User's Manual

Model DRC-7/-70

Digital Cryogenic Thermometer

Model DRC-7C/-70C

Digital Cryogenic Controller

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WARRANTY

Lake Shore Cryotronics, Inc. warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, shipment prepaid, to our factory for that purpose within ONE year of delivery to the original purchaser, provided prior authorization for such return has been given by an authorized representative of Lake Shore Cryotronics, Inc.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. This Warranty likewise shall not apply to any instrument or component not manufactured by others and included in Lake Shore Cryotronics, Inc. equipment; the original manufacturer's warranty is extended to Lake Shore Cryotronics, Inc. customers.

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FIGURE 1.1 MODEL DRC-70 DIGITAL CRYOGENIC THERMOMETER

SECTION I

General Information

1.1 Introduction

This section contains a description for the DRC-7 series digital temperature readout/controller instruments which include the Models DRC-7, DRC-7C, DRC-70, and DRC-70C for use with the Model DT-500-DRC standard silicon diode sensor.

1.2 Description-General

The series DRC-7 is a completely self-contained unit providing the capability of both direct digital readout in kelvin temperature units and temperature control (DRC-7C and DRC-70C) by direct digital comparison to the displayed temperature.

The useful range of operation is 1 to 400 K utilizing the standard DT-500-DRC sensor which has been pre-selected to provide uniform characteristics. Pre-selection allows the series DRC-7 to be used with standard sensors without adjustment of any kind. Since the standard sensors are completely interchangeable, the series DRC-7 may be used to read out any number of sensors with equal accuracy when selected through an appropriate external switch or multiplexer.

The series DRC-7 units contain an internal constant current source which is preset at the factory for 10 microamps.

As a standard feature, all units are equipped with a recorder output providing 0-4 volts in increments of 10 millivolts per degree with a linearity error of 0.5 K (DRC-7 and DRC-7C) and 0.3 K (DRC-70 and DRC-70C).

Both the DRC-7C and DRC-70C readout/controller units have an adjustable fine tuning control for peak output power adjustment. The fine tuning control is continuously adjustable to allow infinite resolution and minimizing of the overshoot value.

1.3 Description-Specific

The following provides a description for each specific instruments in the DRC-7 series digital cryogenic thermometers and controllers.

1.3.1 Model DRC-7

The Model DRC-7 provides direct temperature readout in kelvin temperature units with 1 degree resolution. The error of linearization (conformity) is factory set at 0.5 degrees.

1.3.2 Model DRC-7C

The Model DRC-7C combines the electronics contained in the Model DRC-7 with a time proportional thyristor temperature controller. The control portion is actuated by an internal digital comparison of the BCD output to a digital thumbwheel set point switch. The BCD comparison signal provides an error value (equivalent to the temperature deviation) to a time proportional thyristor control circuit. The thyristor circuit controls the ON time of the powered output available from a continuously adjustable variac with an adjustable power output of 0 to 50 watts.

1.3.3 Model DRC-70

The Model DRC-70, like the DRC-7, provides temperature readout only. However, the resolution has been improved to 0.1 degree and the conformity error has been reduced to 0.3 degrees. Both the Models DRC-7 and DRC-70 have a standard analog output,to compliment the digital display, providing a 0-4 volt output with a slope of 10 millivolts/degree with their respective linearity error.

1.3.4 Model DRC-70C

The Model DRC-70C, as the DRC-7C, provides both temperature readout and control over the useable range of 1 to 400 K.

The DRC-70C combines the DRC-70 with a revolutionary new digital proportional thyristor control unit having an internal factory set bandwidth of 0.5 kelvin. The digital proportion control provides for maximum agreement between the set point temperature and the actual temperature. A fine tuning control is provided on the front panel which allows the maximum peak voltage to be adjusted between 0 and 50 volts rms.

The bandwidth is fixed about the set point value and is equal to ±0.5 K. Operation within the bandwidth zone allows the controller to work in a proportional mode. The proportional mode operation is detectable by a pulsating or blinking heater power ON light. Operation below the proportional zone allows the controller to work in a continuously ON condition.

1.4 General Specifications

The following specifications for the DRC-7 series are applicable when used with the standard DT-500-DRC temperature sensor.

General:

Temperature Range	1 to 400 K
Sensing Material	Silicon (Model DT-500-DRC)
Sensor Excitation	10 microamps
Sensor Current Regulation	±.1%
Sensor Input Connection	2, 3, or 4 wire constant current
Input Resistance	Greater than 100 megohms
Isolation	300V
Operating Environment	10-45°C
Normal Mode Rejection	50 db min. at 60 Hz and up
Common Mode Rejection	120 db at 60 Hz and above
Power Requirements	115 or 230* VAC ±10%, 50/60 Hz
Dimensions	8.9 cm (3.5") high x 20.3 cm (8") wide x 30.5 cm (12") deep
Power Consumption	15 VA[1,3], 60 VA[2,4]
Circuit Design	Solid State Electronics
Weight	3.6 Kg (8 pounds)[1,3], 5.4 Kg (12 pounds)[2,4]

*For 230 VAC, add (-K) to model number; i.e. DRC-70-K

1-Model DRC-7 only
2-Model DRC-7C only
3-Model DRC-70 only
4-Model DRC-70C only

Temperature Readout:

Resolution:	
Digital	1 kelvin[1,2], 0.1 kelvin[3,4]
Analog	Better than 0.1 kelvin (all units)
Conformity to LSCI Standard DRC-7 Silicon Diode Table	0.5 K (4-400 K)[1,2] 0.3 K (4-400 K)[3,4]
Maximum Sensor Power Dissipation	25 microwatts at 4.2 K
Maximum Digitizing Error (8 hours at 25°C)	0.5 K
Temperature Coefficient Error	0.06 K/°C
Repeatability	1 kelvin[1,2], 0.1 kelvin[3,4]
Outputs:	
Analog	10 mV/K at 1 K output impedance. Tracking to digital display of 0.3 K
Digital (optional)	TTL compatible (non-isolated)
Display	3 digits, 14 mm (0.55") high, 7 segment non-blinking
Response Time	2 seconds to rated accuracy

Temperature Control:

Set Point	Digital thumbwheel selection directly in kelvin temperature units
Controllability	0.5 K[2], 0.3 K[4] with a properly designed system
Repeatability	1 kelvin[2], 0.1 K[4]
Settability	1 kelvin[2], 0.1 kelvin[4]
Heater Output	Standard 0-50 watts, 0-1 A, 0-50 VAC
Control Mode	Time proportional thyristor with continuously adjustable variac output[2] Isolated digital proportional with continuously adjustable variac output[4]

1.5 Accessory Equipment and Custom Options Available

The following accessory equipment and custom options are available from the factory.

SECTION II

Installation

2.1 Introduction

This section contains information and instructions necessary for the installation and shipping of the series DRC-7 Digital Readout/Controller. Included are inspection instructions, power and grounding requirements, installation information, and instructions for repackaging for shipment.

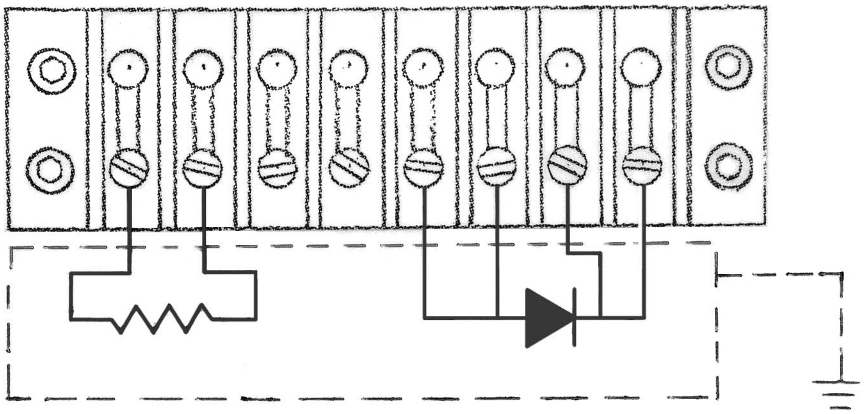
2.2 Initial Inspection

This instrument was electronically and mechanically inspected prior to shipment. It should be free from mechanical damages and in perfect working order upon receipt. To confirm this, the instrument should be inspected visually for obvious damage upon receipt and tested electronically by use to detect concealed damage. All parts should be inventoried before discarding any shipping material. If there is damage to the instrument in transit, be sure to file appropriate claims with the carrier, and/or insurance company. Please advise the company of such filings. In case of parts shortages, please advise company. The standard Lake Shore Cryotronics warranty is given on page ii.

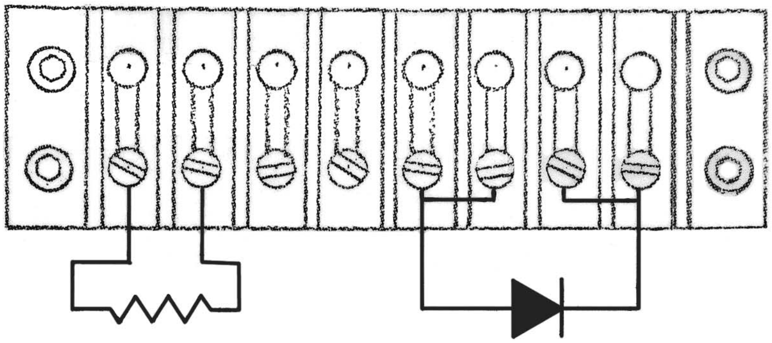
2.3 Power and Grounding Requirements

To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends and some local codes require instruments to be grounded. This instrument is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument.

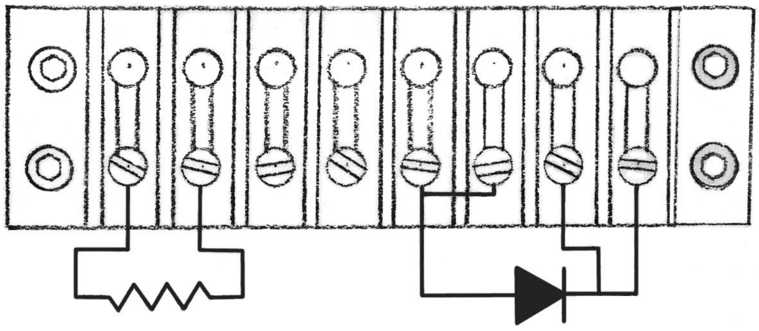
The standard unit is set for 115 VAC ±10%, 50/60 Hertz operation with the designated (-K) units set for 230 VAC ±10, 50/60 Hertz. The standard 115 VAC unit may be converted to 230 VAC by requesting the conversion procedure from the company.



(A) RECOMMENDED SENSOR AND HEATER CABLING



(B) ALTERNATE TWO WIRE HOOK-UP



(C) ALTERNATE THREE WIRE HOOK-UP

FIGURE 2.1 SENSOR AND HEATER CABLES

2.4 Installation

The recommended cable diagrams for the sensor diode and heater element are given in Fig. 2.1 (a). The use of a four wire diode connection is highly recommended to avoid introducing lead IR drops in the voltage sensing pair. The indicated shielding connections are the recommended standard practice to avoid ground loops. For less critical applications, the wiring scheme in Fig. 2.1 (b) and (c) may be used.

The heating element should be floated to preclude the possibility of any of the heater current being conducted into the diode sensor. Electrical feedback, in addition to the desired thermal feedback, may cause oscillations and certainly erroneous temperature readings.

2.5 Repackaging for Shipment

Before returning an instrument to the factory for repair, please discuss the malfunction with a factory representative. He may be able to suggest several field tests which will preclude returning a satisfactory instrument to the factory when the malfunction is elsewhere. If it is indicated that the fault is in the instrument after these tests, the representative will send shipping instructions and labels for returning it.

When returning an instrument, please attach a tag securely to the instrument itself (not on the shipping carton) clearly stating:

(1) Owner and address

(2) Instrument Model and Serial Number

(3) Malfunction symptoms

(4) Description of external connections and cryostats.

If the original carton is available, repack the instrument in a plastic bag, place in carton using original styrafoam popcorn to protect protruding controls, and close carton. Seal lid with paper or nylon tape. Affix mailing labels and "FRAGILE" warnings.

If the original carton is not available, wrap the instrument in protective plastic wrapping material before placing in an inner container. Place shock absorbing material around all sides of the instrument to prevent damage to protruding controls. Place the inner container in a second heavy carton and seal with tape. Affix mailing labels and "FRAGILE" warnings.

SECTION III

Operating Instructions

3.1 Introduction

This section contains a description of the operating controls and their adjustment under normal operating conditions. These instructions are predicated upon the instrument having been installed as outlined in Section II. The diode polarity as shown in Fig. 2.1 (a) in particular must be correct.

3.2 Controls, Indicators and Connectors

The operating controls, indicators and connectors on the instrument's front and rear panels are shown in Figures 3.1 and 3.2. The numbers with leaders to various controls in the figures are keyed to the entries in Table 3.1.

Table 3.1 - Entry Number Correlation

NO. KEY	NAME	FUNCTION
1	Heater	Heater element terminals
2	Analog (Hi & Lo)	Recorder output
3	Input	Sensor input lead terminals (plus I, plus V, minus V, and minus I)
4	NO LABEL	A.C. line cord
5	NO LABEL	Digital temperature display located behind filter panel. Maximum range 1-400 K.
6	NO LABEL	Digital set point switch. Selects desired temperature to be controlled to directly in kelvin units. Adjustable from 2 to 399 K.

NO. KEY	NAME	FUNCTION
7	NO LABEL	Fine tuning power control. Adjusts the maximum power available from 0-50 VRMS. Infinite resolution through the use of a variac control.
8	PWR	A.C. line switch (ON/OFF)
9	NO LABEL	Heater ON light indicates power is applied to heater load
10	BCD	BCD output (optional)

3.3 Initial Checks

Initial checks, calibration checks, and servicing procedures are described in Section V, Maintenance.

3.4 Temperature Readout/Control

3.4.1 Model DRC-7

The digital panel meter has provisions to accept a connector at the rear of the case. A connector package is supplied which consists of a connector ELCO No. 00-6007-030-980-002 and two screws No. 4-40 thd by ½ inch long binding head.

Table 3.2 provides the necessary pin designation for input and output signals.

Table 3.2 - Pin Designation for Model DRC-7

PIN NO.	FUNCTION	PIN NO.	FUNCTION
1.	+4.8 volts	A.	+9 volts
2.	Analog (+)	B.	Current Test (+)
3.	Print Command	C.	Overrange
4.	Polarity	D.	Hold
5.	BCD 8	E.	BCD 1
6.	BCD 2	F.	BCD 4
7.	BCD 80	H.	BCD 10
8.	BCD 20	J.	BCD 40
9.	Sensor Input (+)	K.	BCD 100
10.	Analog (-), Signal Ground	L.	N/C

PIN NO.	FUNCTION	PIN NO.	FUNCTION
11.	BCD 400	M.	Trip Point
12.	BCD 200	N.	Digital Gnd, BCD Gnd
13.	Current Test (-)	P.	N/C
14.	Sensor Input (-)	R.	Shield
15.	115/230 VAC Line 1	S.	115/230 VAC Line 2

The sensor is connected to the instrument via pins #9 and #14.

The internal current source can be checked by placing a 100 K ohm ±.01% resistor between pins 13 and B and measuring the voltage drop with a voltmeter having an accuracy of 0.01% error.

For those units having the optional BCD output, a binary-coded-decimal (BCD) is provided as listed in Table 3.2. The decade counters provide a 1-2-4-8 code using positive logic with standard TTL levels of 0.4 volts and 2.4 volts for the 0 and 1 state, respectively. The drive is sufficient to sink two standard loads, 3.2 mA, in the low state.

For additional usage, a switch or TTL microcircuit connected to the hold terminal (Pin D) can be used to keep the voltage level low and defeat the synchronizing signal applied to the synchronizing divider. This will prevent the generation of a reset pulse.

3.4.2 Model DRC-7C

The sensor and heater should be installed following the suggestions listed in the "Installation and Application Notes for Cryogenic Sensors" brochure in Section VI.

Connect the sensor and heater to the instrument following the diagrams in Fig. 2.1.

Rotate the fine tuning power control (Key No. 7) full counter-clockwise to minimum power output. Adjust the digital thumbwheel switch (Key No. 6) to 001.

Turn the power switch (Key No. 8) to ON and observe that the display (Key No. 5) shows the proper temperature relative to the sample temperature.

If the display reads -1800, 1090, or blanks, the diode is connected backwards.

The heater ON light (Key No. 9) should be off.

Adjust the set point (Key No. 6) to one degree below the value being displayed (Key No. 5) and observe that the heater power light (Key No. 9) remains off. Advance the set point 2 K and observe that the heater power light turns ON. Return the set point to its original value and check that the heater power light shuts OFF. If light does not shut off, check to see if display is indicating a different temperature.

The heater power light will remain ON as long as the set point is less than the display by at least 1 K.

Increase the set point switch until the desired value is set. If the temperature set point is larger than the temperature being displayed, the heater ON light will illuminate indicating power is being applied to the heater. Observe the display and if the temperature being displayed does not show signs of heating, then increase the maximum power out by rotating, clockwise, the fine tuning control knob (Key No. 7). The knob should be rotated in ¼ turn increments until the proper rate of heating is observed on the temperature display. If the increase in temperature is slow or the temperature does not increase, (and is still below the temperature set point), rotate the fine tuning knob another ¼ turn. Repeat above procedure until the desired rate or temperature is achieved. When the readout is equal to or greater than the temperature set point, the heater ON light will switch OFF.

The maximum controllability will be achieved with the minimum value of amplitude pulse height applied to the heater (controlled by the fine tuning knob (Key No. 7). This condition can be detected by observing a continuous switching between ON and OFF of the heater ON light.

3.4.3 Model DRC-70

The sensor should be connected to both the sample area and instrument following the suggestions noted in Section 3.4.2.

The sensor and readout display should follow Table 6.1 which illustrates typical values expected of the standard DT-500-DRC sensors. If the instrument or sensor does not agree with values listed in the table, consult sections on installation and/or section on troubleshooting to determine cause and cure of malfunction.

For those units equipped with BCD output, the following Table 3.3 illustrates the function of each pin designation.

Table 3.3 - BCD Pin Designation for
Models DRC-7C, DRC-70, and DRC-70C

PIN NO.	FUNCTION
1	N/A
2	N/A
3	Print command
4	Polarity
5	BCD 8
6	BCD 2
7	BCD 80
8	BCD 20
9	BCD 800
10	N/A
11	BCD 400
12	BCD 200
13	N/A
14	BCD 1000
15	Hold
16	BCD 1
17	BCD 4
18	BCD 10
19	BCD 40
20	BCD 100
21	Digital GND, BCD, GND
22	BCD 2000
23	N/A
24	Overload
25	Shift

All terminations for above signals are located at the BCD connector (Key No. 10) type 17-10250 by Amphenol.

3.4.4 Model DRC-70C

Connect the sensor following the procedure outlined in Section 3.4.2.

Before applying power, the fine tuning control (Key No. 7) should be rotated full counterclockwise to minimum power output and the set point switch (Key No. 6) to 002.0 K. Note! If 000.0 K is set in the thumbwheel switch, the unit will apply full power to the heater. Observe the temperature display (Key No. 5) and if it is greater than the set point by 0.5 K (Key No. 6), the heater ON light (Key No. 9) should be off illustrating zero power being applied to heater load.

Adjust the set point to a value equal to 0.5 K less than the value being displayed and observe that the power ON light just begins to illuminate. Adjust in 0.1 K increments, the set point, towards the value being displayed and observe the power ON light begins to appear more frequently. When the set point value equals the display value, the power ON light should be on 50% of the time. Note! This test should be performed with a displayed value less than 150 K.

Continue to increase set point in 0.1 K increments and note that the power ON light continues to increase in frequency. With the set point equal to 0.5 K plus the value on display, the power ON light will be on continuously (100% of the time). If the above observances are met, the unit is functioning properly. If not, see sections on installation and section on troubleshooting for correcting malfunction.

With the unit functioning properly, adjust set point switch to the desired temperature value.

Increase the maximum output power by rotating the fine tuning control (Key No. 7) ¼ turn and observe the rate of heating indicated by the readout display's rate of change. If the increase in temperature is slow or the temperature does not increase, (and is still below the temperature set point), rotate the fine tuning knob another ¼ turn. Repeat the above procedure until the desired rate of increase or the set temperature is achieved. When the readout display is within 0.5 K of the temperature set point, the heater ON light (Key No. 9) will begin to blink proportionally to the difference between the set point temperature and the display temperature. If the overshoot drives the temperature 0.5 K beyond the set point, the heater ON light will switch off.

The maximum controllability will be achieved with minimum value of amplitude pulse height applied to the heater (controlled by the fine tuning knob - Key No. 7). This condition is detected by observing a 50% proportional duty cycle switching between ON and OFF of the heater ON light.

3.5 Customer Calibration

The procedure outlined below is applicable to Table 6.1 for aligning all series DRC-7 instruments.

3.5.1 Model DRC-7*

(A) Ten Microamp Sensor Current Adjustment

(1) Remove the front panel cover on the meter.

(2) Turn the power ON to the instrument and allow about 10 minutes warm up.

(3) Connect a voltmeter with a 0.01% accuracy and a 100 megohm minimum resistance between pins B and 13, the positive terminal of the voltmeter should be connected to pin B. Connect a 10 uF capacitor across pins B and 13 if the connector leads are long.

(4) Adjust the potentiometer marked "1", located at the back of the instrument until the voltmeter reads 100.0 millivolts.

(B) Calibration of the Instrument Between 0-300 K

(1) Connect a voltage standard, such as EDC Model MV-100N, to the probe input terminals and set the value of 2.81586 volts on the voltage standard.

(2) Set the ZERO adjust potentiometer until the meter displays 000. The ZERO potentiometer is located on the front panel, at the right hand side of display.

(3) Set the voltage standard to the value of 0.37721 volts and adjust the SPAN potentiometer until the meter displays 300. The SPAN potentiometer is located to the left of the display.

(4) Repeat steps 1 through 3 until the respective readings are displayed.

(5) Set the voltage standard to the value of 1.09471 volts and adjust the potentiometer labeled "7" until the meter displays 035. This potentiometer is located at the back of the meter.

(6) Repeat above steps, if necessary.

*Note! For DRC-7 units having a serialized number greater than 2000, use calibration procedure under Section 3.5.2.

3.5.2 Models DRC-7C, DRC-70, and DRC-70C

(1) Connect the input terminals to a voltage standard such as EDN Model MV-100N or equivalent and a voltmeter (input ±199.99 mV, resolution 10 uV, ±0.05% accuracy and an input impedance of not less than 1000 megohms) across resistor R_{80}. The positive terminal of the voltmeter should be connected to the test point 1 and the negative terminal to test point 2.

(2) Turn the power on and allow approximately 60 minutes warm up time.

(3) Adjust potentiometer R_{79} until the voltmeter reads 100.0 mV.

(4) Set the voltage standard to 1.9755 volts. Adjust the ZERO potentiometer R_{34} until the panel meter reads 013.1 (013 for Model DRC-7C).

(5) Set the voltage standard to 1.1283 volts. Adjust potentiometer R_{19} to a value of 028.0 on the panel meter display.

(6) Set the voltage standard to 0.9811 volts and adjust potentiometer R_{26} to a value of 077.3 (077 for Model DRC-7C) on the panel meter display.

(7) Set the voltage standard to 0.099 volts and adjust potentiometer labeled "FS" (R_{33}) to a value of 395.2 (395 for Model DRC-7C) on the panel meter.

(8) Repeat above steps, if necessary.

SECTION IV

Theory of Operation

4.1 Introduction

This section contains the theory of operation of the series DRC-7 Digital Readout/Controller to aid the system engineer in designing a stable thermal system. Refer to Figures 4.1, 4.2, 5.1, 5.2, 5.3, 5.4, and 5.5 as an aid in the following discussion.

4.2 General Description

The diode sensor (Model DT-500-DRC) is excited by an adjustable (R79) constant current source and forms the feedback element of the input amplifier (Z2). The output of this amplifier is a voltage referred to the system common (TP #10) and is proportional to the voltage output of the sensor.

The amplifier output voltage is compared with a predetermined voltage reference corresponding to the various linearizer segment break points from the standard DRC-7 voltage versus temperature table. The attenuated output of the input amplifier is fed into two stages of amplifiers (Z3 and Z5) whose gain is variable as a function of the sensor temperature. The gain changing networks are switched by means of analog switches set to close when the voltage output of the sensor amplifier (Z2) is equal to the predetermined voltage reference corresponding to each break point of the DRC-7 standard table. The voltage output of the linearizer is a linear function of the sensor temperature. This output is converted to a linearized output of 10 mV/K and the digital voltmeter reads and displays this output.

4.3 Detailed Description

A detailed description of the voltage temperature conversion is outlined below.

4.3.1 Power Supply and System Common

The output of transformer (T1) is rectified and filtered to 22 VDC by means of a full wave bridge (CR1-4) and a capacitor C24 filter. The line filter C19, C20, and C25 on the power line bypasses the high frequency noise signal in the power line. The filtered, but unregulated, 22 VDC is regulated to 14 VDC by a precision voltage regulator (Z24).

The voltages at various parts of the circuit are referred to the "System Common" which is the output of the amplifier (Z7). The common is located 7 VDC below the positive regulated voltage. This voltage can be adjusted to within ±0.001 volts with potentiometer R71. The amplifiers, comparators, and the analog switches in this system are operated between V+ and V- (14 volts) and the networks for the bias and gain controls work between V+ and common. Therefore, the output of all amplifiers is referred to the "System Common".

4.3.2 Two Wire Input

This diode sensor is supplied by a constant current of 10 microamperes which is adjustable (R79) to provide the current excitation. The sensor forms the feedback element of the amplifier (Z2). The offset adjust potentiometer (R89) provides the exact voltage required by the linearizer. The two-wire input is subject to voltage errors produced by the IR drops along the lead wires with 10 microamps flowing.

4.3.3 Four Wire Input

Since the sensor forms the feedback element of amplifier Z2, the lead resistance will have an appreciable effect on the accuracy as noted in Section 4.3.2. This effect is reduced by utilizing a four-wire input as follows. The output of amplifier Z2 is connected to the negative input of the unity gain amplifier Z11. The positive input of amplifier Z11 is referred to the cathode of the sensor through lead #3 (pin #11). The variation of the output of amplifier Z2 due to the lead resistance of lead #1 (pin #9) and lead #2 (pin #10) is equal and opposite to the variation of the voltage of lead #3 (pin #11). Due to the equality, they cancel at the output of the amplifier Z11 which provides the exact voltages (equal to sensor) required by the linearizer. For long lead runs, it is suggested that shield cables be used to minimize noise pickup.

4.3.4 Linearizer

The series DRC-7 utilizes straight line segments over the range of 1 to 400 kelvin with break points at 6 K, 14 K, 18 K, 23 K, 25 K, 27 K, 30 K, and 80 K. The slope between 18 and 23 K is the largest (75.3 mV/K) and, hence, the gain of the linearizer is the lowest between these points. Similarly, the linearizer has its highest gain between 30 and 80 K where the diode has the smallest slope of 2.66 mV/K.

4.3.5 Comparators and Voltage References

The reference voltages are formed in steps of ascending order corresponding to the voltage output of the input amplifier at the various break points. A ladder network connected between V+ and common provide these voltages.

The reference voltages are compared with the respective output voltages of the input amplifier and analog switches SW4 through SW7 are closed when the amplifier voltage is equal to the reference voltage. The analog switches SW1, SW2, and SW3 are set to open when the amplifier voltage exceeds the reference voltage. This occurs when the initial gain of the linearizer is lower than the lowest gain which occurs between 18 and 23 K. Analog switch SW8 opens at 80 K since the gain over the temperature range 80 to 400 K is lower than the gain between 30 and 80 K.

Due to the sharp increase in gain between 27-30 K and 30-80 K, the analog switches should be closed exactly at the amplifier voltage corresponding to break points 27 K and 30 K. The adjustments for these two break points are accomplished with potentiometers R99 and R98, respectively. The high slope below 27 K guarantees that the error resulting from the set point accuracy of this break point will not have any significant effect on the overall accuracy. The set point accuracy at the break point for 80 K is not very critical since the overall gain between 80 and 400 K is reduced only by 1/28th of the maximum gain.

4.3.6 Amplifier - Stage I

The characteristics of the Model DT-500-DRC (see standard table of DRC-7) shows that the ratio of the highest gain to the lowest gain is 28. Therefore, to operate amplifier Z3 within its linear region, it is necessary to attenuate the signal of the input amplifier Z2 to approximately 1/20 of its actual level. This signal is fed into the positive terminal of unity gain amplifier Z3 to maintain the proper sign, with the negative input terminal following the positive input terminal and with the difference being only the offset voltage of the amplifier. Therefore, when the comparator closes the analog switch, a reference voltage equal to the voltage at the negative terminal is switched. At the point of switching, no current flows through Rswitch. For example, if analog switch SW4 is closed, the reference voltage V_{12} is applied and is equivalent to the voltage at break point 23 K. No current will flow through R_{10} for break point 23 K providing a gain of Z3 equivalent to the gain for segment 18 to 23 K. As the input voltage increases,current, proportional to the input voltage, flows through R_{10} and the gain of amplifier Z3 is modified accordingly.

The gain network at the negative input of amplifier Z3 is divided into 1/3 R and 2/3 R in order to keep the value of R_7 and R_4, respectively, within 1.3 megohms. It is also necessary to keep the value of R_{20} above 10 K ohms so that the resistance of the analog switch will be negligible compared to R_{20}. At break points 27 K and 30 K, the value of (V_{18} and V_{19}) and (V_{25} and V_{26}) should be exactly equal to the voltage at the negative input terminal of Z3 through adjustable potentiometers R_{26} and R_{19}.

Since the gain between 4 and 6 K is lower than that between 6 and 14 K, resistor R_{35} is switched across R_{49} (feedback resistor) to provide the lower gain required.

In the temperature range 18 to 23 K, all switches SW1 through SW7 are open to provide the proper slope and gain for conformity to standard DRC-7 table.

4.3.7 Amplifier - Stage II

Operation between 80 to 400 K is accomplished with the break point set for 80 K which triggers the comparator to operate switch SW8 into an open state. The comparator switches when the voltage at the input to Z5 exceeds 0.97405 volts. With the gain change in this stage only 1/28th of the highest gain, any error introduced by resistor R_{22} and the voltage offset in amplifier Z5 will be negligible.

4.3.8 Output Stage and Digital Display

The output amplifier Z5 provides the necessary offset and gain to yield an overall output of 4.000 volts corresponding to 400.0 kelvin with a linear response of 10 mV/K as indicated by the digital voltmeter (DVM) display.

4.4 Temperature Controller

The function of the controller is to apply power to the heater when the reading on the digital display is below the value set by the digital set point control switch. The full power condition of the heater is indicated by a red light emitting diode (LED), (Key No. 9). The maximum (full power) heater voltage is continuously adjustable (via fine tuning power control, Key No. 7) between 0 and 50 VAC and can supply a maximum output current of 1 amp.

4.4.1 Model DRC-7C

The following description of the controller system refers to Figures 4.1, 4.2, and 5.3.

Assume the temperature set point T_S is greater than the temperature display T_D (Fig. 4.1), then the BCD output of the counters (Z14, Z15, and Z16) is below the BCD code generated by the thumbwheel switch setting. A comparison is attempted with Z10, Z18, Z19, and Z20. However, due to the inequality, a comparison cannot be made and a logic 1 is provided which latches Z13 and full power is applied to the heater and the power ON light (Key No. 9) is turned ON indicating full power for a fixed number of timing cycles determined by updating signal contained in the digital panel meter.

Assume the temperature set point T_S is less than the temperature display T_D (Fig. 4.2), then the BCD output of the counters (Z14, Z15, and Z16) is greater than the BCD code generated by the thumbwheel switch setting. A comparison is made utilizing comparators Z10, Z18, Z19, and Z20 resulting in an equal or greater than condition which drives the comparator output to a logic state 0. This condition is latched with Z13 and remains latched until a reset occurs. The latched condition will occur for both $T_S < T_D$ and $T_S = T_D$.

To prevent full power from being applied during the reset cycle, transistors Q4 and Q5 are equipped with RC networks (R_{123}, C_{35} and R_{131}, C_{30}) for a short time delay.

4.4.2 Model DRC-70C

The digital proportional controller with fixed bandwidth utilizes a new concept for control. The digital proportional circuit samples the temperature display and temperature set point to determine the magnitude of difference and adds a proportionally greater number of signal pulses to the heater output circuit for successively larger deviations between temperature display and temperature set point.

The circuit is factory adjusted (Z16) for a bandwidth of ±½ K about the temperature set point.

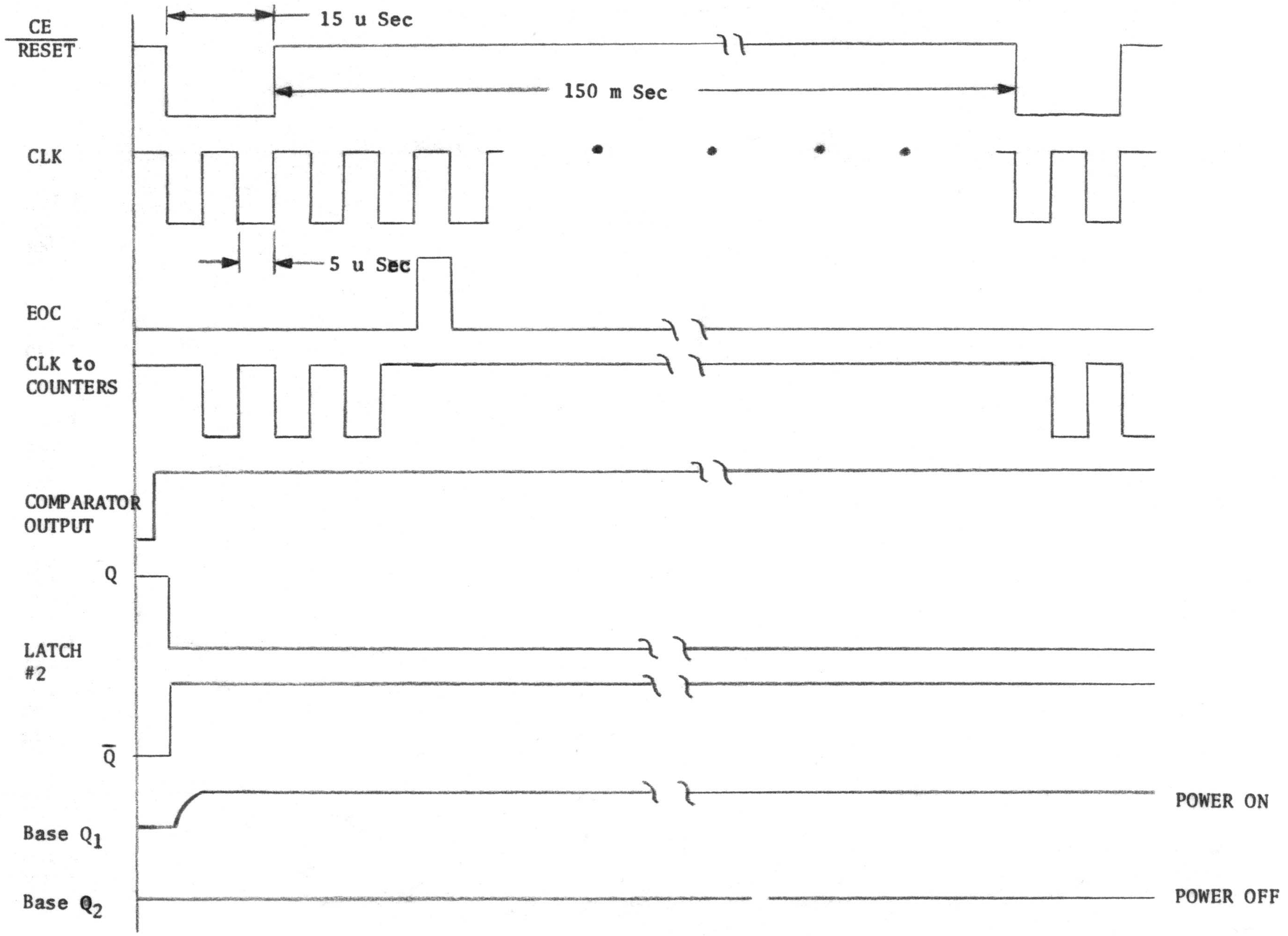


FIGURE 4.1 TIMING DIAGRAM FOR T_S GREATER THAN T_D

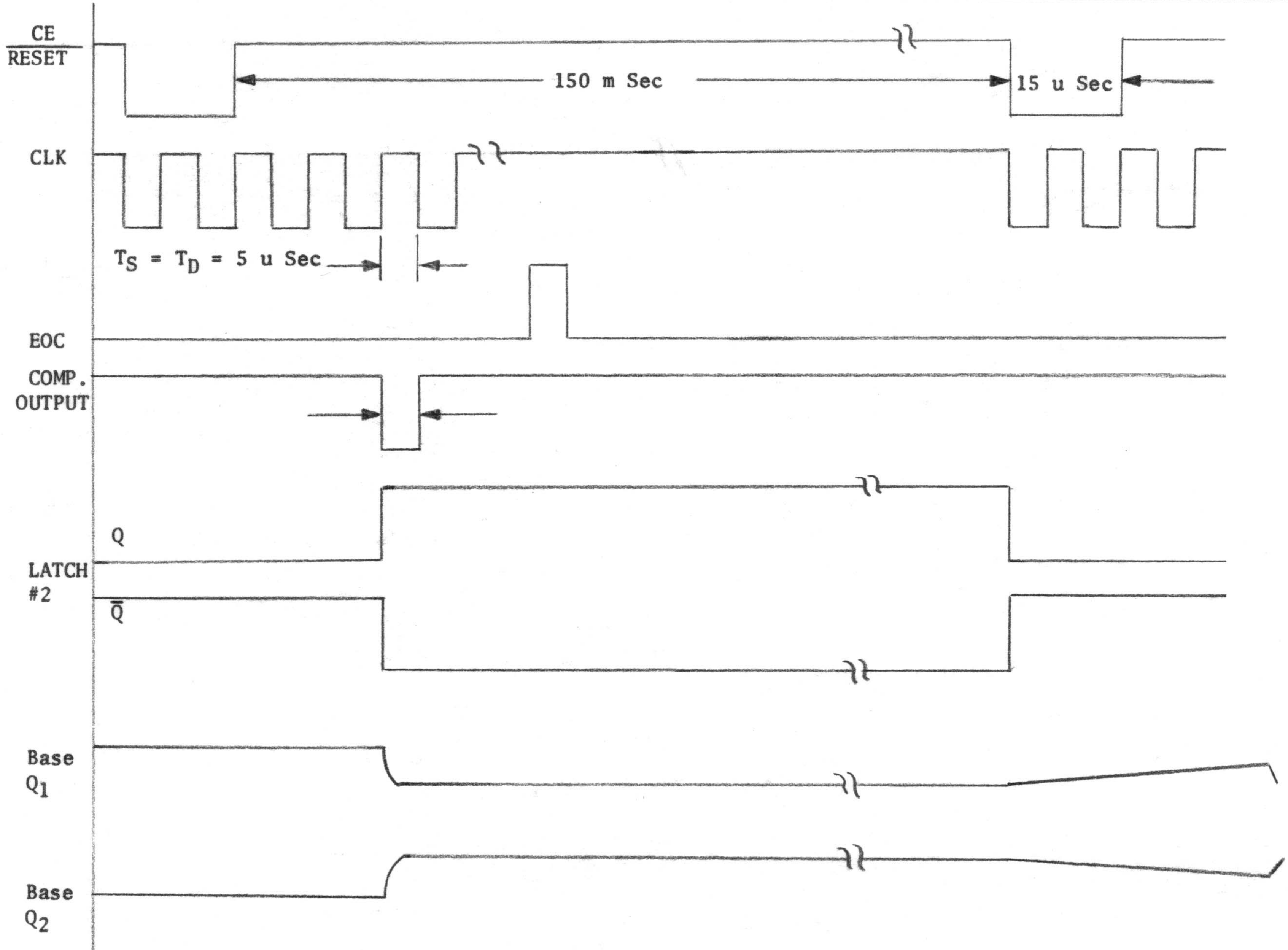


FIGURE 4.2 TIMING DIAGRAM FOR T_S LESS THAN AND EQUAL TO T_D

The bandwidth circuit adds its output to the input from the BCD output of the temperature display allowing the comparators to see an artificial value of real temperature. The bandwidth circuit adds the artificial temperature units to the counter (Z16) by way of additional counts, with each additional count equivalent to 0.1 degree. The artificial temperature is constantly adjusting for changes between actual temperature and set point temperature to arrive at a controlled temperature approximately equal to the displayed temperature.

Assume the artificial temperature (T_A) is ½ K (5 counts) above the actual display temperature T_D and that the temperature set point T_S is equal to T_D then as in Section 4.4.1, the control circuit will provide a logic state 0 to prevent power from being applied except for a small amount of residual power which increases linearity from 0 K (0 power) to 400 K (15% power).

Assume the temperature set point (T_S) is greater than the temperature display T_D. Since the counter circuit is modified to count 5 counts (½ K) above the display, the display will actually be 5 counts (½ K) below the artificial temperature T_A. When the display is 5 counts below the temperature set point setting, then the latch circuit Z17 allows the bandwidth counter (Z16) to register the number of counts above the set point and transfer these to comparison circuit Z10, Z18, Z19, and Z20. The comparison number is converted to a proportional voltage which drives a ramp generator (Z22) to provide an adjustable time period (R_{128}) proportional to the count.

The proportional time period drives transistors Q3 and Q4 to provide power to the heater.

SECTION V

Maintenance and Trouble Shooting

5.1 Introduction

This section contains instructions for maintaining and calibrating the series DRC-7 instrument, nominal voltage values and gains, circuit schematic diagrams, printed circuit board component diagram, and parts list.

5.2 Test Equipment and Accessories

The following test equipment is required to perform the necessary adjustments.

a) Voltage Standard: Electronic Development Corporation, Model MV-100N or equivalent

b) Voltmeter #1:

Input - ±9.999 volts
Resolution - 1 mV
Accuracy - ±0.05% Reading, ±0.05% F.S.
Input Impedance - Not less than 100 megohms

Voltmeter #2:

Input - ±1.999 volts
Resolution - 1 mV
Accuracy - ±0.05% Reading, ±0.05% F.S.
Input Impedance - Not less than 100 megohms

Voltmeter #3:

Input - ±199.9 mV
Resolution - 100 uV
Accuracy - ±0.05% Reading, ±0.05% F.S.
Input Impedance - Not less than 1000 megohms

Voltmeter #4:

Input - ±199.99 mV
Resolution - 10 uV
Accuracy - ±0.05% Reading, ±0.05% F.S.
Input Impedance - Not less than 1000 megohms

All voltmeters should have their leads with E-Z hook terminals.

5.3 General Remarks

Upon initial installation, the single most probable cause of system malfunction is an improperly connected temperature sensing diode. If the display blanks or a negative temperature is displayed, carefully examine the cable/diode assembly to insure that the diode polarity is correct, that the sensor is connected to the proper terminals, and that there are good solder joints at the interface connection.

Because of the highly reliable solid state design of the readout/controller, it is most unlikely that the readout/controller will be a source of difficulty. For this reason, it is advisable to examine other portions of the cryogenic system before testing the readout/controller proper. Some suggested checks are:

(1) Open or shorted sensor and heater leads, particularly in the vicinity of the sample holder if it is subject to frequent disassembly.

(2) Leakage paths between heater and sensor leads giving rise to electrical feedback in addition to thermal feedback.

(3) Poor thermal lagging of sensor input leads normally results in an indicated temperature several degrees higher than the actual temperature.

(4) Extraneous resistance in the sensor's voltage leads which increases the apparent sensor's voltage proportional to the voltage drop (I times R) across extraneous lead resistance. This normally manifests itself as an indicated temperature which is lower then the actual temperature.

(5) Premature loss of cryogens due to thermal shorts in dewar, ice blocks in lines, sample holder immersed in cryogen directly, sample holder in vapor whose temperature is above the controller set point temperature, etc.

(6) Excessive thermal path phase lags will cause the control loop to be unstable due to large internal gain values. Physical separation between the diode and heater, particularly by paths of small thermal cross-section, should be avoided.

If it is indicated that the controller is malfunctioning after performing the tests to be described below, it is recommended that the instrument be returned to the factory or to an authorized factory repair representative for repair. The components used in the instrument are costly and may be permanently damaged if subjected to inappropriate test voltages or excessive soldering iron heat. Although premium materials and techniques have been used to fabricate the instrument circuit board, there is always the risk of lifting a connection pad or cracking the board when unsoldering a component.

5.4 Operational Checks

Replace the sensor diode with a test fixture containing a precision resistor or resistance decade box and a 100 ohm, 20 watt resistor.

The precision resistor replaces the diode sensor and the high wattage resistor replaces the cryostat heater.

With 10 microamperes flowing through the test resistor, a 1.0 volt potential should develop across a 100 K ohm resistor. This test condition should provide a temperature display of 70 K and a corresponding analog output value of 0.70 V. As a further check, an independent voltmeter equivalent to Voltmeter #1 may be used to monitor directly the voltage drop developed across the test resistor. Comparison of this voltage to the standard DRC-7 silicon diode table determines the temperature value expected as well as the accuracy of the factory adjusted internal current source.

Adjust the temperature set point switch to equal the temperature value displayed. With the set point switch equal to or less than the display, the power heater ON light will illuminate indicating the power being applied to the heater load. With the set point value greater than the display value, the controller's ON light should be off indicating no power applied to the heater load. For operation of the Model DRC-70C, the ON will not shut off until the display temperature is greater than the set point temperature by 0.5 K.

If the instrument responds to the tests outlined above as indicated, either the trouble lies elsewhere in the system or the malfunction in the controller is of a subtle nature. As an aid in troubleshooting in the latter case, typical voltages and gains are given in Section 5.5.

5.5 Nominal Operating Voltages and Gains

5.5.1 Initial Adjustments

Connect the voltage standard such as EDN-MV 100N as listed in Section 5.2 across the input terminals (+ and - input voltage terminals) and Voltmeter #4 across R_{80} (positive terminal to test point #1 and negative terminal to test point #2).

The adjustment procedure is divided into several small sections. Care should be taken not to touch integrated circuits 4016 (Z6 and Z8) since any static charge on the body might cause permanent damage to the integrated circuits.

Turn the "POWER ON" to the instrument and allow one hour warmup time.

Connect the positive lead of Voltmeter #1 to test point #9 (R_{80}) and the negative lead to test point #10 (R_{27}). Adjust potentiometer R_{71} until the DVM reads 7.000 volts (±0.001 volts).

With Voltmeter #4 indicating the voltage across R_{80}, adjust R_{79} until a reading of 100.00 millivolts is obtained.

Connect the positive lead of Voltmeter #2 to test point #3 (Z4-pin #14). Connect the negative lead of Voltmeter #2 to test point #10. Set the voltage standard to 1.6884 volts and adjust the potentiometer R_{82} until Voltmeter #2 indicates 0.977 volts.

Now connect the positive lead of Voltmeter #2 to test point #4 (Z4-pin #1), retaining the negative lead at test point #10. Adjust R_{99} until the voltmeter indicates 1.527 volts. Connect the positive lead of Voltmeter #1 to test point #5 (Z4-pin #3), retaining the negative lead at test point #10. Set the voltage standard to 1.1390 volts. Voltmeter #1 should indicate positive saturation voltage (approximately 6 volts).

Set the voltage standard to 1.1395 volts and observe the reading on Voltmeter #1 is a negative saturation voltage (approximately -6 volts). If necessary, adjust R_{99} until this condition is achieved. This guarantees that the comparator changes its state both above and below the set point.

Connect the positive lead of Voltmeter #2 to test point #6 (Z7-pin #1) and adjust R_{98} for an indication of 1.559 volts on Voltmeter #2.

Connect the positive lead of Voltmeter #1 to test point #7 (Z4-pin #4) and set the voltage standard to 1.1071 volts. Voltmeter #1 should indicate a positive saturation voltage (approximately 6 volts). Set the voltage standard to 1.1075 volts and verify the Voltmeter #1 now indicates a negative saturation voltage (approximately -6 volts). Readjust R_{98} until the above conditions are achieved. The comparator is now set for proper switching levels.

For setting the amplifier gain, adjust the voltage standard to 1.6884 volts. Adjust R_{89} for a reading of 46.5 millivolts as indicated on Voltmeter #3 when connected between test point #8 (R_{49}) and test point #10.

5.5.2 Final Adjustments

Set the voltage standard to 1.9755 volts and adjust the potentiometer labeled ZERO (on front panel) for a reading of 013.1 kelvin (013 for the Models DRC-7 and DRC-7C) on the readout/controller display.

Set the voltage standard to 1.1736 volts and adjust the potentiometer labeled "FS" for a front panel display reading of 026.0 kelvin (026 for Models DRC-7 and DRC-7C).

Set the voltage standard to 1.1283 volts and adjust potentiometer R_{19} for a reading of 028.0 kelvin (028 for Models DRC-7 and DRC-7C).

Finally, set the voltage standard to 0.9811 volts and adjust potentiometer R_{26} for a reading of 077.4 kelvin (077 on Models DRC-7 and DRC-7C), on the front panel display. The final calibration is the same as outlined under "Customer Calibration" in Section 3

5.6 Alignment of Controller Section

5.6.1 Model DRC-7C

No alignment or adjustments are required for this section.

5.6.2 Model DRC-70C

With the circuit board removed following instructions in Section 5.8, connect the flat ribbon cable connector and three single wire connectors to their appropriate spots on the printed circuit board using clip leads.

Connect a 100 ohm, 20 watt load across the heater terminals. Set the fine tuning control to minimum.

Connect an oscilloscope across the 100 ohm load as follows:

a) Time setting at 50 m sec./div.

b) Voltage setting to 5 volts/div. using times 1 probe

c) Set coupling to Auto

d) Select trigger mode for line

Set the thumbwheel switch to 150.0 and turn power ON. Adjust the sensor input voltage such that the meter display reads 149.0 and increase the fine tuning control until 10 volts AC is indicated across the 100 ohm resistor.

The AC waveform will appear throughout the time sweep. Adjust the sensor voltage such that the digital display indicates 149.6. Set R_{129} until 9 cycles of the AC waveform appears on the screen. The proportional bandwidth has now been adjusted for proper cycling.

5.7 Troubleshooting Panel Meter

In normal use, the panel meter does not require calibration. However, should the reading on the panel meter differ by more than 2 K from the analog output, calibration of the panel meter is indicated. At this point, consult manufacturer.

If it is indicated that the panel meter is faulty, the following procedure should be followed for removal.

5.8 Circuit Board Removal

Disconnect all electrical connections to the terminal strip at the rear of the instrument. Remove the six screws located at the rear of the instrument and slide the board gently out of the case.

On Models DRC-7C and DRC-70C, to remove the circuit board, slide the board out of the case approximately 1", disconnect the three single wires connect by pulling the pins down. The connectors are of different sizes to facilitate their correct replacement. Slide the board until it is approximately half way out of the case. Disconnect the connector tied to the flat ribbon cable by pulling downward on the flat cable. Slide the circuit board all the way out.

5.9 Panel Meter Removal

Removal of the panel meter is accomplished after the printed circuit board is removed. Unscrew two screws in the front section of the piggy-back panel meter board from the main readout/controller mother board. Slide the meter forward out of the connector.

5.10 Parts List, Printed Circuit Board Component Locator, and Schematic

Table 5.1

PARTS LIST

REF. DESIG.	DESCRIPTION	MODEL DESIG.	LAKE SHORE PART NO.
R1	1 Meg., 1/8W, 1%		RN60D1004F
R2	100 K, 1/8W, 1%		RN60D1003F
R3	324, 1/8W, 1%		RN60D3240F
R4	511 K, 1/8W, 1%		RN60D5113F
R5	100 K, 1/8W, 1%		RN60D1003F
R6	513, 1/8W, 1%		RN60D5130F
R7	634 K, 1/8W, 1%		RN60D6343F
R8	388, 1/8W, 1%		RN60D3880F
R9	100 K, 1/8W, 1%		RN60D1003F
R10	634 K, 1/8W, 1%		RN60D6343F
R11	100 K, 1/8W, 1%		RN60D1003F
R12	931, 1/8W, 1%		RN60D9310F
R13	475 K, 1/8W, 1%		RN60D4753F
R14	100 K, 1/8W, 1%		RN60D1003F
R15	1004, 1/8W, 1%		RN60D10040F
R16	63.4 K, 1/8W, 1%		RN60D6342F
R17	100 K, 1/8W, 1%		RN60D1003F
R18	1.02 K, 1/8W, 1%		RN60D1021F
R19	50 ohm, VARIABLE		3006P-1-500
R20	13.3 K, 1/8W, 1%		RN60D1332F
R21	100 K, 1/8W, 1%		RN60D1003F
R22	98.8 K, 1/8W, 1%		RN60D9882F
R23	8.47 K, 1/8W, 1%		RN60D8471F
R24	100 K, 1/8W, 1%		RN60D1003F
R25	1.05 K, 1/8W, 1%		RN60D1051F
R26	50 ohm, VARIABLE		3006P-1-500
R27	100, 1/4W, 5%		RCR07G101JS
R28	90.9 K, 1/8W, 1%		RN60D9092F
R29	5.11 K, 1/8W, 1%		RN60D5111F
R30	51.1, 1/8W, 1%		RN60D51R1F
R31	6.49 K, 1/8W, 1%		RN60D6491F
R32	100 K, 1/8W, 1%		RN60D1003F
R33	10 K, VARIABLE		3006P-1-103
R34	50 ohm, VARIABLE		3006P-1-500
R35	1.1 Meg., 1/8W, 1%		RN65D1104F

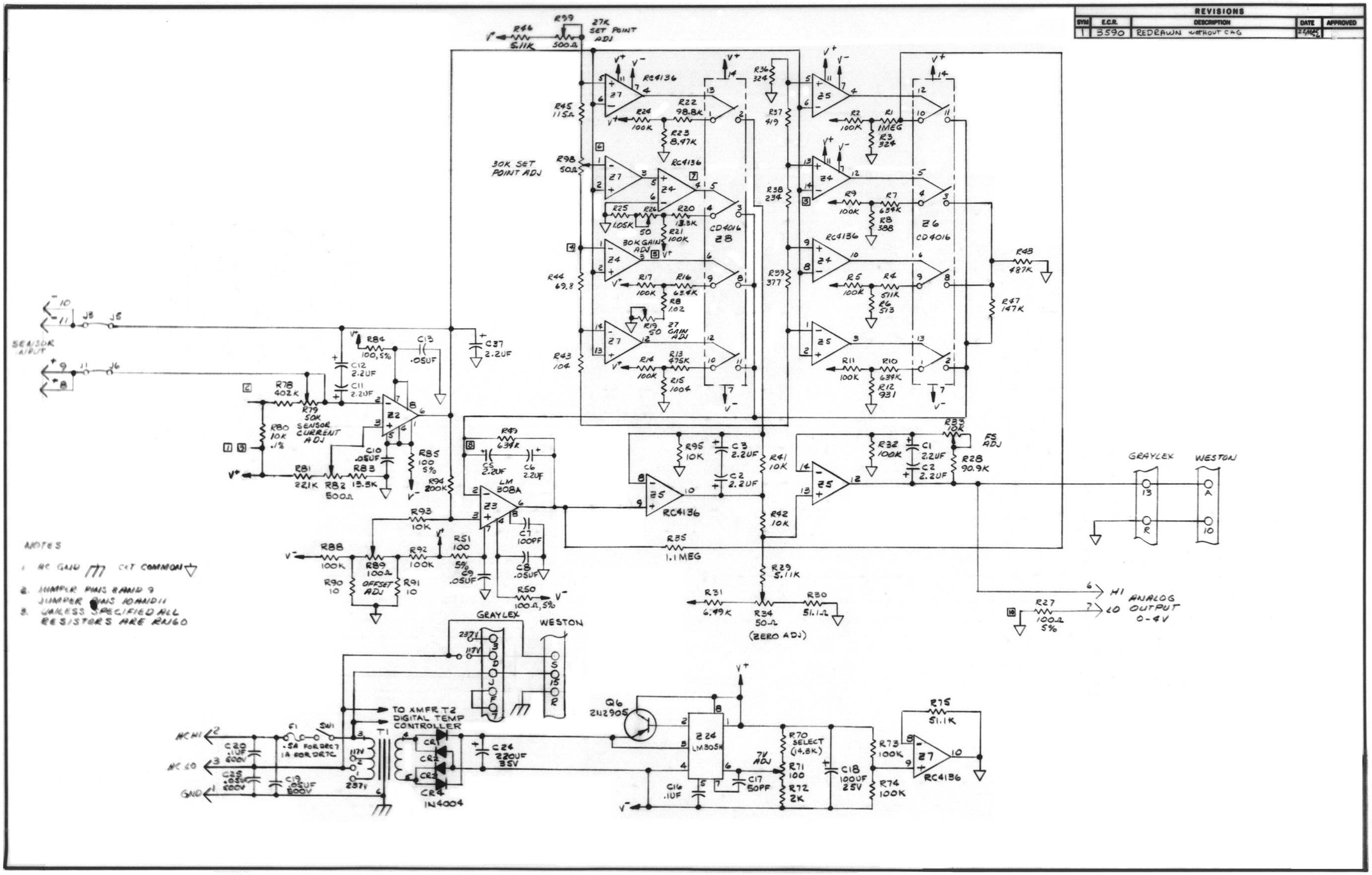
REF. DESIG.	DESCRIPTION	MODEL DESIG.	LAKE SHORE PART NO.
R36	324, 1/8W, 1%		RN60D3240F
R37	419, 1/8W, 1%		RN60D4190F
R38	234, 1/8W, 1%		RN60D2340F
R39	377, 1/8W, 1%		RN60D3770F
R40	100, 1/4W, 5%		RCR07G101JS
R41	10 K, 1/8W, 1%		RN60D1002F
R42	10 K, 1/8W, 1%		RN60D1002F
R43	104, 1/8W, 1%		RN60D1040F
R44	69.8, 1/8W, 1%		RN60D69R8F
R45	115, 1/8W, 1%		RN60D1150F
R46	5.11 K, 1/8W, 1%		RN60D511F
R47	147 K, 1/8W, 1%		RN60D1473F
R48	487 K, 1/8W, 1%		RN60D4873F
R49	634 K, 1/8W, 1%		RN60D6343F
R50	100, 1/4W, 5%		RCR07G101JS
R51	100, 1/4W, 5%		RCR07G101JS
R52-R69			
R70	TRIM, 1/8W, 1%		RN60D
R71	100 ohm, VARIABLE		3006P-1-101
R72	2 K, 1/8W, 1%		RN60D2001F
R73	100 K, 1/8W, 1%		RN60D1003F
R74	100 K, 1/8W, 1%		RN60D1003F
R75	51.1 K, 1/8W, 1%		RN60D5112F
R76 & R77			
R78	402 K, 1/8W, 1%		RN60D4023F
R79	50 K, VARIABLE		3006P-1-503
R80	10 K, 0.1%, TEL LABS		SA1
R81	22.1 K, 1/8W, 1%		RN60D2212F
R82	500 ohm, VARIABLE		3006P-1-501
R83	13.3 K, 1/8W, 1%		RN60D1332F
R84, 85	100, 1/4W, 5%		RCR07G101JS
R86, 87	100 K, 0.1%, TEL LABS		SA1
R88	100 K, 1/8W, 1%		RN60D1003F
R89	100 ohm, VARIABLE		CTSX201R101B
R90, 91	10, 1/8W, 1%		RN60D10R0F
R92	100 K, 1/8W, 1%		RN60D1003F

REF. DESIG.	DESCRIPTION	MODEL DESIG.	LAKE SHORE PART NO.
R93	10 K, 1/8W, 1%		RN60D1002F
R94	200 K, 1/8W, 1%		RN60D2003F
R95	10 K, 1/8W, 1%		RN60D1002F
R96, R97			
R98	50 ohm, VARIABLE		3006P-1-500
R99	500 ohm, VARIABLE		3006P-1-501
R100-113			
R114	47 K, 1/4W, 5%		RCR07G473JS
R115	300, 1/4W, 5%		RCR07G301JS
R116	22 K, 1/4W, 5%		RCR07G223F
R117	82.5 K, 1/8W, 1%		RN60D8252F
R118	40.2 K, 1/8W, 1%		RN60D4022F
R119	20 K, 1/8W, 1%		RN60D2002F
R120	10 K, 1/8W, 1%		RN60D1002F
R121	22 K, 1/4W, 5%		RCR07G223F
R122	820, 1/4W, 5%		RCR07G821JS
R123	6.8 K, 1/4W, 5%		RCR07G682JS
R124	22 K, 1/4W, 5%		RCR07G223F
R125	330, 1/4W, 5%		RCR07G330JS
R126	150 K, 1/8W, 1%		RN60D1503F
R127	10 K, 1/8W, 1%		RN60D1002F
R128	22.1 K, 1/8W, 1%		RN60D2212F
R129	5000, VARIABLE		3006P-1-502
R130	100 K, 1/4W, 5%		RCR07G104JS
R131	6.8 K, 1/4W, 5%		RCR07G682JS
R132	100 K, 1/4W, 5%		RCR07G104JS
R133	22 K, 1/4W, 5%		RCR07G223F
R134, 135	39 K, 1/4W, 5%		RCR07G393JS
R136	100, 1/4W, 5%		RCR07G101JS
C1-6	2.2 MFD		196D2250025
C7	100 PFD		DD101
C8-10	0.05 MFD, 500 V		5GA & 50
C11	2.2 MFD		196D2250025
C12			

REF. DESIG.	DESCRIPTION	MODEL DESIG.	LAKE SHORE PART NO.
C13, 14	0.05 MFD, 500 V		5GAS50
C15			
C16	0.1 MFD, 500 V		DD104
C17	50 PFD		DD500
C18	100 MFD, 25 V		TE1211
C19	0.05 MFD, 500 V		5GAS50
C20	0.1 MFD, 500 V		DD104
C21			
C22	22 MFD, 15 V		196D226X0015
C23			
C24	220 MFD, 35 V		196D2250035
C25	0.05 MFD, 500 V		5GAS50
C26	100 MFD, 10 V		196D107V0010
C27	1000 PFD		DD102
C28, 29			
C30	10 MFD, 25 V		196D106X0025
C31	1000 PFD		DD102
C32-34	2.2 MFD, 25 V		196D2250025
C35	10 MFD, 25 V		196D106X0025
C36	0.05 MFD, 500 V		5GAS50
C37	2.2 MFD, 25 V		196D2250025
CR1-4	SILICON RECTIFIER		IN 4004
CR5-20	SILICON DIODE		IN 914
Q1-5	TRANSISTOR		2N4124
Q6	TRANSISTOR		2N2905
Z2	I.C. AMPLIFIER		LF355H
Z3	I.C. AMPLIFIER		LM308A
Z4, 5	I.C. AMPLIFIER		RC4136
Z6	I.C. ANALOG SWITCH		CD4016AE
Z7	I.C. AMPLIFIER		RC4136
Z8	I.C. ANALOG SWITCH		CD4016AE
Z9			

REF. DESIG.	DESCRIPTION	MODEL DESIG.	LAKE SHORE PART NO.
Z10	I.C. COMPARATOR		CD4030AE
Z11	I.C. AMPLIFIER		LF355H
Z12	I.C. NANDGATE		CD4011AE
Z13	I.C. NORGATE		CD4001AE
Z14	I.C. COUNTER		CD4029AE
Z15, 16	I.C. COUNTER		CD4518BE
Z17	I.C. FLIP FLOP		CD4013AE
Z18-20	I.C. COMPARATOR		CD4030AE
Z21	I.C. NANDGATE		CD4011AE
Z22	I.C. AMPLIFIER		CA3747
Z23			
Z24	I.C. VOLTAGE REGULATOR		LM305
Z25	I.C. RESISTANCE NETWORK (BOURNS)		4116R
M1	DIGITAL PANEL METER (WESTON)		1230
M2	DIGITAL PANEL METER (GRALEX)		37
T1	TRANSFORMER (GRAND)		S5332
K1	RELAY (HAMLIN)		701-11-5
	INDICATOR (LED-HEWLETT/PACKARD)		5082-4684
SW1	SWITCH		7101-AV2
	FUSE CLIPS (2 each)		798
F1	FUSE, 1 amp		AGC
F2	FUSE, 1/8 amp		AGC
	CONNECTOR, FLAT CABLE		3428-2002
	CONNECTOR		ISM15DRAS
	14 PIN SOCKET (For Z4-8, 10-13, 17-22)		14MSLSC
	16 PIN SOCKET (For Z14-16)		16MSLSC
	Printed Circuit Board		D60109
	Schematic Diagram		D270276
	Schematic Diagram		D270275
	Schematic Diagram		D270274
	Schematic Diagram		D270279

Except where noted under column labeled "MODEL DESIGN", all parts listed are for all units. 1-Model DRC-7, 2-Model DRC-7C, 3-Model DRC-70, and 4-Model DRC-70C.



REVISIONS				
SYM	E.C.R.	DESCRIPTION	DATE	APPROVED
1	3590	REDRAWN WITHOUT CHG	22 MAY 76	

NOTES
1. AC GND /// CKT COMMON ▽
2. JUMPER PINS 8 AND 9
JUMPER PINS 10 AND 11
3. UNLESS SPECIFIED ALL
RESISTORS ARE RN60

FIGURE 5.1 - CIRCUIT SCHEMATIC DIAGRAM - MODELS DRC-7 and DRC-7C TEMPERATURE INDICATOR SECTION

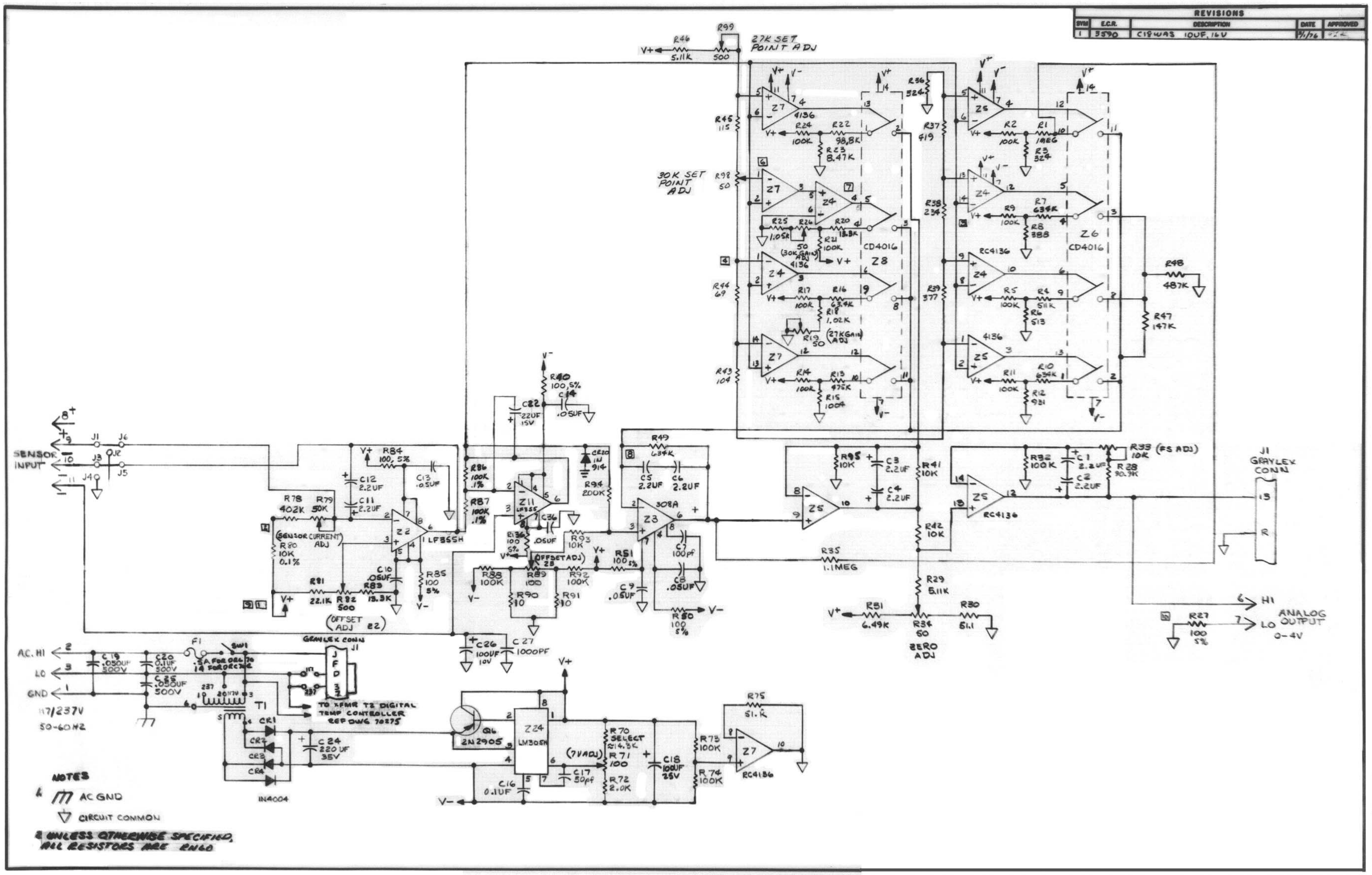
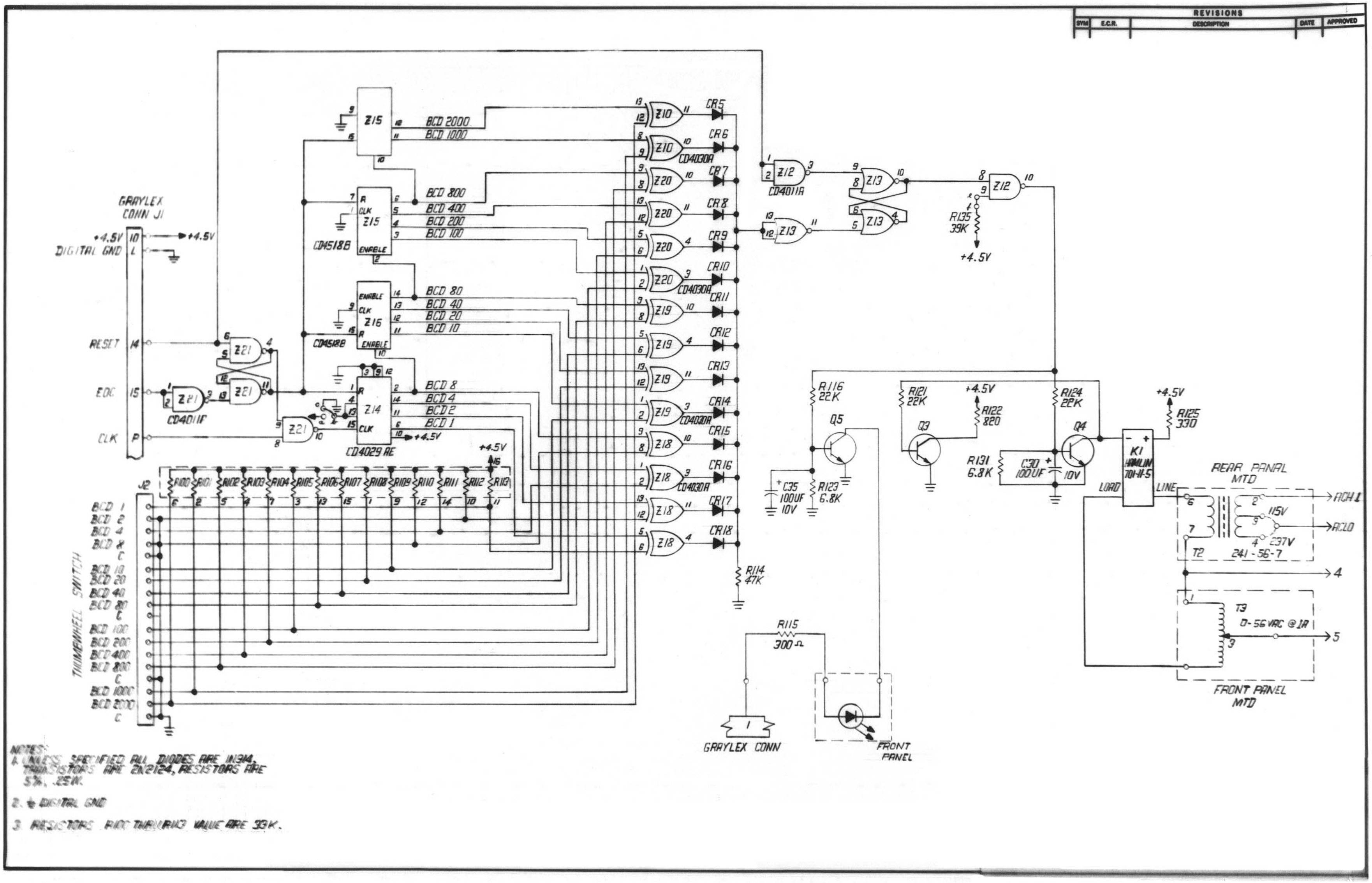


FIGURE 5.2 - CIRCUIT SCHEMATIC DIAGRAM - MODELS DRC-70 and DRC-70C TEMPERATURE INDICATOR SECTION

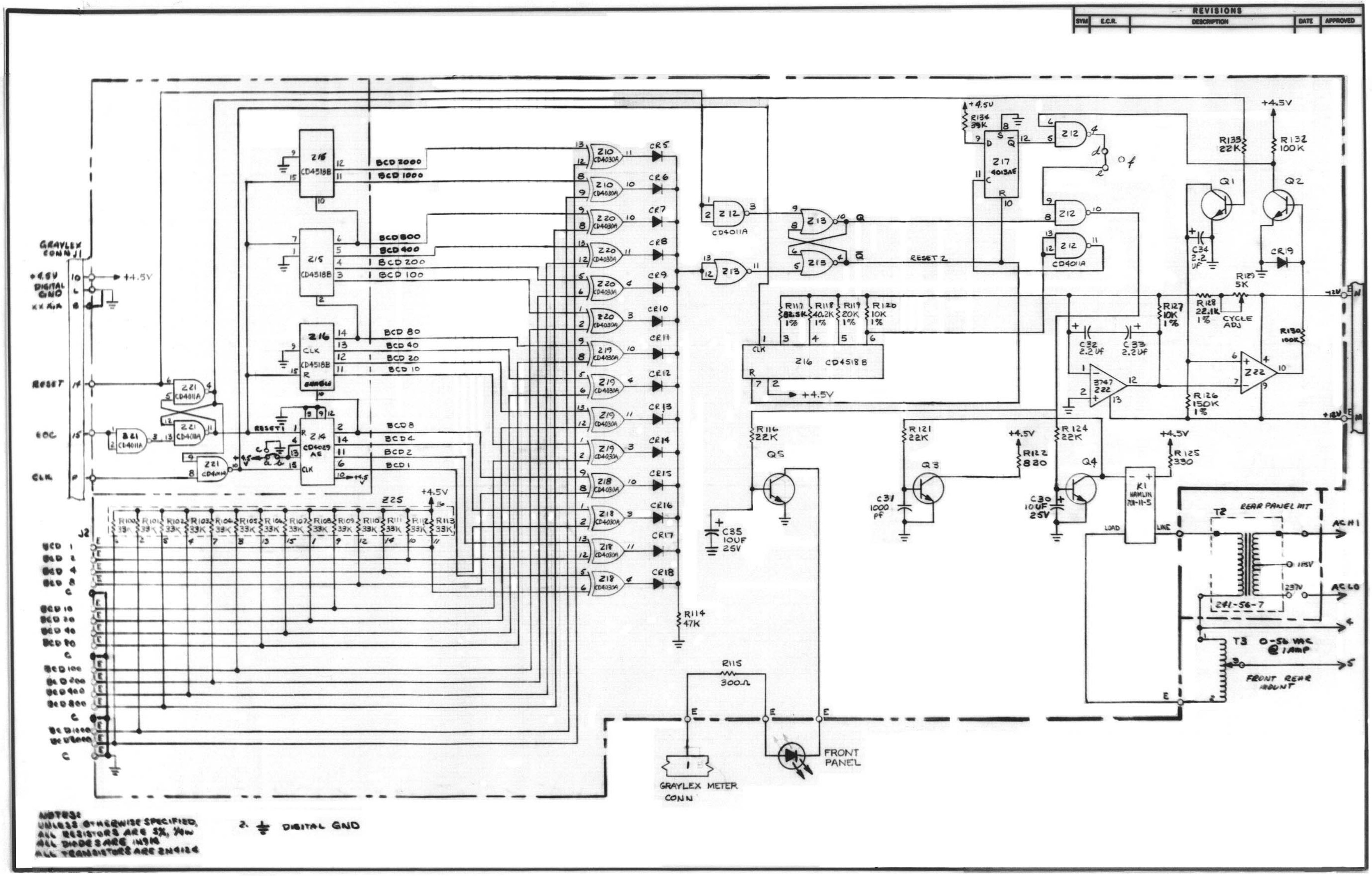


NOTES:
1. UNLESS SPECIFIED ALL DIODES ARE IN914, TRANSISTORS ARE 2N2124, RESISTORS ARE 5%, .25W.

2. ⏚ DIGITAL GND

3. RESISTORS R100 THRU R113 VALUE ARE 33K.

FIGURE 5.3 - CIRCUIT SCHEMATIC DIAGRAM - MODEL DRC-7C TEMPERATURE CONTROLLER SECTION



NOTES:
UNLESS OTHERWISE SPECIFIED,
ALL RESISTORS ARE 5%, 1/4W
ALL DIODES ARE IN914
ALL TRANSISTORS ARE 2N4124

FIGURE 5.4 - CIRCUIT SCHEMATIC DIAGRAM - MODEL DRC-70C TEMPERATURE CONTROLLER SECTION

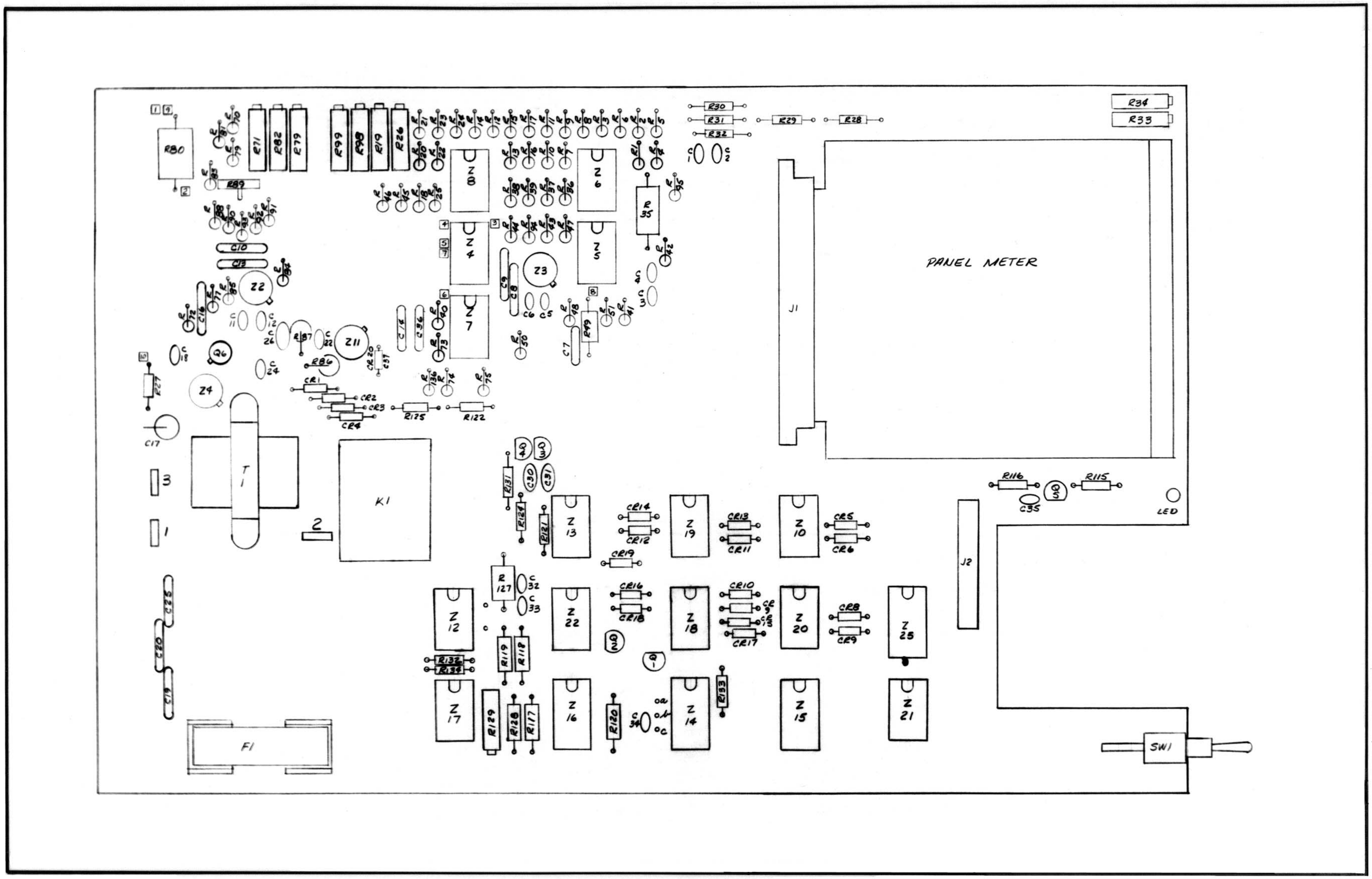


FIGURE 5.5 - PRINTED CIRCUIT BOARD COMPONENTS LOCATOR

SECTION VI

APPENDIXES

DRC-7 SERIES
STANDARD SILICON
DIODE TABLE 4-400 K
A-020-009

TABLE 6.1

Temp. (K)	Voltage (V)
4	2.46200
4.2	2.45000
5	2.40200
6	2.34200
7	2.28964
8	2.23727
9	2.18491
10	2.13255
11	2.08018
12	2.02782
13	1.97545
14	1.92309
15	1.86442
16	1.80574
17	1.74707
18	1.68839
19	1.61309
20	1.53778
21	1.46248
22	1.38717
23	1.31187
24	1.26000
25	1.20813
26	1.17357
27	1.13900
28	1.12833
29	1.11769
30	1.10705
35	1.09375
40	1.08045
45	1.06715
50	1.05385
55	1.04055
60	1.02725
65	1.01395
70	1.00065
75	0.98735
77.34	0.98113
80	0.97405
85	0.96017
90	0.94630
95	0.93242
100	0.91855
105	0.90467
110	0.89079
115	0.87692
120	0.86304
125	0.84917
130	0.83529
135	0.82141
140	0.80754
145	0.79366
150	0.77979
155	0.76591
160	0.75203
165	0.73816
170	0.72428
175	0.71041
180	0.69653
185	0.68265
190	0.66878
195	0.65490
200	0.64103
205	0.62715
210	0.61327
215	0.59940
220	0.58552
225	0.57165
230	0.55777
235	0.54389
240	0.53002
245	0.51614
250	0.50227
255	0.48839
260	0.47451
265	0.46064
270	0.44676
275	0.43289
280	0.41901
285	0.40513
290	0.39126
295	0.37738
300	0.36351
305	0.34963
310	0.33575
315	0.32188
320	0.30800
325	0.29413
330	0.28025
335	0.26637
340	0.25250
345	0.23862
350	0.22475
355	0.21087
360	0.19699
365	0.18312
370	0.16924
375	0.15537
380	0.14149
385	0.12761
390	0.11374
395	0.09986
400	0.08599

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716-992-3411
TELEX: 91-396 CRYOTRON EDNE

INSTALLATION And APPLICATION NOTES
For
Cryogenic Sensors

CONTENTS:

While certain thermometers have specific characteristics which must be considered during installation, generally all thermometers have common installation constraints. Many of these general constraints and specific application and installation notes are listed below.

General:

1. Always heat-sink the temperature sensor and sensor leads when soldering or otherwise attaching the lead wires.

2. Thermal heat-sink of diode thermometry is not as critical as it is, for example, for resistance thermometers. For most resistance thermometers, construction of the sensor is such that the sensing element is both thermally and usually electrically isolated from its case (Figures 1 and 2). The result is that the main thermal input to the device is through the electrical leads. Therefore, the resistors have a tendency to read the lead temperature rather than the case temperature. To solve this problem, considerable care must be taken to properly heat-sink these leads.

   The opposite is true for diode sensors where the temperature sensing element is mounted directly on its header (case) with the cathode lead directly connected to the case (Figure 3). The positive anode lead is electrically isolated and makes electrical contact to the sensor through a short two mil gold wire. The sensor therefore measures the case temperature and thermal heat sinking of the electrical leads is of secondary importance.

   The direct thermal connection to its case for the diode thermometers results in a substantial decrease in the thermal time constant for its sensor. Due to the low heat capacity at or near 4 K, the sensor follows relatively fast temperature changes. Within this range, under appropriate conditions, it can control at better than 8 K/sec.

3. Although varnish or a heat-sink compound such as CryCon grease (see reference 5-6) may be used to heat-sink the device, somewhat more satisfactory results may be obtained if the sensor is mounted with low melting temperature solder. Woods Metal may be an appropriate choice for most applications. However, due to its superconductive characteristics at low temperatures, it may be preferable to use a substitute. For example, 26% Sn/ 54% Bi/ 20% Cd by weight melts at 103° C. with a $T_c = 3.69$ K.

   Useful references which provide data on heat-sinking and heat-sinking materials are:

   1. Warren, W. H., Jr.; and Bader, W. G.: "Superconductivity Measurements in Solders Commonly Used in Low Temperature Research." Rev. of Sci. Instr. 40, p. 180 (1969).
   2. Anderson, A. C.; and Peterson, R. E.: "Selection of a Thermal Bonding Agent for Temperatures Below 1 K." Cryogenics 10, p. 430 (1970).
   3. Brown, M. A.: "A Reliable Low Thermal Resistance Bond Between Dielectrics and Metals for Use at Low Temperatures." Cryogenics 10, p. 439 (1970).
   4. Anderson, A. C.; and Rauch, R. B.: "Low-Temperature Thermal Conductivity of a Suspension of Copper Particles." Jour. App. Physics 41, p. 3648 (1970).
   5. Kreitman, M. M.: "Low Temperature Thermal Conductivity of Several Greases." Rev. of Sci. Instr. 40, p. 1562 (1969).
   6. Anderson, A. C.; Rauch, R. B.; and Kreitman, M. M.: "Another Comparison of Thermal Bonding Agents." Rev. of Sci. Instr. 41, p. 469 (1970).

7. Hust, J. G.: "Thermal Anchoring of Wires in Cryogenic Appartus." Rev. of Sci. Instr. 41, p. 622 (1970).

8. Kopp, J.; and Slack, G. A.: "Thermal Contact Problems in Low Temperature Thermocouple Thermometry." Cryogenics 11, 22 (1971).

4. Platinum sensor leads can be easily soldered to if a flux is used. Care should be taken to remove all flux after making the joint. One suitable flux is: Stay Clean Solder and Tinning Flux from the J. W. Harris Co., 433 W. 9th, Cincinnati 3, Ohio.

5. Because of the many varied installations for cryogenic temperature sensors, many are supplied without strain relief at the stem-lead interface. A strain relief, however, is recommended particularly when the sensor is not permanently installed.

   A satisfactory material is RTV silicone. This material is waterproof, dries quickly and is soft at room temperature. A small amount carefully placed at the base of the sensor leads will protect them from sharp bends and possible fracture.

6. Special care must be given in mounting sensors or thermocouples with gold leads. Gold wire will dissolve in the solder if ordinary soldering techniques are used. Extreme care must be used in soldering this lead to another lead. It is suggested that the other lead be pretinned. Then the gold lead should be wrapped around the pretinned lead and heat applied above the tinned region. As soon as the solder starts to melt, the soldering iron should be removed from the pretinned lead. A low power microscope may be of use here.

   A second equally satisfactory approach is to use pure Indium as the solder.

   In either instance great care must be taken to insure the sensor is properly heat-sinked as described above.

7. In addition to properly heat-sinking the temperature sensor and sensor leads at the site to be measured, it is most important that the lead wires be carefully lagged to the equipment surface (sometimes called thermally tempered) at regular intervals as they are brought out to room temperature. In this manner. thermal loads to both the equipment and the temperature sensor are minimized.

8. Specific care should be taken in mounting epoxy encased sensors to assure no interaction with solvents, overheating, etc. Ge-7031 varnish with its xylene solvent is particularly dangerous.

9. Always make ample allowance for thermal contractions when sizing hookup wire lead length and thus prevent possible lead fractures.

10. Because most cryogenic sensors are small and their lead wires are of negligible diameter, it is sometimes difficult to find an optimum tie-down material that will maintain strength at cryogenic temperatures and not lose its adherence. One good choice is wax impregnated dacron thread commonly known as "dental floss".

Diode Temperature Sensors:

1. Forward voltage measurements should be made at a constant current of 10 or 100 microamperes. The silicon diode can withstand 200 Volts in the reverse direction and up to five milliamperes in the forward direction. In the case of the gallium arsenide diode do not apply a current of greater than one milliampere in the forward direction or a voltage of greater than five volts in the reverse direction. Either condition can result in permanent damage to the temperature sensor.

   This dangerous condition can be generated specifically with the use of a multimeter type ohmmeter. The solution is straightforward however: For the Simpson 260 types, use the Rx100 ohm scale with a 2 K resistor in series with one lead; for Triplett 630 types, do the same with either the Rx100 or Rx1000 ohm scales. This will limit the back voltage to 1.5 volts and the forward current to less than 1 mA. - yet the forward-reverse difference can easily be seen.

2. If power input to your cryogenic system is critical, the 10 uA current should be used. The power dissipated at helium temperatures by the sensor is approximately 15 micro watts for gallium arsenide and 21 micro watts for silicon for this current. If power input is not critical, then the 100 uA current may be preferred.

3. The static impedance of the silicon diode is 210 K ohms at helium temperatures with 10 microamperes excitation current and 21 K ohms with 100 microampere excitation current. The static impedance of the gallium arsenide sensor at helium temperatures is approximately 150 K ohms at 10 microamperes and 15 K ohms at 100 microamperes, i.e., R = V/I.

To accurately measure the forward voltage to 100 microvolts or better, consideration must be given to the input impedance of the voltage measurement system being used. For example, a digital voltmeter with a ten megohm input impedance will have an effect on the 10 millivolt position for a current of 10 microamperes. For the 100 microampere current source, the loading effect will be seen in the one millivolt position. Therefore, for a calibrated device, readings must be taken with a very high input impedance voltage measurement system. If, however, a sensor is calibrated with a voltmeter of less than infinite impedance, as long as the same system is used, (i.e., the loading is not changed), accurate temperature measurement should be possible.

Insufficient evaluation of and attention to this feature can result in serious temperature measurement errors. For this reason, 10 megohm input impedance DPM's or DVM's at 10 uA diode excitation are not recommended. Fortunately, there is no dearth of DVM's or DPM's with the desired characteristics, i.e., 1 Volt range with 100 or 200% overrange and input in the 10^9 to 10^{10} range. Differential voltmeters are also a proper choice.

4. The dynamic impedance of the sensor is approximately 1000 ohms at 10 uA and 100 ohms at 100 uA. This is extremely fortunate since it reduces the requirements on the constant current source by nearly two orders of magnitude over that of the voltage measurement system. For example, a current source regulated to 0.1% will cause a change in the 100 microvolt position.

   The required temperature accuracy vs. the instrumentation current regulation and voltmeter resolution is:

Required Temperature Accuracy	Current Source Resolution	Voltmeter Resolution
1.0 K	5%	1 mV
.1 K	.5%	100 uV
.01 K	.05%	10 uV

5. Epoxy encased sensors should not be used in vacuum as self-heating (as a result of the epoxy acting as an insulator) can cause large temperature errors below 10 K.

6. Heat dissipation in diode thermometers can be calculated two ways, both yielding the same result. In the first case, the power dissipated is the product of the DC voltage across the diode and the DC current through the diode. In the second case, an equivalent circuit can be considered where the power is the sum of the DC current times the equivalent voltage plus the square of the DC current times the DC dynamic resistance.

7. Diode thermometer construction techniques allow a wide and diverse variety of envelope configurations. Because of this characteristic, it is important that the user assure himself that the material in the package does not affect his experiment. For example, several configurations utilize gold plated "Kovar" or "Rodar" material (nominal 50-50 Ni-Fe). This material will not effect the sensing element in a magnetic field, but its presence will certainly affect the homogenity of the field adjacent to the sensor.

8. "TO-5" headers have been designed to withstand no more than 16 inch ounces of torque.

Capacitance Temperature Sensors:

1. Capacitance sensors (Figure 4) may be connected to terminal points outside the cryostat with two unshielded insulated fine wires alongside the other wires leading to the sample area. No appreciable change in the measured capacitance arising from the leads should result, provided changes in lead capacitance due to mechanical movement are avoided. When the mechanical stability is not assured, each sensor lead should be connected to a thin coaxial cable brought out to the external terminal points, with the shield of each cable electrically insulated from the cryostat. Two coaxial cables, one for each lead, with the shield insulated from each other, should be used to complete the wiring.

2. The total length of coaxial cable (internal plus external) is not critical, i.e., 100 feet is not unreasonable.

   An increasingly popular lead material is a family of ultraminiature coaxial cables. This coax has a diameter of less than .020. To prepare the ultraminiature coax for termination, the inexpensive Miller wire stripper (available at any radio supply store) is ideally suited. Care should be taken to set the opening on the wire stripper to remove just the outer two wraps of aluminized Mylar and Vylex thus exposing the drain wire and the insulated center conductor. A similar Miller wire stripper set for the appropriate opening will strip the dielectric cleanly from the center conductor.

3. These sensors may be depended upon for 1 or 2 mK stability during many hours or even days of consecutive operation, as long as a settling period of up to an hour is allowed after the device is thermally cycled (defined as a cooldown from liquid N_2 temperature or higher to some lower temperature such as 4.2 K). In its present state of development, the sensor should not be expected to reproduce to better than 0.2-0.4 K from one thermal cycle to the next. Depending on the extent and rate of cooldown, a shift in dC/dT of as much as 2% may also be observed. However, it should be recognized that none of the above constraints limits the <u>primary</u> function of the thermometer, viz, as a control device to hold temperature at some preset level while a magnetic field is being applied.

4. Large and erratic error signals will result from the presence of water vapor and/or ice contacting the sensor leads and lead-in cabling particularly when the sensor is used at temperatures over 200 K or when bare (unshielded) lead wires are used. Presence of the water greatly increases the loss tangent of the measuring system and hence, the capacitance readings are erroneous.

5. It should be noted that the excitation of capacitance sensors utilized in cryostats below 0.1 K will cause most resistance thermometers to self-heat and become effectively useless unless the capacitance sensor leads are fully shielded.

6. Due to a very small amount of ferro-electric phase (or interfacially-polarized phase), a large surge voltage, for example, from the measuring field will induce time-dependent dielectric phenomena which will appear as a drifting or instability in the capacitive signal of the sensor. Such effects have been observed immediately following the brief application of a five fold increase in AC sensor voltage. An example is a capacitance bridge unbalance produced by the accidental switching of the bridge range switch.

7. Excitation frequency and amplitude must not change during temperature readout or control. For example, with the recommended 50 mV rms. amplitude excitation signal held to 0.1%, and with the frequency variation less than 0.1%, temperature readout and control errors (due to these variables) can be held to 1 mK.

Resistance Thermometers:

1. These thermometers are normally used as secondary standards and should be treated in the same manner as any precision instrument. It is recommended that they not be subjected to any unnecessary shock or rough mechanical treatment.

2. Copper wires, as well as other types of wire, positioned in a thermal gradient will develop small EMF's due to inhomogenieties along the wire. These defects may be slight differences in crystal structure, may be due to work-hardening, mechanical strains, etc., which behave as small parasitic thermocouples. These EMF's change with the thermal gradient and can be a source of serious error in those temperature measurements, where sub-microvolt levels are involved. To overcome this error, it is good practice to inspect each wire by connecting each end to a suitable measuring instrument and then pull it through a liquid nitrogen bath observing the EMF readings. Any voltages greater than .1 microvolt are sufficient to cause an error in the measurement of temperature unless such effects are averaged by taking resistance readings on the thermometer with reverse polarity of the excitation current. Of course, another possibility is the use of AC measuring techniques.

Hall Generator:

1. The Hall generator is fragile. It cannot be handled the same way most other electronic components are handled. The aluminum oxide substrate is brittle and very sensitive to bending stress. Use the leads to move and locate it. Do not handle the substrate. The lead to substrate bond strength is on the order of several ounces. Avoid tension on the leads and avoid bending them close to the substrate. The leads may be bent at any angle as long as the bend is at least 1/8" away from the substrate connection.

2. The preferred mounting procedure is to locate the chip in a slot that is any depth, .003 inch wider and .010 inch longer than the substrate. Tack the leads outside the slot with Sylgard 186* or a similar substance. Don't get Sylgard 186* inside the slot. If an extreme temperature range is expected, check the coefficients of thermal expansion to be certain that the slot will always have clearance for the chip. This procedure is not recommended for installations that will be subject to any acceleration greater than 10 G.

3. Surface mounting is acceptable when necessary. The mounting surface may be any non-flexible solid with a flat, smooth (±.001") surface at least the size of the substrate. The substrate must not overhang the mounting surface. Steel, ferrite, ceramic, and glass are examples of mounting surfaces. For extended temperature ranges, choose a material with a coefficient of thermal expansion no greater than a factor of three different from that of the aluminum oxide substrate ($\cong 7\times10^{-6}$IN/IN/^{o}C). For a permanent mount, sparingly coat the mounting surface with Eastman 910 contact cement or other similar cement. The ceramic side of the substrate is visible as non-red or as opposite the Hall element. Locate the ceramic side on the clean, degreased surface and apply extremely light pressure with a foam pad until the bond is made. Wipe off the excess contact cement. Use an epoxy such as Bacon Industries FA8 or Emerson and Cuming 2850FT to form a fillet around the plate and to secure the leads. Don't get epoxy on top of the chip. If encapsulation is absolutely necessary use a light coating of Sylgard 186* or a similar soft material.

   For a non-permanent surface mount, secure the substrate against the surface with a foam padded mounting jig. The jig should apply only light pressure. Fillet the plate and secure the leads with Sylgard 186* or a similar material.

4. After the Hall generator has been mounted, check the misalignment voltage per the proper specification. A large misalignment voltage shift (100 uV or more) is a sign of Hall generator physical damage.

Vacuum Regulator Valve:

1. The 329 Valve was offered initially as a vacuum control for vacuum pumped cryostats. In this application, it is necessary to ensure that the temperature of the gas entering the valve is not lower than 175 K (-100 C). Generally, this means that the piping between the cryostat and the valve will be 2-3 feet or more.

2. For the most sensitive and stable operation, the remote sensing port should be used. This allows the valve to "see" the controlled vacuum through a static line as opposed to a line with flow.

3. If tight shut-off is necessary in the system, a separate shut-off valve should be used in series with the valve, and should be placed between the vacuum chamber and the valve.

4. A small inboard bleed from atmosphere is necessary for the proper operation of the valve. This bleed is through the small recessed screen in the end of the valve near the control handle. The most probable cause of problems with the 329 Valve is restricted flow through the screen. This part of the valve should be inspected periodically to ensure that plugging has not occurred. When flush panel mounted the shallow channel from the circumference of the valve to the bleed port ensures that sufficient air is available and no special provisions need be made in the panel.

   During normal operation, the bleed flow is approximately 1.5 SCFH through the valve and out through the vacuum pump port. There is little chance of air from the bleed entering the controlled vacuum even if the vacuum system fails as this condition will cause the bleed to be shut off completely.

Controller Heater Installation:

1. Most cryogenic temperature controllers utilize the thermal relaxation method for control. That is, heat is continually added to provide the proper balance between the payload (whose temperature is to be controlled) and the surrounding environment. Therefore, the optimum balance is best achieved with both the source of refrigeration and heat emanating from the same direction with as large an area and as even a source of each as possible.

2. The cryogenic temperature controller system including control sensor, heater, controller, lead-in wiring, etc. can all perform perfectly and the system be an abject failure, if the total system integration is not adequate. Some considerations include:

   a. The heater area should be as large as possible. For this reason, wire heaters of several feet wound on the payload are preferred to point source heaters such as carbon resistors, etc.

   b. To prevent "hunting" within a closed loop thermal control system, thermal contact between heater and load should be as close as possible. This can be accomplished by utilizing insulation materials such as formvar or bicalex. Both offer a good thermal short, with an electrical open circuit, to the load. The heater may then be appropriately cemented by Glyptal or G.E. 7031 varnish to mechanically hold and thermally anchor the heat input system to the load.

---

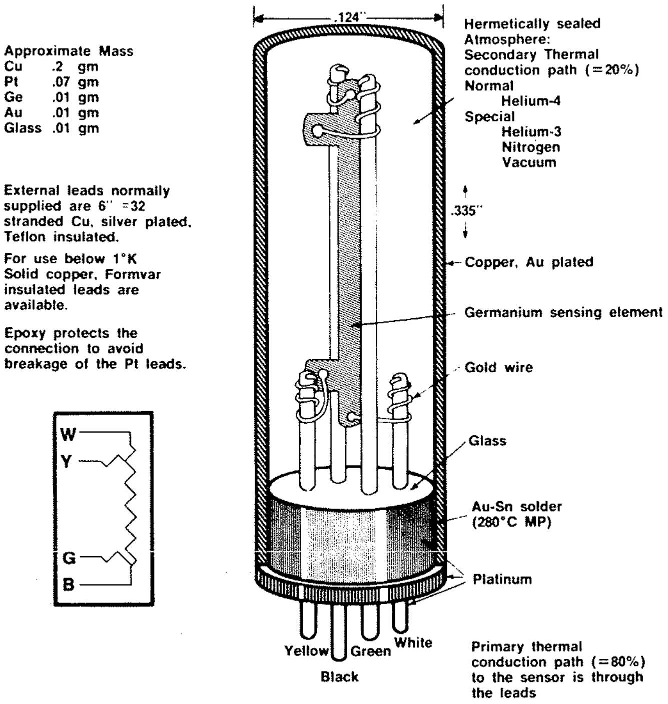
*Product of the Dow Corning Corporation

c. The controller heater output circuit sees the total heater load; e.g. heater plus lead wires. Therefore, the heater proper should be designed for as close to 100% of the heater lead-in wire-heater resistance total as possible to avoid heat leaks to the system (I^2R) from the lead-in wires and to assure proper thermal control at the heater.

d. The heater-heater lead wire combined resistance should be accurately matched to the controller. For example: a 20 ohm heater matched to a 10 ohm controller output will halve the useful heat available.

e. Control sensor preferred mounting is as near to the test specimen as practical and always between the heater and the test specimen.

Germanium Resistor Construction



Approximate Mass	
Cu	.2 gm
Pt	.07 gm
Ge	.01 gm
Au	.01 gm
Glass	.01 gm

External leads normally supplied are 6" =32 stranded Cu, silver plated, Teflon insulated.

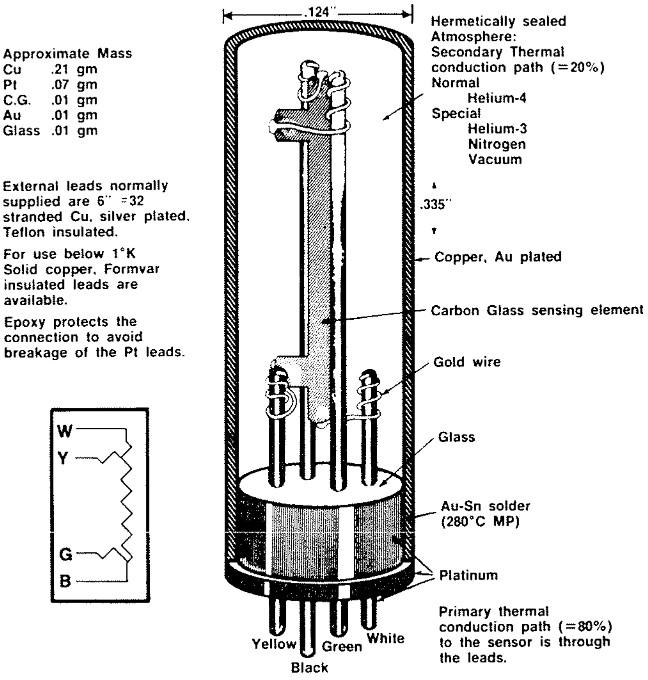
For use below 1°K Solid copper, Formvar insulated leads are available.

Epoxy protects the connection to avoid breakage of the Pt leads.

Primary thermal conduction path (≈80%) to the sensor is through the leads

Figure 1

Carbon Glass Resistor Construction



Approximate Mass	
Cu	.21 gm
Pt	.07 gm
C.G.	.01 gm
Au	.01 gm
Glass	.01 gm

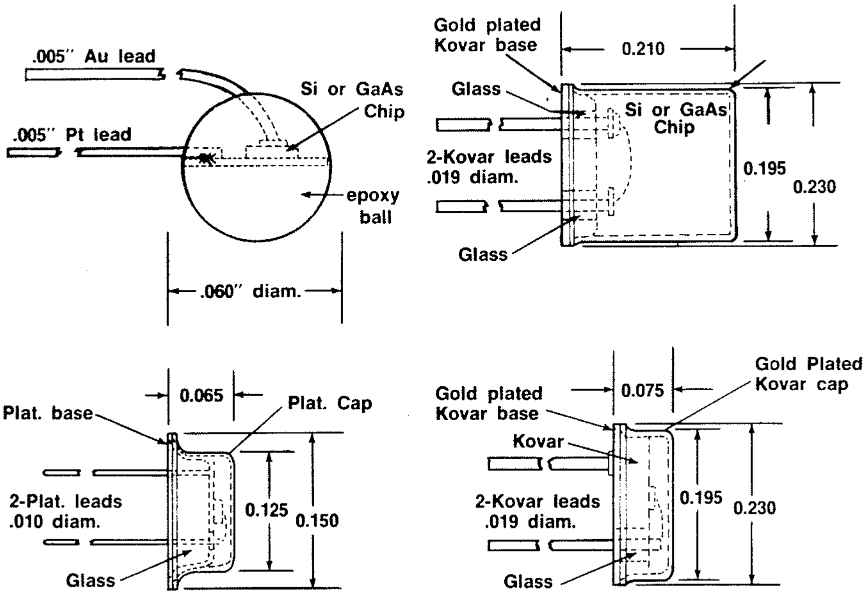
External leads normally supplied are 6" =32 stranded Cu, silver plated, Teflon insulated.

For use below 1°K Solid copper, Formvar insulated leads are available.

Epoxy protects the connection to avoid breakage of the Pt leads.

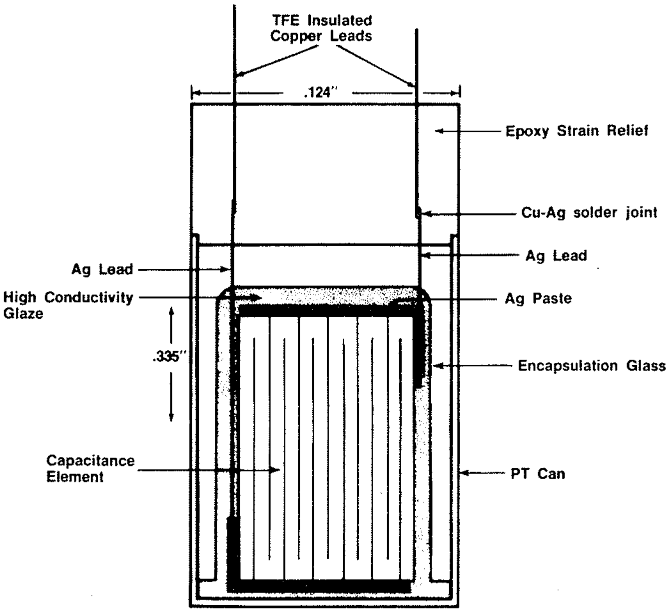
Primary thermal conduction path (≈80%) to the sensor is through the leads.

Figure 2



TYPICAL DIODE THERMOMETERS

Figure 3



Capacitance Temperature Sensor

Figure 4

Description of Operation for Model 329 Vacuum Regulator Valve:

The Model 329 Vacuum Regulator Valve consists of a balanced poppet main valve which is sealed at one end by a sensitive lip and the other end by a rolling diaphragm. This poppet is driven by a diaphragm. The reference side of the diaphragm is gas loaded by means of two orifices in series with an absolute pressure aneroid which controls a frictionless lever and inboard bleed valving system.

Vacuum is applied to the vacuum pump port. Since the main valve is balanced, it doesn't want to move in either direction. If the poppet is open, the regulated side of the regulator will start to lower in pressure. This decrease in pressure will be sensed through the poppet, will lower the pressure under the diaphragm, and pull the valve closed. This same vacuum is applied to the dome volume through an orifice. This will lower the reference pressure (dome pressure) and cause the main valve to open. When the dome pressure gets to the set point, the aneroid expands allowing ambient air into the dome through the second orifice and maintains dome pressure at set point.

Ultraminiature Coaxial Cable
Construction Detail

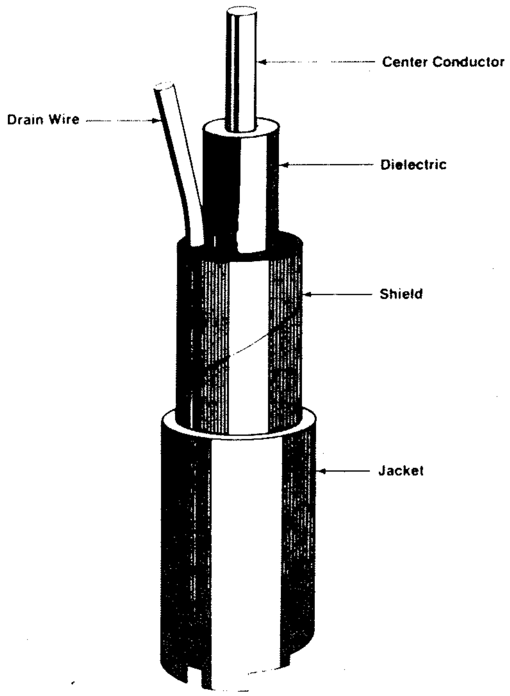


Figure 5

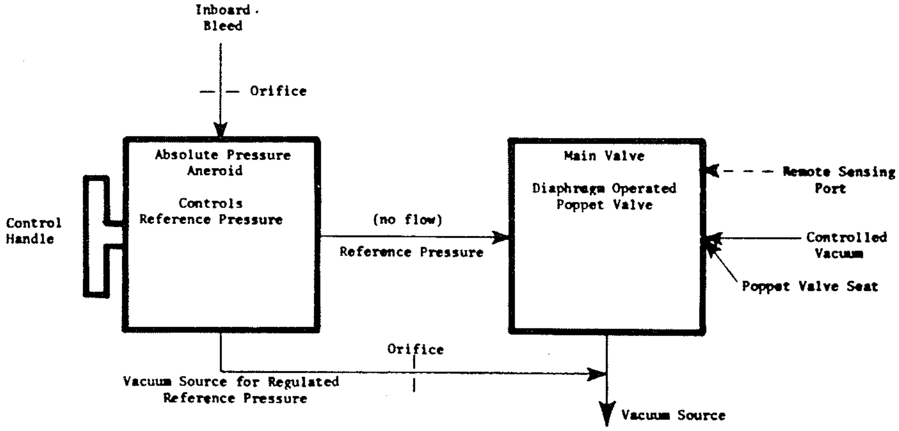


Figure 6

LAKE SHORE CRYOTRONICS, INC.
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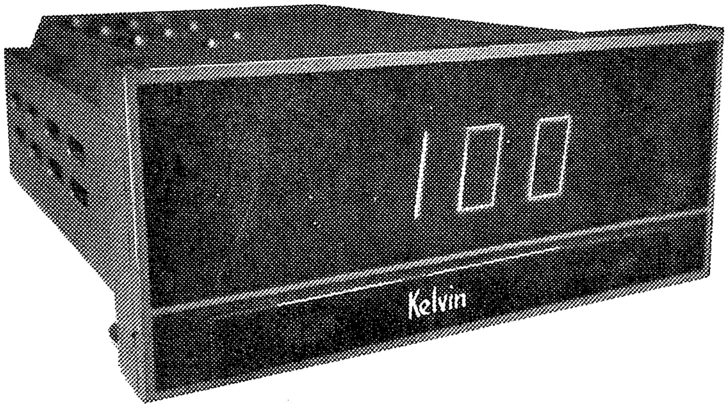
TELEX 91-396 CRYOTRON EDNE

SERIES DRC
DIGITAL THERMOMETERS
Technical Specification: DRC-7

MODEL DRC-7 DIGITAL CRYOGENIC THERMOMETER



- **1 to 400 K Range**
- **Silicon Diode Sensor**
- **Recorder Output**
- **BCD Output**
- **Optional 10 Sensor Input**
- **115 or 230 VAC Power**

The Model DRC-7 Digital Cryogenic Thermometer is designed to cover the range from 1 to 400 K utilizing the Lake Shore Cryotronics DT-500 Silicon diode sensor.

Six segments of digital linearization are used to achieve 0.5 K conformity accuracy to the Lake Shore Cryotronics DRC-7 standard DT-500 Silicon diode table from 4 to 300 K.

In addition to a TTL compatible BCD output, an analog 0-100 mV recorder output is provided and is proportioned to the actual diode forward voltage drop and thus gives a 0.1 K resolution capability.

The temperature sensor is excited by a 10 uA constant current source with ±0.1% regulation. The thermometer is designed to connect to the sensor in a 2 or 3 wire configuration, or a four lead potentiometric configuration which significantly reduces errors due to lead wire resistance.

A selector switch is available as an option which allows one to select and read out up to 10 separate sensors.

TECHNICAL SPECIFICATIONS

TEMPERATURE RANGE:	1 to 400 K
SENSING MATERIAL:	Silicon
RESOLUTION:	
Digital	1 kelvin
Analog	0.1 kelvin or better
CONFORMITY TO: LSCI STANDARD: DRC-7 SILICON DIODE TABLE:	0.5 K (4-300 K)
DIGITAL LINEARIZATION:	6 segments
SENSOR EXCITATION:	10 microamps
SENSOR CURRENT: REGULATION:	± .1%
SENSOR INPUT CONNECTION:	2 or 3 wire or 4 wire potentiometric
MAXIMUM SENSOR: POWER DISSIPATION:	25 uW at 4.2 K
MAXIMUM DIGITIZING ERROR: (8 hrs. at 25°C):	0.5 K
TEMPERATURE: COEFFICIENT ERROR:	0.05 K/°C
REPEATABILITY:	± 1 K

:	
:	
OPERATING ENVIRONMENT:	0-45°C
	TTL compatible (non-isolated) 0-100 mV at 1 K output impedance
DISPLAY:	3½ digits, 1.4 cm (0.55") high, Sperry 7 segment non-blinking
RESPONSE TIME:	2 seconds to rated accuracy
NORMAL MODE REJECTION:	50 db min. at 60 Hz and up
COMMON MODE REJECTION:	120 db at 60 Hz and above
POWER REQUIREMENTS:	115 V C, ± 10 % at 50/60 Hz Optional 230 VAC ± 10% at 50/60 Hz
DIMENSIONS	
DPM Case:	4.3 cm (1.7") high x 10.2 cm (4") wide x 11.4 cm (4½") deep
Instrument Case:	8.9 cm (3½") high x 22.9 cm (9") wide x 22.9 cm (9") deep

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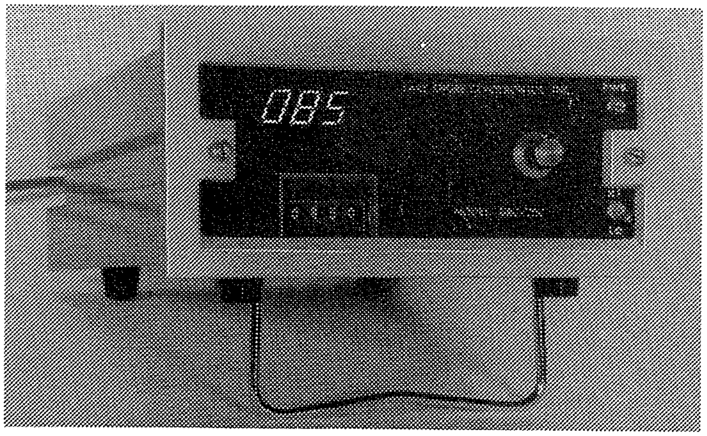
TELEX 91-396 CRYOTRON EDNE

SERIES DRC
DIGITAL THERMOMETERS
Technical Specification: DRC-7C

MODEL DRC-7C DIGITAL CRYOGENIC THERMOMETER/CONTROLLER



- **1-400K Range**
- **1K Resolution**
- **Silicon Diode Sensor (Model DT-500-DRC)**
- **0 to 50 Watt Heater Output**
- **Recorder Output and Optional BCD Output**
- **115 or 230 VAC Power**

The Model DRC-7C utilizes the latest state-of-the-art electronics to provide both direct temperature readout and control over the 1-400 kelvin range with a resolution of 1 K. The Model DRC-7C utilizes the proven DT-500 silicon diode sensor (Model DT-500-DRC) as the temperature sensor. All DT-500-DRC sensors are interchangeable and can be used with any of the DRC-7, DRC-7C, DRC-70, or DRC-70C instruments.

In addition to direct digital display, the DRC-7C provides an analog output with 0.1K resolution and an optional BCD output. Separate zero and span adjustments are provided which enable the user to calibrate his system for increased accuracies.

The temperature control portion of the DRC-7C is actuated by internal digital comparison of the BCD output to a digital thumbwheel setpoint switch. The BCD comparison signal provides an error value (equivalent to the temperature deviation) to a time proportional thyristor control circuit. The thyristor circuit controls the ON time of the powered output available from a continuously adjustable variac with an adjustable power output of 0 to 50 watts.

TECHNICAL SPECIFICATIONS

General:	
TEMPERATURE RANGE:	1-400 K
SENSOR:	Silicon (Model DT-500-DRC)
SENSOR INPUT:	4 terminal connection with constant current exitation or a max. of 100 ohms in a 2 wire system
SENSOR CURRENT:	10 microamps
SENSOR CURRENT REGULATION:	± 0.1%
VOLTAGE INPUT:	115 or 230* VAC, ±10% 50/60 Hz
POWER COMSUMPTION:	60VA
CONSTRUCTION:	Solid State Electronics
OPERATING ENVIRONMENT:	10-45°C
WEIGHT:	3.6 Kg. (8 lbs.)
DIMENSIONS:	8.9 cm (3.5″) high x 20.3 cm (8″) wide x 30.5 cm (12″) deep

*For 230 VAC, add (-K) to model number; I.E. DRC-70-K

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Temperature Control:

SET POINT:	Digital thumbwheel selection directly in kelvin temperature units
CONTROLLABILITY:	0.5 K with a properly designed system
REPEATABILITY:	1 K
SETTABILITY:	1 K
HEATER OUTPUT:	Standard 0-50 watts, 0-1 A, 0-50 VAC
CONTROL MODE:	Time proportional thyristor with continuously adjustable variac output

Temperature Readout:

RESOLUTION:	
ANALOG	0.1 kelvin or better
DIGITAL	1 kelvin
CONFORMITY TO LSCI STANDARD DRC-7 SILICON DIODE TABLE:	0.5 K (4-400K)
MAXIMUM SENSOR POWER DISSIPATION:	25 uW at 4.2 K
MAXIMUM DIGITISING ERROR (8 HRS. at 25°C):	0.5 K
TEMPERATURE COEFFICIENT ERROR:	0.06K/°C
REPEATABILITY:	1 K
INPUT RESISTANCE:	Greater than 100 megohms
ISOLATION:	300V
OUTPUTS: ANALOG	10 mV/K at 1 K output impedance. Tracking to digital display of 0.3K
DIGITAL (Optional)	TTL compatible (non-isolated)
DISPLAY:	3 digits, 14mm (0.55") high, 7 segment non-blinking
RESPONSE TIME:	2 seconds to rated accuracy
NORMAL MODE REJECTION:	50db min. at 60 Hz and above
COMMON MODE REJECTION:	120db min. at 60 Hz and above

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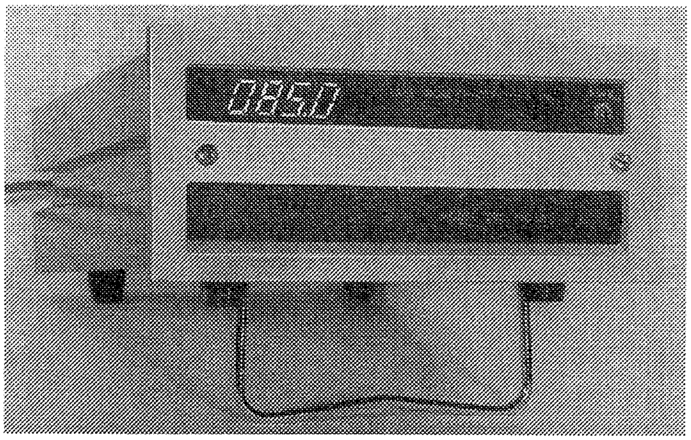
SERIES DRC
DIGITAL THERMOMETERS
Technical Specification: DRC-70

MODEL DRC-70 DIGITAL CRYOGENIC THERMOMETER



- **0.1K Resolution**
- **1 to 400K Range**
- **Silicon Diode Sensor (Model DT-500-DRC)**
- **Recorder Output and Optional BCD Output**
- **Optional 10 Sensor Input**
- **115 or 230 VAC Power**

The Model DRC-70 Digital Cryogenic Thermometer is designed to cover the range from 1 to 400K utilizing the Lake Shore Cryotronics Model DT-500-DRC Silicon diode sensor.

The DRC-70 linearization circuit combined with the completely interchangeable model DT-500-DRC sensor allows the DRC-70 to achieve 0.3K conformity to the standard DRC-7 Silicon Diode table from 4 to 400 K.

In addition to an analog output (with 0.1K resolution) an optional BCD output is available.

The temperature sensor is excited by a 10 uA constant current source with ±0.1% regulation. The thermometer is designed to connect to the sensor in a 2, 3, or 4 wire configuration.

A push-button selector switch is available as an option which allows one to select and read out up to 10 separate sensors.

TECHNICAL SPECIFICATIONS

TEMPERATURE RANGE:	1 to 400K
SENSING MATERIAL:	Silicon (Model DT-500-DRC)
RESOLUTION:	
ANALOG	0.1 kelvin or better
DIGITAL	0.1 kelvin
CONFORMITY TO LSCI STANDARD DRC-7 SILICON DIODE TABLE:	0.3K (4-400K)
SENSOR EXCITATION:	10 microamps
SENSOR CURRENT: REGULATION:	± .1%
SENSOR INPUT CONNECTION:	2, 3, or 4 wire constant current
MAXIMUM SENSOR POWER DISSIPATION:	25 uW at 4.2 K
MAXIMUM DIGITIZING ERROR (8 hrs. at 25°C):	0.5 K
TEMPERATURE COEFFICIENT ERROR:	0.06K/°C
REPEATABILITY:	0.1K

INPUT RESISTANCE:	Greater than 100 megohms
ISOLATION:	300V
OPERATING ENVIRONMENT:	10-45°C
OUTPUTS: ANALOG	10m V/K at 1K output impedance. Tracking to digital display of 0.3K
DIGITAL (Optional)	TTL compatible (non-isolated)
DISPLAY:	4 digits, 1.4 cm (0.55″) high, 7 segment non-blinking
RESPONSE TIME:	2 seconds to rated accuracy
NORMAL MODE REJECTION:	50 db min. at 60 Hz and up
COMMON MODE REJECTION:	120 db at 60 Hz and above
POWER REQUIREMENTS:	115 or 230* VAC, ±10% 50/60 Hz
DIMENSIONS	8.9 cm (3.5″) high x 20.3 cm (8″) wide x 30.5 cm (12″) deep

*For 230 VAC, add (-K) to model number; I.E. DRC-70-K.

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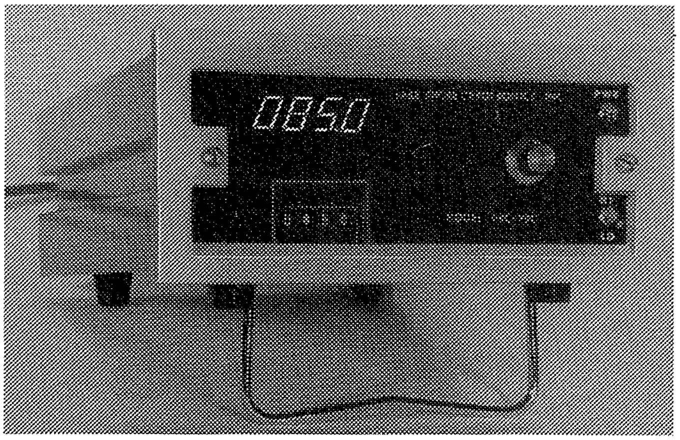
SERIES DRC
DIGITAL THERMOMETERS
Technical Specification: DRC-70C

MODEL DRC-70C DIGITAL CRYOGENIC THERMOMETER CONTROLLER



- **1-400K Range**
- **0.1 K Resolution**
- **Silicon Diode Sensor (Model DT-500-DRC)**
- **0 to 50 Watt Heater Output**
- **Recorder Output and Optional BCD Output**
- **115 or 230 VAC Power**

The Model DRC-70C goes a step beyond the Model DRC-7C and provides 0.1 K readout and setpoint resolution with controllability of 0.3 K in a properly designed system.

As with other members of the DRC instrument family, the DRC-70C utilizes the latest state-of-the-art electronics to achieve stable operation and long term reliability over the range from 1 to 400K.

In addition to an analog output (with 0.1K resolution), an optional BCD output is available.

The temperature control portion of the DRC-70C is actuated by internal digital comparison of the BCD output to a digital thumbwheel set point switch. The BCD comparison signal provides an error value (equivalent to the temperature deviation) to a digital proportional thyristor control circuit. The thyristor circuit controls the ON time of the powered output available from a continuously adjustable variac with an adjustable power output of 0 to 50 watts.

TECHNICAL SPECIFICATIONS

General:

TEMPERATURE RANGE:	1-400K
SENSOR:	Silicon (Model DT-500-DRC)
SENSOR INPUT:	4 terminal connection with constant current exitation or a 3 wire system.
SENSOR CURRENT:	10 microamperes
SENSOR CURRENT REGULATION:	±0.1%
VOLTAGE INPUT:	115 or 230* VAC, ±10% 50/60 Hz
POWER CONSUMPTION:	60VA
CONSTRUCTION:	Solid State Electronics
OPERATING ENVIRONMENT:	10-45°C
WEIGHT:	3.6 kg. (8 lbs.)
DIMENSIONS:	8.9 cm (3.5″) high x 20.3 cm (8″) wide x 30.5 cm (12″) deep

*For 230 VAC, add (-K) to model number; I.E. DRC-70C-K.

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Temperature Control:

SET POINT:	Digital thumbwheel selection directly in kelvin temperature units
CONTROLLABILITY:	0.3 K with a properly designed system
REPEATABILITY:	0.1 K
SETTABILITY:	0.1 K
HEATER OUTPUT:	Standard 0-50 watts, 0-1 A, 0-50 VAC
CONTROL MODE:	Isolated digital proportional with continuously adjustable variac output

Temperature Readout:

RESOLUTION:	
ANALOG	0.1 kelvin or better
DIGITAL	0.1 kelvin
CONFORMITY TO LSCI STANDARD DRC-7 SILICON DIODE TABLE:	0.3K (4-400K)
MAXIMUM SENSOR POWER DISSIPATION:	25 uW at 4.2 K
MAXIMUM DIGITIZING ERROR (8 HRS. at 25° C):	0.5 K
TEMPERATURE COEFFICIENT ERROR:	0.06K/°C
REPEATABILITY:	0.1 K
INPUT RESISTANCE:	Greater than 100 megohms
ISOLATION:	300 V
OUTPUTS: ANALOG	10 mV/K at 1000 ohms output impedance Tracking to digital display of 0.3K.
DIGITAL (Optional)	TTL compatible (non-isolated)
DISPLAY:	4 digits, 14mm (0.55″) high, 7 segment non-blinking
RESPONSE TIME:	2 seconds to rated accuracy
NORMAL MODE REJECTION:	50 db min. at 60 Hz and above
COMMON MODE REJECTION:	120 db min. at 60 Hz and above

CRYOGENIC TEMPERATURE SENSING ELEMENTS
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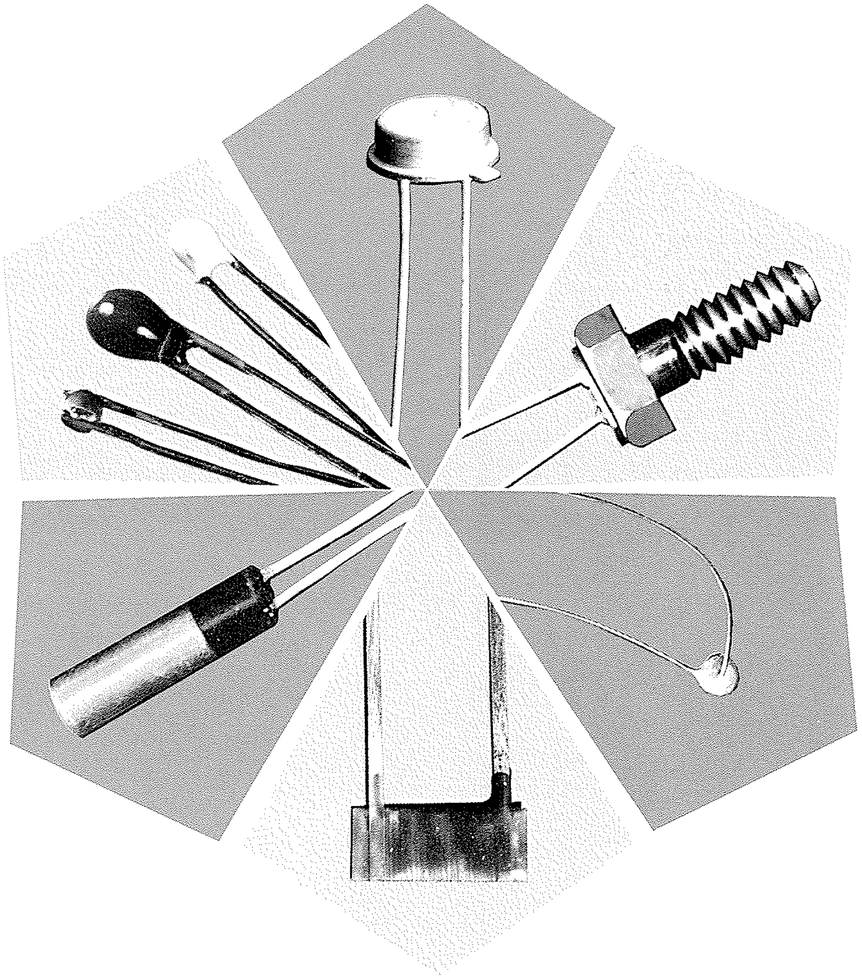

CAPACITANCE TEMPERATURE SENSORS

CS-400
- Strontium Titanate
- Unaffected by Magnetic Fields
- .005 K to 400 K

DIODE TEMPERATURE SENSORS

TG-100
- Gallium Arsenide
- 1 K to 400 K Full Range
- Useful in Modest Magnetic Fields

DT-500
- Silicon
- 1 K to 400 K Full Range
- Highest Sensitivity
- Interchangeable

RESISTANCE SENSORS

CGR
- Carbon Glass
- 1 K to 300 K
- Monotonic Temperature Response
- Useful in Magnetic Fields

GR-200
- Germanium
- Repeatability
- <.030 K to 100 K
- Secondary Standard

LR-700
- Copper
- 70 K to 475 K
- Essentially Linear with Temp. Coeff. .43%/K

MISCELLANEOUS
- Rhodium-Iron Resistor
- Platinum Resistor
- Nickel Resistor

Sensor Type	Available Configuration (See Pages 6 and 7)														Sensing Element Material	Heat Dissipation (at 4.2K and recommended operating current)	Useful Temperature Range	Output Signal or Nominal Value at 4.2k	Sensitivity	Inter-changeability
	1	2	3	4	5	6	7	8	9	10	11	12	13	14						
Diode Thermometry																				
TG-100	●		●	●	●	●	●	●	●						Gallium Arsenide	15 uW at 10 uA	1 K to 400 K	1.45 V at 4.2 K 0.7 V at 295 K	0.6 mV/K at 4.2 K at 77 K 2.75 mV/K See Fig. 2, 4	N.A.
DT-500	●	●		●	●	●	●	●	●						Silicon	25 uW at 10 uA	1 K to 400 K	2.4 V at 4.2 K 0.4 V at 295 K	50 mV/K at 4.2 K at 77 K 2.75 mV/K See Fig. 1, 4	±0.1 K @ 4.2 K ±1K @ 77 K ±1K @ 300 K (see remarks)
Capacitance Thermometry																				
CS-400											●	●	●		Strontium Titanate	$<10^{-12}$ W at 1 K Hz and 50 mv excitation	<10 mk to 60 K 70 K to 400 K	3 nF to 40 nF See Fig. 3	250 pF/K at 4.2 K at 4.2 K 160 pF/K (-FP only) See Fig. 3	N.A.
Resistance Thermometry																				
CGR-1										●					Carbon Glass	CGR-1 (2000) 0.2 uW 10 uA .1 uW 3.0 uA CGR-1 (10,000)	0.3K to 100K (300K)	250 ohm 1000 ohm 2000 ohm 5000 ohm 10,000 ohm	See Figures 4, 5, 7	Consult Factory
GR-200										●					Germanium	GR-200-1000 0.1 uW at 10 uA	< 0.03 K to 100 K with several Elements	30 ohm 100 ohm 1000 ohm	See Figures 4, 5, 7	Limited, with Bridge Techniques
LR-700														●	Copper	N.A.	70 K to 475 K	2340 ohms at 273.2 K (0°C)	10 Ω/K	Yes, with Current Adjustment
RF-800															Rhodium with 0.5 atomic % Iron		2 K to 300 K	20, 47, or 100 ohms at 273.2 K (0°C)	90 uV/K at 4.2 K and 500 uA	No
	Data sheet available on request														Platinum Nickel					

ASK FOR BULLETIN "CRYOGENIC INSTRUMENTATION"

Thermal Response (at 4.2K) (Configuration Dependent)	Repeatability (at 4.2K)	Magnetic Field Effect (Data taken ⊥ to field at 5 Tesla and 4.2K)	° Reliability (Typical cycling life 300K to 4.2K)	Suggested Temperature or Signal Read Out Accuracy	REMARKS	Sensor Type
						Diode Thermometry
100 K/sec	100 uV	0.7 K See Fig. 6	200 to 300 Cycles Nominally	100 uV	Useful in modest magnetic fields	**TG-100**
100 K/sec	50 uV	2.4 K See Fig. 6	Excellent	100 uV	Sensors of same config.can be matched at LHe, LN_2 and room temperature. If quantites to be matched exceed 5, discuss applicaton with factory	**DT-500**
						Capacitance Thermometry
100 K/sec		No Effect See Fig. 6	Excellent	±3 pF	Unaffected by magnetic fields to 18 T. Recommended for control purposes Request detailed information from factory	**CS-400**
						Resistance Thermometry
	$\leq$ 0.5 mK at 4.2 K	< 0.05K See Fig. 6	Excellent	± 0.002 K at 4.2 K	Useful in Magnetic Fields Large useful range, essentially no piezo-resistance, monotonic R vs T and dR/dT curves. 250 ohm 0.3 - 4.2k 1000 ohm 1.5 -100K (300K) 2000 ohm 2 - 100K (300K) 5000 ohm 2.5 - 100K (300K) 10,000 ohm 3-100K (300K)	**CGR**
	0.5 mK at 4.2 K	Not Recommended	Excellent	± 0.002 K at 4.2 K For R=1000Ω at 4.2 K	Recognized secondary standard 30 ohm 0.010 - 1.5k (4.2k) 100 ohm 0.3 - 4.2K 1000 ohm 1.5 - 40K (100K)	**GR-200**
N.A.	N.A.	N.A.	Excellent	0.1 K or better	Essentially linear in response over most of the useful temperature range	**LR-700**
	0.3 mK at 4.2 K	— 0.3 K	Excellent	0.008 K or better	Model RF-802-Perf. is a perforated can version for gas or liquid use. Request detailed information from factory	**RF-800**
					Data sheet available on request	

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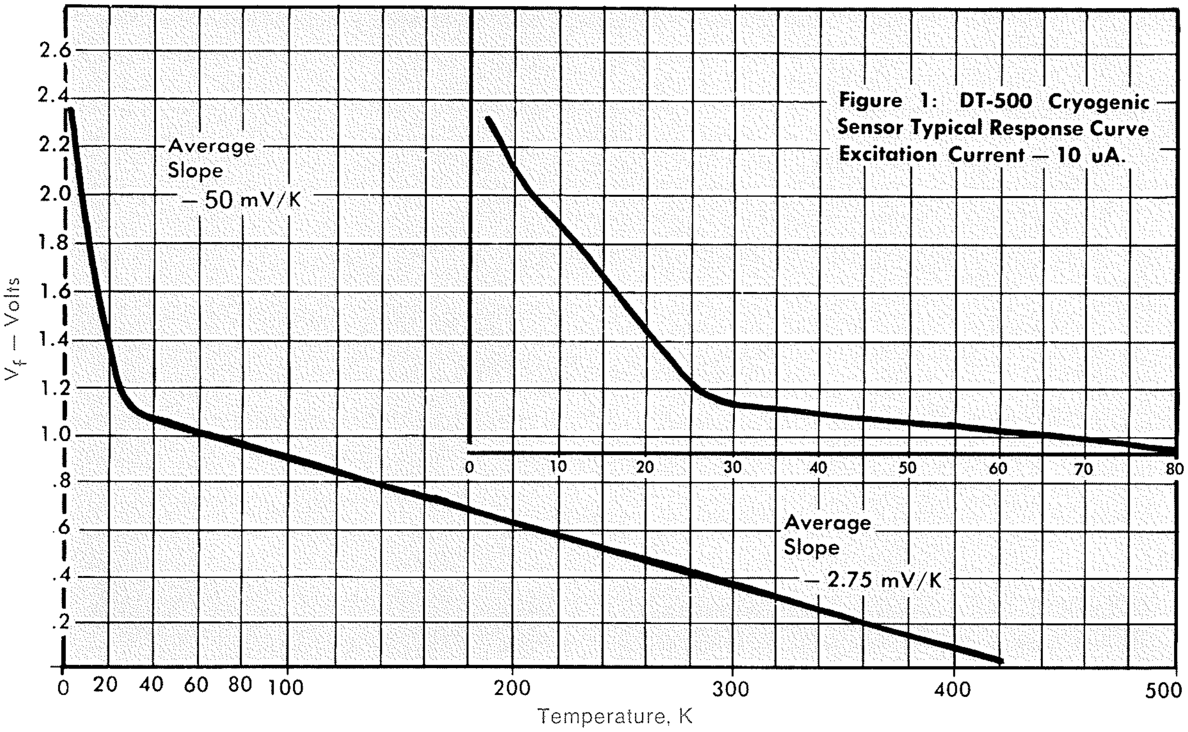

Figure 1 Detailed Response of DT-500 Silicon Diode Temperature Sensor

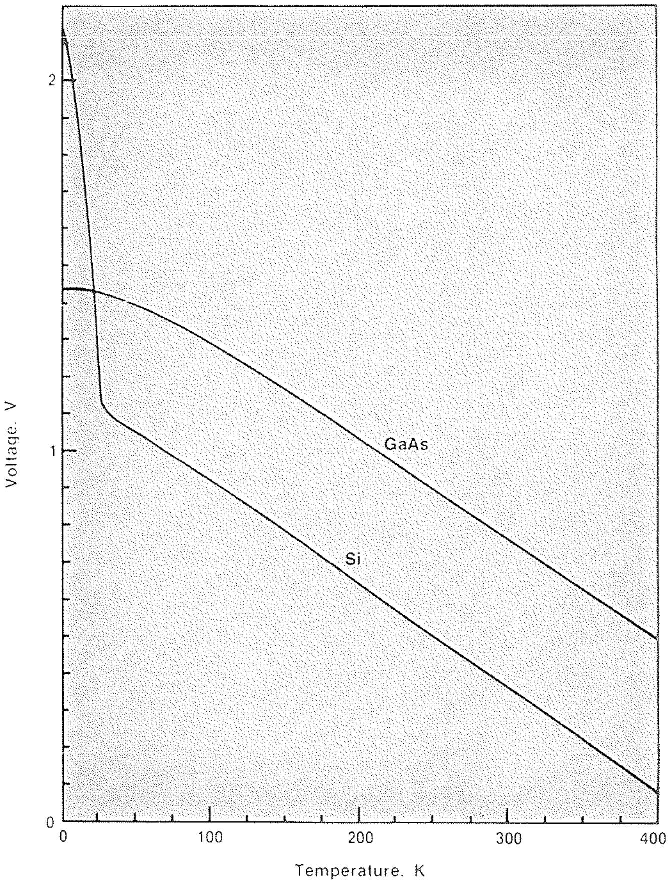

Figure 2

Comparison of typical forward voltage versus temperature characteristics for the gallium arsenide (GaAs) and silicon (Si) diode thermometers.

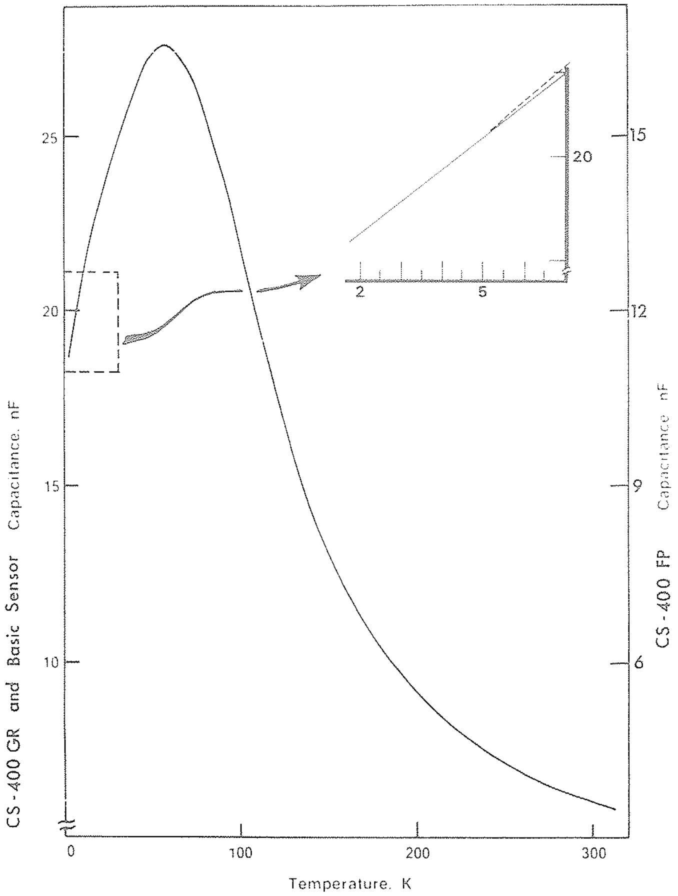

Figure 3

Typical capacitance temperature characteristics for $SrTiO_3$ capacitance thermometers.

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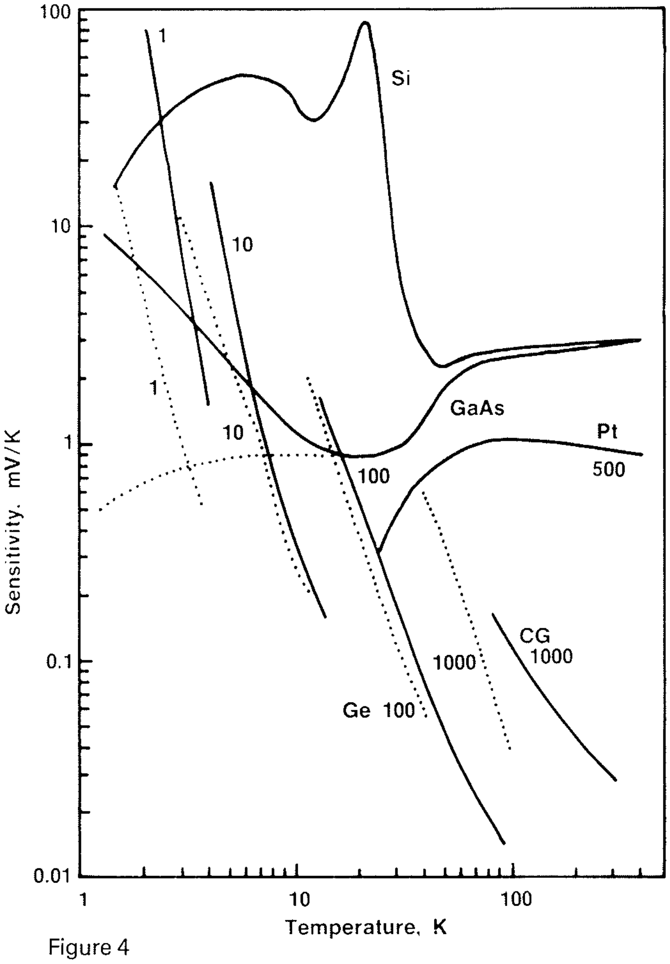


Figure 4

Temperature sensitivity of voltage (dV/dT) as a function of temperature for silicon (Si) and gallium arsenide (GaAs) diode (solid and dotted line) thermometers and carbon glass (CG) (solid line), germanium (Ge) (dotted line), and platinum (Pt) (R_0= 470 ohms) resistors. Numbers for resistors indicate current in microamperes. Diode thermometer data is at 10 microamperes.

Magnetic Field-T	2.5	5	10	15
TG-100 GaAs	-.2K	-.7K	-2.3K	N.R.*
DT-500 Silicon	-1.4K	-2.4K	N.R.*	N.R.*
CS-400 $SrTiO_3$	0	0	0	0
CGR Carbon Glass	−.015K	−.045K	−.14K	−.23K
GR-200 Germanium	-1.25K	N.R.*	N.R.*	N.R.*

Figure 6

Typical Magnetic Field Induced Temperature Errors at Selected Field Levels at 4.2 K.

*N.R. — Not Recommended

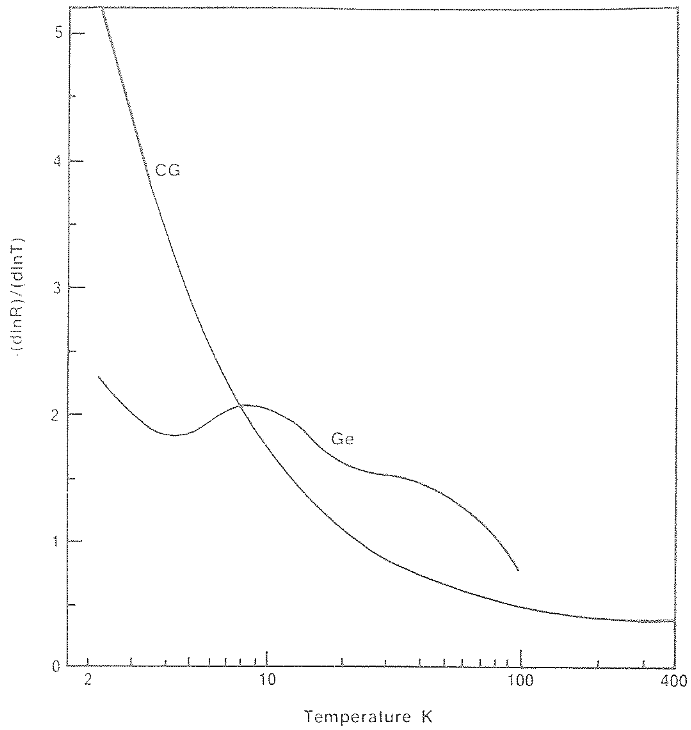


Figure 5

Relative sensitivity data (dlnR)/(dlnT) versus temperature for carbon glass (CG) and germanium (Ge) resistors.

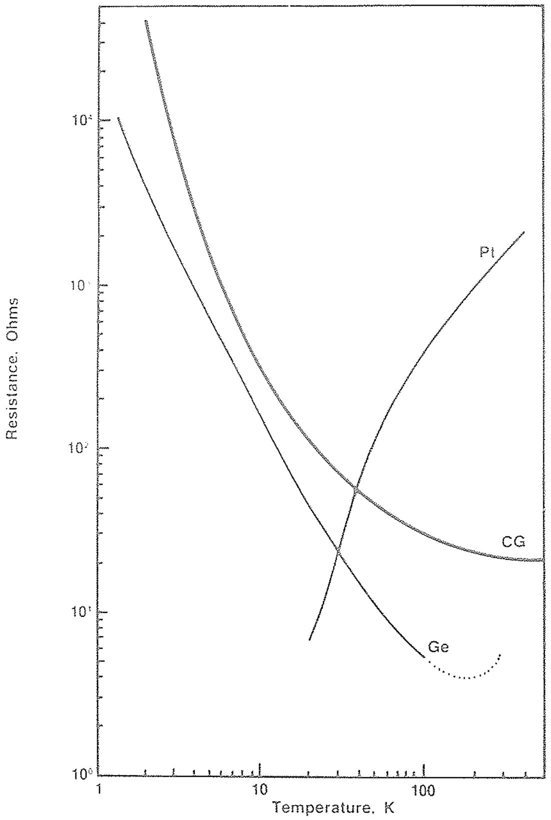
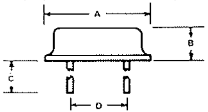
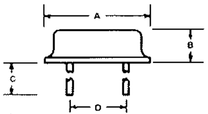
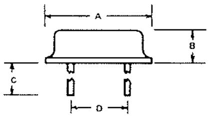
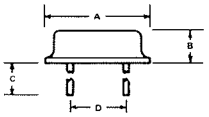
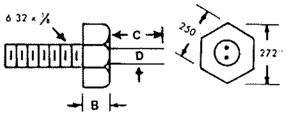
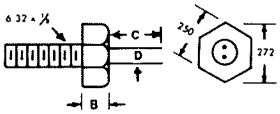
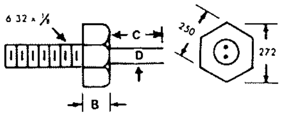
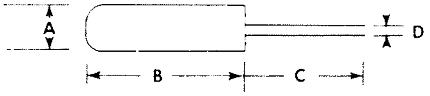
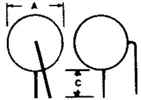
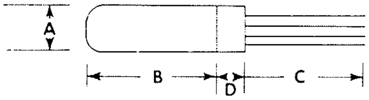
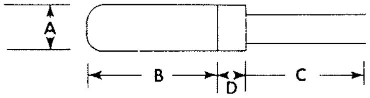
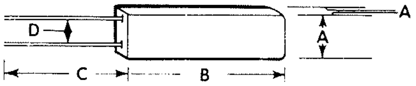
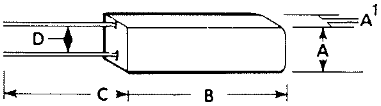
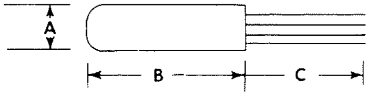


Figure 7

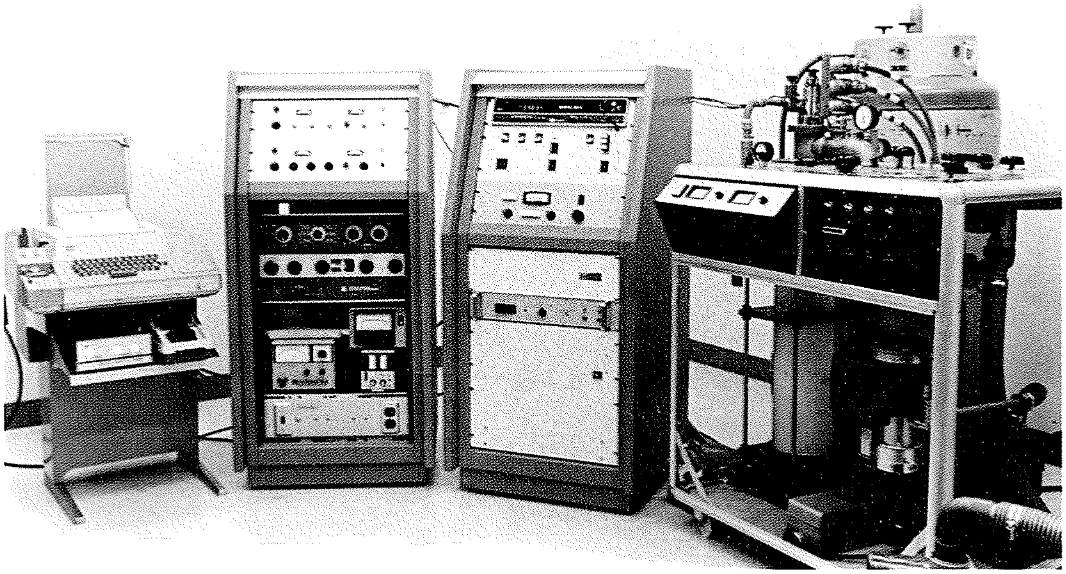
Resistance-temperature characteristics of the germanium (Ge), platinum (Pt) (R_0=1380 ohms), and carbon glass (CG) resistors.

SENSOR SERIES DESIGNATION	REF. NO.	LEAD IDENT. AND ISOLATION	CONFIGURATION
TG-100K **DT-500K** DT-500K-DE	1	Cathode is at case potential Tab index is anode	
DT-500KL DT-500KL-DE	2	Both leads isolated Tab index is anode	
TG-100KL	3	Both leads isolated Tab index is anode	
TG-100P **DT-500P**	4	Cathode is at case potential anode is shorter lead	
TG-100K-T05 **DT-500K-T05** DT-500K-T05-DE	5	Cathode is at case potential Tab index is anode	
TG-100KL-T05 **DT-500KL-T05** DT-500KL-T05-DE	6	Both leads isolated Tab index is anode	
TG-100P-T05 **TG-100P-T05/I** **DT-500P-T05** **DT-500P-T05/I**	7	Standard version Same as Ref #4 /I designates both leads isolated	
TG-100P-GR **TG-100P-GR/I** **DT-500P-GR** **DT-500P-GR/I** DT-500P-GR-MIN /I DT-500P-GR-ULTRA /I	8	Standard version Same as Ref #4 — /I designates both leads isolated Short lead — Anode	
TG-100FP **DT-500FP** DT-500FP-MIN	9	Gold lead—anode Plat lead—cathode Min. short lead – Anode	
CGR-1, **GR-200**	10	White: +I Yellow: +V Green: −V Black: −I	
CS-400-GR	11	Interchangeable — Leads have no polarity	
CS-400FP	12	Interchangeable — Leads have no polarity	
CS-400 Basic	13	Interchangeable — Leads have no polarity	
LR-700GR	14	Pairs are interchangeable— see instructions with sensor	

OTHER CONFIGURATIONS ENGINEERED ON REQUEST

DIMENSIONS: INCHES MM.								
A	B	C	D	LEADS	LEAD DIAM.	WEIGHT	ENCAPSULATION MATERIALS	REMARKS
.23 5.8	.08 2	1.5 38	.10 2.5	2, Gold Plated Ni-Fe 3-DE	.019 .5	.3 gr.	Gold Plated Kovar TO-46 Package	Thermal transfer thru body of unit one lead grounded DE-Dual Element w/ Common Cathodes
.23 5.8	.08 2	1.5 38	.07 1.8	2, Gold Plated Ni-Fe 3-DE	.019 .5	.3 gr.	Gold Plated Kovar TO-46 Package	Both leads isolated from case DE-Dual Element w/ Common anodes
.23 5.8	.21 5.3	1.5 38	.07 1.8	2, Gold Plated Ni-Fe	.019 .5	.5 gr.	Gold Plated Kovar TO-18 Package	Both leads isolated from case
.15 3.8	.065 1.65	1.0 25.4	.06 1.5	2, Plat.— 10% Ir	.01 .25	.18 gr.	Platinum & Glass	No ferromagnetic materials are utilized in the construction of these sensors
—	.09 2.3	1.5 38	.10 2.5	2, Gold Plated Ni-Fe 3-DE	.019 .5	1.24 gr.	Gold Plated Kovar TO-46 base set in a 6-32 x ⅜″ copper alloy hex head cap screw	TG-100K or DT-500K set into the top of a copper alloy hex head cap screw DE-Dual Element w/ Common Cathodes
—	.09 2.3	1.5 38	.07 1.8	2, Gold Plated Ni-Fe 3-DE	.019 .5	1.24 gr.	Gold Plated Kovar TO-46 base set in a 6-32 x ⅜″ copper alloy hex head cap screw	TG-100KL or DT-500KL set into the top of a copper alloy hex head cap screw DE-Dual Element w/ Common anodes
—	.09 2.3	1.0 25.4	.06 1.5	2, Plat.— 10% Ir	.01 .25	1.24 gr.	Platinum and glass header set in a a 6-32 x ⅜″ copper alloy hex head cap screw	TG-100P or DT-500P set into the top of a copper alloy hex head cap screw DE-Dual Element w/ Common Cathodes
.125 3.18 Min. .06 1.5 Ultra .04 1.0	.35 8.9 Min. } .16 Ultra } 4.1	1.0 25.4	.06 1.5 Min. } .01 Ultra } .254	2, Plat.— 10% Ir	.01 .25 Min. } .005 Ultra } .13	.42 gr. Min. 45 mg. Ultra 35 mg.	Platinum and glass header set into a gold plated copper cylinder Min. & Ultra — Platinum, Brass, & Epoxy	TG-100P or DT-500P set into a gold plated copper cylinder except Min. & Ultra
.05 1.27 Min. .030 .76	—	1.5 38	—	1 gold, 1 plat.— 10% Ir Min. 2-pt. 10% Ir	Anode .002 .05 Cathode .005 .13 2 - .005 / .13	25 mg. Min. 17 mg.	Platinum, Gold and Epoxy Min. — Platinum & Epoxy	No ferromagnetic materials are utilized in the construction of these sensors
.125 3.18	.335 8.5	6 152	.1 2.5	4 Copper	32 AWG teflon insulated	.3 gr.	Platinum and glass header set into a gold plated copper cylinder & an epoxy lead strain relief	Sensor has ^{4}He in can to act as a heat transfer medium. ^{3}He and other gases are avail. for GR-200
.125 3.18	.335 8.5	6 152	.1 2.5	2, Copper	32 AWG	.55 gr.	Platinum, Glass and Epoxy	Sensor can is completely filled with sensor element and glass.
A=.107 2.7 A^1=.044 1.1	.340 8.6	1.0 25.4	.06 1.5	2, Silver	.008 .2	.1 gr.	Glass	No ferromagnetic materials are utilized in the construction of CS-400 sensors
A=.098 2.5 A^1=.093 2.4	.340 8.6	1.0 25.4 1.5 38	.06 1.5	2 Silver	.008 .2	.15 gr.	Glass	This is unencapsulated CS-400 GR element
.12 3.0	.320 8.1	2 51	—	4 Copper	32 AWG	.6 gr.	Gold plated copper can and high temperature epoxy	Leads are polyimide insulated

CALIBRATION SERVICE



The equipment shown is utilized for temperature calibrations from 1.3 to 400 K. Other available equipment includes a ^{3}He cryostat for .3 to 1.5 K calibrations and a dilution refrigerator for lower temperatures.

Standard calibrations are supplied according to the following table unless otherwise specified:

Temperature	Maximum Interval	Temperature	Maximum Interval
0.3 to 1.3 K	0.05 K	30 to 40 K	2.0 K
1.3 to 2.0 K	0.1 K	40 to 80 K	5.0 K
2.0 to 3.0 K	0.2 K	80 to 400 K	10.0 K
3.0 to 4.2 K	0.4 K		
5.0 to 30 K	1.0 K		

Computer printouts are provided where applicable.

All diode and resistor calibrations are performed with a 4 wire potentiometric configuration. Capacitance temperature sensors are calibrated with a 3 wire bridge configuration.

Resistor calibration currents are selected to produce a potential difference between 1 and 15 mV for the desired temperature. Diodes are calibrated with a 10 uA excitation current. Capacitors are calibrated with a 50 mV rms. excitation signal at 5 kilohertz.

Note: Consult factory for special printouts

LAKE SHORE CRYOTRONICS, INC.

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