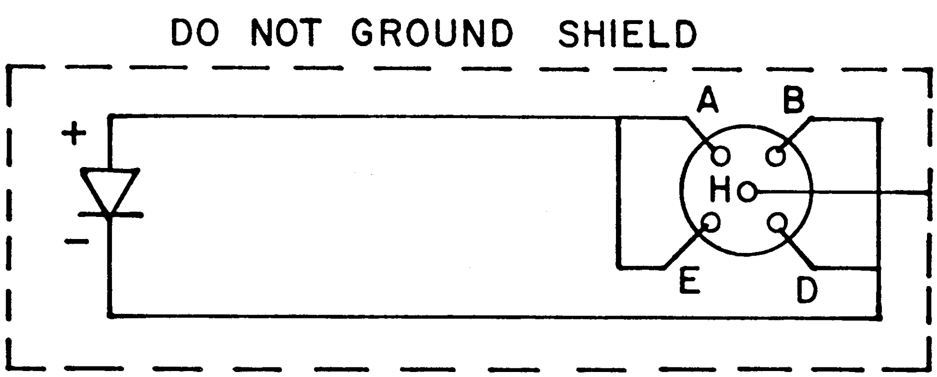
A list of components on the circuit board is given in Figure 8. The final boards have been built with socket pins so that IC's may be removed for easy maintenance. Figure 9 shows the printed circuit component layout.

Figure 10 is a drawing for the front panel, power supply plate, and support pillars. Figure 11 is a photograph of the completed unit.

FIG. 7 SENSOR CONNECTION



(A) RECOMMENDED SENSOR CABLE



(B) ALTERNATE SENSOR CABLE

COMPONENT LIST FOR TEMPERATURE MONITOR CIRCUIT BOARD

Integrated Circuits:

AD 7513JN
AD 581LH
AD 521KD
OP 11FY
LM 339N
LM 334Z

Diodes:

1N456A
1N914

Resistors:

1%	5%	Variable (Helitrum
3160	1.0 K	2 x 89PR 500
2 x 7150	1.5 K	3 x 89PR 5K
7680	10.0 K	
2 x 10 K	13.0 K	
24.9 K	4 x 100.0 K	
38.3 K	10.0 K	
49.9 K		
88.7 K		
90.9 K		
5 x 100.0 K		
124.0 K		

Capacitors:

Erie Red Cap

3 x 0.47
1 x 0.1
1 x 0.001

FIGURE 8

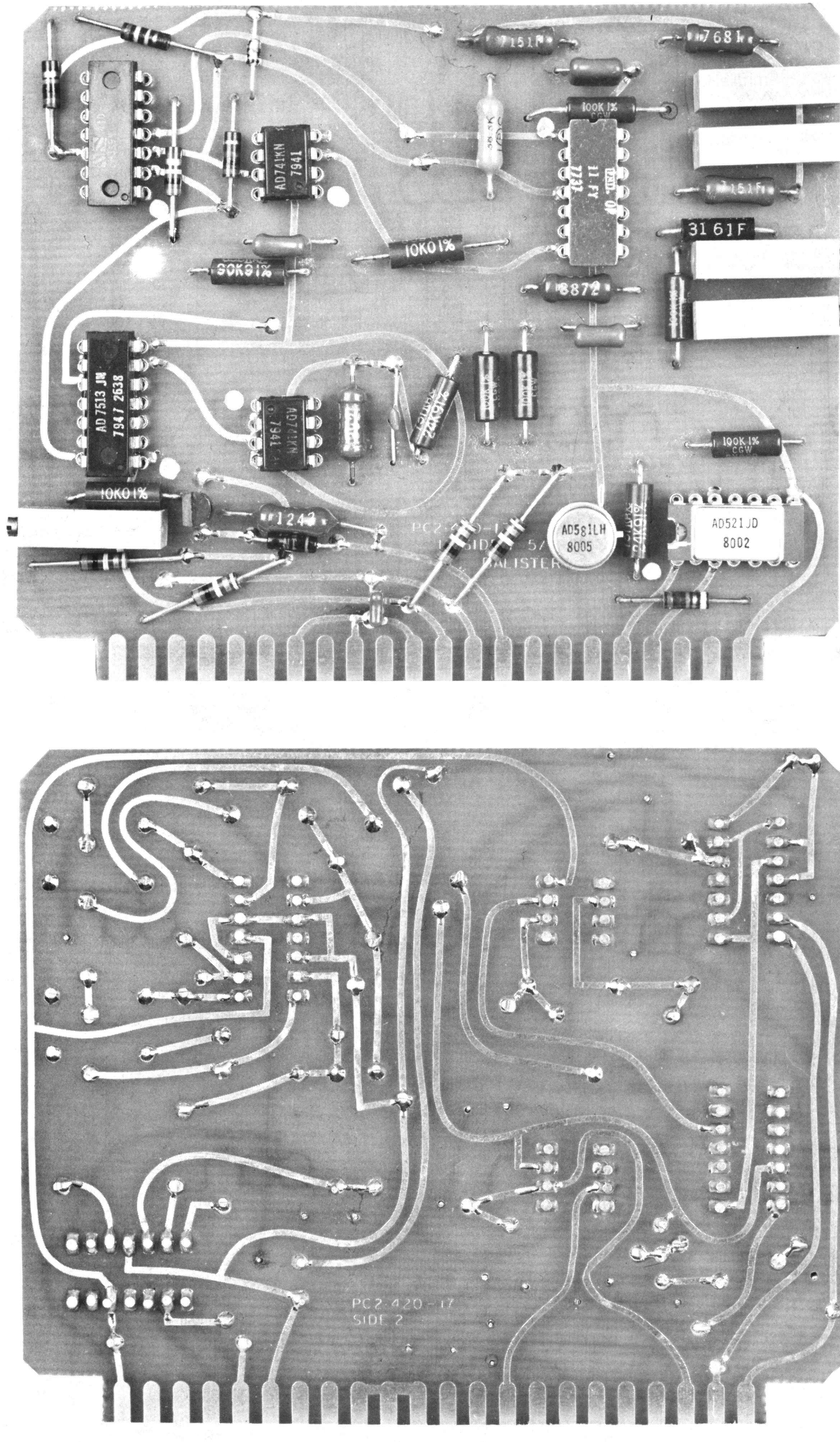
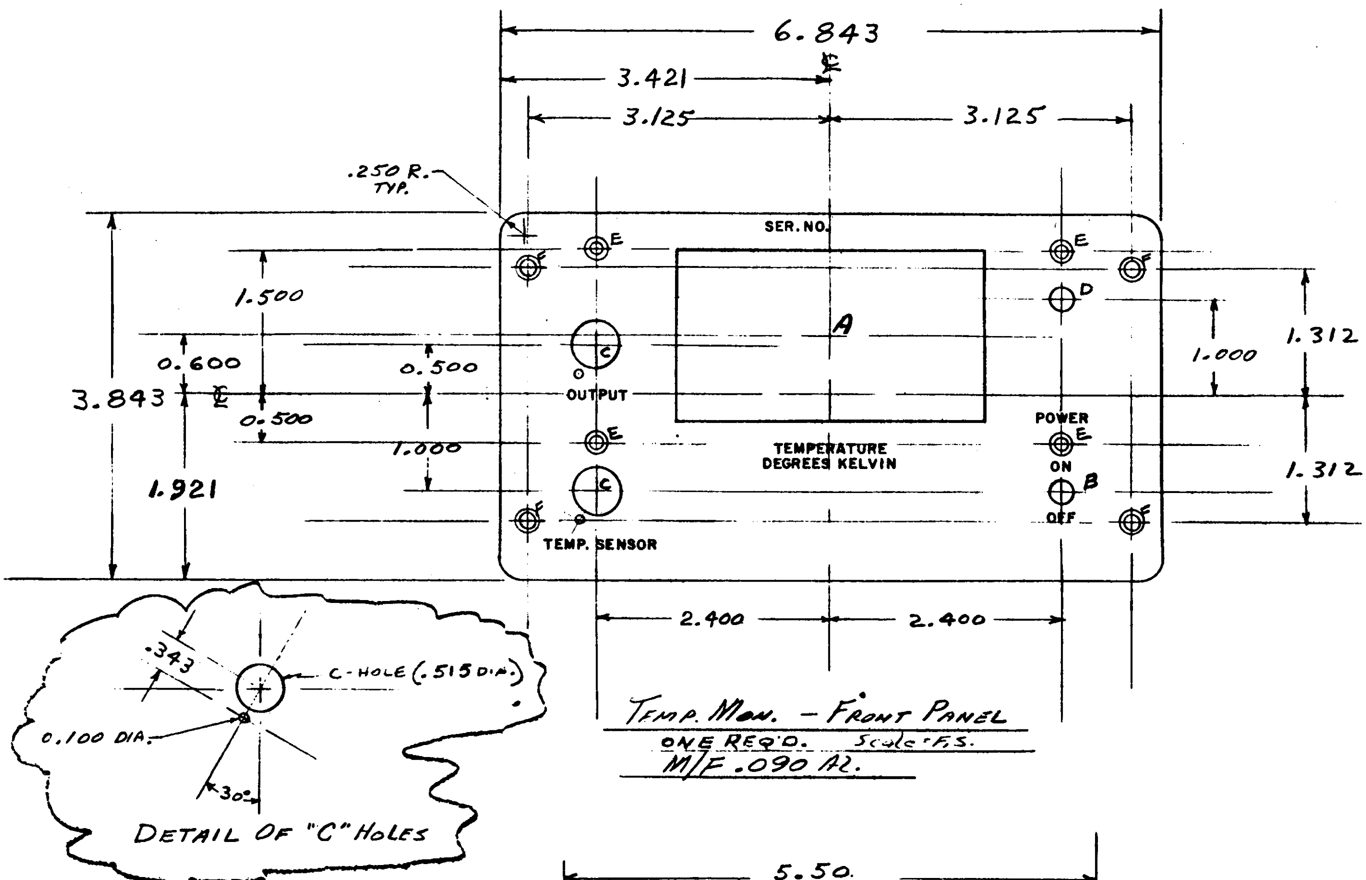
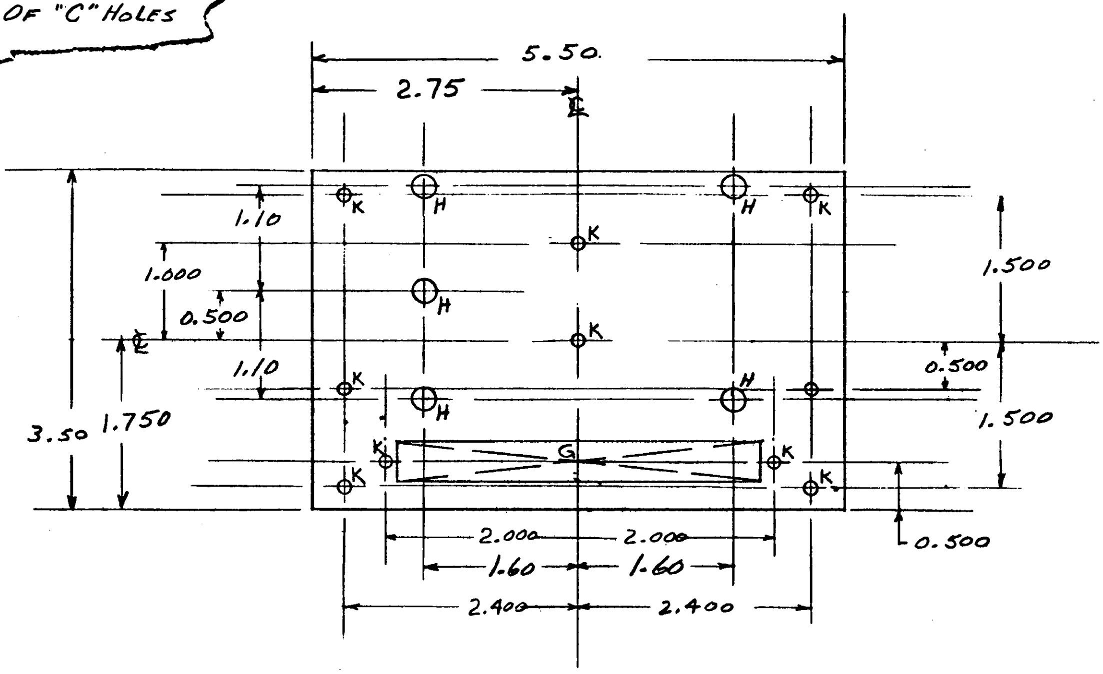


Figure 9: Printed Circuit Layout



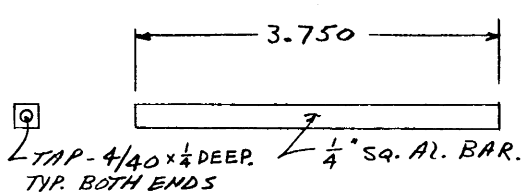
TEMP. MON. - FRONT PANEL
ONE REQ'D. Scale: F.S.
M/F .090 AL.

HOLE SIZE
- =1.810 x 3.175
- =TAP 1/4 x 40
- =.515 DIA.
- =1/4 DIA.
- =DRILL & C/S F.S., 4-40
- =DRILL & C/S F.S., 6-32
- =11/32 x 3 3/4
- =1/4 DIA.
- =Clear - 4-40



BACK PLATE
M/F. 1/16" AL. scale = F.S.
ONE REQ'D.

NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE: TEMP. MON. - FRONT PNL. AND REAR PNL. (STAND OFF BARS) Fabrication & Engraving	
DESIGN BY: M. Balister	DATE: 9/79
APPROVED BY:	DRAWN BY: TM
DWG No. PF & PE 2-420-3	



STAND-OFF BARS
4 REQ'D. Scale = F.S.