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USER'S MANUAL

Model DRC-91C

Temperature Controller

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Manual No. MAN-DRC-91C

December, 1987

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SERIAL NUMBER _____

SOFTWARE _____

I N S T R U C T I O N M A N U A L

M O D E L D R C - 9 1 C
T E M P E R A T U R E C O N T R O L L E R

Input Card Configuration

		Input A	Input B
9210-3	Standard 3 volt Configuration	☐	☐
-6	6 Volt Diode Configuration	☐	☐
9215-15	Standard 15 Nanofarad Capacitance Input	☐	☐
-150	150 Nanofarad Configuration	☐	☐
9220-3	Standard 3 volt Configuration	☐	☐
-6	6 Volt Configuration	☐	☐
-P2	100 ohm platinum conversion module	☐	☐
-P3	1000 ohm platinum conversion module	☐	☐
-R1	27 ohm Rh-Fe conversion module	☐	☐
9305	Thermocouple Input Card	☐	☐
9317C	Ultra-low (0.3K) Germanium input Card	☐	☐
9318C	Germanium/Carbon Glass Input Card	☐	☐
	No Input Card	☐	☐

		Precision Option(s)			
8223 RS-232C Interface	☐	8001	☐	8002	☐
8225 Analog Output Interface (0-10 volt)	☐	Output Power Option			
8229 Scanner Input Option	☐	W50	☐	W60	☐
High Resolution Set Point	☐				

This manual applies directly to instruments with Serial Number 16000 and higher.

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S E C T I O N I

G E N E R A L I N F O R M A T I O N

1.1 INTRODUCTION

The information contained in this operations manual pertains to the installation, operation, remote programming, options and accessories for the Lake Shore Cryotronics, Inc. Model DRC-91C Temperature Controller. This manual also contains troubleshooting and calibration procedures, schematics, component layouts and a complete parts list.

This section contains general information for the Lake Shore Cryotronics, Inc. DRC-91C Temperature Controller. Included is an instrument description, specifications, instrument identification, option and accessory information.

1.2 DESCRIPTION

The DRC-91C Temperature Controller is a microprocessor based instrument which provides true analog control. It is capable of scanning multiple sensor inputs and displaying temperature with up to 5 digits of resolution in K, °C or °F or sensor units (volts, ohms or nanofarads) to five digits.

The DRC-91C can be used with either 1 or 2 input cards. When two input cards are used, these cards can be different to allow two separate types of sensors to be used with the controller.

The dual sensor input with the optional 8229 Scanner Conversion Card expand the input capability of the DRC-91C to up to 6 input sensors. Depending on the input option selected, the DRC-91C handles silicon (9210-3 or 9220-3) or the patented Gallium-Aluminum-Arsenide (9210-6 or 9220-6) diodes, platinum or rhodium-iron resistors (9220 series), germanium or carbon glass resistors (9317C, 9318C), or capacitance sensors (9215).

With or without the 8229 Scanner Card, the DRC-91C can be set to scan automatically with an individual dwell time of 1 to 99 seconds per channel or stepped to any available input and held there. Setting the dwell time to zero causes a particular channel to be skipped. If all dwell times are zero, the instrument stays on the channel selected.

The DRC-91C gives a direct reading in temperature when used with any DT-470 Series Temperature Sensor. All DT-470 Sensors follow the same temperature response curve. Four bands of tracking accuracy are available. Refer to DT-470 technical data for details.

Diode sensor voltages are digitized to a resolution of 100 microvolts with full scale dependent on input card configuration. The temperature display has a resolution capability of 0.01 kelvin above 100 kelvin and 0.001 kelvin below 100 kelvin.

For greater precision individual sensor calibrations can be accommodated with the 8001 Precision Calibration Option which programs the instrument with calibration data for a specific Sensor. The algorithm within the instrument

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interpolates between data points to an interpolation accuracy which exceeds 0.01K over the entire temperature range of the Precision Option. The 16 bit analog-to-digital converter is accurate to plus or minus the least significant bit, which for the 470 series sensor results in an uncertainty of 1mK below 28K and 45mK above 40K with a transitional region between these two temperatures. Therefore, at temperatures below 28K, the overall system accuracy, the sum of the instrument accuracy (11mK) and that of the calibration itself (Lake Shore calibrations are typically better than 20mK within this region) is ± 0.03K. Above 28K, system accuracy gradually moderates to a typical value of ±75mK above 40K. See the Lake Shore Cryotronics, Inc. Low Temperature Calibration Service brochure for additional discussion of calibration accuracy.

The Model DRC-91C can also be used with the 9220 input card which handles both diodes and positive temperature coefficient metallic resistors., i.e., platinum or rhodium-iron resistors. The DIN curve is standard within the instrument and is called up automatically unless a positive temperature coefficient precision option is selected by the SENSOR ID for that input. The accuracy of the reading is dictated by the sensor and its conformity to the DIN curve. The tolerance on these devices is given on the technical data sheet for the Lake Shore PLATINUM RTDs. The combined accuracy of the instrument and a calibrated resistor with a precision option is on the order of 40mK over the useful range of the sensor (above 40K for the platinum). Note that a precision option is required for a rhodium-iron to read correctly in temperature.

The Model DRC-91C with the 9318C germanium/carbon-glass input card results in the most accurate system below 50K in temperature. For both sensors, a precision option is required to read in temperature. Near 4K, the overall accuracy of the system, including the calibration accuracy, the software interpolation accuracy and the calculation of the resistance results in an overall accuracy on the order of 10mK.

These input option cards are easily installed by the user; thus, units can be changed or upgraded to satisfy changing requirements.

The ample memory space provided in the DRC-91C allows several response curves to be stored in the instrument. Depending on the complexity of the curves, up to 25 can be programmed into the unit. A rear-panel DIP switch (Sensor ID) is used to select the particular sensor response curve for each input.

The data for calibrated sensors can be stored in the instrument as an 8001 Precision Option or by the customer via the IEEE-488 interface. These curves can contain up to 99 sensor temperature data points. With the standard precision option format of 31 data points and an 18 character information line, up to twenty curves can be stored.

Although data points are stored as a table, the interpolation algorithm used results in the equivalent of a high order Chebychev polynomial calculation in the converting of the input voltage

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(or resistance) to temperature. This is done by means of a proprietary algorithm developed at Lake Shore Cryotronics.

An averaging algorithm can be selected to average up to ten temperature readings. This mode eliminates noise within the system analogous to averaging with a digital voltmeter. This averaging mode can be deselected by switch 2 of the SENSOR ID dip switch on the back panel for a given input if the customer prefers not to average readings.

The control set-point selection is made via increment and decrement buttons on the front panel. The display above the buttons indicates the set-point value. The set-point units may be selected independently from the display sensor units.

The standard set point temperature can be set to 0.1 degree. This temperature is converted to an equivalent voltage with a resolution of 100 microvolts out of 3 volts full scale. The optional High Resolution Set Point expands the set point resolution to 0.01 kelvin above 100K and 0.001 kelvin below 100K. the equivalent voltage is expanded to 25 microvolts out of 3 volts full scale. This results in a setability of approximately 0.01 kelvin above 40K and 0.001 kelvin below 28K for the DT-470 series sensors.

The control section of the DRC-91C provides three-term temperature control. Proportional (GAIN), integral (RESET) and derivative (RATE) are individually tuned via front-panel potentiometers. The gain, reset and rate are in a nominal log per cent.

Heater power output of the DRC-91C Temperature Controller is a maximum of 25 watts when a 25 ohm heater is used. A digital meter on the front panel displays the output as a percentage of output range selected. Thus, the user can conveniently monitor power applied to his system. To accommodate systems which require lower heater power, the maximum output can be attenuated in three steps of a decade each. When greater output power is required, the optional W50 and W60 output stages can provide either 50 or 60 watts respectively.

An IEEE-488 interface is standard in the DRC-91C. This interface can be used to remotely control all front-panel functions. When two input cards are used, data from both inputs is available via the interface.

1.3 SPECIFICATIONS

Instrument specifications are listed in Table 1.1. These specifications are the performance standards or limits against which the instrument is tested.

1.4 OPTIONS

The options for the DRC-91C Controller are listed in Section VI.

Three option ports are designed into the DRC-91C. The options are field installable by the user.

822x-series options can be factory installed in the DRC-91C or field-installed at a later time. The 8223 RS-232C Interface Option operates similar to the IEEE-488 interface. The Model 8225 Analog Output option is available to provide a linearized analog output

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of 10mV/K independent of the display temperature units. If the display is in sensor units, the output for diodes is 1V/V; for 100 ohm platinum, 10mV/ohm; for 1000 ohm platinum, 1mV/ohm; for rhodium-iron, 100mv/ohm; and for capacitance units, 100mV/nF and 10mV/nF.

The Model 8229 Scanner Option provides four additional channels of sensor input to the "A" input. The A input is channel A0 with the additional inputs designated A1-A4 with the selection indicated on the display.

Table 1.1. Specifications, Model DRC-91C Temperature Controller

Input Characteristics:

Inputs: Two Sensor Inputs. The 8229 Scanner Conversion Option provides for four additional channels of Sensor Input. Display sensor can be selected from front panel or interface, or display can be set to scan between sensor inputs. Dwell time per channel can be set independently from 0 (skip) to 99 seconds. Input characteristics are a function of Sensor Input Option Installed. The DRC-91C can accommodate two input options which allows the A input and the B input to each be assigned their own input card. This allows concurrent use of different sensors dependent on the application.

Sensors: Ordered Separately. DRC-91C will handle all types of diodes; germanium, carbon glass, carbon, etc. negative temperature coefficient resistors, thermistors; platinum, rhodium-iron, etc. metallic resistors and thermocouples as well as capacitance thermometers with proper choice of input option cards. See the Lake Shore Cryotronics, Inc. Sensor catalog for details on the above Sensors.

Display Readout:

Display: 5-digit LED Display of Sensor reading in Sensor Units (Volts, Ohms or Nanofarads) or temperature in K, °C, or °F shown with annunciators.

Resolution: Display resolution is 0.001K below 100K, 0.01K above 100K (0.0001K below 10K for 9317C Resistance Sensor Input Card). Resolution can be user-limited to 1K, 0.1K or 0.01K. Same resolution considerations apply for °C, °F and Sensor Units. Changes made by front panel keys or over interface.

Temperature Accuracy: Dependent on Sensor Input Card and Sensor. See Input Options available.

Temperature Range: Dependent of Sensor Input Card and Sensor.

Temperature Control:

Set Point: Button increment (either fast or slow) of set-point in set-point units.

Set Point Resolution: Selection in kelvin, celsius, fahrenheit or Sensor Units. Temperature to 0.1 in corresponding units; in Sensor Units, 0.1mV in voltage, 0.01 ohms but limited to five digits in resistance and 0.001 nanofarads out of 15 nanofarads (0.01 nanofarads out of 150 nanofarads for second scale) in capacitance. May also be set over the interface.

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Typical Controllability: Dependent on Sensor, its temperature and the resultant Sensor "gain", i.e., sensitivity. Typically better than 0.001K in a properly designed system below 30K and 10mK above 30K using a Diode Sensor. But, for example, a thermistor, due to its large sensitivity, may result in a controllability approaching 0.5mK above 200K over a narrow temperature range in certain systems and a germanium below 10K may control to 0.1mK in another system.

Control Modes: Proportional (GAIN), integral (RESET) and derivative (RATE). Set via front-panel knobs or with interface.

Heater output: Up to 25 watts (1A,25V) standard. Four output ranges can be selected either from front-panel or interface and provide approximate decade step reductions of maximum power output. Optional 50 or 60 watt outputs available. Rear panel maximum current limit for MAX scale.

Heater output Monitor: LED display continuously shows heater current or power output as a percentage of range with a resolution of 1%.

Control Sensor: Either Sensor Input (designated from rear panel).

General:

Sensor Voltage Monitor: For 9210 and 9220 diode Option configurations (-3, -6), buffered output of diode sensor voltage. Multiplier is 0.457771 for -6 configurations. For 9220 Option positive temperature coefficient configurations (-P2, -P3, -R1), buffer is sensor voltage output times -10. Buffered outputs for 9210-6 and 9220-6 are multiplied by 0.457771. For 9215, signal is proportional to capacitance value; for 9317C or 9318C, monitor not of use.

Response time (electronics): Less than 1 second to rated accuracy for non-Lagrangian calculations. Lagrangian curves result in update times between one and two seconds. Three readings on channel change or range change to reach rated accuracy.

IEEE-488 Interface: Allows remote control of set-point, gain, rate, reset, units and heater power range. Provides output of display in units chosen, units and all front panel functions (except power on/off and Display Sensor Selection). Allows input of curve data for calibrated sensors.

Dimensions, Weight: 432mm wide x 102mm high x 330mm deep (17in. x 4in. x 13in.) Style L, full-rack package. Net weight 8kg (17 lb.).

Power: 90-110, 105-125, or 210-250 VAC (selected via rear panel with instrument off), 50 or 60 Hz, 75 watts.

Accessories Supplied: Mating connector for sensor/monitor connector, instruction manual.

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S E C T I O N I I

I N S T A L L A T I O N

2.1 INTRODUCTION

This Section contains information and instructions pertaining to instrument set-up. Included are inspection procedures, power and grounding requirements, environmental information, bench and rack mounting instructions, a description of interface connections, and repackaging instructions.

2.2 INITIAL INSPECTION

This instrument was electrically, mechanically and functionally inspected prior to shipment. It should be free from mechanical damage, and in perfect working order upon receipt. To confirm this, the instrument should be visually inspected for damage and tested electrically to detect any concealed damage upon receipt. Be sure to inventory all components supplied before discarding any shipping materials. If there is damage to the instrument in transit, be sure to file appropriate claims promptly with the carrier, and/or insurance company. Please advise Lake Shore Cryotronics, Inc. of such filings. In case of parts shortages, advise LSCI immediately. LSCI can not be responsible for any missing parts unless notified within 60 days of shipment. The standard Lake Shore Cryotronics Warranty is given on the first page of this manual.

2.3 PREPARATION FOR USE

2.3.1 Power Requirements

The Model DRC-91C requires a power source of 100, 120, 220 or 240 VAC (+5%, -10%), 50 to 60 Hz single phase.

CAUTION

Verify that the AC Line Voltage Selection Wheel (Figure 3-2, Key 1) located on the rear panel of the Model DRC-91C is set to the AC voltage to be used (Table 2-1) and that the proper fuse is installed before inserting the power cord and turning on the instrument.

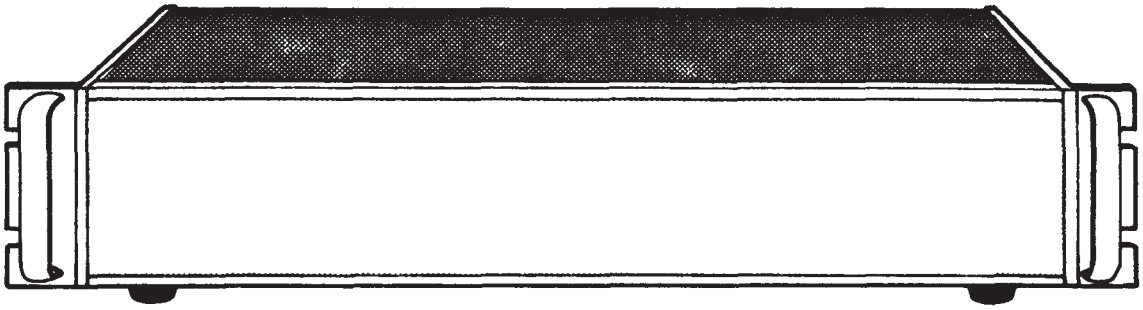
Table 2-1. Line Voltage Selection

Line Voltage (Volts)	Operating Range (Volts)	Fuse (A)
100	90-105	1 - SB
120	108-126	1 - SB
220	198-231	0.5- SB
240	216-252	0.5- SB

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Figure 2-1. Typical Rack Configuration



2.3.2 Power Cord

A three-prong detachable power cord for 120 VAC operation which mates with the rear panel UL/IEC/ICEE standard plug is included with the instrument.

2.3.3 Grounding Requirements

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

2.3.4 Bench Use

The DRC-91C is shipped with plastic "feet" and a tilt stand installed and is ready for use as a bench instrument. The front of the instrument may be elevated for convenient operation and viewing by extending the tilt stand.

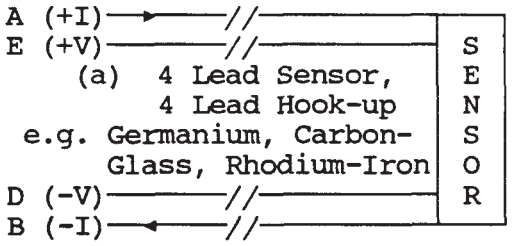
2.3.5 Rack Mounting

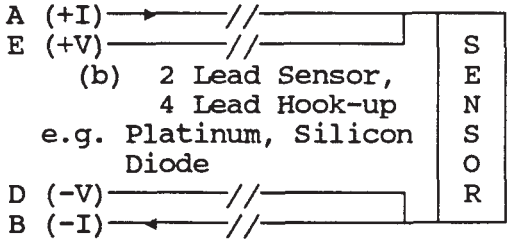
The DRC-91C can be installed in a standard 19 inch instrument rack by using the optional RM-3F or RM-3F-H rack mounting kit. A typical RM-3F-H kit installation is shown in Figure 2-1.

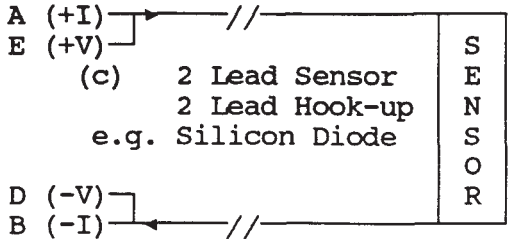
2.3.6 Sensor Input Connections

The DRC-91C has two rear panel 5-pin input connectors for diode and resistance sensors. The lead connection definition for the sensor(s) is given in Table 2-2 and is shown in Figure 2-2.

Figure 2-2. Sensor Connections







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Connections for capacitance sensors and thermocouples are made through alternate connectors. Refer to the appropriate input card section for sensor connections.

The four lead connection (a) is required for a four lead sensor.

The use of a four wire connection (Figure 2-2b) is highly recommended for two lead resistive elements and diodes to avoid introducing IR drops in the voltage sensing pair which translates into a temperature measurement error.

An alternate two line wiring method (Terminals A and E shorted together, B and D shorted) may be used for the DT-470 and TG-120 series diodes in less critical applications where lead resistance is small and small readout errors can be tolerated (c). Measurement errors due to lead resistance for a two lead hook-up can be calculated using; $\delta T = IR/[dV/dT]$ where I is 10 microamperes, R is the total lead resistance; dV/dT is the diode sensitivity and δT is the measurement error. For example, R = 250Ω with dV/dT = 2.5 mV/K results in a temperature error of 1 kelvin. Two wire connections are not recommended for other sensor types.

Table 2-2. INPUT Connections for J1 Input A and J2 Input B

Terminal	Description
A	+ Current Out
B	- Current Out
D	- Voltage Sense
E	+ Voltage Sense
H	Shield

The Lake Shore Cryotronics, Inc. QUAD-LEAD™ 36 Gauge Cryogenic wire is ideal for connections to the sensor since the four leads are run together and color-coded. The wire is Phosphor Bronze with a Formvar insulation and Butryral bonding between the four leads. Color coding is red, green, clear and blue on the four leads which makes it extremely easy to determine one wire from another.

2.3.7 J3 Sensor Output MONITORS

Buffered voltage outputs for both Sensor Input A and B are available on the J3 connector on the back panel of the instrument. The voltage from the Model 8225 Analog Output Option is present on this connector also. The connector pin assignments are given in Table 2-3.

Table 2-3. J3 MONITORS Connections

Terminal	Description
A	Voltage Output (Input A)
B	Voltage Output (Input B)
C	10 mV/K Analog Output
D	Ground for Analog Output
E	Setpoint Output
F	Ground (A + B, Setpoint)
H	(Optional Shield)

2.3.8 SENSOR ID Switches

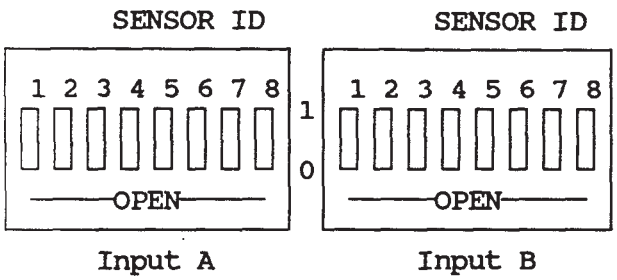
The A SENSOR ID and B SENSOR ID switches determine slope for a 9215 capacitance input card, if present, activate or deactivate digital filtering and enables thermal averaging on the 9317C or 9318C resistance input card when present or ice-point compensation when a 9305 thermocouple input card is present. Switch 4 determines whether Switches 5-8 select a stored curve directly or a curve via the position correlation table, i.e., a table of position versus curve number for non-thermocouple inputs. Switches 5-8 define the thermocouple type when a 9305 thermocouple input card is present. The switch information is described in Figure 2-3.

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Table 2-4 indicates the position of the address switches to select standard curves stored within the instrument. Information on Precision Option Curves is given in Appendix B.

Figure 2-3. SENSOR ID Definitions



Switch	Setting	Description
1	OPEN CLOSED	- Negative T. C. - Positive T. C.
2	OPEN CLOSED	- Continuous Update - Digital Filter On
3	OPEN CLOSED	- No Thermal Cnsdrd - Thermal Considered
4	OPEN CLOSED	- Curve Selection - Position selection
5		Multiple Bit 3
6		Multiple Bit 2
7		Multiple Bit 1
8		Multiple Bit 0

Table 2-4. SENSOR ID Standard Curve Address

SENSOR ID 4 5 6 7 8	Crve #	Non-TC Card	TC Card
0 0 0 0 0	00	DRC-D	Au0.07%Fe
0 0 0 0 1	01	DRC-E1	Au0.03%Fe
0 0 0 1 0	02	CRV 10	E
0 0 0 1 1	03	DIN-PT	K
0 0 1 0 0	04	CRV 10	T
0 0 1 0 1	05	RSVRD	RSVRD

See SECTION III for more information on sensor selection and the operation of the SENSOR ID switches and J5 REMOTE SENSOR ID. Note that Curve 10 is given twice; Curve 02 has a set point limit of 325K and Curve 04 has an upper limit of 475 kelvin. Switch 4 of the SENSOR ID, must be 0 for the instrument to read the curve directly from the rear panel SENSOR ID hardware.

If a thermocouple card is present, the SENSOR ID switches select the appropriate thermocouple table instead of the diode or platinum curves.

2.3.9 Heater Power

The heater output leads should be electrically isolated from the sensor(s) ground(s) to preclude the possibility of any of the heater current affecting the sensor input signal. The heater leads should not run coincident with the sensor leads due to the possibility of capacitive pick-up between the two sets of leads. If they are in close proximity, they should be wound so as to cross the sensor leads at ninety degrees if at all possible.

The heater output is a current drive and does not have to be fused. The DRC-91C is designed to power a 25 ohm heater for maximum heater output. If a smaller resistance is used, the maximum heater power corresponds to the heater resistance, i.e., 10 ohms yields 10 watts. A larger heater can also be used. Since the compliance voltage is 25 volts; a 50 ohm heater will allow a maximum power output of 12.5 watts $[(25)^2/50]$.

Two optional output power stages (W50 and W60) of 50 and 60 watts respectively are available for the DRC-91C. The W50 is rated at 1 ampere and 50 volts (into 50 ohm

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load) while the W60 is rated at 1.5 amperes at approximately 43 volts (into 25 ohm load).

A 50 ohm, 50 watt (1/4" dia. x 1" long) cartridge heater is available as well as a 25 ohm, 25 watt (3/8" dia. x 1" long) cartridge heater.

A 30 gauge stranded copper lead wire (ND-30) is recommended for connecting to the heater.

2.3.9.1 MAX HEATER POWER Limit

Make sure that the MAX HEATER POWER limit potentiometer is turned fully clockwise during the setup of the instrument so that full power is available on the MAX power scale, if desired. Fully clockwise corresponds to approximately 1 ampere while fully counterclockwise corresponds to the -1 range (330mA).

2.3.9.2 Current or Power Output Display

The HEATER % meter can be set to read either % of output power or % of output current. The internal DIP switch setting (main board S7, switch 1) controls whether the meter reads in % current (closed) or % power (open). The DRC-91C is shipped to read in % power.

2.4 REMOTE SENSOR ID Connector

The REMOTE SENSOR ID connector, J5, on the rear panel receives POSITION DATA from a Model 8084 or 8085 Sensor Scanner or a Model SW-10A Ten-Sensor Selector Switch. The REMOTE SENSOR ID Interconnecting Cable and REMOTE SENSOR ID connector assignments are given in Table 2-5.

Table 2-5. REMOTE SENSOR ID Connector Assignments

REMOTE SENSOR ID Connector Pin	Function
10	Bit 0 (B0-LSB)
8	Bit 1 (B1)
6	Bit 2 (B2)
4	Bit 3 (B3)
14	Bit 4 (B4-MSB)
12	Digital Ground

The POSITION DATA is the binary representation of the remote position. Table 3-4 gives the POSITION DATA binary combinations. The remote position input can be used to select specific sensor curve tables stored in the DRC-91C. The correlation between remote position and sensor curve is given in Section III. The REMOTE SENSOR ID can be expanded to allow for the use of up to three 8084 or 8085 Sensor Scanners with the 8082 Position Data Adapter. Remote position 1F (31) is reserved to indicate that more than one scanner is active to the 8082. When this condition is present, the DRC-91C displays ERR09 until the fault is corrected.

2.5 IEEE-488 INTERFACE Connector

The IEEE-488 Connector on the back of the DRC-91C is in full compliance with the IEEE Standard 488-19-78. The connector has metric threaded mounting studs, visually indicated by the color black. Metric threaded cable lockscrews (also black) must be used to secure an IEEE-488 interface cable to the instrument. Model 8072 IEEE-488 Interconnect Cables (one meter long) are available from Lake Shore.

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2.6 OPTIONS

2.6.1 The 8223 RS-232C Interface. The RS-232C option is described in Section VI of this manual including connections.

2.6.2 The 8225 Linear Analog output is described in Section VI of this manual.

2.6.3 The 8229 Scanner Input Option is described in Section III and Section VI of this manual.

2.6.4 The High Resolution Set Point expands the set point resolution to 0.01 kelvin above 100K and 0.001 kelvin below 100K. The equivalent voltage is expanded to 25 microvolts out of 3 volts full scale. This results in a setability of approximately 0.01 kelvin above 40K and 0.001 kelvin below 28K for the DT-470 series sensors.

2.6.5 8001 Precision Option. Custom programming of specific Sensor calibration curve(s) at factory. Provides highest degree of readout accuracy.

2.6.6 The W50 and W60 Output Options will deliver 50 or 60 watts respectively. The W50 is rated at 1 ampere and 50 volts into a 50 ohm load with the W60 rated at 1.5 amperes at approximately 43 volts into a 25 ohm load. These are factory options only.

2.7 ENVIRONMENTAL REQUIREMENTS

WARNING

> To prevent electrical fire or shock hazards, do not expose the instrument to rain or excess moisture.

2.7.1 Operating Temperature

In order to meet and maintain the specifications in Table 1-1, the DRC-91C should be operated at an ambient temperature range of 23°C ± 5°C. The unit may be operated within the range of 15-35°C with less accuracy.

2.7.2 Humidity/Altitude

The DRC-91C is for laboratory use and no humidity or altitude specifications have been determined for this unit.

2.8 REPACKAGING FOR SHIPMENT

If the Model DRC-91C appears to be operating incorrectly, refer to the Technical Service Guide for troubleshooting advice. If these tests indicate that there is a fault with the instrument, contact LSCI or a factory representative for a Return Goods Authorization (RGA) number before returning the instrument to our service department.

When returning an instrument for service, the following information must be provided before Lake Shore can attempt any repair.

1. Instrument Model and Serial #s
2. User's Name, Company, Address, and Phone Number
3. Malfunction Symptoms
4. Description of system
5. Returned Goods Authorization #

If the original carton is available, repack the instrument in a plastic bag, place it in the carton using original spacers to protect protruding controls. Seal the carton with strong paper or nylon tape. Affix shipping labels and "FRAGILE" warnings.

If the original carton is not available, pack the instrument similar to the above procedure, being careful to use spacers or suitable packing material on all sides of the instrument.

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SECTION III

OPERATING INSTRUCTIONS

3.1 INTRODUCTION

This section contains information and instructions concerning the operation of the Model DRC-91C Temperature Controller. Included is a description of the front and rear panel controls and indicators.

3.2 INSTRUMENT CONFIGURATION

3.2.1 Input Card Configurations

The Model DRC-91C can be used with either one or two input cards. The input cards available for use with the DRC-91C are summarized in Section I. The input cards available allow the 91C to be used with almost any type of cryogenic sensor. Input cards can be mixed, allowing two different sensor types to be used with the DRC-91C.

3.2.2 Single Input Card

When only one input card is present within the unit, it occupies the A INPUT CARD slot of the DRC-91C mainframe and is connected to the Sensor A input of the controller. Only one sensor can be used with the controller under these conditions.

3.2.3 Dual Input Cards

When two input cards are present in the unit, the input card that occupies the A INPUT CARD slot is routed to the Sensor A input and the input card that occupies the B INPUT CARD slot is routed to the Sensor B input. Consequently, both sensors are energized at all times.

The second input card allows the instrument to mix sensor types, e.g., both a diode thermometer and a resistance thermometer can be used on the two inputs. Another possibility with the 9318C and 9220 Options would be the presence of a GR-200A Series Germanium Sensor as well as a PT-100 Series Platinum Resistance Sensor. Both inputs are updated independently, which allows them both to be queried under IEEE-488 or RS-232C control independent of which input is displayed.

The addition of the 8229 Sensor Scanner Option adds capability for 4 additional inputs to the A channel resulting in up to 5 sensors of the same type being allowed on inputs A, A1, A2, A3 and A4.

3.2.4 Old Version Input Cards

The 8210, 8211 diode input cards can be used in the 91C as well as the 8219 series resistance input card. The installation of these cards is covered in Section VI of this manual. Note that there are Dip Switch settings on the main board which must be set in order for these older cards to work properly.

3.3 CURVE ENTRY

The DRC-91C allows the user to enter his own sensor calibration over the remote interface. Section IV of the manual covers entry over the IEEE-488 or RS-232C interfaces. The curve is stored in a battery back-up non-volatile RAM (NOVRAM) which can be read and wrote to an unlimited number of times and that the number of data points stored per curve can be anywhere between 2 and 99; two being the lower limit which defines a straight line.

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3.4 PRECISION OPTIONS

3.4.1 The Model 8000 Precision Option

There are three types of Precision Options available for the DRC-91C. The Model 8000 Precision Option generates the data table from a Lake Shore calibrated sensor. The upper limit of data points is again 99, with a typical calibration ranging between 30 and 40 points, depending on sensor type and temperature range for the calibration. The data and accuracy of the fit is supplied to the user as a separate document. This information can then be entered by the user over the computer interface.

3.4.2 The Model 8001 Precision Option

Lake Shore can also generate custom sensor response curves from the individual sensor calibrations as indicated above and store them in the DRC-91C via the 8001 Precision Option prior to shipment. The data and accuracy of the fit is then supplied to the user as a Appendix to this manual.

3.4.3 The Model 8002-05 Precision Option

The 8002 Precision Option is used when the customer already owns a DRC-91C and wants new sensor calibration data stored in the instrument. LSCI stores the calibration data in a NOVRAM and sends the programmed chip to the customer. The PROM is then installed in the DRC-91C by the customer.

Note that additional calibrations can be added to the instrument at a later time by specifying with the sensor calibration at time of order, the serial number of the instrument and with which input the sensor will be associated if remote operation is used.

3.5 CONTROL FUNDAMENTALS

An application note entitled "Fundamentals for Usage of Cryogenic Temperature Controllers" is included as an appendix in this manual and should be read in detail if you are not familiar with cryogenic temperature controllers.

3.6 CONTROLS AND INDICATORS

Figures 3-1 and 3-2 identify the DRC-91C displays, annunciators, controls, and connectors. The identification of each item is keyed to the appropriate figure.

FRONT PANEL DESCRIPTION

3.7 POWER ON

Before connecting AC power to the DRC-91C, make sure the rear panel voltage selector is set to correspond to the available power line voltage. Be certain the correct fuse is installed in the instrument.

3.7.1 POWER UP SEQUENCE

Immediately on POWER ON the 91C runs through a power up sequence as follows:

1. The Display Block indicates ±8.8.8.8.8. in both the upper and lower displays and the Heater % indicates 188. In addition all the annunciators and LED's are turned on. The annunciators A1 A2 A3 A4 are displayed in a column on the left of the display. The LED's include: DISPLAY SENSOR A, B, and ↑↓ (scan); CONTROL SENSOR A and B as well as six sets of units for both DISPLAY SENSOR and CONTROL SENSOR; HEATER POWER RANGE from OFF to MAX; LOCAL and REMOTE.

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Figure 3-1. DRC-91C Temperature Controller Front Panel

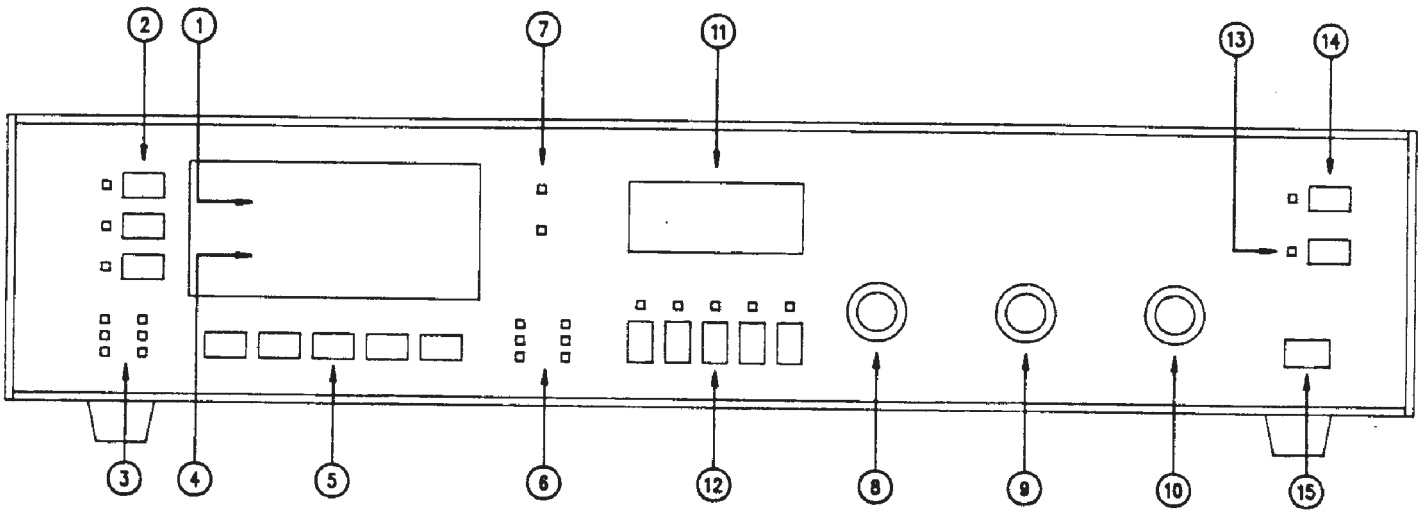


Figure 3-1. Model DRC-91C Cryogenic Thermometer Front Panel Description

Display Sensor

1. Display Sensor reading in temperature (kelvin, celsius, or fahrenheit), or sensor units (voltage, resistance or capacitance).
2. Annunciated Display Sensor Selector Buttons with annunciated Scan Button.
3. Annunciators indicating units of Display Sensor.

Set Point

4. Display of Set Point in temperature (kelvin, celsius, or fahrenheit), or sensor units (voltage, resistance or capacitance) as indicated by Set Point Units annunciators.
5. Buttons which increment or decrement Units, Set Point, Dwell and where appropriate change sign of Set Point.
6. Annunciators indicating units of Set Point.

Control

7. Annunciated CONTROL SENSOR indicator.
8. Variable GAIN (proportional) control potentiometer.
9. Variable RATE (derivative) control potentiometer.
10. Variable RESET (integral) control potentiometer.
11. HEATER CURRENT or HEATER POWER INDICATOR in percent of full scale.
12. Full Scale selection of HEATER CURRENT or HEATER POWER for four orders of magnitude. Includes output power OFF position.
13. Return-to-LOCAL key with annunciator.
14. REMOTE key with annunciator.
15. POWER ON-OFF switch

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2. Next the unit displays -91C- in the upper display and indicates the IEEE-488 interface address in the lower display. For a factory set IEEE address of 12 the display would indicate Add12. This address can obviously be changed by the user and verification of that change is always given on power-up. Note that this address is only read by the instrument on power-up.

3. The unit then displays for INPUT A the curve number associated with that input on the upper display and on the lower display the input option card and its configuration.

4. The unit then displays the same information for Input B.

5. The unit then goes into normal operation.

3.7.2 POWER-UP STATUS

A provision has been made to store parameter changes in the DRC-91C memory (NOVRAM). The A and B units, the control units, heater range and set point, as well as the scan dwell times can be stored as power-up settings. When enabled, any time the parameter is changed, either in the LOCAL or REMOTE mode, the NOVRAM is updated. The internal DIP switch setting (main board S7, switch 2) controls whether or not the settings are updated. The updating is disabled (switch 2 off) at the factory prior to shipment.

3.8 DISPLAY SENSOR Block

3.8.1 DISPLAY SENSOR Input

The choice of DISPLAY SENSOR input as well as enabling the ↑↓ (scan) function is made with keys located in the DISPLAY SENSOR Block. The selection of A or B input and SCAN is indicated by the LEDs to the left of these keys.
When the 8229 Scanner Conversion Option is not present the display can be toggled between the A and B inputs with the A and B keys or automatically toggle between the two inputs by pressing the SCAN button for less than one second to initiate the scanning function.

3.8.2 8229 Scanner Input Option

With the addition of the Model 8229 Scanner Input Option, four more inputs are added to the A channel input. These additional inputs are designated A1-A4 and their selection identified in the left side of the display window.

With the scanner conversion option present, the SENSOR A button increments the inputs in the sequence A-A1-A2-A3-A4-A etc.

The 8229 Scanner Input Option is covered in Section VI of this manual.

3.8.3 SCAN Function

The SCAN function allows the instrument to step between the two inputs with a scan rate independently set between 0 (Skip) and 99 seconds for each input. If the scanner option is present, inputs (A1-A4) are included in the SCAN function and may each be set independently in their dwell (scan) time. Setting a dwell time to zero automatically skips the channel only when in the SCAN mode.

3.8.4 The SCAN Dwell Time

The dwell time for each input can be displayed and changed by selecting an input for DISPLAY, pressing the SCAN key down for more than one second and using the ▲ and ▼ keys to increment or decrement the displayed dwell time for the input chosen. A similar result may be obtained by holding down the A or B

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input button for longer than one second. This operation differs if a scanner is present. If the A button is pressed, the A input increments; also for both the A and B buttons, the resolution as well as the dwell time is displayed.

3.8.5 DISPLAY AND DISPLAY SENSOR Units

3.8.5.1 Units Select

The display units are indicated by LEDs in the block directly below the DISPLAY SENSOR block. The units of the display are changed by simultaneously depressing the +/- UNITS button with the double UP ARROW ▲▲ or double DOWN ARROW ▼▼ until the units desired are obtained. Each time the ▲▲ key is pressed the units cycle clockwise and each time the ▼▼ key is pressed the units cycle counterclockwise. The units which do not pertain to the input card selected are automatically skipped, i.e., only one of the sensor units (V, Ω , or nF) is possible depending on which sensor input card is present within the instrument.

For any input card **except** the 9215, the DRC-93C will read temperature regardless of whether a curve is stored within the instrument which corresponds to the temperature sensor being interrogated. For diodes, germanium, carbon glass, and all other negative temperature dependence sensors; the default curve is Curve 00 which is the D curve for the DT-500-DRC sensors. For a positive temperature dependence temperature sensor such as platinum and rhodium-iron, the default curve is Curve 03 which is the standard 3750 DIN curve for platinum. This default will only occur if a curve of opposite temperature dependence has been inadvertently selected by the user. In the case of the 9215 card, temperature units are not allowed due to the inability of this sensor to hold a calibration upon cycling.

3.8.5.2 Sensor Units Mode

3.8.5.3 Voltage Units

The voltage mode is allowed for the 9210-3 and -6 configurations, the 9220-3 and -6 configurations as well as the older version 8210 and 8211 cards. In the voltage mode, the display has a resolution of 0.1 millivolt with the full scale range dependent on the input card (2.9999 volts for the -3 configurations and the 8210 card and 6.5535 volts for the -6 configurations and the 8211 input card). The actual Input Card resolution is 0.05 millivolts and 0.1 millivolts, respectively. If a voltage exceeding full scale is applied to the displayed input an overload condition is present and is indicated by OL on the display.

3.8.5.4 Resistance Units

The Resistance mode is allowed for the 9317C, 9318C, and the 9220-P2, -P3, and -R1 configurations as well as the older 8219-P2, the 8219-P3 and 8219-R1 cards. The display range and resolution for the 9317C is 0.000 to 9999.9 ohms; the 9318C is 0.000 to 99999 ohms. Note that the resistance automatically ranges from --.--- to ---.-- to ----.- to ----- as the resistance increases in value. If the input resistance exceeds the resistance range for the card, an overload condition is present and is indicated by OL on the display.

The display ranges and resolutions for the 9220-P2 (and 8219-P2), 9220-P3 (and 8219-P3) and 9220-R1 (and 8219-R1) are 0.00 to 299.99 ohms, 0.0 to 2999.9 and 0.000 to 99.999 ohms respectively. Again, if a resistance exceeding full scale is applied to the input, OL is indicated on the display.

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3.8.5.5 Capacitance Units

The capacitance mode is allowed for the 9215 Input Card which can be configured in the -15 or -150 configurations. The display range and resolution is 0.000 to 30.000 or 0.00 to 150.00 nanofarads, respectively. An input in excess of the configured maximum is indicated by OL on the display.

3.8.6 Display Resolution

The Model DRC-91C allows the user to set the display resolution over the range from 1 kelvin to 1 millikelvin (0.1 millikelvin for the 9317C input card). The temperature is rounded to the least significant digit of the resolution range selected. Since the temperature display resolution is dependent on both the sensor units (voltage, resistance or capacitance) resolution of the Input Card as well as the sensor sensitivity, temperature resolution is greatly dependent on the sensor. Refer to Table 3-1 for a representative summary of "system" resolution, (sensor plus instrument resolution, versus sensor sensitivity).

3.8.6.1 Temperature Display Resolution Set

To change the display resolution from the front panel, hold in the DISPLAY SENSOR A or B button or the ↑↓ (scan) button for longer than one second. The display will read ---. , ---.- , ---.-- , --.--- or -.---- . Use the ▲▲ or ▼▼ keys to move the decimal point in the direction of increased or decreased resolution. Changing the display resolution fixes the resolution transmitted over the bus as well but does not change the resolution of the "system". Display resolution can also be different for each input card, i.e., A and B. Also note, that the chosen resolution will only be displayed when "appropriate". In other words, only five digits can be displayed.

In the temperature mode, the chosen input is displayed in the selected scale (K, °C or °F) with a maximum display capability of 0.01 degrees above 100 kelvin, to 0.001 degrees between 1 and 100 kelvin and in the case of the 8217 resistance card to 0.0001 kelvin (0.1 millikelvin) below 1 kelvin. Please note that this is display capability and **neither** system resolution **nor**

TABLE 3-1. SYSTEM RESOLUTION VERSUS SENSOR SENSITIVITY

Sensor Sensitivity	Maximum Temperature Resolution (in K)		Sensor Sensitivity	Maximum Temperature Resolution (in K)
Voltage Mode	9210/9220		Resistance Mode	9317C/9318C
mv/K	-3[1]	-6[1]	(1/R)(dR/dT), K^{-1}	9220-P2,-P3,-R1[2]
0.1	0.5	1.	0.001	0.1 to 0.01
1.0	0.05	0.1	0.01	0.01 to 0.001
10.0	0.005	0.01	0.1	0.001 to 0.0001
100.0	0.0005	0.001	1.	0.0001 to 0.00001

Note 1. The input resolution is 0.05 millivolts for the 9210/9220-3 and is 0.1 millivolts for the 9210/9220-6.

Note 2. This assumes an ability to resolve between 1 part in 10^4 and 1 part in 10^5, where $\blacktriangle T = (\blacktriangle R/R)/[(1/R)(dR/dT)]$ and $(\blacktriangle R/R)$ varies between 10^{-4} and 10^{-5}.

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necessarily accuracy of the reading. Also note that if the sensitivity of the sensor is too low to support this resolution, i.e., one bit corresponds to greater than the above resolution, some temperatures may be skipped. This will be true for a silicon diode sensor between 30 kelvin and 100 kelvin where the sensitivity is approximately 2.5 millivolts per kelvin and the voltage resolution is 0.05 millivolts. For this case, the resulting temperature resolution is 0.05/2.5 = 0.02 kelvin. However, below 30 kelvin the silicon diode sensitivity is approximately 25 millivolts per kelvin which results in an approximate resolution of 0.002 kelvin (0.05/25).

3.8.7 Filtering the Display

An averaging algorithm within the instrument is available which averages up to ten readings. This reading mode eliminates noise within the cryogenic system analogous to averaging within a digital voltmeter. This function can be selected or deselected by switch 2 of the SENSOR ID on the back panel for each input separately. The DRC-91C is shipped from the factory with the filtering function selected for both inputs.

The decimal point on the sign digit at the far left of the display window flags "Filter-on" and will indicate whether the averaging algorithm is being used for that input. The averaging algorithm is a moving average in that when a A/D reading is taken, the new reading replaces the oldest reading and the new average is displayed. If the averaging algorithm is used, displayed temperature is on the average somewhere between 1 and ten readings depending on the temperature variation. If an abrupt change in temperature is observed, averaging is disabled and the last calculated reading is displayed. As the disturbance is reduced in value, the averaging gradually increases until a total of ten readings are considered.

3.9 SENSOR CURVES

3.9.1 Standard Curves

The standard curves with their curve number, temperature range and SENSOR ID switch position are given in Table 3-2.

Table 3-2. Standard Curve Information

Curve No.	Switch 45678	Temperature Range(K)	Curve Dscrptn
00	00000	1 - 324.9	DRC-D
01	00001	1 - 324.9	DRC-E1
02	00010	1 - 324.9	CRV 10
03	00011	14 - 799.9	DIN-PT
04	00100	1 - 474.9	CRV 10
05	00101		RESVRD

3.9.2 The Precision Option Table

Table 3-3 gives the standard curves present in the DRC-91C as well as any Precision Options which are factory installed including their address and the number of data points associated with each curve. This Table should be updated for the instrument if additional curves are added at a later time.

A Precision Option Curve can have up to 97 points with two additional end points automatically put into the curve table by the DRC-91C software. Up to 25 Precision Option Curves can be stored in the DRC-91C with an average of 31 points per curve.

Note: For Lake Shore stored Germanium and Carbon Glass Precision Option Curves, a proprietary algorithm is used to fit the calibration data to within a few millikelvin over the entire temperature range.

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Table 3-3. Sensor Curve Table Information Precision Option Table

Crve No.	Switch 45678	# of Lines	Address	Dscrptn
00	00000	31	1D40	DRC-D
01	00001	31	1DF0	DRC-E1
02	00010	31	1EA0	CRV 10
03	00011	31	1F50	DIN-PT
04	00100	31	2000	CRV 10
05	00101	31	20B0	RESVRD
06	00110	____	____	_____
07	00111	____	____	_____
08	01000	____	____	_____
09	01001	____	____	_____
10	01010	____	____	_____
11	01011	____	____	_____
12	01100	____	____	_____
13	01101	____	____	_____
14	01110	____	____	_____
15	01111	____	____	_____
16		____	____	_____
17		____	____	_____
18		____	____	_____
19		____	____	_____
20		____	____	_____
21		____	____	_____
22		____	____	_____
23		____	____	_____
24		____	____	_____
25		____	____	_____
26		____	____	_____
27		____	____	_____
28		____	____	_____
29		____	____	_____
30		____	____	_____
31		RESERVED		(ERR 09)

3.10 SENSOR CURVE SELECTION

3.10.1 SENSOR ID Switch 4 Open (0)

The DRC-91C software interrogates the appropriate SENSOR ID switch (i.e., A or B) to determine which standard curve or Precision Option curve has been selected (Switches 5-8). The SENSOR ID switch functions are defined in Figure 2-3.

The first sixteen curves (00 through 15) in Table 3-3 can be selected from the SENSOR ID switches 5-8 with switch number 4 off.

3.10.1.1 Display of Accessed Curve

To determine which curve you are using is a simple matter for the DRC-91C. Select either the A or B input and depress and hold the LOCAL key. After approximately one second, the display will show the following format:

A 02
20-3

Since the HEATER % display is now blank, we know that SENSOR ID switch number 4 is off and the curve is being selected from the SENSOR ID Switches (5-8). The above example indicates that a 9220 card is installed in Input A and that the input is reading Curve 2, which from Table 3-2 we know is the CRV 10 for the DT-470 Series Sensors. Consequently, switches 4-8 for the A SENSOR ID are 00010.

Since the DRC-91C knows which type of input card is present for each input (assuming that two input cards were installed), it will not, for example, allow the selection of the platinum curve (Curve No. 03) for a diode input card. If Curve 03 is selected from the back panel SENSOR ID switch, the DRC-91C will default to the lowest curve number with the correct temperature coefficient, in this case, curve 00.

For the case of a platinum input card and no Precision Option curves present, the DRC-91C will select Curve Number 03, regardless of the settings for switches 5-8, unless, of course a Precision Option exists for a positive coefficient temperature sensor and that curve has been selected by the SENSOR ID.

This is true for any type of input card. If the SENSOR ID selects the wrong type of curve, the DRC-91C will default to the lowest order

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curve of the correct type. The input card type and curve number for each input is also displayed on Power Up for a fraction of a second.

Table 3-4. Position # versus Curve # Correlation Table-SENSOR ID Switch 4=1

REMOTE SENSOR ID	SNSRID Switch 45678	Internal Correlation Table INPUT A	INPUT B
*	*0010000	**A00** _____	B00 _____
01	10001	**A01** _____	B01 _____
02	10010	**A02** _____	B02 _____
03	10011	**A03** _____	B03 _____
04	10100	**A04** _____	B04 _____
05	10101	A05 _____	B05 _____
06	10110	A06 _____	B06 _____
07	10111	A07 _____	B07 _____
08	11000	A08 _____	B08 _____
09	11001	A09 _____	B09 _____
10	11010	A0A _____	B0A _____
11	11011	A0B _____	B0B _____
12	11100	A0C _____	B0C _____
13	11101	A0D _____	B0D _____
14	11110	A0E _____	B0E _____
15	11111	A0F _____	B0F _____
16		A10 _____	B20 _____
17		A11 _____	B21 _____
18		A12 _____	B22 _____
19		A13 _____	B23 _____
20		A14 _____	B24 _____
21		A15 _____	B25 _____
22		A16 _____	B26 _____
23		A17 _____	B27 _____
24		A18 _____	B28 _____
25		A19 _____	B29 _____
26		A1A _____	B2A _____
27		A1B _____	B2B _____
28		A1C _____	B2C _____
29		A1D _____	B2D _____
30		A1E _____	B2E _____
31		A1F ERR09	B1F ERR09

It is possible to store up to 31 curves total in the DRC-91C. These additional Precision Option Curves (25 possible), if present, can be accessed by means of the Position Number versus Curve Number Correlation Table. The first 10 Precision Options (Curves 06 through 15) can also be accessed through either SENSOR ID with Switch 4 open (0).

3.10.2 SENSOR ID Switch 4 Closed (1) - No REMOTE SENSOR ID Present

With no external Remote Position, i.e., REMOTE SENSOR ID reading 00, and SENSOR ID switch 4 closed (1), switches 5 through 8 give an equivalent sensor "position" in the Position # versus Curve # Correlation Table 3-4, Column 2.

It is therefore possible to assign any curve number (00 through 30) to any of 16 "positions" - [A00 through A0F] for the A SENSOR ID and [B00 through B0F] for the B SENSOR ID.

3.10.3 SENSOR ID Switch 4 Closed (1) - REMOTE SENSOR ID Present

Up to three 8084 or 8085 Scanners can be daisy-chained together to give 30 remote positions for either the A input or the B input of the DRC-91C. If the remote position is non-zero, then the correlation table of Table 3-4, column 1 is valid for positions 01 through 30. The differences from the SENSOR ID's is that the position can be changed remotely and 30 positions rather than 16 are available for one (but not both) of the inputs. Note that A00 (or B00) is available over the REMOTE SENSOR ID if the SENSOR ID switch is set at 10000. The DRC-91C is shipped from the factory with curve 02 stored in all positions of this table.

Caution

Do not set both SENSOR ID switch 4's to 1 since only one input should be tied to the REMOTE SENSOR ID and its position.

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3.10.4 Addition of 8229 Scanner Option

Adding the 8229 Scanner to Input A with Switch 4 closed (1) overrides the correlation Table for that input and switches 5678 of the A SENSOR ID. Scanner Inputs A0 through A4 now correspond to positions A00 through A04, which are indicated in Bold letters in Table 3-4. Consequently, different curves can be assigned to each of the five scanner inputs if desired.

3.10.5 Display of Accessed Position and Assigned Curve

By holding in the LOCAL key for more than one second, the Display and the Heater % windows will have the following format:

Display	Heater %
07 00 20-3	09

For the input chosen, switches 45678 are set as 10111 selecting position 7, the curve selected is curve 09. Either that curve does not exist or it is not a diode curve since the instrument is defaulting to the lowest number diode curve, 00. Since the Heater % display is not blank, we know that the SENSOR ID switches are indicating position and **not** curve number. The other possibility is that the REMOTE SENSOR ID is on position 7.

3.10.6 Sensor Curve assignment to Sensor Position

After selecting either the A or B input along with the selected position from the SENSOR ID, the REMOTE SENSOR ID or the position from the 8229 scanner option, the curve number associated with the selected position number is changed by depressing the LOCAL button for more than one second simultaneously with the ▲ or ▼ as desired to select the Sensor Curve. The current curve number selected is displayed in the Heater % window with the default curve number shown in the display window along with selected position.

Curves associated with positions 00 through 15 in Table 3-4 are changed as described above. Curves associated with positions 16-30 can only be changed over the IEEE-488 Bus (see Section 4.16.7).

3.11 CONTROL BLOCK

3.11.1 SET POINT

To change the Set Point numerically, pressing the ▲ or ▼ key increments or decrements the least significant digit, pressing the ▲▲ or ▼▼ key changes the third digit from the right and using the combination of the ▲▲ and ▲ keys or ▼▼ and ▼ keys alters the fourth digit from the right. If one of these keys is held down for over 1 second, the rate at which the set point changes is increased by a factor of five.

If in degrees celsius or degrees fahrenheit, the (+/-) button can be used to toggle the sign of the set point.

The set point is limited in temperature to the range of the curve stored in the instrument. Table 3-2 gives these limitations in kelvin for curves 00 through 04.

3.11.2 GAIN. Variable gain (proportional) allows adjustment of overall controller gain over a 1000 to 1 range. Maximum gain is full clockwise. Logarithmic scaling is used; Therefore a gain setting of x100 is approximately two-thirds of full rotation.

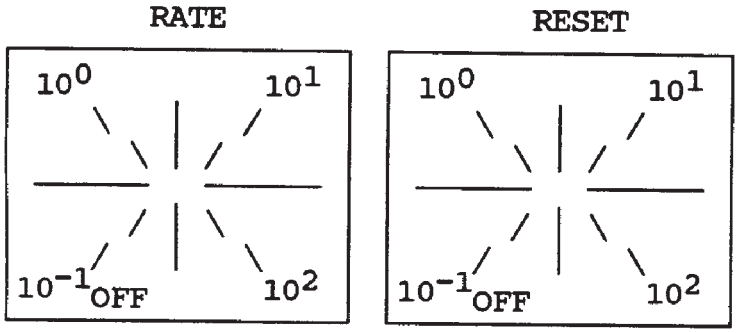
3.11.3 RATE. Adjusts rate time constant of differentiator. Effectively sets time constant between 1000 seconds and 1 second with full clockwise rotation representing the shortest time constant (or between 0.001 and 1 beat(s) per

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second [BPS]). For a discussion of beats per second and time constants, see the Application Note enclosed as an Appendix to this manual.

3.11.4 RESET. Adjusts reset (integral) time constant of integrator. Effectively sets time constant between 1000 seconds and 1 second with full clockwise rotation representing the shortest time constant.

Figure 3-3 Reset and Rate Times for 91C



SETTING-LOG%	TIME(SEC)	BPS
OFF	∞	0
0.1 (10^{-1})	1000	0.001
0.5	300	0.003
1. (10^0)	100	0.01
5.	30	0.03
10. (10^1)	10	0.1
50.	3	0.3
100. (10^2)	1	1.

3.11.5 HEATER %. Displays the magnitude of the heater power in percent of full scale. Full scale is defined as the product of the maximum heater current of one ampere squared times the heater resistance times the range setting. The DRC-91C Temperature Controller is shipped from the factory with the front panel meter indicating power. If the user prefers, he can change this to a current meter by turning on switch 6 of S7 (the eight station dip switch located at the rear center of the main board).

3.11.6 The HEATER POWER RANGE setting is determined by the Push Buttons directly below the HEATER POWER display. MAX corresponds to a 10^0 or 1 multiplier, while -1, -2 and -3 corresponds to a 10^{-1}, 10^{-2}, and 10^{-3} multiplier respectively. The OFF button turns off the output power independent of the set point and the control parameters.

NOTE. The DRC-91C is equipped with a current limit vernier on the rear panel which can limit the output current on the MAX scale between 0.33 and 1 ampere, dependent on setting. If your instrument will not deliver full power, this vernier may be set wrong or your load resistance may be too large and you are compliance voltage limited.

NOTE: On a range change, the DRC-91C ramps the GAIN to 0 and turns OFF the RESET and RATE prior to changing ranges. After the range is changed, the settings are returned to what they were prior to the range change. This protects the load from seeing the increase or decrease in range power as a step function.

3.12 LOCAL/REMOTE BLOCK

3.12.1 LOCAL. The LOCAL key is used to return the instrument from remote control by the IEEE-488 BUS or the RS-232C optional interface to front-panel control. When the LOCAL key is depressed and held down for more than one second, the display shows the curve information for the input indicated.

3.12.2 REMOTE

The REMOTE key is used to place the controller under remote control and to disable the front panel. When the REMOTE key is depressed for more than one second, the display shows the IEEE-488 address of the instrument.

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Figure 3-2. DRC-91C Temperature Controller
Rear Panel

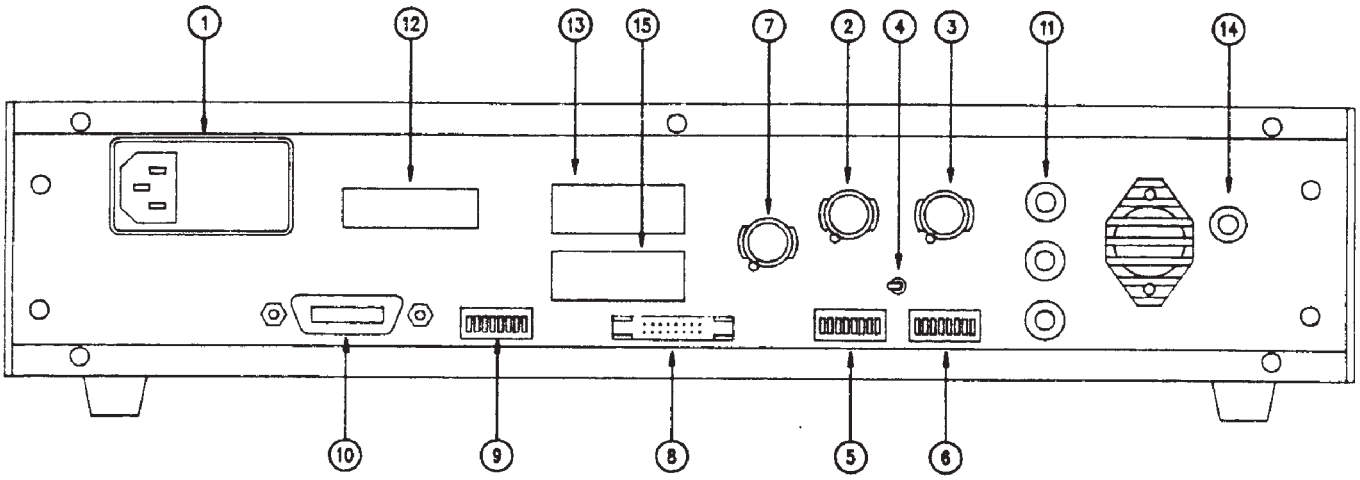


Figure 3-2. Model DRC-91C Cryogenic Thermometer Rear Panel Description

1. Line cord receptacle with fuse and voltage selection
2. Sensor INPUT A connector (J1)
3. Sensor INPUT B connector (J2)
4. CONTROL input selector switch
5. SENSOR A ID
6. SENSOR B ID
7. Monitors output of Sensor INPUT A and Sensor INPUT B buffered voltages and 8225 linear analog output option (J3)
8. REMOTE SENSOR ID (J5) - Position data for option only
9. IEEE-488 address switch
10. IEEE-488 connector (J4)
11. HEATER OUTPUT Power terminals (J6, J7, J8)
12. Optional interface access plate (J10) (8223 RS-232C Option)
13. Optional interface access plate (J9) (8229 Scanner Option)
14. MAX HEATER POWER Limit
15. Optional connector access plate (J11)

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REAR PANEL DESCRIPTION

3.13 REMOTE SENSOR ID

The REMOTE SENSOR ID connector receives position data from a Model 8084 or Model 8085 Sensor Scanner or a Model SW-10A ten-position switch. This input allows the user to automatically call up different curves for different sensor/channel positions when the instrument is used with either remote switch (see Section 3.10.2). The Parallel input data format is given in Table 3-5.

Table 3-5. Pin Assignments for the J5 REMOTE SENSOR ID Connector

J5 CONNECTOR Pin Assignments

15	13	11	**9**	7	5	3	**1**
16	**14**	**12**	**10**	**8**	**6**	**4**	**2**

ONLY BOLD PINS USED

J5	Function
1	+5
2	RESERVED
4	Bit 3
6	Bit 2
8	Bit 1
10	Bit 0 (LSB)
12	DIGITAL GROUND
14	Bit 4 (MSB)
16	RESERVED

The user may supply to the REMOTE SENSOR ID his own parallel BCD 5 volt signal referred to the DIGITAL GROUND on pin 12.

3.14 HEATER CURRENT LIMIT

The DRC-91C Temperature Controller has a current drive output with a maximum current rating of one ampere unless the optional 1.5 ampere output (W60) was ordered, or the current-limiting vernier has been set at a lower value.

With the current-limiting vernier on the back of the instrument, the output current on the MAX scale can be limited anywhere between 1 ampere and the maximum current for the 10^{-1} scale (330 mA). This allows the user to limit the maximum power to between 25 watts and 2.5 watts, dependent on his requirements.

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S E C T I O N I V

R E M O T E O P E R A T I O N

4-1. IEEE-488 INTERFACE

The IEEE-488 INTERFACE is an instrumentation bus with hardware and programming standards designed to simplify instrument interfacing. The IEEE-488 INTERFACE of the DRC-91C fully complies with the IEEE-488-1978 standard and incorporates the functional, electrical and mechanical specifications of the standard. It also follows the supplement to that standard titled "Code and Format Conventions for use with IEEE Standard 488-1978". This section contains general bus information, Model DRC-91C interface capabilities, addressing and the programming instructions that control the DRC-91C functions.

4.2 GENERAL IEEE SPECIFICATIONS AND OPERATION

The following discussion covers the general operation of the IEEE-488 interface. For a more detailed description of signal level and interaction, refer to the IEEE Standard 488-1978 publication "IEEE Standard Digital Interface for Programmable Instrumentation".

All instruments on the interface bus must be able to perform one or more of the interface functions of TALKER, LISTENER, or BUS CONTROLLER. A TALKER transmits data onto the bus to other devices. A LISTENER receives data from other devices through the bus. The BUS CONTROLLER designates to the devices on the bus which function to perform.

The DRC-91C performs the functions of TALKER and LISTENER but cannot be a BUS CONTROLLER. The BUS CONTROLLER is your Digital Computer which tells the DRC-91C which functions to perform.

The interface works on a party line basis with all devices on the bus connected in parallel. All the active circuitry of the bus is contained within the individual devices with the cable connecting all the devices in parallel to allow the transfer of data between all devices on the bus.

The following discussion of the signal lines on the bus are for general information. Your digital computer handles these lines through its circuitry and software. The user need never concern himself with these lines or signals, however, knowledge of their purpose will help one to understand the operation of the Interface.

There are 16 signal lines contained on the bus:

1. 8 Data Lines
2. 3 Transfer Control Lines
3. 5 General Interface Management Lines

The data lines consist of 8 signal lines that carry data in a bit parallel, byte serial format. These lines carry universal commands, addresses, program data, measurement data and status to all the devices on the bus.

The three Transfer Control lines and the five Interface Management lines are asserted low which means that they carry out their function when pulled low. When the voltage on one of these lines is high then the line is not asserted and the function is inhibited. The General Interface Management Lines IFC (Interface Clear), ATN (Attention), REN (Remote Enable), EOI (End or Identify) and the SRQ (Service request) manage the bus and control

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the orderly flow of commands on the bus. The IFC, ATN, and REN management lines are issued only by the BUS CONTROLLER.

The IFC (Interface Clear) management line is pulled low by the BUS CONTROLLER to clear the interface.

The ATN (Attention) line is the management line used by the BUS CONTROLLER to get the attention of the devices on the bus. The BUS CONTROLLER does this by pulling the ATN line low and sending talk or listen addresses on the DATA lines. When the ATN line is low, all devices listen to the DATA lines. When the ATN line goes high, then the devices addressed to send or receive data (for example, the DRC-91C) perform their functions while all others ignore the DATA lines.

The REN (Remote Enable) management line is pulled low by the BUS CONTROLLER to enable a device (the DRC-91C) to perform the functions of TALKER or LISTENER.

The EOI (End or Identify) management line is pulled low by the BUS CONTROLLER or a TALKER (the DRC-91C) to indicate the end of a multiple byte transfer sequence. Also the EOI line along with the ATN line are pulled low by the BUS CONTROLLER to execute a polling sequence.

The SRQ (Service Request) management line is pulled low by a device (for example, the DRC-91C) to signal the BUS CONTROLLER that a process is completed, a limit, overload or error encountered. In some cases this means that service is required.

Transfer of the information on the data lines is accomplished through the use of the three signal lines: DAV (Data Valid), NRFD (Not Ready for Data) and NDAC (Not Data Accepted). Signals on these lines operate in an interlocking handshake mode. The two signal lines, NRFD and NDAC, are each connected in a logical AND to all devices connected to the bus.

The DAV line is pulled low by the TALKER after it places its data on the DATA lines. This tells the LISTENERS that information on the DATA lines is valid. A LISTENER holds the NRFD line low to indicate it is not ready. Since these lines are connected in a logical AND to all other devices, then the NRFD line will not go high until all of the devices are ready.

The NDAC line is pulled low by a LISTENER while it is receiving the DATA and lets it go high when the DATA is captured. Since the NDAC lines of all devices are connected in a logical AND, the NDAC line will not go high until all devices have received the DATA.

4.3 INTERFACE CAPABILITIES

The IEEE-488 Interface capabilities of the Model DRC-91C are listed in Table 4-1 as well as in mnemonic format on the instrument's rear panel.

Table 4-1. Interface Functions.

Mnemonic	Interface Function Name
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T5	Basic TALKER, serial poll capability, Talk only,Unaddressed to Talk if addressed to Listen
L4	Basic LISTENER, Unaddressed to Listen if addressed to Talk
SR1	Service Request capability
RL1	Complete Remote/Local capablty
PP0	No Parallel Poll capability
DC1	Full Device Clear capability
DT0	No Device Trigger capability
C0	No System Controller capablty
E1	Open Collector Electronics

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4.4 DRC-91C IEEE-488 ADDRESS SWITCH

The IEEE-488 Address Switch is located on the instrument's rear panel (see Figure 3-2, Key No. 9). Refer to Figure 4-1 for the following discussion.

4.4.1 Terminating Characters (delimiters)

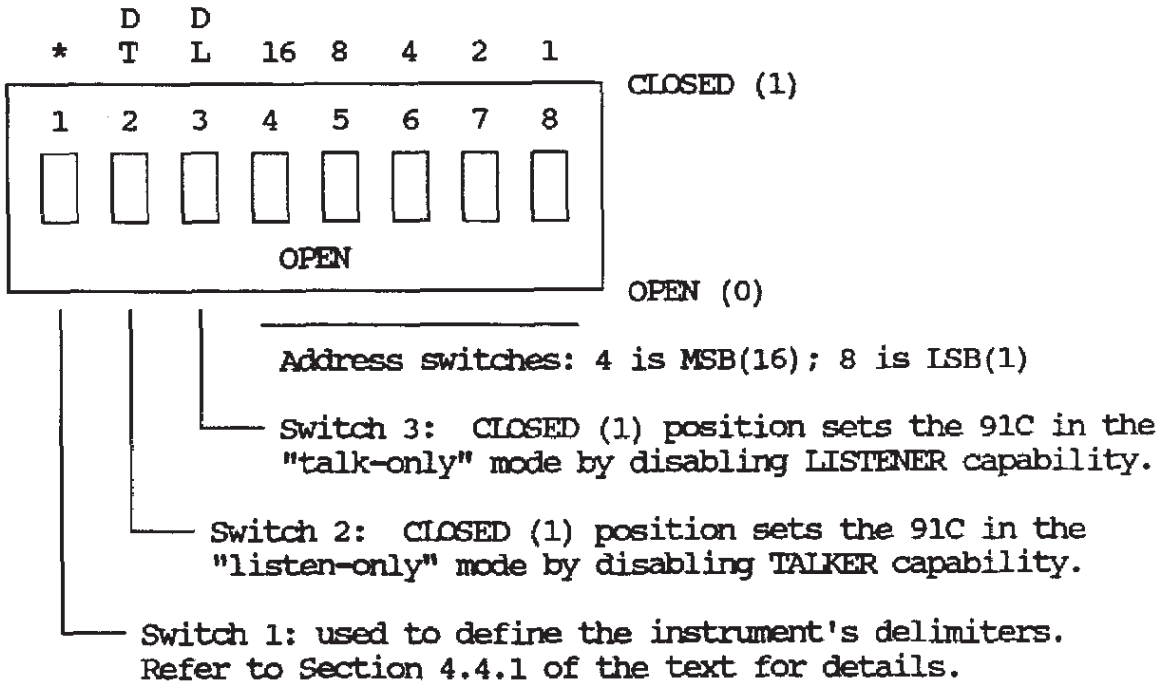
Switch 1 (*) is used to define the instrument's terminating characters (delimiters). The OPEN (0) position selects the ASCII characters CR and LF (Carriage Return and Line Feed) as the terminating characters for input and output data. For the output data from the DRC-91C back to the computer over the Bus, the EOI line is set by the DRC-91C with the output of the Line Feed (LF). This setting (0) for switch 1 is the setting for all Hewlett-Packard computers.

When Switch 1 (*) is CLOSED (1), a variable terminating character format may be selected for the input and output data. In this configuration the power-up (default) terminating characters are LF and CR with the EOI line being set with the output of the Carriage Return (CR). However, the two terminating characters can be changed via input data to the DRC-91C as detailed in Table 4-6. If the terminating characters are changed by the user, these are only in effect until the instrument is turned off.

4.4.2 TALKER and/or LISTENER Configuration

Since the DRC-91C is both a TALKER and a LISTENER, normally switches two and three should both be OPEN (0). These switches are usually of use when one instrument is a TALKER and another instrument is a LISTENER and they are to share the same address.

Figure 4-1. IEEE-488 Address Switch for the DRC-91C



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Table 4-2. Allowable Address Codes for the DRC-91C
(Factory preset address is decimal 12)

ASCII Code Character		Bit 2*	3	Address Switches 4	5	6	7	8	5-bit Decimal Code	
Listen	Talk	B7	B6	B5	B4	B3	B2	B1		
SP	@	0	0	0	0	0	0	0	00	
!	A	0	0	0	0	0	0	1	01	
"	B	0	0	0	0	0	1	0	02	
#	C	0	0	0	0	0	1	1	03	
$	D	0	0	0	0	1	0	0	04	
%	E	0	0	0	0	1	0	1	05	
&	F	0	0	0	0	1	1	0	06	Factory preset address
'	G	0	0	0	0	1	1	1	07	
(	H	0	0	0	1	0	0	0	08	
)	I	0	0	0	1	0	0	1	09	
*	J	0	0	0	1	0	1	0	10	
+	K	0	0	0	1	0	1	1	11	
,	L	0	0	0	1	1	0	0	12	
-	M	0	0	0	1	1	0	1	13	
.	N	0	0	0	1	1	1	0	14	
/	O	0	0	0	1	1	1	1	15	
0	P	0	0	1	0	0	0	0	16	
1	Q	0	0	1	0	0	0	1	17	
2	R	0	0	1	0	0	1	0	18	
3	S	0	0	1	0	0	1	1	19	
4	T	0	0	1	0	1	0	0	20	
5	U	0	0	1	0	1	0	1	21	
6	V	0	0	1	0	1	1	0	22	
7	W	0	0	1	0	1	1	1	23	
8	X	0	0	1	1	0	0	0	24	
9	Y	0	0	1	1	0	0	1	25	
:	Z	0	0	1	1	0	1	0	26	
;	[	0	0	1	1	0	1	1	27	
<	\	0	0	1	1	1	0	0	28	
=	]	0	0	1	1	1	0	1	29	
>	^	0	0	1	1	1	1	0	30	

* Only the first five bits of the binary code are listed. These bits are the same for the TALK and LISTEN address. The sixth and seventh bits (BUS CONTROLLER originated) determine whether the instrument is being addressed to TALK or LISTEN.

Function	Bit 2	3
TALK	1	0
LISTEN	0	1

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4.4.3 The IEEE-488 INTERFACE bus address for the DRC-91C is set by switches 4 through 8 which are reserved for the address selection. Switch 4 is the most significant bit (MSB[=16]) and 8 is the least significant bit (LSB[=1]).

The factory preset address of this instrument is 12 (see Table 4-2). Address switch numbers 5 and 6 should be CLOSED (1) which will result in the Address Switch having a setting of 00001100 or 10001100 dependent on the requirements for the delimiters.

4.5 IEEE-488 BUS COMMANDS

4.5.1 A Uniline Command

A Uniline Command (Message) is a command which results in a single signal line being asserted. The DRC-91C recognizes two of these messages from the BUS CONTROLLER, REN and IFC (See Table 4-3). When the BUS CONTROLLER executes the appropriate software code the effect is to pull the corresponding Interface Management line low. For example, when the software command REMOTE712 is executed by the HP86 digital computer, the management line REN is pulled low and the listen address 12 issued to signal the instrument having address 12 (DRC-91C) to go into the remote mode.

The SRQ is a uniline command asserted by the DRC-91C when it wishes to signal the BUS CONTROLLER. The BUS CONTROLLER will in turn use the Addressed command SPE (Serial Poll Enable) described below to interrogate the DRC-91C about the reason or reasons for the communication.

4.5.2 The Universal Commands shown in Table 4-3 are those multiline commands that address all devices on the bus. A multiline command involve a group of signal lines. All devices equipped to implement such commands will do so simultaneously when the command is transmitted. As with all multiline commands, these commands are transmitted with ATN line asserted (low). There are two Universal commands recognized by the DRC-91C, LLO (Local Lockout) and DCL (Device Clear).
LLO (Local LOckout)-LLO is sent to instruments to lock out (prevent the use of) their front panel controls.

DCL (Device CLear)-DCL is used to return the DRC-91C to the power-up conditions.

4.5.3 The Addressed Commands shown in Table 4-3 are multiline commands that must include the DRC-91C listen address before it will respond to the command in question. Note that only the addressed device will respond to these commands. The DRC-91C recognizes three of the Addressed commands; SDC (Selective Device Clear), GTL (Go To Local), and SPE (Serial Poll Enable).

SDC (Selective Device Clear)-The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local)-The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

SPE (Serial Poll Enable), SPD (Serial Poll Disable) - Serial polling is used to obtain the SRQ Status Register. The Status Register contains important operational information from the unit requesting service. The SPD command ends the polling sequence.

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4.5.4 The Unaddress Commands

The Unaddress Commands in Table 4-3 are used by the BUS CONTROLLER to remove any TALKERS or LISTENERS from the bus. The ATN line is asserted (low) when these commands are asserted.

UNL (Unlisten) - LISTENERS are placed in the listener idle state by the UNL command.

UNT (Untalk) - Previous TALKERS will be placed in the TALKER idle state by the UNT command.

Table 4-3 summarizes the IEEE-488 Bus Commands acknowledged by the DRC-91C.

4.5.5 Device-Dependent Commands

The DRC-91C supports a variety of device-dependent commands to allow the user to program the instrument remotely from a digital computer and to transfer measurements to the computer. These commands are sent from the computer (BUS CONTROLLER) to the DRC-91C as one or more ASCII characters that tell the device to perform a specific function. For example, the command sequence F0K sent by the BUS CONTROLLER to the DRC-91C is used to select kelvin as the set point units. The IEEE-488 bus actually treats these commands as data in that ATN is high when these device-dependent commands are transmitted.

4.5.6 TALKER and LISTENER Status

For the DRC-91C to be a LISTENER, it has to be in REMOTE and can be returned to LOCAL with the M0 (device-dependent) command or GTL (addressed) command as desired. For most, but not all computers, the DRC-91C as a TALKER does not have to be placed in REMOTE operation, but can remain under LOCAL control. This allows the user to collect data while maintaining front panel control. The HP computers will allow this mode of operation. If your computer automatically places the DRC-91C in remote and keeps it in remote after the transmission is over, sending the additional command M0 after the request for data will return the DRC-91C to LOCAL.

Table 4-3. IEEE-488 Bus Commands

Message Mnemonic	HP9825A Command	HP86 Command	IEEE-488 Bus Format
Uniline Commands			
Remote/REN	rem712	REMOTE712	?U*
Interface Clear/IFC			(IFC)
Universal Commands			
Local Lock Out/LLO	llo7	LOCAL LOCKOUT 7	?U(LLO)
Device Clear/DCL	clr7	CLEAR7	?U(DCL)
Addressed Command			
Selected Device Clear/SDC	clr712	CLEAR712	?U,(SDC)
Go to Local/GTL	lcl712	LOCAL712	?U,(GTL)
Serial Poll Enable/SPE	rds(712)→S	S=SPOLL(712)	?U,(SPE)
Unaddress Commands			
Unlisten/UNL			?
Untalk/UNT			-

* U is the controller (computer) Talk Address (Address 21)

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4.6 PROGRAMMING INSTRUCTIONS

The following discussion references the DRC-91C at address 12. The allowable address codes are given in Table 4-2. Therefore, its Talk ASCII Code is "L" and its LISTENER ASCII Code is "," (comma). The controller referred to in the following discussion is the BUS CONTROLLER and is normally a digital computer. It should not be confused with the temperature controller on the bus (DRC-91C). Set the IEEE Address of the DRC-91C to 12 by making Switches 5 and 6 CLOSED (1), 4, 7 and 8 (OPEN) (0) and make sure Switch 1 is OPEN (0) to select (CR)(LF) as the terminating characters. Note that this should be done prior to turning on the instrument since the DRC-91C updates the IEEE address on power-up only. Confirm that the address selected is correct by holding in the REMOTE button for longer than one second and observe the IEEE address on the front panel display as follows:

-91C-
Add12

Table 4-4. DRC-91C Command Summary of Instrument Setup

Summary of Input Command Formats. Choices of the commands are:		
Table 4-6	Interface Setup Commands:	
	ZN_1	Selects EOI status
	MN_1	Selects Remote Interface Mode
	TN_1	Changes terminating Characters
	C	"Clear" Command
Table 4-7	Instrument Setup Commands:	
	$F0C_1$	Select Control Units
	$F1AC_1$,$F1BC_1$	Select A or B Input Units
	$F2C_1N_1$	Select Display Sensor
	$F3AN_1$,$F3BN_1$	Select the A or B Input Resolution
Table 4-9 4-10	Control Setup Commands:	
	S,etc	Set Point Input
	PN_1N_2,etc.	Proportional (GAIN)
	IN_1N_2,etc.	Integral (RESET)
	DN_1N_2,etc.	Derivative (RATE)
	RN_1	Heater Range
Table 4-11 4-10	Scanner Setup and Selection Commands:	
	$YAN_1N_2N_3$	Set the Scanner channel dwell time
	or $YB0N_2N_3$	
	$YCAC_1$	Select Channel AC_1 (A0 thru A4).
	YS	Enable the (S)CAN function.
	YH	Disable, or (H)old, the SCAN.
Table 4-13	Status Register Mask Command:	
	QC_1C_2	Set the Status Register mask

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4.6.1 Commands and Requests

The device-dependent commands to program the DRC-91C are given in Table 4-4. The 91C must be addressed as a "LISTENER" to receive any instruction or string of instructions from the Command list.

The DRC-91C input data format does not require a set number or set sequence of Commands to implement proper instrument set-up. These Commands are processed only after the terminators [TERM1][TERM2] are sent across the bus. The listing and explanation of the 91C commands are summarized in Table 4-4. There are commands for Interface Setup, Instrument Setup, Control Setup, Scanner Setup and Status Register.

The Output Statement Requests are sent by the BUS CONTROLLER to the DRC-91C to tell the 91C what data to output when data output is requested. These requests are listed in Table 4-5 and the data formats are described in detail in the following tables as well as the adjoining text associated with those tables.

4.7 INSTRUMENT SETUP COMMANDS AND REQUESTS

4.7.1 EOI Status - The ZN_1 Command

When EOI (end or identify) is enabled ("Z0"; Table 4-6), the EOI line is set active concurrent with the last byte of a transfer. Use of EOI identifies the last byte allowing for variable length data transmissions. EOI can be disabled ("Z1"; Table 4-6).

4.7.2 Interface Mode - the MN_1 Command

4.7.2.1 Local - This message ["M0"; Table 4-6] clears the remote operation of the DRC-91C and enables front panel operation. Pressing the front panel LOCAL button also sets the instrument to local, provided the button has not been disabled by the Local Lockout Message (see Section 4.7.2.3).

See Section 4.5.6 for a discussion of the DRC-91C under local operation while acting as a TALKER.

Table 4-5. DRC-91C Summary of Output Requests

Table	Request	Output
4-6	W2 WI	Interface Status Input and Option Card Data
4-7	W1	Sample, Control,A and B Input Information
4-9	WP	Set Point Data
4-10	W3	Control Data (Gain, Reset, etc.)
4-11	WY	Scan Information
4-13	WQ	Service Request Data
4-15	WS WC W0	Display Sensor Data Control Sensor Data Display, Control Sensors and Set Point Data

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Table 4-6. DRC-91C Interface Setup Commands and Request Status

Command	Functional Description
ZN_1[a]	Selects IEEE EOI status. Forms of the command are Z0 and Z1. When N_1 is: — EOI Status is: 0 — EOI line is set/accepted on last character input or output. 1 — EOI line is not set on last character output or acknowledged on input.
MN_1	Selects Remote Interface mode. Forms of the command are M0, M1 and M2. When N_1 is: — Mode is: 0 — Local 1 — Remote 2 — Remote with Local Lockout
TN_1	Changes terminating characters (when IEEE Address Switch #1 is CLOSED [1]). Forms of the command are T0, T1, T2 and T3. When N_1 is: — Terminators are:[b] 0 — (CR)(END[c] ^ LF) [also with Switch OPEN] 1 — (LF)(END ^ CR) [default, unless changed] 2 — (END ^ LF) 3 — (END ^ DAB[d])
C	"Clear" command, returns unit to power up state (Restart).

****

Request	Functional Description
W2	Interface Status - ZN_1,MN_2,TN_3 8 Characters plus up to 2 Terminators where: ZN_1 is EOI status MN_2 is Mode status TN_3 is Terminator status
WI	Input and Option Card Data[e] A-$C_1C_2C_3C_4C_5C_6C_7$,B-$C_8C_9C_{10}C_{11}C_{12}C_{13}C_{14}$, 1-$C_{15}C_{16}C_{17}C_{18}$,2-$C_{19}C_{20}C_{21}C_{22}$,3-$C_{23}C_{24}C_{25}C_{26}$ 40 Characters plus up to 2 Terminators where: C_1-C_7 is the A Input Card. C_8-C_{14} is the B Input Card. C_{15}-C_{18} is the Option 1 Present. C_{19}-C_{22} is the Option 2 Present. C_{23}-C_{26} is the Option 3 Present.

a) N_i corresponds to a numeric value (0 - 9)
b) The AND symbol (^) is used to indicate messages sent concurrently.
c) END = EOI; d) DAB = last data byte
e) C_i corresponds to an alphanumeric (0 - F)

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4.7.2.2 Remote - The DRC-91C is in the local front panel mode when first turned on. A remote message ["M1"; see Table 4-6] allows the 91C to be controlled over the IEEE-488 interface. In Remote, the front panel controls are disabled (except the LOCAL button) and are then controllable over the IEEE Bus. The instrument's initial set up is determined by the front panel settings at the time when the instrument is placed into Remote. The DRC-91C may also be placed into remote by pressing the REMOTE button on the front panel or addressed to talk by the BUS CONTROLLER.

4.7.2.3 Local Lockout - This message ["M2"; Table 4-6] disables the DRC-91C's Local Front Panel controls, including the LOCAL button. The message is in effect until the message is cleared over the Bus or power is cycled.

Many IEEE-488 cards (for IBM PC's) automatically place addressed instruments into Local Lockout. To be able to place the DRC-91C into Remote without Local Lockout the user may need to reconfigure his IEEE-488 card.

4.7.3 Terminating Characters - The TN_1 Command

Terminating characters ["T0", "T1", "T2" and "T3"; Table 4-6] are used to indicate the end of a record. Record terminators are used when the unit has completed its message transfer. Switch 1 of the IEEE address defines the terminator status. If switch 1 is OPEN (0) the terminator status is defined as "T0" [(CR)(LF)] and terminator status can not be changed over the interface. When switch 1 is CLOSED (1) the terminator status is defined as "T1" [(LF))(CR)] and the status can be changed using the "T0", "T1", "T2" or "T3" commands.

4.7.4 Clear

The (C)lear Message [see Table 4-6] sets the DRC-91C to the turn-on state. This action is similar to turning the instrument OFF and then turning it back ON, except that it occurs in milliseconds, rather than seconds and the DRC-91C does not go through the power-up display sequence.

4.7.5 The "W2" Data String

For the case of W2, the data string would have the following format:

Z0,M2,T1[TERM1][TERM2]

where the Z0, M2 and T1 are defined in Table 4-6.

4.7.6 The "WI" Data String

This Data String gives the input cards present (9210, 9220, 9215, 9305, 9317C or 9318C) in Input A and B, whether the analog option is presentand the interface option is present. A typical data string would be:

A-9220-P2,B-9318C,1-8225,2-8223,
3-8229

which indicates 9220 card configured as a 100 ohm platinum input for Input A; a germanium/carbon glass input for Input B; a linear analog option in Option Slot 1; a RS-232C option in Option Slot 2 and a Scanner Card option in Option Slot 3.

4.8 SELECTION OF SET POINT UNITS, INPUT UNITS, DISPLAY SENSOR, AND RESOLUTION (Table 4-7)

4.8.1 Units for Set Point - The FOC_1 Command

The FOC_1 command sets the temperature or sensor units for the set point. Sensor units (volts, ohms or nanofarads) are selected automatically by the input card type.

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Consequently, the command for selecting sensor units for control is F0S. Temperature units are selected with the same command with K, C, or F substituted for S. Note that only one choice of sensor units (volts, ohms or nanofarads) is available which is dependent on the control input and the input card type and configuration selected.

4.8.2 Units for A and B Inputs - The $F1AC_1$ and $F1BC_1$ Commands

The A input units and the B input units may be set independently by the commands $F1AC_1$ and $F1BC_1$, respectively. The units are tied to the input and not to the display. Sensor units are selected automatically by the input card type. Consequently, the command for selecting sensor units is F1AS (or F1BS). Temperature units are selected with the same command with K, C, or F substituted for S for either input.

4.8.3 Display Sensor Selection - The $F2C_1N_1$ Command

The sensor to be selected for display can be changed by the $F2C_1N_1$ command. This command is important with a scanner card because it chooses which sensor on Input A will be read over the bus when data is output from the instrument.

4.8.4 Resolution for A and B Inputs- The $F3AN_1$ and $F3BN_1$ Commands

The resolution for the A input and the B input can be set independently with the $F3AN_1$ and $F3BN_1$ commands. The resolution is tied to the A and B inputs and **not** to the display. The quantity N_1 is a number 0 through 4 where

0	for a resolution of	xxx.
1	for a resolution of	xxx.x
2	for a resolution of	xxx.xx
3	for a resolution of	xx.xxx
4	for a resolution of	x.xxxx

4.8.5 The A and B SENSOR ID Information - The AC_1C_2 and BC_1C_2 Commands

The purpose of this command is to select Filtering of the A and B input, whether the Remote Position Data is used to establish the curve numbers, the Temperature Coefficient sign for the 9215 card, and whether or not the thermal correction is desired on the 9317C/9318C cards.

The information for these commands is sent to the DRC-91C to set the functional parameters as described in Table 4-7.

Table 4-7 defines the AC_1C_2 and BC_1C_2 definitions as independent functions. If multiple functions are to be selected, the character equivalents are additive (see examples below, which are given as SENSOR A ID's - they pertain to SENSOR B ID's as well).

A20 - Select Sensor Curve02 to be used to determine temperature.

A22 - Enable digital filtering and select Sensor Curve 02 to be used to determine temperature.

A28 - Enables the REMOTE SENSOR ID. If the remote position data is 0, then the sensor curve reverts to the curve in A00 (or B00) rather than being selected from the REMOTE SENSOR ID Table.

A2A - Enable digital filtering in addition to the A28 description.

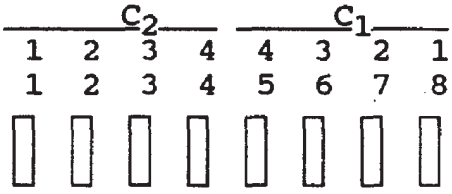
4.8.6 The SENSOR ID on Return to Local

When the DRC-91C is returned to local, the SENSOR ID's on the back panel are read and data entered over the IEEE-488 Bus using the commands AC_1C_2 or BC_1C_2 is lost.

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Table 4-7. DRC-91C Command Summary for Instrument Setup

<table>
<tr><th>Command</th><th>Functional Description</th></tr>
<tr><td colspan="2">Selection of Units, Sensors, Resolution, and Deviation</td></tr>
<tr><td>F0C_1</td><td>Function 0 - Select Set Point (Control) Units. Forms of the command are F0K (kelvin), F0C (celsius), F0F (fahrenheit), and F0S for Sensor Units in volts, ohms or nanofarads.</td></tr>
<tr><td>F1AC_1
or F1BC_1</td><td>Function 1 - Select the A or B Input Units. Forms of the command are F1K (kelvin), F1C (celsius), F1F (fahrenheit), and F1S for Sensor Units in volts, ohms or nanofarads.</td></tr>
<tr><td>F2C_1N_1</td><td>Function 2 - Select Display Sensor (Input A or Input B). Forms of the command are F2A0, F2A1*, F2A2*, F2A3*, F2SA4* and F2SB (or F2SB0). * With 8229 Scanner Card Only.</td></tr>
<tr><td>F3AN_1
or
F3BN_1</td><td>Function 3 - Select the A or B Input Resolution. N_1 is 0 (xxx.), 1 (xxx.x), 2 (xxx.xx), 3 (xx.xxx) or 4 (x.xxxx). Forms of the command are F3A0 (or F3B0), F3A1 (or F3B1), etc.</td></tr>
<tr><td>AC_1C_2
or
BC_1C_2</td><td>Input A ID and B ID. C_1C_2 are 00 thru FF. Forms of the command are A00 thru AFF. C_1 ranges between 0 and F. If C_2 is between 0 and 7, then C_1 selects the Sensor Curve number 00(0) thru 15(F). If C_2 is between 8 and F, then C_1 corresponds to a Remote Position between 0 and F.


<table>
<tr><th>C_1</th><th colspan="4">C_2</th></tr>
<tr><th>Curve # or Remote Position</th><th>Select Curve # (0) or Remote Position (8)</th><th>9317C/9218C Card Thermal Correction</th><th>Digital Filtering</th><th>9215 Card Temperature Coefficient</th></tr>
<tr><td>0 to F</td><td>0 or 8</td><td>OFF (0)</td><td>OFF (0)</td><td>+ (0)</td></tr>
<tr><td>"</td><td>1 or 9</td><td>OFF (0)</td><td>OFF (0)</td><td>- (1)</td></tr>
<tr><td>"</td><td>2 or A</td><td>OFF (0)</td><td>ON (2)</td><td>+ (0)</td></tr>
<tr><td>"</td><td>3 or B</td><td>OFF (0)</td><td>ON (2)</td><td>- (1)</td></tr>
<tr><td>"</td><td>4 or C</td><td>ON (4)</td><td>OFF (0)</td><td>+ (0)</td></tr>
<tr><td>"</td><td>5 or D</td><td>ON (4)</td><td>OFF (0)</td><td>- (1)</td></tr>
<tr><td>"</td><td>6 or E</td><td>ON (4)</td><td>ON (2)</td><td>+ (0)</td></tr>
<tr><td>"</td><td>7 or F</td><td>ON (4)</td><td>ON (2)</td><td>- (1)</td></tr>
</table>
</td></tr>
</table>

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Table 4-8. DRC-91C Output Request Summary for Instrument Setup

****

Request	Functional Description
W1	A and B Input Information $C_1C_2,C_3C_4,C_5,C_6C_7,AC_8C_9,N_1N_2,N_3,C_{10},BC_{11}C_{12},N_4N_5,N_6,C_{13}$ 32 characters plus up to 2 terminators where: C_1C_2 is the Display Sensor A0, A1, A2, A3, A4 or B0. C_3C_4 is the Control Sensor A0, A1, A2, A3, A4 or B0. C_5 is the Set Point Units K, C, F, V, N or R. C_6C_7 is the Remote Position (00 through 1F). C_8C_9 is the A ID (00 through FF). N_1N_2 is the A curve number (00 through 31). N_3 is the A Input Resolution 0 (xxx) to 4 (x.xxxx) C_{10} is the A Display Units (K, C, F, V, N or R). $C_{11}C_{12}$ is the B ID (00 through FF). N_4N_5 is the B Curve Number (00 through 31). N_6 is the B Input Resolution 0 (xxx) to 4 (x.xxxx) C_{13} is the B Input Units (K, C, F, V, N or R).

4.8.7 The "W1" Data String

This Data String gives the Display Sensor, Control Sensor, Set Point Units, Remote Position; the A ID, A curve number, A display resolution and units; the B ID, B curve number and the B display resolution and units. The data string will have the following format:

A0,B0,K,00,A20,02,3,K,B42,04,2,K

The above string indicates that the Display Sensor is A0; the Control Sensor is B0; set point is in kelvin units; the remote position is off; the SENSOR A ID indicates that the Digital Filtering for this channel is ON and the curve assigned is 4; the curve being used is also 4; B resolution is 10mK; B units are also in kelvin.

Both channels are using the DT-470 "Curve 10", the difference is that INPUT A is set for an upper limit of 325K and INPUT B is set with an upper limit of 475K.

4.9 THE CONTROL COMMANDS

4.9.1 The Set Point Value - The S Command

The set point is sent from the controller to the DRC-91C in a free field format of which examples are given in Table 4-9. Note that the sign only has to be present if negative celsius or fahrenheit settings are desired. Although the limits on the input range above the values possible for the various sensors, the set point is limited by the input card present as shown in the table. Note that the temperature limit can be different for the DT-470 depending on whether curve number 02 (324.9K) or curve number 04 (474.9K) has been selected. If a number above the limitation for the card is entered, the set point is set to the upper temperature limit. Also note that an S sent by itself to the 91C sets the set point to 0 kelvin (or its equivalent in the units chosen) which will result in shutting down the heater

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output stage of the temperature controller.

Note: Although limitations on the range of the set point are set within the software when in temperature units; these limits are not possible for sensor units due to the different characteristics for each sensor.

Since the set point is soft, the transition from REMOTE to LOCAL does not result in a change in the set point.

4.9.2 The "WP" Request Data String

This request is a subset of the "WO" command; the "WP" command giving the set point value by itself.

Table 4-9. DRC-91C Command/Request Summary for Setpoint Setup

Command	Functional Description
S or SN_1 or $SN_1.N_2$ or SN_1N_2 or $SN_1N_2.N_3$ or $SN_1N_2N_3.N_4$ or $SN_1.N_2N_3$ etc. or ( )SN_1 or ( )$SN_1.N_2$ or ( )SN_1N_2 or ( )$SN_1N_2.N_3$ etc.	Set Point Input. The decimal point is "FREE FIELD" and its allowable position depends on the control units. Limits are Units — Range K: 0 through 999.9 C,F: -999.9 through 999.9 V: 0.0000 through 9.9999 R: 0 through 99999 N: 0 through 99.999 or 999.99 The Set Point is limited based on input card and Sensor. Lower limit is 0 K (-273.1 °C or -459.6 °F).

Input Card	Sensor Type	Upper Set Point Limit K	°C	°F	Sensor Units
9210/20-3	DT-470, DT-500	324.9	51.7	125.1	2.9999 volt
9210/20-6	TG-100,TG-120	"	"	"	6.5535 volt
9317C	Germanium/Carbon Glass	"	"	"	9999.9 ohms
9318C	Germanium/Carbon Glass	"	"	"	99999 ohms
9215-15	CS-400,CS-501	N/A	N/A	N/A	29.999 nF
9215-150	CS-401,CS-501	N/A	N/A	N/A	149.99 nF
9210/20-3	DT-470	474.9	201.7	395.1	2.9999 volt
9220-P2	PT-100 Series	999.9	526.7	980.1	299.99 ohms
9220-P3	PT-1000 Series	"	"	"	2999.9 ohms
9220-R1	Rhodium-iron	"	"	"	99.999 ohms

****

Request	Output of Instrument Data
WP	Set Point Data - ( )$N_{11}N_{12}N_{13}$(.)$N_{14}N_{15}$( ) 8 Characters plus up to 2 terminators where the N_{11}-N_{15} variations are the same as for WO (see Table 4-15).

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4.9.3 Setting the GAIN (Proportional) - The P Command

The gain is a multiplier between 0.1 and 99., a range of 990, i.e., 99./0.1 = 990. A gain of 0.0 is not allowed. The format is free field with examples of the command being P.1, P0.1, P9, P9., P9.0, P99, P99., etc.

The string P987.12 will be interpreted as P87, i.e., the first valid combination tied to the decimal point or end of string will be retained. A P transmitted by itself is equivalent to P0 or P0.0 and sets the gain to 0.1. When returning to LOCAL, the gain setting if changed over the IEEE-488 Bus is no longer valid since the 91C will now read the front panel gain potentiometer setting.

Table 4-10. DRC-91C Command/Request Summary for the Control Parameters

Command	Functional Description
	Setting of all other Control Parameters
$PN_1.N_2$ or PN_1N_2	Proportional (GAIN). N_1N_2 is 0.1 through 99. Examples the command are P, P0, P0.0 and P99.
$IN_1.N_2$ or IN_1N_2	Integral (RESET). N_1N_2 is 0.0 (OFF) through 99. (three characters including the decimal point). Forms of the command are I0 (I0.0) through I99.
$DN_1.N_2$ or DN_1N_2	Derivative (RATE). N_1N_2 is 0.0 (OFF) through 99. (three characters including the decimal point). Forms of the command are D0 (D0.0) through D99.
RN_1	Heater Range. N_1 is 0 through 5. Forms of the command are R0 through R5. N_1 — Range — Heater Current 0 — OFF — 0 1 — OFF — 0 2 — -3 — 33 mA 3 — -2 — 100 mA 4 — -1 — 330 mA 5 — MAX — 1 A

****

Request	Functional Description
W3	Control Parameters $N_1N_2N_3$,$N_4N_5N_6$,$N_7N_8N_9$,N_{10},$N_{11}N_{12}N_{13}$ 17 characters plus up to 2 terminators where: $N_1N_2N_3$ is the Gain Value $N_4N_5N_6$ is the Rate Value $N_7N_8N_9$ is the Reset Value N_{10} is the Heater Range $N_{11}N_{12}N_{13}$ is the % of Heater Power or Current out.

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4.9.4 Setting the RESET (Integral) - The I Command

The reset is set from 0.1 through 99 (1 to 990) seconds. Like the gain command, it is free field with the same characteristics and format. It will also revert back to front panel settings under LOCAL control. A setting of 0.0 turns the reset off.

4.9.5 Setting the RATE (Derivative) - The D Command

The rate is also set in seconds/10 (0.1 to 99, 0.0 off). It handles its input format exactly the same as both gain and reset commands as well as the transition to front panel control from REMOTE.

4.9.6 Heater Range - The R Command

The heater range can be changed over the bus with the RN_1 command. R1 or R6 and up are equivalent to the R0 command (see Table 4-10).

4.9.7 NOTE: The Return to Local

Although the Gain, Rate, Reset and Sensor ID's can be changed over the IEEE Bus with the 91C in REMOTE, when the 91C returns to LOCAL, these settings are read and updated from the hardware, i.e., the front panel (gain, rate and reset) and the SENSOR ID switches on the back panel.

4.9.8 The "W3" Data String

The settings for the gain, rate, reset, heater range as well as the instantaneous % of Heater Power can be transmitted from the DRC-91C with the "W3" command.

The command "SPIDR" or any combination without a value following the letter sets the chosen parameters to 0, e.g., "SP" sets the set point and gain to 0.

4.10 THE SCANNER INPUT CARD

4.10.1 SCAN Programming Instructions

NOTE: The YA, YB and YC commands should be issued when the SCAN mode is Holding. Changing a SCAN time or Scanner Channel while the unit is actively scanning may cause unpredictable results.

4.10.2 Setting the Dwell Time - The $YAN_1N_2N_3$ and $YBON_2N_3$ Commands

The time spent on a given scanner channel can be varied between 0 and 99 seconds by setting the dwell time for that channel. This can be done over the IEEE-488 Bus with these commands or from the front panel. Setting the dwell time to 0 skips that channel.

4.10.3 Selecting the Scanner Channel - The $YCAC_1$ Command

The A channel input (A0, A1, A2, A3 or A4) is selected by this command. This channel will be read over the IEEE-488 Bus only if the channel is designated as the Display Sensor or Control Sensor. Normal operation would be for the B input to be Control Sensor input with the Display assigned to the A channel selected by this command directing the appropriate sensor from the scanner input to the A input card.

4.10.4 Enabling the Scan Function - The YS Command

Upon sending the YS command from the BUS CONTROLLER, the DRC-93C starts its scan of the inputs from the channel input which it is currently on. The scan sequence is A0, A1, A2, A3, A4, B, A0, etc. with any channel whose dwell time is set to zero being skipped.

It is strongly recommended that the control channel be the B channel when the scanner is used. If it is not, it will be changed if a scanner

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Table 4-11. DRC-91C Command/Request Summary for Scanner

Command	Functional Description
$YAN_1N_2N_3$ or $YB0N_2N_3$ (After YH cmmd)	Set the AN_1 (A0 - A4) or B0 Scanner channel dwell time time to N_2N_3 seconds. N_2N_3 is 00 to 99 seconds. Forms are YA000 thru YA099, YA100 thru YA199, etc.
$YCAN_1$	Select Scanner Channel AC_1 (A0 thru A4). Forms of the Command are YCA0< YCA1, YCA2, YCA3 and YCA4. Command asynchronously selects a scanner channel for readout.
YS	Enable the (S)CAN function.
YH	Disable, or (H)old, the SCAN.

****

Request	Functional Description
WY	Scan Information $C_1,C_2C_3,C_4C_5,C_6C_7,C_8C_9,C_{10}C_{11},C_{12}C_{13},C_{14}C_{15}$ 22 characters plus up to 2 terminators where: C_1 is the SCAN status, (H)olding or (S)canning. C_2C_3-$C_{12}C_{13}$ is the A0 - A4 and B0 dwell times in seconds. $C_{14}C_{15}$ is the SCAN position A0, A1, A2, A3 or A4.

card is present, since one current source is associated with the A0-A4 inputs. The display which will scan is the sample display.

4.10.5 Holding the Scan Function - The YH Command

The Scan can be stopped any time over the IEEE-488 Bus by sending out the YH command. The scanner should be in hold when any of the other scanner commands are sent to the scanner.

4.10.6 The "WY" Data String

This command gives the scan information, including whether the instrument is scanning or holding, the channel dwell information and the scan position.

4.11 The Service Request, Status Register, Status Reports, and the Status Register Mask

As mentioned earlier, a Service Request can be initiated by the DRC-91C to indicate a function has been performed, or a limit, overload or error has been encountered. The DRC-91C does this by pulling its SRQ (Service Request) management line low. The BUS CONTROLLER uses the serial poll (SPOLL) to obtain the contents of the register in the DRC-91C called the Status Register.

The DRC-91C Status Register is a single byte of data from the DRC-91C containing five bits called the Status Reports. These Status Reports indicate when certain processes are complete, whether the channel was changed, or a limit, overload or error encountered. The Status Register Mask is provided so that the Status Request interrupt and

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