

DIGITAL COMPUTER CONTROL OF RESISTIVITY AND
HALL MEASUREMENTS OF SEMICONDUCTORS

Roman Krawczyniuk

A THESIS
in
The Department
of
Physics

Presented in Partial Fulfillment of the Requirements for
the Degree of Master of Science at
Sir George Williams University
Montreal, Canada

September, 1971

ABSTRACT

DIGITAL COMPUTER CONTROL OF RESISTIVITY AND HALL MEASUREMENTS OF SEMICONDUCTORS

by

Roman Krawczyniuk

A digital-computer-based, real-time data acquisition, processing, and control system has been developed for resistivity and Hall measurements of semiconductors and is described in detail. System components consist of a reed relay multiplexer, an integrating digital voltmeter, a teletype, a magnetic tape unit, and a digital plotter. Programmed system operations include: (1) monitoring of the temperature and initiation of a measuring cycle at temperature intervals preselected by the operator; (2) interactive communication between the operator and the computer; (3) acquisition of analog data voltages and printing of these voltages on the teletype; (4) storage of the data voltages on magnetic tape for further off-line data reduction; and (5) on-line processing and display of Hall data on the digital plotter. Computer programs have also been developed for further off-line data processing. The experimental results are presented by the system in the form of conventional plots of Hall coefficient, electrical resistivity, and Hall mobility as a function of absolute temperature.

Measurements on germanium were performed at low temperatures and low magnetic field strength. The results for germanium agree with published data and therefore confirm the proper operation of the system.

ACKNOWLEDGEMENTS

The author wishes to acknowledge his indebtedness to his research supervisor, Dr. A.L. Kipling, for his interest, cooperation, and advice in many aspects of the work reported herein. Thanks are also due to Mr. J. Blaison for his valuable technical assistance.

ABSTRACT

A digital-computer-based, real-time data acquisition, processing, and control system has been developed for resistivity and Hall measurements of semiconductors and is described in detail. System components consist of a reed relay multiplexer, an integrating digital voltmeter, a teletype, a magnetic tape unit, and a digital plotter. Programmed system operations include: (1) monitoring of the temperature and initiation of a measuring cycle at temperature intervals preselected by the operator; (2) interactive communication between the operator and the computer; (3) acquisition of analog data voltages and printing of these voltages on the teletype; (4) storage of the data voltages on magnetic tape for further off-line data reduction; and (5) on-line processing and display of Hall data on the digital plotter. Computer programs have also been developed for further off-line data processing. The experimental results are presented by the system in the form of conventional plots of Hall coefficient, electrical resistivity, and Hall mobility as a function of absolute temperature.

Measurements on germanium were performed at low temperatures and low magnetic field strength. The results for germanium agree with published data and therefore confirm the proper operation of the system.

TABLE OF CONTENTS

INTRODUCTION	1.
CHAPTER I - THE DATA ACQUISITION AND PROCESSING SYSTEM	3.
1.1 System Components	3.
1.2 System Programs	5.
CHAPTER II - EXPERIMENTAL APPARATUS AND PROCEDURE	11.
2.1 The Cryogenic Temperature Control System	11.
2.2 The Magnet Control System	12.
2.3 The Electrical Measuring Circuit	13.
2.4 Experimental Procedure	14.
CHAPTER III - ELEMENTS OF SEMICONDUCTOR THEORY	18.
3.1 Charge Carrier Excitation	18.
3.2 Mobility	23.
3.3 Measurement of the Transport Properties	28.
CHAPTER IV - DISCUSSION OF EXPERIMENTAL RESULTS	32.
CHAPTER V - CONCLUSIONS	39.
REFERENCES	41.
APPENDIX A	42.
APPENDIX B	99.

INTRODUCTION

This work is the first stage of a program of research on electrical properties of various elemental and compound semiconductors. The most important electrical properties are electrical resistivity, Hall coefficient, and Hall mobility. These quantities are measured as a function of temperature and magnetic field. The results are then analysed to provide information concerning band structure, scattering mechanisms, energy levels, and concentration of donor and acceptor impurities. This work requires a large number of measurements on many samples in order that theories may be developed and substantiated. The conventional methods of measuring and evaluating the data are, however, tedious and very time consuming.

This thesis reports the development of a digital-computer-based, real-time data acquisition, processing, and control system for electrical resistivity and Hall measurements of semiconductors. The system hardware components consist of a reed relay multiplexer, an integrating digital voltmeter, a magnetic tape unit, a digital plotter, and a teletype. Computer programs have been written to measure the data voltages, to print the voltages and corresponding temperature on the teletype, to store the raw data on magnetic tape for further off-line analysis by the system, and to plot on line the Hall coefficient as a function of the absolute temperature. Other programs have been developed for further off-line data reduction. Measurements were performed on a germanium sample to verify the operation of the system.

The components and programmed operation of the system are discussed in Chapter I. The experimental apparatus and procedure are described in Chapter II. Chapter III contains a brief review of the basic theory of electronic transport in semiconductor materials. In Chapter IV the results of computer-controlled resistivity and Hall measurements of germanium are reported and are discussed in the light of existing theory. The merits, limitations, and recommendations for the improvement of the system are presented in Chapter V.

CHAPTER I

THE DATA ACQUISITION AND PROCESSING SYSTEM

1.1 System Components

The digital-computer-controlled data acquisition and processing system to be described below is a completely programmable general-purpose dc voltage measuring, recording, and processing system. The system can be used with any experimental arrangement provided, of course, the quantities to be measured are reducible to dc voltage determinations. A block diagram of the system is shown in Fig. 1.

The system is built around the Digital Equipment Corporation PDP-8/L computer which functions both as the control element in data acquisition and as the data processing facility. The PDP-8/L is a one-address, 12-bit fixed-word-length, parallel digital computer using two's complement arithmetic. Cycle time of the 4096-word random-address magnetic-core memory is 1.6 μ sec. Input-output is accomplished either through the accumulator or through the data break facility.

The components between the experiment and the computer consist of a guarded relay multiplexer and a digital voltmeter. The computer-controlled multiplexer has eight Digital Equipment Corporation Type All1 switch modules; each module contains two 3-pole reed-relay switches. Up to 16 different analog dc voltage inputs (channels) can be multiplexed under program control to the digital voltmeter. The system is prewired

for expansion to 64 channels. The digital voltmeter is a Hewlett-Packard Model 2402A integrating digital voltmeter (IDVM). The IDVM measures dc voltage on any of five ranges: 0.1, 1, 10, 100 and 1000 V full scale. Autoranging is provided over all five ranges. The resolution is 1 μ V on the 0.1 V range. The voltage, including decimal point, polarity, and unit, is indicated on a direct reading six-digit nixie display. By means of active integration the voltmeter reads the average value of the input voltage over a 1/60 sec time interval in order to reject 60 Hz noise: The maximum rate of voltage measurement is 43 measurements per second. The manufacturer's specifications give the accuracy of the voltmeter to be 0.01% of the reading \pm 0.003% of the full scale for all ranges except the 0.1 V range where the accuracy is slightly less. This accuracy has not been verified due to the lack of suitable standards equipment. The input impedance of the voltmeter for the .1, 1, and 10 V ranges is $10^9 \Omega$. The measured voltage appears in binary-coded-decimal form on a connector at the rear of the IDVM and is available for transfer to the core memory of the computer.

The data-handling peripheral equipment consists of a teletype, a magnetic tape unit, and a digital plotter. An ASR-33 teletype is used as the basic information interchange device between the operator and the computer. It consists of a printer, keyboard, paper-tape reader and paper-tape punch. The ASR-33 teletype is a standard machine operating with serial 8-level ASCII-code characters at the rate of 10 characters per second. It inputs information to the computer from the paper-tape reader and by means of the keyboard, and outputs data in the form of punched paper tape and printed copy. A Peripheral Equipment Corporation Model 3520-7 digital magnetic tape unit is used to store data for

further off-line processing. The transport reads and writes on seven tracks at a speed of 25 inches per second and a density of 556 bytes per inch. The maximum transfer rate is seven thousand 12-bit words per second. A Houston Model DP-1-1 digital plotter provides a graphical display of the processed data. The plotter operates at the rate of 3 inches per second in 0.01 inch steps.

1.2 System Programs

Two system program packages have been developed. The programs were written in machine language to obtain maximum programming flexibility and to minimize the amount of core memory required. The first program package is divided into two parts. The first part enables: (1) real-time acquisition of data voltages from electrical resistivity and Hall effect measurements; (2) printing of the data voltages on the teletype; (3) storage of this data on magnetic tape; and (4) on-line plotting of the logarithm of the Hall coefficient as a function of the reciprocal temperature. The second part of the first program package has been written to measure the analog dc voltages appearing on channels 0 to 6, to print the data voltages on the teletype, to store them on magnetic tape, and to calculate and print the temperature at which these measurements were taken. This part of the package is not used and therefore is not discussed below, but is included in Appendix A. It will be used in future work to measure magnetoresistance. The second package permits the reading of raw data from the magnetic tape into the core memory of the computer, and plotting of either the logarithm of the electrical resistivity as a function of the reciprocal temperature or the logarithm of the Hall mobility versus the logarithm

of the temperature. Both system program packages are described below.

Real-Time Data Acquisition and Analysis

Execution of the Data Acquisition and Analysis Program begins with a "dialogue" between the operator and the computer. The dimensions of the sample to be measured, the temperature interval between measurements, and the scale factors required for plotting the processed data are requested on the teletype printer. This information is typed by the operator on the teletype keyboard and is entered into the core memory of the computer. Upon termination of this "dialogue", the data headings are printed. The program enters the acquisition stage.

To start data acquisition the operator types a command on the keyboard. The analog dc voltages appearing on channels 0 to 6 (see Fig. 3) are multiplexed under program control to the IDVM. Each voltage is measured and digitized by the IDVM and then three 12-bit BCD words, representing the channel number of the voltage measured and the digits, polarity, and multiplier of this voltage, are transferred under program control to the core memory of the computer. Input data voltages are measured and stored in core memory at the rate of five channels per second. This rate is set by a programmed delay. Once all the channels have been measured, the voltages are printed out in fixed-point notation. The operator then turns on the magnetic field and initiates the next measurement cycle. The second set of data voltages is measured, stored in core memory, and printed out on the teletype. The voltages stored in core memory are converted to binary floating-point notation to facilitate data processing. Both sets of data voltages are then recorded onto magnetic tape through the 3-cycle data break

facility. The subroutines enabling data transfer between the computer and the magnetic tape unit have been provided by Digital Systems Associates. The execution of the program now enters the processing stage.

The data in core memory is processed with the aid of the Digital Equipment Corporation Floating-Point Package (DEC-C8-YQ4A-PB) which contains a variety of mathematical subroutines. The temperature at which the measurement was performed is calculated from a polynomial relating the resistance of the temperature sensor and the corresponding temperature. The calculated temperature is printed on the teletype. The common logarithm of the absolute value of the Hall coefficient is calculated, its value is scaled and then plotted as a function of the reciprocal absolute temperature. The Digital 8-12-U subroutine used for plotting was provided by Digital Equipment Corporation. Execution of the program enters the monitor stage.

Three courses of action are available to the operator. He may decide to maintain the initial temperature interval between Hall measurements, to input a different temperature interval into memory, or to terminate execution of the program. If the decision to continue the experiment has been made, the dc voltages from the temperature sensors are measured and read into core memory. The temperature is calculated to within 1% accuracy and monitored continuously. When the desired temperature has been attained, program control is transferred to the acquisition stage and the data acquisition and analysis process is repeated. The above program package enables computer-controlled electrical resistivity and Hall measurements to be performed from 1.5 °K to 300 °K.

The Data Acquisition and Floating-Point Packages occupy approximately 4000 12-bit words of core memory. System operating instructions, flow charts, and program listings are provided in Appendix A.

Off-Line Data Processing

The Off-Line Data Processing Package when used in conjunction with the Floating-Point Package enables raw data to be read from magnetic tape into the core memory of the computer, to be processed, and to be displayed by the digital plotter. The program is divided into two main parts: (1) information transfer, and (2) data processing and display. The execution time of the program is limited only by the speed of the peripheral devices.

The operator begins program execution by entering the sample dimensions and the scaling parameters, required for plotting the processed data into core memory, through the teletype keyboard. One record of data, containing the 14 measured voltages represented by forty-two 12-bit words, is read from the magnetic tape into core memory. The data is processed, scaled, and a point is plotted. The next record is read in and the process is repeated. An end-of-file character appears after the last record and indicates to the program that all available data has been processed. This character terminates program execution. Subroutines have been written to calculate the common logarithm of the electrical resistivity and of the Hall mobility and to plot the former as a function of the reciprocal absolute temperature and the latter as a function of the common logarithm of the absolute temperature.

The Off-Line Data Processing Package and the Floating-Point Package occupy approximately 3300 words of core memory. Operating instructions, flow charts, and program listings are provided in Appendix B.

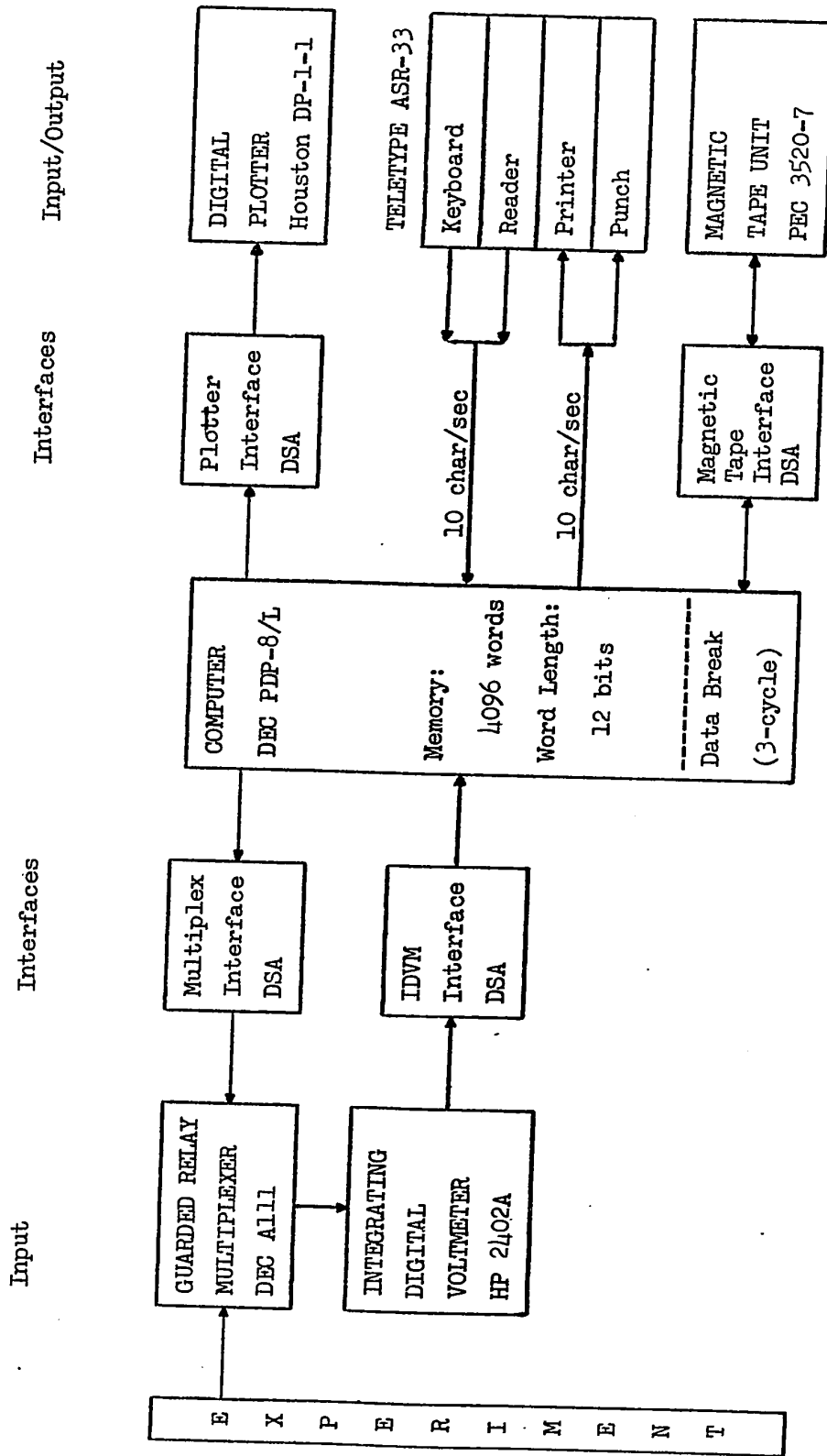


Fig. 1. Block diagram of the data acquisition and processing system.

CHAPTER II

EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 The Cryogenic Temperature Control System

The design of the Andonian MHD-3L-30N cryostat used in performing the electrical resistivity and Hall effect measurements is shown in Fig. 2. The totally metallic and modular construction of the cryostat allows for larger sample assemblies without increase in magnet air gap and subsequent loss of magnetic field intensity.

The sample is mounted on the end of the support tube (Q), beneath the sample heater (L), and lowered into the exchange gas chamber (N) through an opening at the top of the dewar. All electrical leads are brought up through a feedthrough flange located inside the support tube and are terminated on multipin electrical connectors. The electrical connectors (A) are hermetically sealed and feature closed-entry socket contacts.

The sample zone in the exchange gas chamber is thermally shielded by a radiation shield (K) cooled by thermal conduction to the liquid nitrogen in the top container (G). The outer casing of the tail section (J), Andonian O-25-200, is hermetically secured to the main body of the modular helium dewar. A common insulation space (I) between the outer shell of the dewar and the exchange gas chamber forms part of a high vacuum system that is connected to an oil diffusion pump through

the monel tubing (D). Since molecular thermal energy conduction disappears at pressures only below 10^{-5} mm Hg, it is essential that the insulation space be evacuated to this pressure or below.

To lower the temperature of the sample, liquid helium is admitted from the main helium reservoir (H) to the sample zone through a throttle valve (P) and vaporization heater (M). The exchange gas flows around and in intimate contact with the sample and exits to a high speed rotary vacuum pump via the off-gas line (B). The throttle valve controls the flow rate of liquid helium into the sample zone and consequently the rate of energy removal from it.

Temperature control from 1.5 °K to 300 °K is obtained by maintaining a constant exchange gas pressure of 5 mm Hg in the sample region and adding just sufficient electrical power to the sample heater to bring this region to the desired temperature. The variable power supply of the Andonian A-8B manual temperature control system is capable of controlling the temperature to within 0.1 °K over the entire temperature range. Since the sample is immersed in high-conductivity helium gas, temperature gradients are extremely small. The temperature is determined from two calibrated resistance thermometers located in the sample mounting platform. The Andonian CG-1AC germanium resistance thermometer (GT) is used from 1.5 °K to 30 °K; the Andonian PR-1 platinum resistance thermometer (PT) is used for temperatures between 30 °K and 300 °K.

2.2 The Magnet Control System

A 12-inch Varian V-3900 electromagnet with pole faces 9 inches in diameter and a pole gap of 3 inches is used. The maximum field intensity

is 10 kG. The Varian VFR-2803 control unit permits direct magnetic field selection with visual indication of field intensity in kilogauss. The panel operating controls, in addition to the field set controls, include a field reversing switch along with a test selection switch and meter to monitor the magnet system operation. A temperature-controlled Hall-effect crystal probe mounted on one magnet pole cap maintains the field to within 1% of the selected value during variations caused by line voltage excursions, electronic system noise, and magnet system fluctuations.

2.3 The Electrical Measuring Circuit

A schematic diagram of the electrical measuring circuit is shown in Fig. 3. The temperature sensing circuit consists of two calibrated resistance thermometers connected in series with a 10 k Ω standard resistor. The excitation power supply of the Andonian A-8B manual temperature control system maintains a constant current through the temperature sensing elements. This current is determined by measuring the voltage across the standard resistor. The voltage across each resistance thermometer is measured and then divided by the current to obtain the resistance. From calibration tables relating temperature and resistance, the temperature is determined. The magnetic field intensity is determined from a calibration curve relating field intensity, measured using a Rawson Model 829 rotating coil gaussmeter, and the voltage across a 0.33 Ω standard resistor which is connected in series with the magnet windings in the magnetic field control unit. The sample current, provided by a regulated current supply, is determined by measuring the voltage drop across a 100 k Ω standard resistor connected

in series with the sample. The electrode configuration for the measurement of the resistivity and Hall voltages is shown in Fig. 3. The seven dc voltages to be measured are terminated through coaxial cables on a 24-pin Amphenol connector located at the input to the data acquisition and processing system.

2.4 Experimental Procedure

Electrical resistivity and Hall effect measurements were performed on a germanium sample to demonstrate that correct experimental results are obtained with the system. The p-type germanium sample used was obtained from RCA Victor, Montreal. The sample was 1.2 cm in length, 0.1 cm in width, and 0.1 cm in thickness. Strands of tinned copper wire (0.005 inches in diameter) attached directly to the sample with solder composed of 63% Pb - 35% Sn - 2% In, served as the current and voltage leads. Good Ohmic contacts were obtained by first rinsing the sample with acetone and then applying solder using zinc chloride flux. The solder spots for the potential leads were kept as small as possible in order to prevent electrical shorting of the sample. Excess flux was removed by rinsing the sample with trichloroethylene. The four voltage leads and the two current leads were arranged as shown in Fig. 3. The electrical leads attached to the sample were terminated on pins of the connector which supports the sample holder.

The electrical resistivity of the sample was determined by measuring the voltage between two contacts, 0.9 cm apart, along the length of the sample. The room-temperature resistivity of the sample was approximately 3 Ω cm. No electric field dependence of the resistivity was observed at any temperature for electric fields between

10^{-3} and 10^{-1} V cm^{-1} . A regulated sample current between 100 nA to 150 μA was used. At low temperatures, low current was used to avoid electrical breakdown and excessive Joule heating; at higher temperatures the current was increased in order to raise the measured voltages to detectable levels.

The Hall coefficient is determined by measuring the voltage between the Hall contacts with the magnetic field on and then subtracting the voltage appearing between these contacts with the field off. The zero field voltage comes from two sources. The first is due to the fact that the Hall contacts are not directly opposite each other; since there is a potential gradient due to the sample current, a part of this gradient will be seen between the two contacts. The second is due to contact potential. The measurements of the Hall coefficient were performed with a magnetic field of 8 kG to make the Hall voltages as large as possible. The condition that the transverse Hall electric field be small compared to the applied electric field was fulfilled.

- LEGEND
- A ELECTRICAL CONNECTORS
 - B OFF-GAS LINE
 - C HELIUM FILL AND VENT
 - D INSULATION LINE
 - E NITROGEN VENT
 - F OUTER SHELL
 - G NITROGEN RESERVOIR
 - H HELIUM WELL
 - I INSULATION SPACE
 - J OUTER TAIL SECTION
 - K NITROGEN-TEMPERATURE RADIATION SHIELD
 - L SAMPLE HEATER
 - M VAPORIZATION HEATER
 - N EXCHANGE GAS CHAMBER
 - O CAPILLARY
 - P THROTTLE VALVE
 - Q SAMPLE SUPPORT TUBE
 - R THROTTLE-VALVE STEM
 - S NITROGEN FILL
 - T HELIUM GAUGE PORT
 - U THROTTLE-VALVE TOP WORKS

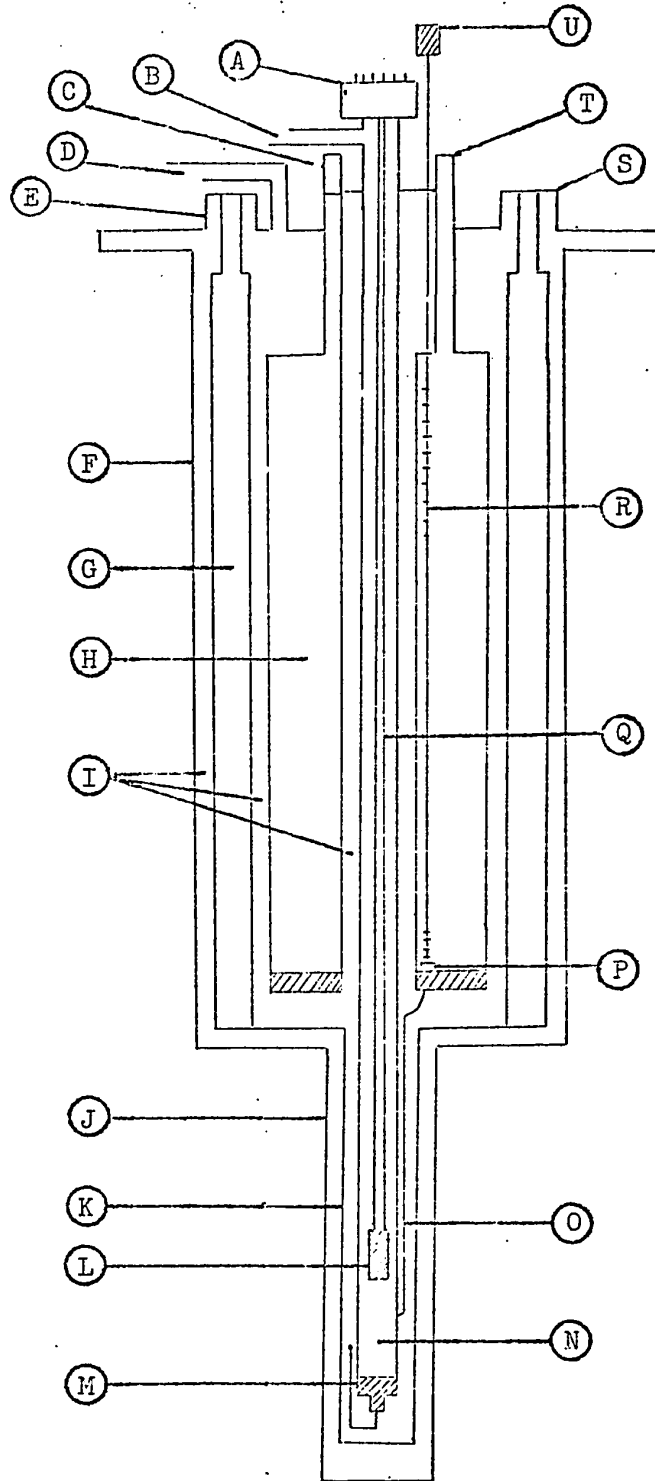


Fig. 2. Cryostat for Hall effect and electrical conductivity measurements.

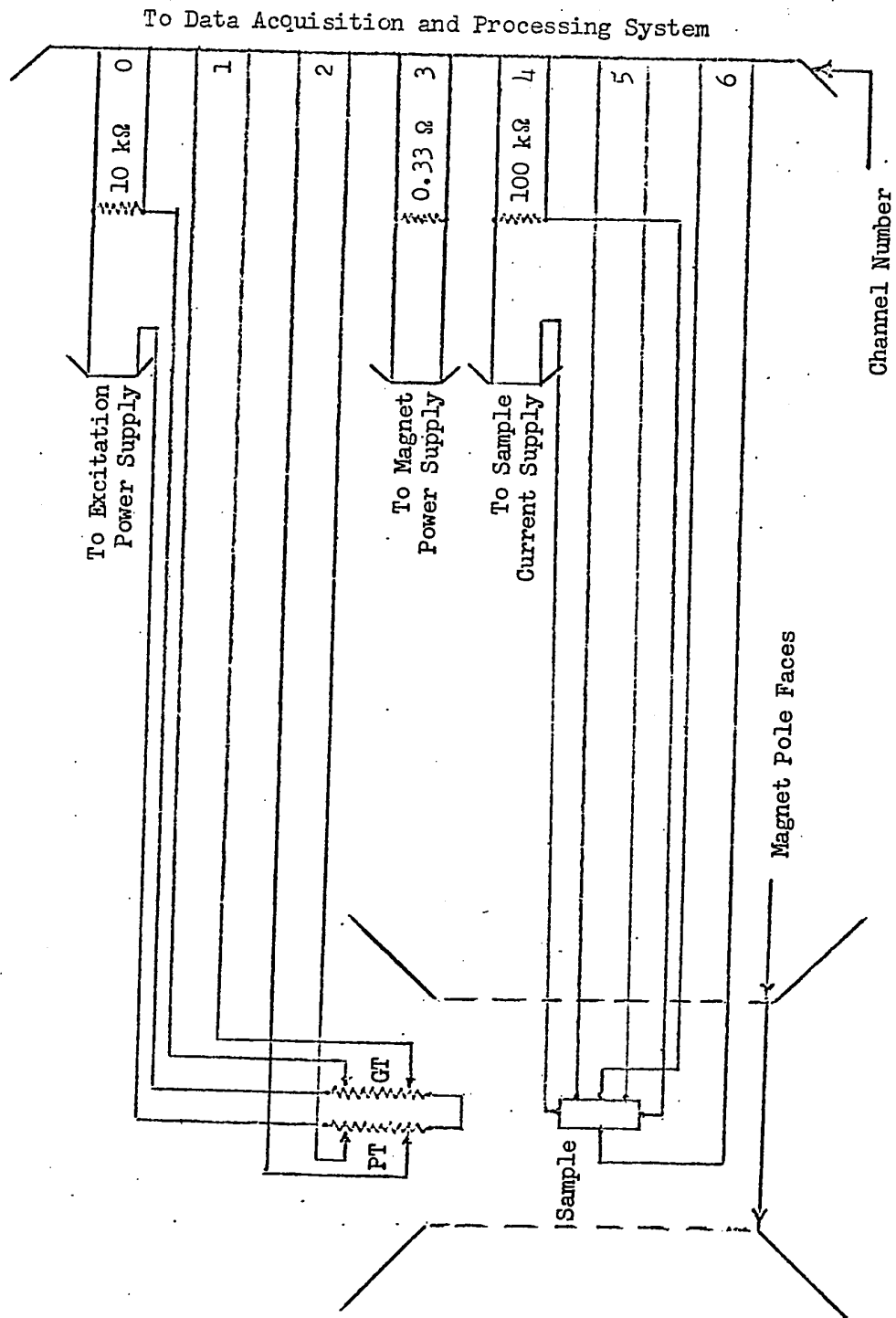


Fig. 3. The electrical measuring circuit.

CHAPTER III

ELEMENTS OF SEMICONDUCTOR THEORY

3.1 Charge Carrier Excitation

Semiconductors are characterized by an electrical conductivity (associated with the motion of electrons or holes or both) which on the one hand is considerably smaller than that of metals, and on the other hand, is much larger than that of insulators. Furthermore, the conductivity increases with temperature in contrast with the behavior of metals at normal temperatures. The forbidden energy gap between the highest normally filled (valence) band and the ionization (conduction) band is of the order of 1 eV . At absolute zero the ideally pure semiconductor is an insulator. A semiconductor is referred to as intrinsic when the number of electrons thermally excited into the conduction band is equal to the number of holes in the valence band. Below the intrinsic temperature range the electrical properties are dependent on the concentrations and types of impurities present, and here one speaks of an impurity or extrinsic semiconductor.

* Elements from Group III and Group V of the periodic table are used for doping semiconductor elements such as germanium and silicon. A pentavalent atom, having one valence electron left over after establishing the four covalent bands with the tetrahedrally spaced germanium atoms may donate an electron to the conduction band and is thus called a donor. The behavior of a trivalent atom as an acceptor

can be explained by similar considerations.

An estimate of the ionization energy of the impurity atom is made by employing the Bohr model of the hydrogen atom modified by taking into account both the dielectric constant of the medium and the effective mass of the conduction carrier in the periodic potential of the crystal. According to this model, the ionization energy of the ground state of the impurity atom is given by

$$\epsilon = m^* e^4 / 2\hbar^2 \chi^2 \quad (3.1)$$

where m^* is the effective mass of the conduction carrier, e is the electronic charge, \hbar is Planck's constant/ 2π , and χ is the dielectric constant of the medium. Using a dielectric constant of 16 and the value, given by cyclotron resonance, of the anisotropic effective mass of the electron, Kittel and Mitchell (1954) obtained 0.00905 eV for the ionization energy of donor impurities in germanium. The calculation for acceptor impurities is complicated by the fact that the top of the valence band is threefold degenerate for orbital motion, or sixfold degenerate if the two spin orientations are included. Taking this into account, Fan (1955) estimated the ionization energy of the acceptors in germanium to be approximately 0.02 eV.

The ionization energies can be determined experimentally by direct optical absorption methods or by electrical conductivity and Hall effect measurements. In general, the experimental values are found to be in good agreement with the values given above. Tables of the known ionization energies of both donor and acceptor impurities in germanium and silicon, along with references to the original works, have been compiled by Burton (1954).

Since the energy gap between the donor band and the conduction band (or the valence band and the acceptor band) is of the order of 10^{-2} eV for semiconductors such as germanium and silicon, free charge carriers are made available in these materials at temperatures far lower than those required for intrinsic excitation. If donors are present in considerably greater number than acceptors, the current is due to the motion of electrons in the conduction band. The material is called n-type. If acceptors are dominant, the conductivity is due to the motion of holes in the valence band and the material is called p-type.

When a semiconductor is in a state of thermodynamic equilibrium it is possible to express the occupancy of all electron states in terms of a single normalizing parameter, the Fermi level. The probability at temperature T for the energy state ϵ_C in the conduction band to be occupied by an electron is, according to the Fermi-Dirac distribution function,

$$f(\epsilon_C) = \left\{ 1 + \exp[(\epsilon_C - \epsilon_F)/kT] \right\}^{-1} \quad (3.2)$$

where ϵ_F is the Fermi energy and k is Boltzmann's constant. The probability for the energy state ϵ_V in the valence band to be vacant or occupied by a hole is given by

$$1 - f(\epsilon_V) = \left\{ 1 + \exp[(\epsilon_F - \epsilon_V)/kT] \right\}^{-1} . \quad (3.3)$$

For a slightly doped semiconductor Eqs. (3.2) and (3.3) reduce to the classical Maxwell-Boltzmann distribution function. The semiconductor is said to be nondegenerate. The concentration of electrons in the conduction band is given by

$$n = N_C \exp[(\epsilon_F - \epsilon_C)/kT] \quad (3.4)$$

and the concentration of holes in the valence band is given by

$$p = N_V \exp[(\epsilon_V - \epsilon_F)/kT] . \quad (3.5)$$

N_C is the effective density of states in the conduction band and N_V is the same for the valence band:

$$\begin{aligned} N_C &= 2(2\pi m_e^* kT/h^2)^{3/2} , \\ N_V &= 2(2\pi m_h^* kT/h^2)^{3/2} \end{aligned} \quad (3.6)$$

where m_e^* and m_h^* are the effective masses of the electron and hole respectively. The product of the concentration of electrons and holes is a function of the energy gap, $\epsilon_g = \epsilon_C - \epsilon_V$, and temperature, and is given by

$$np = n_i^2 = N_C N_V \exp(-\epsilon_g/kT) \quad (3.7)$$

where n_i is the intrinsic concentration of electrons and holes. In an intrinsic semiconductor the concentration of electrons and holes is the same, namely n_i given by Eq. (3.7).

Let us now consider the case of an n-type semiconductor containing a donor impurity concentration N_D and an acceptor impurity concentration N_A . Assume that each donor atom and each acceptor atom can furnish one charge carrier. From the condition of electrical neutrality,

$$n = p + (N_D - N_A) - N_D f_D + N_A f_A \quad (3.8)$$

where f_D is the probability that the donor atom is not ionized and f_A is the probability that the acceptor atom is not ionized, and

$$f_D = \left\{ 1 + \frac{1}{g_D} \exp[(\epsilon_D - \epsilon_F)/kT] \right\}^{-1} . \quad (3.9)$$

The probability f_A is given by a similar expression. In the equation above, ϵ_D is the ground state of the donor impurity

center and the factor g_D is the degeneracy of the ground state. It is usually assumed that $g_D = 2$ in consequence of the twofold choice of spin for the bound electron. With $n > p$, by using Eqs. (3.4) and (3.9), and the fact that $N_D f_D > N_A f_A$, Eq. (3.8) becomes

$$\frac{n(n + N_A)}{N_D - N_A - n} = \frac{N_C}{2} \exp[-(\epsilon_C - \epsilon_D)/kT] \quad (3.10)$$

where $(\epsilon_C - \epsilon_D)$ is the ionization energy of the donors.

At sufficiently high temperatures the intrinsic concentration n_i becomes large compared to $(N_D - N_A)$; Eq. (3.8) reduces to $n \approx p$. The semiconductor becomes intrinsic. As the temperature is lowered, the electron concentration becomes a constant,

$$n \approx N_D - N_A. \quad (3.11)$$

This is the temperature range of exhaustion where practically no electrons are left in the donor levels. At very low temperatures when $n \ll N_D$, Eq. (3.10) reduces to

$$n = \frac{N_D - N_A}{N_A} \frac{N_C}{2} \exp[-(\epsilon_C - \epsilon_D)/kT]. \quad (3.12)$$

The slope of $\ln n$ versus $1/T$ in this temperature range gives the ionization energy of the donor impurity. A minor part of the temperature dependence of the electron concentration in the conduction band is contributed by the $T^{3/2}$ dependence of N_C . With a very small N_A , there is a temperature range where n is much smaller than N_D but much larger than N_A ; Eq. (3.10) reduces to

$$n = \left(\frac{N_D N_C}{2} \right)^{1/2} \exp[-(\epsilon_C - \epsilon_D)/2kT]. \quad (3.13)$$

For the analogous case of a p-type semiconductor, the concentration of holes where $p \ll N_A$ is given by

$$p = \frac{N_A - N_D}{N_D} \frac{N_V}{2} \exp[-(\epsilon_A - \epsilon_V)/kT] . \quad (3.14)$$

When $N_D \ll p \ll N_A$,

$$p = \left(\frac{N_A N_V}{2} \right)^{1/2} \exp[-(\epsilon_A - \epsilon_V)/2kT] . \quad (3.15)$$

3.2 Mobility

Consider a nondegenerate extrinsic semiconductor in which the conduction carriers, electrons or holes, behave as quasi-free electronic charges having a scalar effective mass m^* ; in this case the constant-energy surfaces in momentum space are spheres. At thermodynamic equilibrium the velocity distribution of the carriers is given by the classical Maxwell-Boltzmann distribution function.

The application of a weak electric field introduces a small but systematic perturbation of the equilibrium velocity distribution function. Solution of the Boltzmann transport equation for the steady-state condition gives a non-zero drift velocity for all conduction carriers, and hence a finite electrical conductivity. The mobility (drift velocity per unit electric field) is then given by

$$\mu = \frac{e}{m^*} \frac{\langle v^2 \tau \rangle}{\langle v^2 \rangle} \quad (3.16)$$

where e is the electronic charge, v is the drift velocity, and τ is the relaxation time. The mean values are taken over the Maxwell-Boltzmann distribution function. The relaxation time τ is the fundamental

parameter in transport phenomena and is a function only of the energy of the carriers. Expressions for τ have been derived for various scattering mechanisms. The major scattering processes are discussed below.

Lattice Scattering

In a rather pure semiconductor crystal elastic scattering of charge carriers through the absorption or emission of acoustic phonons may be important down to fairly low temperatures. Interactions of electrons or holes with optical vibrations is usually significant at room temperature and above. Bardeen and Shockley (1950), using time-dependent perturbation methods, showed that the relaxation time for carrier-acoustic-phonon interactions is expressed in terms of the deformation potential by

$$\tau_L = \frac{2\pi h^4 \rho V_P^2}{(2m^*)^{3/2} \epsilon_1^2} \frac{\epsilon^{-1/2}}{kT} \quad (3.17)$$

for the rather idealized situation in which the effective mass is isotropic and energy-independent. In this equation V_P denotes the speed of the acoustic phonons, ρ is the mass density of the crystal, ϵ_1 is the deformation potential constant, and ϵ is the energy of the carrier. Since

$$\lambda = \tau v \quad (3.18)$$

and $v \propto \epsilon^{1/2}$ for spherical energy surfaces, the mean free path λ is inversely proportional to the temperature and is independent of the carrier energy. Substituting the expression for the relaxation time into Eq. (3.16)

$$\mu_L = \frac{2^{3/2} \pi^{1/2} h^4 \rho V_P^2}{3 \epsilon_1^2} m^{*-5/2} (kT)^{-3/2} . \quad (3.19)$$

The important features of Eq. (3.19) are contained in the last two terms. In the temperature region in which lattice scattering by acoustic phonons plays the dominant role, the lattice mobility μ_L should decrease with increasing temperature and the mobility should be large if the effective mass of the carriers is small. Experimentally observed deviations of the mobility from the $T^{-3/2}$ law arise from a variety of competing effects, including the nonspherical shapes of constant-energy surfaces in semiconductors such as germanium, and the scattering of the more energetic carriers at higher temperatures by optical branch phonons.

Scattering by Ionized Impurities

A quantum-mechanical treatment of electronic scattering by ionized impurity atoms was developed by Brooks (1951). In his approach, Brooks assumes the scattering process to be incoherent and perfectly elastic. The potential due to each ion is taken as a screened Coulomb potential in a medium of dielectric constant χ . The differential scattering cross section is obtained by perturbation methods and the result used to calculate the relaxation time. For a nondegenerate electron gas

$$\tau_I = \frac{2^{1/2} \chi^2 m^{*1/2} \epsilon^{3/2}}{\pi e^4 N_i} \frac{1}{F(b)} \quad (3.20)$$

where

$$F(b) = \ln(1 + b) - \frac{b}{1 + b}; \quad b = \frac{2\chi m^* \epsilon kT}{\pi e^2 n \hbar^2}. \quad (3.21)$$

In Eq. (3.20) N_i denotes the concentration of ionized impurities; n in Eq. (3.21) represents the carrier density. The above expression

for τ_I implies that the mean free path between collisions depends implicitly on the temperature and is proportional to the square of the carrier energy.

The mobility is obtained by substituting τ_I into Eq. (3.16). Since $F(b)$ is a rather slowly varying function of the carrier energy, a fairly reliable analytical expression for μ_I is obtained by replacing $F(b)$ by a constant. The mobility expressed as a function of the absolute temperature is then

$$\mu_I = \frac{2^{7/2} \chi^2 (kT)^{3/2}}{\pi^{3/2} e^3 m^{*1/2} N_i} \frac{1}{F(b)}. \quad (3.22)$$

For temperatures which are not too small, the term $F(b)$ plays a rather insignificant role in the temperature dependence of the mobility; μ_I has essentially a $T^{3/2}$ dependence provided, of course, that the number of ionized centers does not change with temperature. At rather low temperatures, carriers begin to "freeze out" on donors (or acceptors) and the number of ionized impurities decreases very rapidly; the mobility increases with decreasing temperature. At these temperatures the perturbation approach used by Brooks is no longer valid and therefore Eq. (3.22) is incorrect. It is important to note, however, that μ_I has the inverse temperature dependence to μ_L and that μ_I is expected to become dominant when the phonon population is depleted by cooling. Experimental observations made by Debye and Conwell (1954) show that with increasing impurity concentration the departure of the mobility from a $T^{-3/2}$ dependence appears at higher temperatures due to the greater importance of ionized impurity scattering relative to lattice scattering.

Scattering by Neutral Impurities

With decreasing temperature the probability for ionization of uncompensated impurities diminishes. At sufficiently low temperatures, provided the number of minority impurity atoms is small, the concentration of neutral impurities becomes quite significant. A simple model for the scattering of low energy conduction carriers by neutral impurities has been suggested by Erginsoy (1950). In his treatment, Erginsoy assumes that the scattering mechanism involved is similar to the scattering of electrons by a hydrogen atom. Allowance is made for the effective mass of the carrier and for the high dielectric constant of the medium. At carrier energies considerably smaller than the ionization energy of the impurity atom, the relaxation time to a good approximation is given by

$$\tau_N = \frac{m^* z e^2}{20 \chi \hbar^3 N_n} \quad (3.23)$$

where N_n is the concentration of neutral impurity atoms. Since the relaxation time is independent of the carrier energy, the mean free path is directly proportional to the velocity of the carrier and the mobility is simply

$$\mu_N = \frac{m^* e^3}{20 \chi \hbar^3 N_n} \cdot \quad (3.24)$$

Although μ_N does not depend on the temperature explicitly, there is, in fact, a very pronounced temperature dependence that has its origin in N_n . As the temperature is lowered the number of neutral impurities increases very rapidly causing the mobility to decrease. At extremely low temperatures N_n becomes constant; the mobility is independent of the temperature. In practice, neutral impurity scattering

is particularly effective at low temperatures for the faster moving electrons in the thermal distribution since the ionized impurity scattering process is weighted in favor of scattering by slow electrons.

Combination of Mobilities

In general, lattice scattering, ionic scattering, and scattering by neutral impurities must be treated simultaneously. The relaxation time for a given velocity of the charge carriers may then be obtained from

$$1/\tau_{\text{eff}} = 1/\tau_L + 1/\tau_I + 1/\tau_N \quad (3.25)$$

because the probabilities for scattering are additive, each being proportional to the reciprocal of the corresponding relaxation time. The mobility is computed by inserting the effective relaxation time, τ_{eff} , into Eq. (3.16). The combined effect of lattice scattering and scattering by ionized impurities has been investigated in some detail by Johnson and Lark-Horovitz (1951).

In addition to the major scattering processes discussed above, carrier-carrier scattering, dislocations, and point defects such as interstitials and vacancies also affect the carrier mobility. The results of recent investigations of these scattering mechanisms have been summarized by Platt (1968).

3.3 Measurement of the Transport Properties

Electrical conductivity and Hall effect measurements provide the most useful information about the electrical transport properties of semiconductors. For these measurements it is assumed that isothermal conditions exist and that the electrical conduction is isotropic.

Electrical Resistivity

Providing Ohm's law is obeyed, the electrical resistivity (the reciprocal of the electrical conductivity) of a sample is given by

$$\rho = \frac{V_c}{I} \frac{tw}{d} \quad (3.26)$$

where V_c is the voltage between the sample contacts a distance d apart, I is the current passing through the sample, t is the thickness, and w is the width of the sample. If I and V_c are measured in amperes and volts respectively and the linear dimensions are measured in centimeters, ρ is calculated from Eq. (3.26) and is expressed in ohm centimeters.

Hall Coefficient

Upon application of a magnetic field \underline{B} perpendicular to the direction of current flow, current carriers of charge e travelling with an average drift velocity \underline{v} experience a force $e\underline{v} \times \underline{B}$. Due to this force, the charge carriers accumulate on one side of the sample leaving a deficiency of the same amount of charge on the other side and thereby cause an electric field \underline{E}_H across the sample known as the Hall electric field. The Hall field exerts a force $e\underline{E}_H$ on the carriers which is opposite in direction to the force $e\underline{v} \times \underline{B}$. As soon as $e\underline{E}_H$ becomes equal in magnitude to $e\underline{v} \times \underline{B}$, that is $E_H = vB$, the charge carriers traverse the length of the sample without deviation.

The Hall coefficient is defined as

$$R = \frac{E_H}{JB} \quad (3.27)$$

where J is the current density. It is inversely proportional to the

concentration of conduction carriers and its sign coincides with the sign of the carriers. The Hall coefficient is expressed in terms of measured quantities by assuming that E_H and J are constant throughout the sample, in which case $E_H = \frac{V_H}{w}$ and $J = \frac{I}{tw}$. V_H is the voltage across the w dimension of the sample. In terms of V_H and I , Eq. (3.27) becomes

$$R = \frac{V_H t}{IB} . \quad (3.28)$$

Usually V_H is measured in volts, I in amperes, t in centimeters and B in gauss. If R is to be given in $\text{centimeter}^3 \text{ coulomb}^{-1}$, the right-hand side of Eq. (3.28) must be multiplied by 10^8 when the above units are used.

The Hall coefficient defined by Eq. (3.27) reduces to

$$R = \frac{1}{ne} \frac{\langle v^2 \rangle \langle v^2 \tau^2 \rangle}{\langle v^2 \tau \rangle^2} = \frac{r}{ne} \quad (3.29)$$

for a nondegenerate semiconductor in which the electrical conductivity is assumed to be isotropic. The value of r depends on the way in which the relaxation time τ varies with the carrier energy ϵ . If τ is independent of ϵ (as in neutral impurity scattering) r is unity. For acoustic-phonon scattering (τ proportional to $\epsilon^{-1/2}$) r is $\frac{3\pi}{8}$. For ionic scattering (τ proportional to $\epsilon^{3/2}$) r is 1.93. The criteria for the determination of r is discussed by Putley (1960).

Hall Mobility

Having estimated n from Eq. (3.29), the resistivity and Hall data are combined to give Hall mobility, defined as R/ρ . The Hall mobility in terms of the measured quantities is

$$\mu_H = \frac{V_H}{V_C} \frac{d}{w} \frac{l}{B} \quad (3.30)$$

and is expressed in centimeter² volt⁻¹ second⁻¹. For a Maxwell-Boltzmann distribution of carriers the Hall mobility is related to the actual drift mobility μ by

$$\frac{\mu_H}{\mu} = r . \quad (3.31)$$

The error involved in setting r equal to unity for the entire temperature range under investigation is usually much smaller than other uncertainties in the interpretation of the results.

CHAPTER IV

DISCUSSION OF EXPERIMENTAL RESULTS

Electrical resistivity and Hall measurements were performed on a p-type germanium sample from 25 °K to 300 °K and are reported herein. Measurements below 25 °K were not recorded because the resistance of the sample at these temperatures exceeded 1% of the input resistance of the voltmeter ($10^9 \Omega$). A magnetic field strength of 8 kG was used except as noted below. The constant current source provided a minimum sample current of 100 nA. The maximum sample current was determined by the 15 V maximum output of the constant current supply and the resistance across the supply. Since a $10^5 \Omega$ standard resistor was connected in series with the sample, the maximum current was 150 μ A when sample resistance $\ll 10^5 \Omega$. The $10^5 \Omega$ resistor was chosen to give a voltage drop of 10 mV when the current was 100 nA.

The fundamental experimental data obtained in this study are the resistivity and Hall voltages as a function of temperature. From this data the plots of Hall coefficient, resistivity, and Hall mobility were made. The curves are analysed to determine the variation of concentration of current carriers and mobility with temperature. The results are interpreted in terms of existing theory of electrical conduction in semiconductors.

Hall Coefficient

The common logarithm of the Hall coefficient R is plotted as a

function of the inverse absolute temperature in Fig. 4. From the Hall curve one can identify three different regions of electrical behavior: the exhaustion region, the extrinsic region, and the electrical breakdown region.

The transition from the extrinsic to the exhaustion region begins at approximately 150 °K. The impurity concentration is estimated to be of the order of 10^{15} cm^{-3} from the value of the Hall coefficient in the exhaustion region using $n = 6.25 \times 10^{18}/R$, Eq. (3.29), when the Hall factor equals unity. This represents a doping ratio of one part in ten million. The magnetic field was increased from 8 kG to 10 kG for the 3 points at the highest temperature (when the sample current was the maximum value, 150 μA) to increase the Hall voltage. This accounts for the discontinuity in the curve since R decreases with increasing magnetic field strength.

The extrinsic region is the linear region from 40 °K to 100 °K. The relation between hole concentration and temperature in this region is given by Eq. (3.14). From the slope of the linear region the ionization energy of the impurity atoms is found to be 0.049 eV. This suggests that the p-type sample contains gold impurities since the ionization energy of gold atoms in germanium is reported by Sze and Irvin (1968) to be 0.04 eV.

The behavior of the sample below 40 °K is caused by electrical breakdown: the ionization of both impurity and germanium atoms by impact of charge carriers. Due to the extra carriers, the Hall coefficient is less than its value for extrinsic conduction only. The electric field across the sample, with the magnetic field on, at 25 °K was 1.2 V cm^{-1} using the lowest sample current available (100 nA).

As the temperature was raised, the electric field approached 0.2 V cm^{-1} at the temperature where the extrinsic region begins. These results are in fair agreement with Fritzsche (1955) who states that electric fields less than 0.5 V cm^{-1} do not cause electrical breakdown.

Resistivity

Figure 5 shows the common logarithm of the electrical resistivity as a function of the inverse absolute temperature. At room temperature the sample has a resistivity of about $1.6 \text{ } \Omega \text{ cm}$. The resistivity decreases with temperature from $300 \text{ } ^\circ\text{K}$ to $175 \text{ } ^\circ\text{K}$. This variation with temperature is due to the fact that the carrier concentration is constant in this region and hence the resistivity has the temperature dependence of the Hall mobility, which is explained later. As the temperature is lowered below $80 \text{ } ^\circ\text{K}$ the resistivity increases exponentially to about $10^3 \text{ } \Omega \text{ cm}$ at $40 \text{ } ^\circ\text{K}$. This linear region is the extrinsic temperature range. The ionization energy obtained from the slope in the linear region is found to be in agreement with the value obtained from the Hall coefficient in Fig. 4. With further decrease in temperature, at minimum sample current, the electric field in the sample exceeds 0.5 V cm^{-1} causing electrical breakdown. Electrical breakdown increases the concentration of charge carriers and hence decreases the resistivity. This effect is observed below $40 \text{ } ^\circ\text{K}$ and extends to the lowest temperature at which measurements were performed.

Hall Mobility

Resistivity and Hall data are combined to give Hall mobility, $\mu_H = R/\rho$. The log-log plot of the Hall mobility versus the absolute temperature is shown in Fig. 6. At room temperature the Hall mobility of the holes was found to be about $1900 \text{ cm}^2 \text{ V}^{-1} \text{ sec}^{-1}$ in agreement with

data collected by Blatt (1968). For purposes of discussion, the Hall mobility curve can be broken down into the following regions: (1) the electrical breakdown region; (2) the acoustic phonon scattering region; and (3) the combined acoustic and optical phonon scattering region.

Electrical breakdown extends from 40 °K down to the lowest temperatures. Ionized atom scattering dominates in this region. The fluctuations in mobility in this region are due to the varying concentrations of ionized atoms brought on by impact ionization of both the impurity and the germanium atoms. The dependence of the mobility on the ionized-atom concentration is predominant and therefore little information can be obtained on its temperature dependence.

The acoustic phonon scattering region extends from 50 °K to 120 °K, the lower limit determined by the concentration of impurity atoms. The temperature dependence of the mobility in this region was calculated from the slope of $\log \mu_H$ versus $\log T$ and was found to be $T^{-1.6}$. This temperature dependence is in good agreement with the results obtained by Brown and Bray (1962). The higher variation with temperature than the $T^{-3/2}$ law predicted by theory (see Eq. (3.19)) is due to intervalley and/or optical mode scattering.

The transition from the acoustic phonon scattering region to the combined acoustic and optical phonon scattering region occurs from 120 °K to 150 °K. In the region above 150 °K optical scattering is responsible for the greater rate of decrease of Hall mobility with temperature.

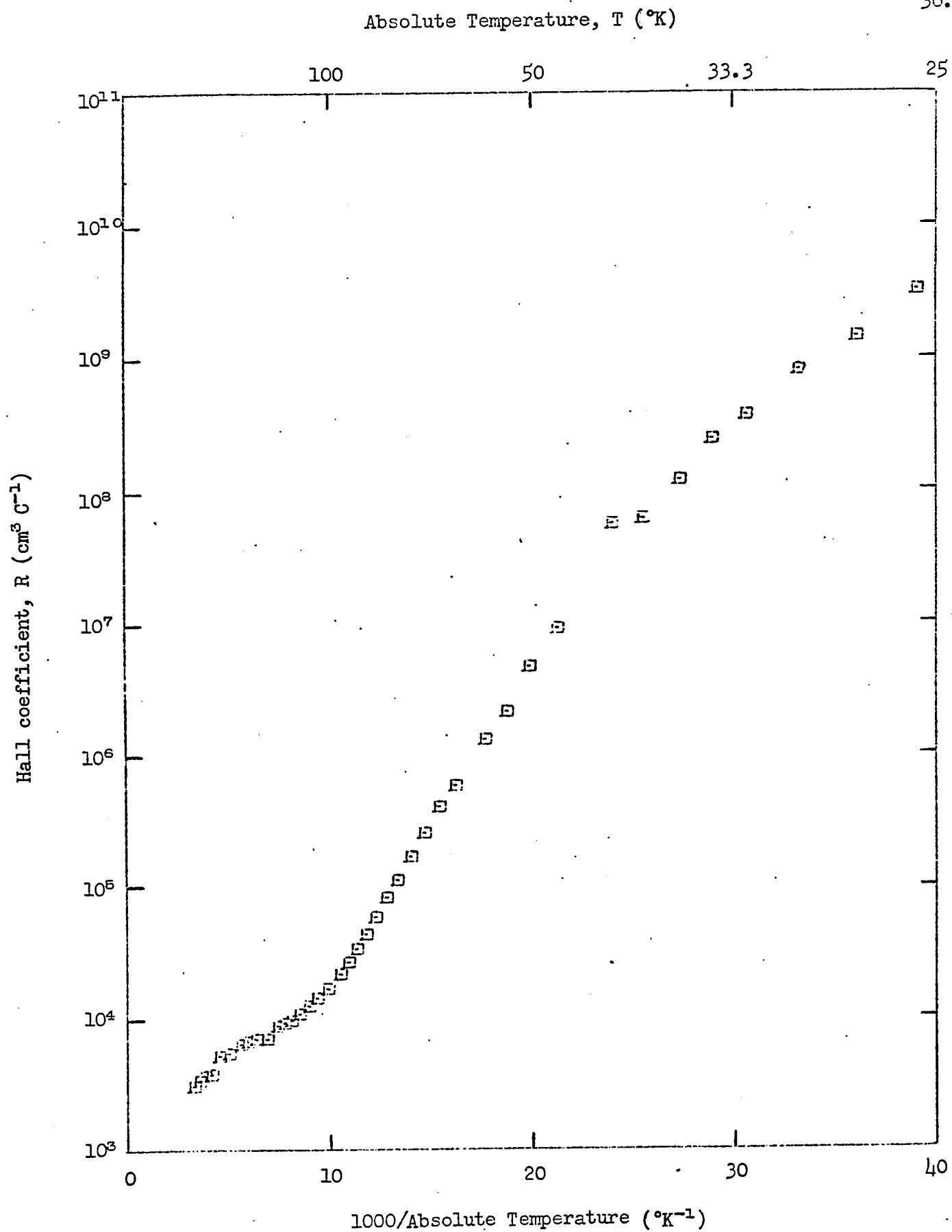


Fig. 4. Hall coefficient of a p-type germanium sample as a function of inverse absolute temperature.

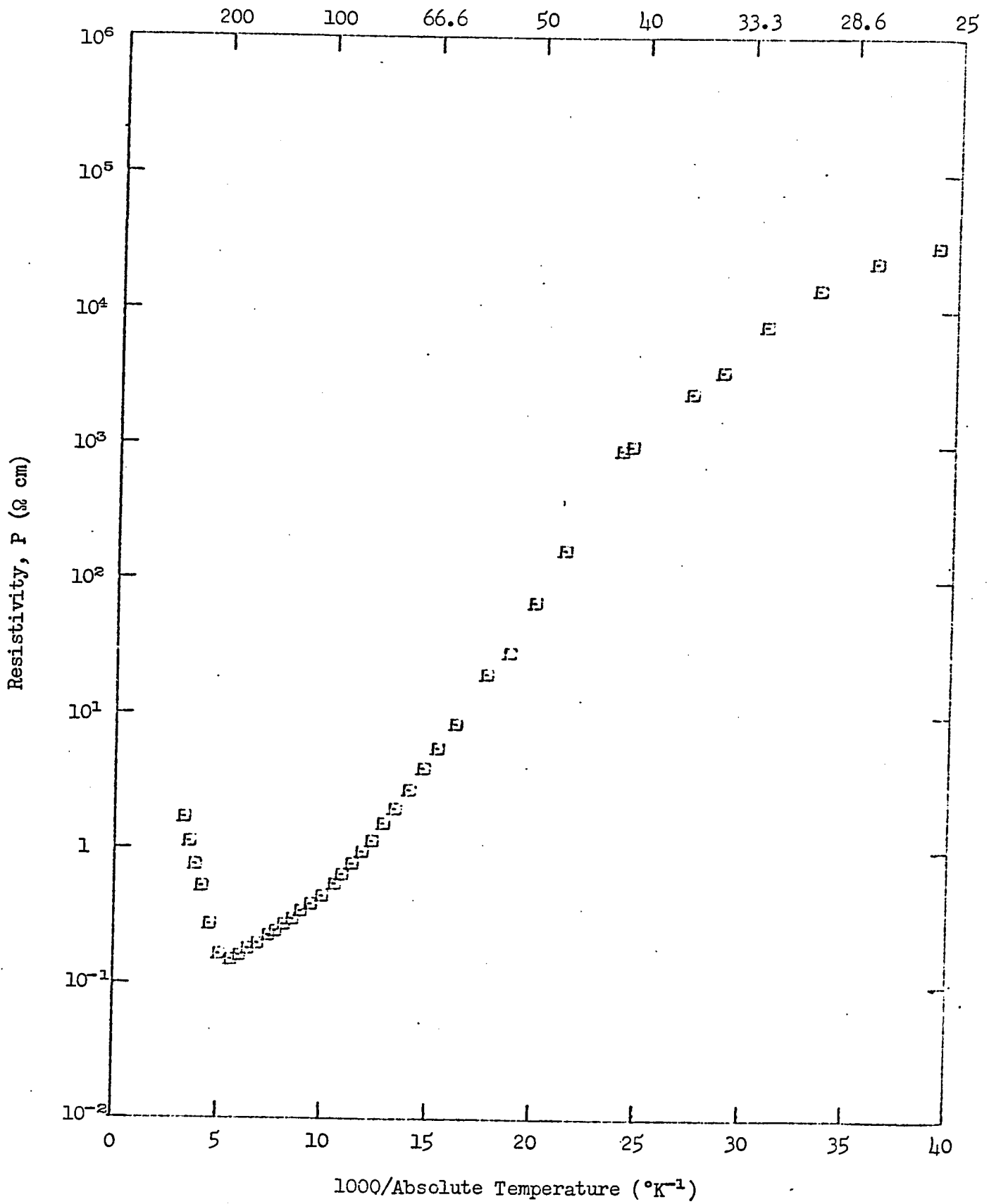


Fig. 5. Resistivity of a p-type germanium sample as a function of inverse absolute temperature.

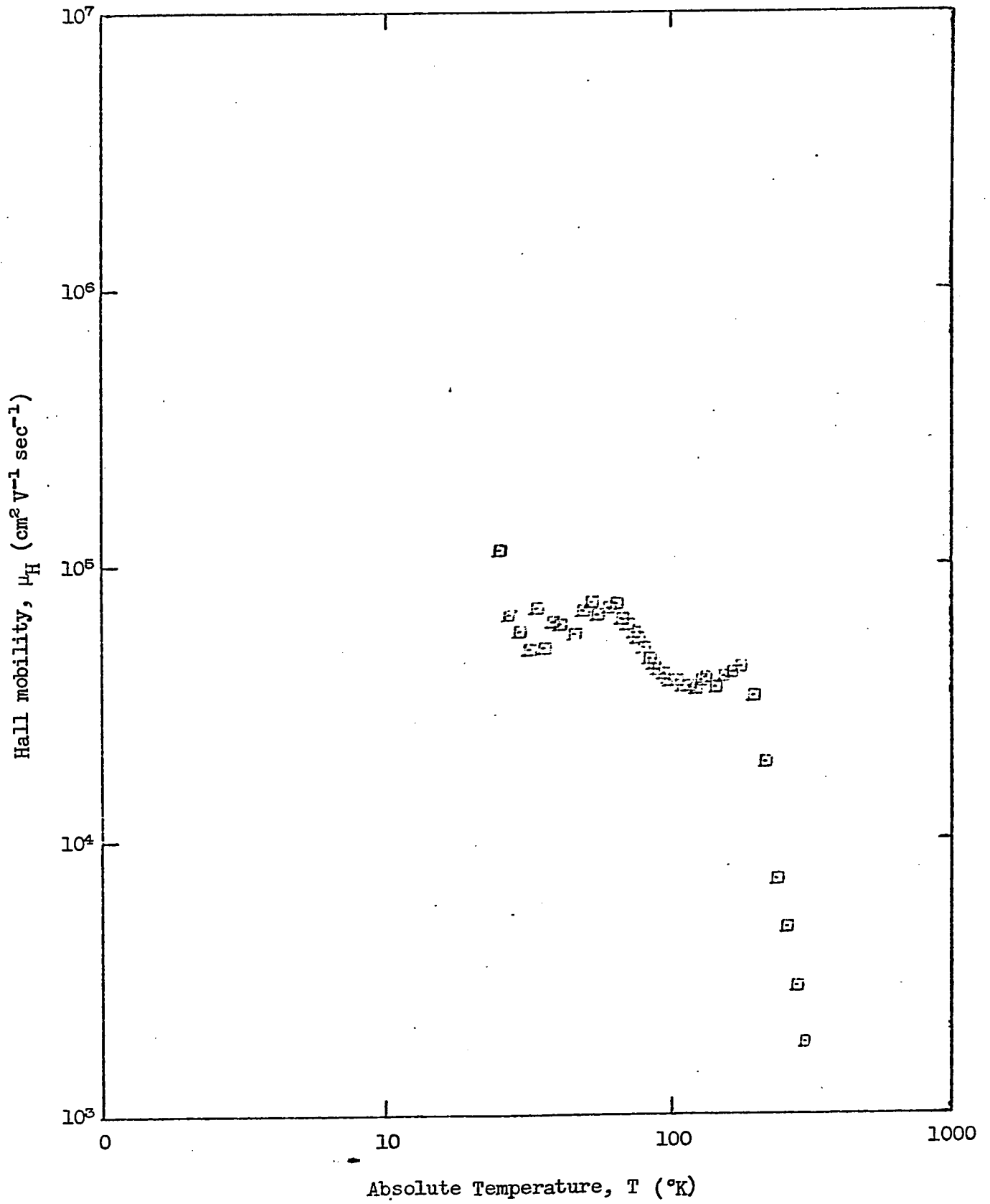


Fig. 6. Hall mobility of a p-type germanium sample as a function of absolute temperature.

CHAPTER V

CONCLUSIONS

A digital-computer-based real-time data acquisition, processing, and control system was developed for electrical resistivity and Hall coefficient measurements of semiconductors. System programs were written to enable real-time open-loop control of the experiment, to collect the data voltages, to store these voltages on magnetic tape, to process the data on-line, and to permit further off-line data processing. Computer-controlled measurements were performed on a germanium sample to verify the operation of the system. The measurements performed illustrate the many advantages of computerized data acquisition and processing compared to manual methods. The experiment and analysis of results are completed error free in hours rather than days or weeks by manual methods. Control of the temperature enables the operator to concentrate data acquisition on areas of greatest interest. The system not only permits accurate and rapid measurements of the data voltages but also offers an on-line display of the processed data on the plotter. The results of off-line data processing are available within minutes after the completion of the experiment.

The experimental results agree with published data and thus confirm the proper operation of the system. These results indicate that the only limitation of the system is due to the integrating digital voltmeter. The lowest temperature at which the electrical properties of a high resistance semiconductor can be measured is determined by the

voltmeter's input impedance of $10^9 \Omega$. In addition to the system limitation, it was found that the range of the sample-current supply is inadequate for low temperature measurements on high resistance semiconductors.

On the basis of this work two recommendations are made to improve the system: the use of closed-loop control instead of open-loop control and the use of the language FOCAL instead of assembly language. At present the operator completes the open loop by controlling the sample current, the temperature, and the magnetic field. To implement closed-loop control, that is, control of the above quantities by the program, additional equipment is required. A 12-bit digital to analog converter has already been installed. All programs are written at present in assembly language, the vocabulary of which is mnemonics for machine language instructions. Specialized knowledge is required to use assembly language. This limits the number of people who can use the system. Secondly, it is very time consuming to make changes, no matter how small, to assembly language programs. FOCAL is an interpretive-level language which is basically a subroutine caller. It is easy to learn and additions or changes to FOCAL programs are easily made. FOCAL can be extended so that it can communicate with the equipment in Fig. 1. The relatively slow execution of FOCAL programs compared to machine language programs is not a limitation for this system.

REFERENCES

- Bardeen, J. and Shockley, W. 1950. Phys. Rev. 80: 72-80.
- Blatt, F.J. 1968. Physics of electronic conduction in solids.
New York: McGraw-Hill.
- Brooks, H. 1951. Phys. Rev. 83: 879.
- Brown, D.M. and Bray, R. 1962. Phys. Rev. 127: 1593-1602.
- Debye, P.P. and Conwell, E.M. 1954. Phys. Rev. 93: 693-706.
- Erginsoy, C. 1950. Phys. Rev. 79: 1013-1014.
- Fan, H.Y. 1955. Valence semiconductors, germanium and silicon.
Solid State Phys. 1: 283.
- Fritzsche, H. 1955. Phys. Rev. 99: 406-419.
- Johnson, V.A. and Lark-Horovitz, K. 1951. Phys. Rev. 82: 977-978.
- Kittel, C. and Mitchell, A.H. 1954. Phys. Rev. 96: 1488-1493.
- Putley, E.H. 1960. The Hall effect and related phenomena.
London: Butterworths.
- Sze, S.M. and Irvin, J.C. 1968. Solid-State Electronics 11: 599-602.

APPENDIX A

1. IDENTIFICATION
 - 1.1 Phys - 8L - YYA - D
 - 1.2 On-Line Data Acquisition Package

2. ABSTRACT

This software package, used in conjunction with the Floating-Point Package (DEC-08-YQ4A-PB), enables the "on-line" acquisition of resistivity and Hall effect data on semiconductor crystals.

The package consists of two independent programs:

Program 1 inputs and records voltages on magnetic tape for varying temperatures. The common logarithm of the absolute value of the Hall coefficient versus the reciprocal of the absolute temperature is plotted "on-line".

Program 2 inputs and records voltages on magnetic tape for varying magnetic fields.

Upon acquisition of data, programs available in the Processing and Display Package (Phys-8L-YYYB-PB) can be called upon to plot other transport properties.

3. REQUIREMENTS

3.1 Equipment

Computer, DEC PDP-8/L with 4K memory

Teletype, ASR-33

Plotter, Houston DP-1-1

Integrating Digital Voltmeter, HP 2402A

Guarded Relay Multiplexer, DEC A111

Magnetic Tape Unit, PEC 3520-7

3.2 Storage

	Locations	Registers
Data Acquisition Package (Phys-8L-YYA-PB)	0-4556	2415
Floating-Point Package (DEC-08-YQA-PB)	4557-7577	1553

A total of 3,968 registers are required.

4. USAGE

4.1 The Data Acquisition Package (Phys-8L-YYA-PB) and the Floating-Point Package (DEC-08-YQA-PB) are loaded individually into the computer memory by means of the Binary Loader. For proper loading procedure refer to PDP-8/L User's Handbook.

4.2 Start Up and/or Entry

To execute Program 1 set the switch register on the computer console to 0200, depress LOAD ADD and then START. Program 2 starts in location 0400.

4.3 Errors in Usage and Recovery from Such Errors.

4.3.1 Program 1

A) An error committed while typing in a parameter may be corrected by the use of one special input character, "Rubout". If it is struck before the input delimiter, "Return", the input routine is restarted and the previous number deleted. The user then re-types the parameter on the same line. For further information refer to Floating-Point System Programming Manual.

B) The program will halt after printing out the second set of voltages, if the voltages have been incorrectly recorded on the

magnetic tape. The error code will be displayed in the accumulator.

Remedy: Correct the error, then depress the CONT key on the computer console. The program will cause the magnetic tape unit to backspace one record, rewrite the data on the tape, and continue execution.

N.B. A discussion of errors which may be committed while recording data on magnetic tape and their correction is given in DSA Operating Instructions Manual.

C) If the EOF (End of File) mark has been incorrectly written on the magnetic tape, the program will halt with the error code displayed in the accumulator.

Remedy: Same as in section 4.3.1B.

N.B. The computer halts with 2100 displayed in the accumulator upon successful completion of the execution of the program.

4.3.2 Program 2

A) The program will halt after printing out a set of voltages, if the voltages have been incorrectly recorded on the magnetic tape. The error code will be displayed in the accumulator.

Remedy: Same as in section 4.3.1B.

B) If the EOF (End of File) mark has been incorrectly written on the magnetic tape the program will halt with the error code displayed in the accumulator.

Remedy: Same as in section 4.3.1B.

N.B. The computer halts with 2100 displayed in the accumulator upon successful completion of the execution of the program.

5. RESTRICTIONS

5.1 Program 1

The plotting area is confined to six (6) inches along the abscissa and eight (8) inches along the ordinate. A point having its X and/or Y coordinate external to this periphery will not be plotted; program control re-enters the acquisition phase.

Recalling that the plotter pen moves in increments of 0.01 inches per step, it is imperative that the user provide the proper scale factors. The scale factor in this context is defined as the number of steps per logical unit.

5.1.1 Scaling of the Abscissa

Since values of $1000/T$ will be plotted along the abscissa, the scale factor is thus the number of steps per unit inverse temperature. By typing in the appropriate scale factor, the user may select the temperature range throughout which the experimental results will be plotted.

5.1.2 Scaling of the Ordinate

The common logarithm of the absolute value of the Hall coefficient is plotted along the ordinate. Here the scale factor is defined as the number of steps per unit logarithmic

cycle. An arbitrary number of cycles are made available depending on the scale selected. The scale factor must be such that the full scale (800 steps) divided by the scale factor is equal to the number of cycles desired.

5.2 Program 2 (Not applicable)

6. DESCRIPTION

6.1 Program 1

This program consists of four stages:

- 1) Parameter Input
- 2) Data Acquisition and Storage
- 3) Data Processing and Display
- 4) Monitor

6.1.1 Parameter Input

The computer types out appropriate comments, and when it is ready to receive a parameter it enters a waiting loop. This loop is signalled by the computer typing an "=" or a ":". The user then inputs the parameter in either the fixed or the floating-point notation. Input is terminated by typing a delimiting character. "Return" typed on the keyboard will terminate the input and provide a CRLF (carriage return and line feed).

This dialogue between computer and user permits the input of sample dimensions, scale factors, and the desired increment in temperature. Upon termination of the dialogue, the computer types out the data headings and initializes the plotting phase.

The program then enters the second stage.

6.1.2 Data Acquisition and Storage

When the desired initial temperature has been attained, the user depresses the letter "M" (Measure) on the keyboard to start acquisition. Any other character typed will be disregarded and the computer will remain in the waiting loop. The command "M" is not echoed by the printer. The computer then inputs and prints out the first set of voltages (with the magnetic field off) and re-enters the waiting loop. The user next sets the magnetic field to the desired value and depresses "M" on the keyboard. The second set of voltages is entered and printed out. Both sets of voltages are then converted to the floating-point notation and recorded on magnetic type. The program enters the third stage.

6.1.3 Data Processing and Display

The absolute temperature T is printed. The computer then calculates the common logarithm of the absolute value of the Hall coefficient and the value of $1000/T$, scales these values and plots the point (providing its coordinates fall within the plotting area). Having plotted the point, the program enters the Monitor stage.

6.1.4 Monitor

This fourth and final stage of the program is signalled by the computer typing a CRLF (carriage return and line feed) followed by a period. The computer is now ready to accept a

command. Only three legal commands may be issued. An illegal command will be disregarded and the program will remain in the command mode. Only legal commands will be echoed by the printer. The valid commands along with their functions are listed below:

1. "\$" will cause an EOF (End of File) mark to be written on the magnetic tape and will terminate execution of the program.
2. "C" (Continue) causes the computer to continuously measure the temperature until it equals the last temperature at which measurements were made plus the temperature increment. Program control is then transferred to stage 2 of the program.
3. "D" (Delta) allows the user to input a new temperature increment. The computer calculates the new temperature desired, and when attained, transfers control to stage 2 of the program.

6.2 Program 2

Data headings are typed out and the program enters a waiting loop. The user depresses the letter "M" (Measure) on the keyboard to start acquisition of data. Any other character typed will be disregarded and the program will remain in the waiting loop. The command "M" is not echoed by the printer. The computer inputs and prints out the set of voltages. The voltages are then converted to the floating-point notation and written on magnetic tape.

The temperature is then calculated and printed out. Temperatures

are printed to assist the user in manually maintaining a constant temperature. The program re-enters the waiting loop. The magnetic field is then varied and when "M" is depressed, the second set of voltages is entered and recorded on magnetic tape. To terminate execution of the program and to write an EOF (End of File) mark on the magnetic tape, the user depresses "\$" on the keyboard. This command is echoed by the printer.

7. EXECUTION TIME

The acquisition and plotting of data is limited by the speed of peripheral devices.

8. PROGRAM LISTINGS AND FLOW CHARTS ARE PROVIDED.

9. REFERENCES

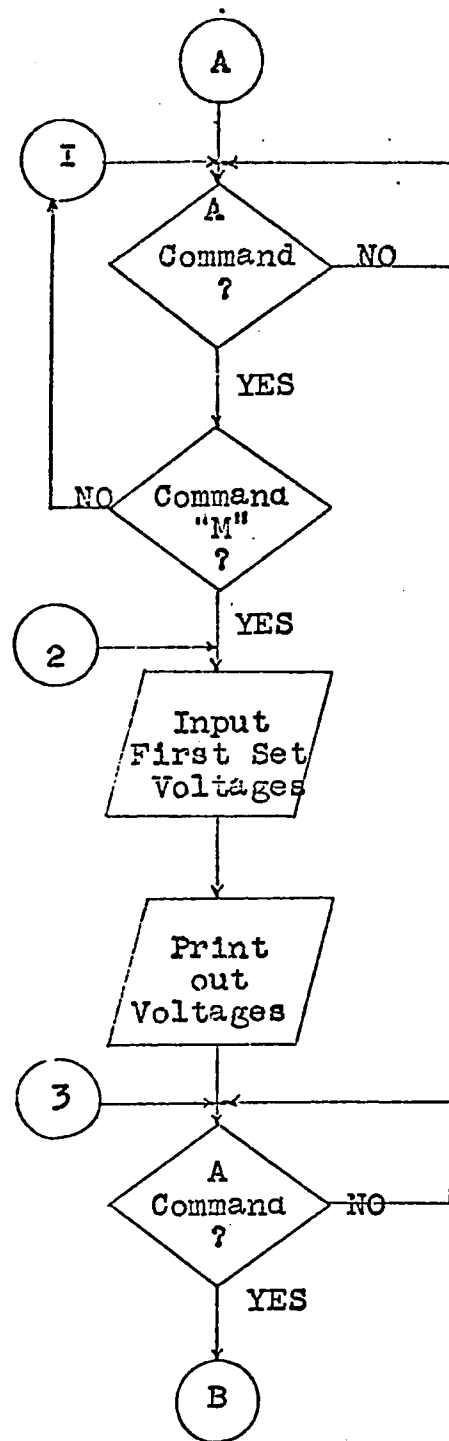
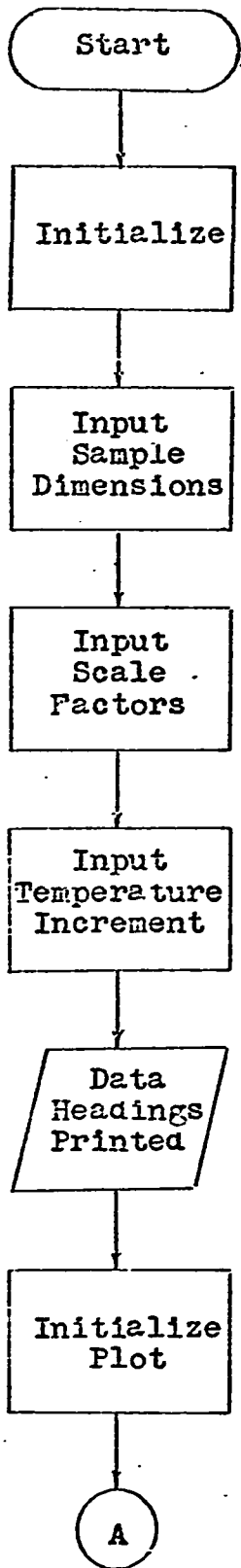
Digital Equipment Corporation Manuals

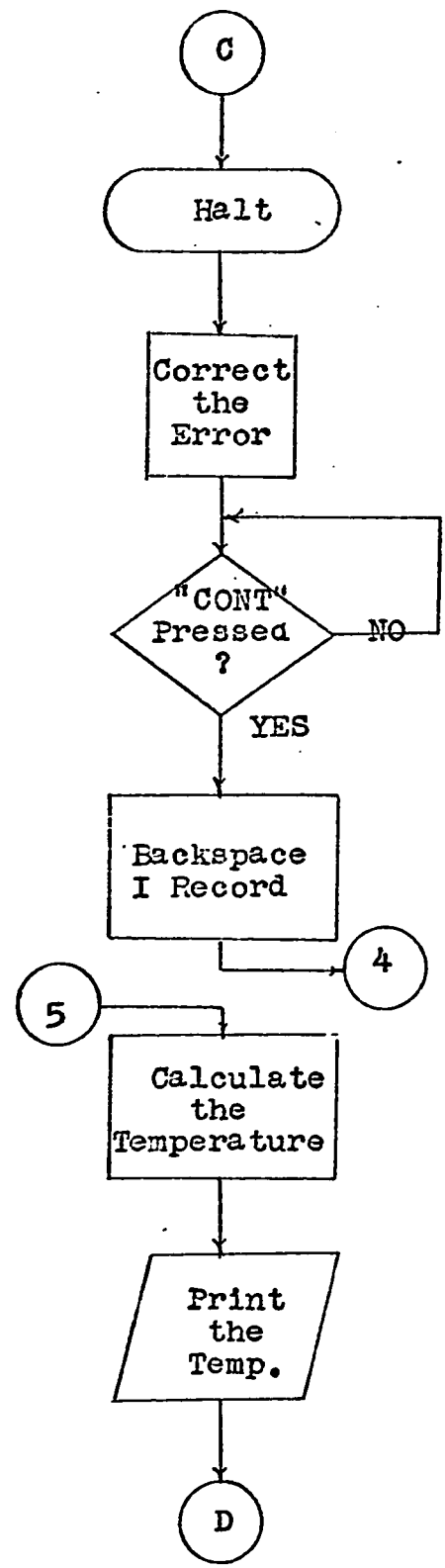
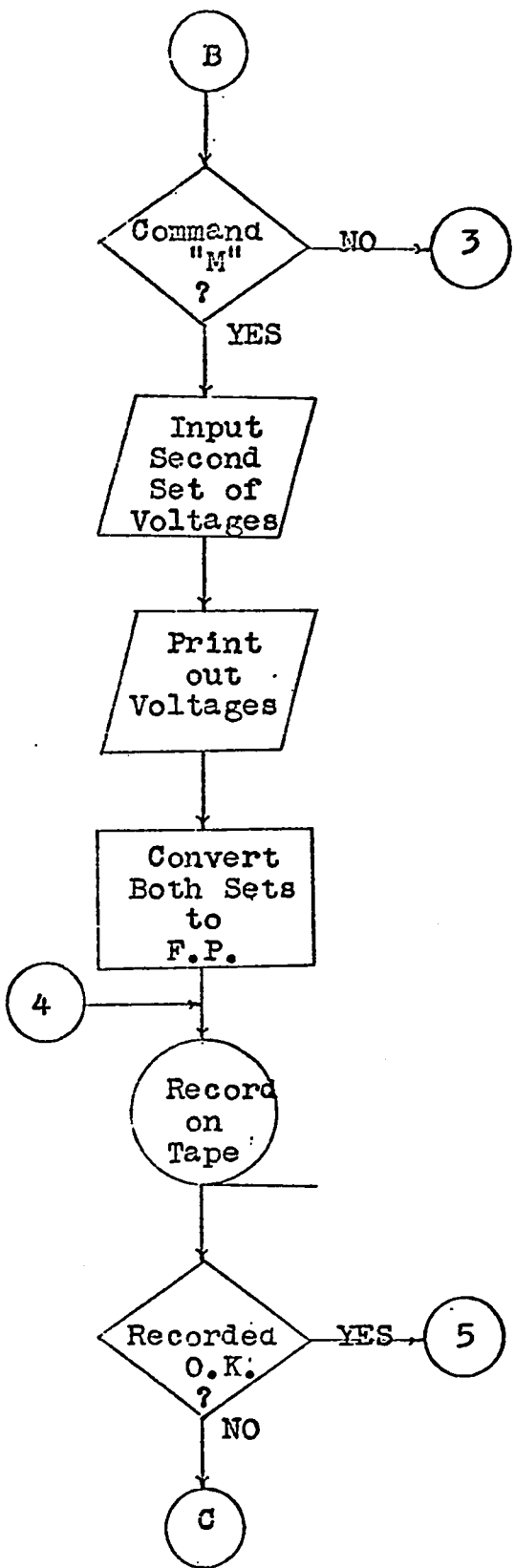
1. Introduction to Programming (1969)
2. PDP-8/L User's Handbook
3. Floating-Point System Programming Manual

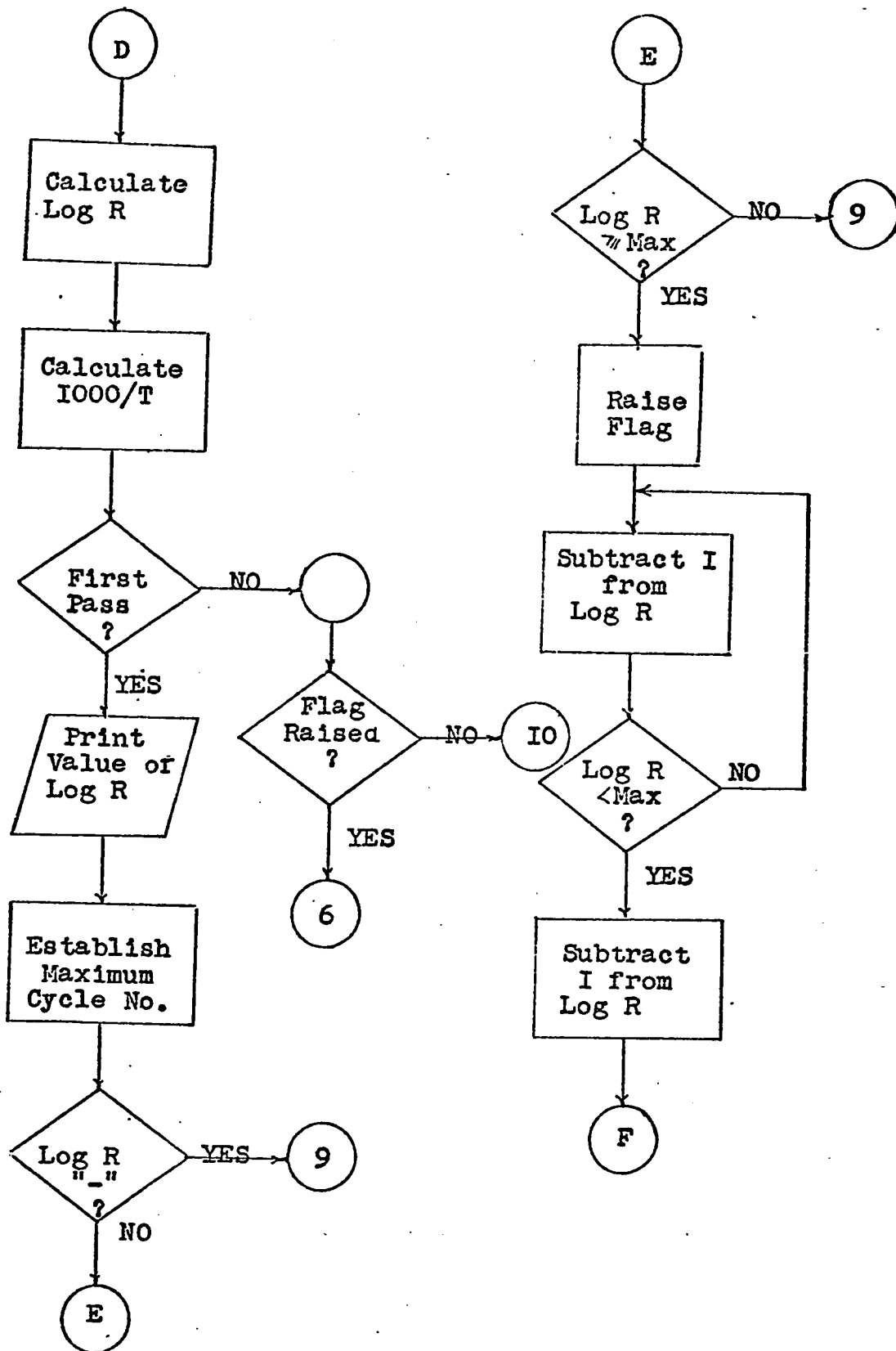
Digital Systems Associates Ltd. Manuals

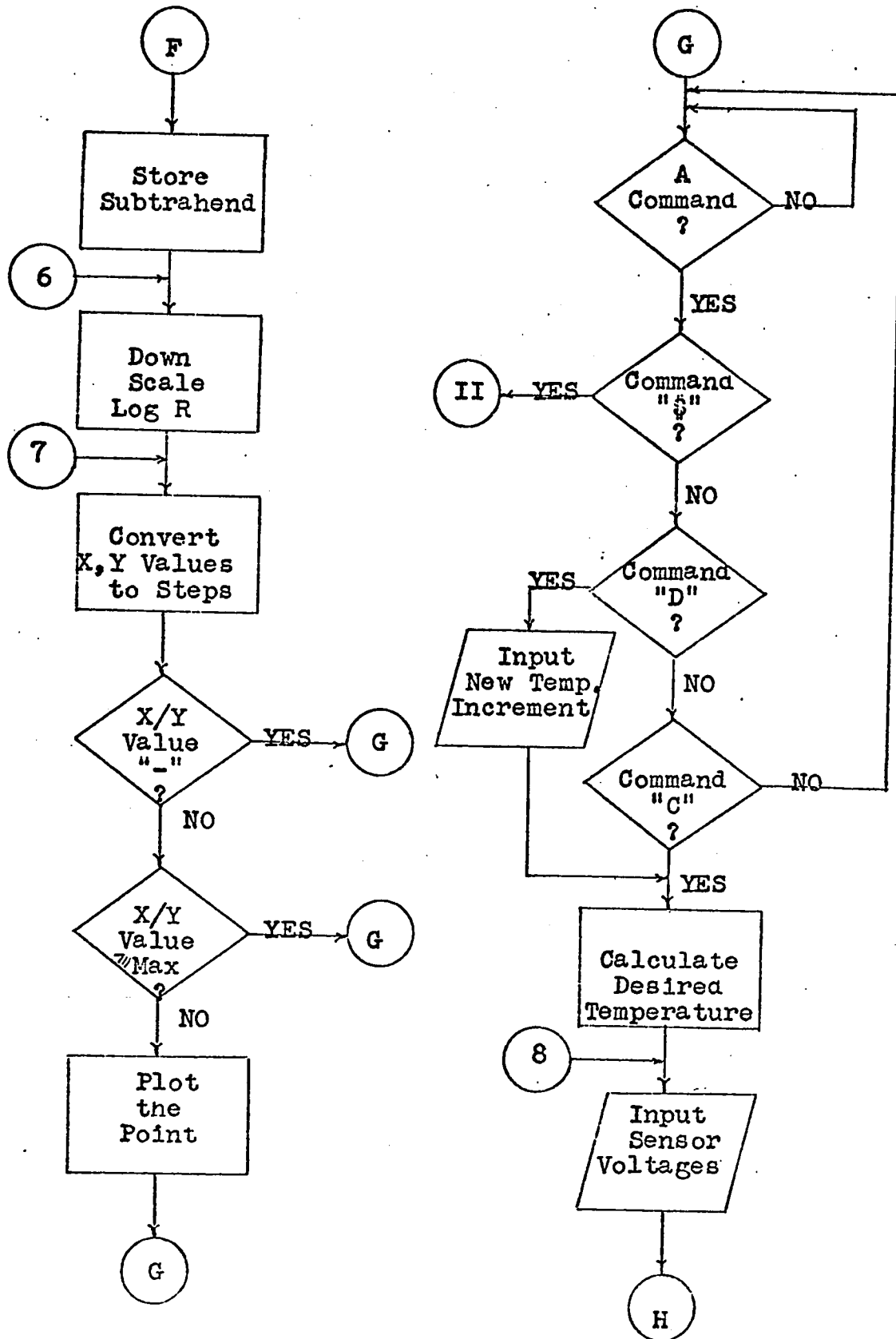
1. Seven Track Magnetic Tape Unit for the PDP-8/L
2. Data and Control Word Formats

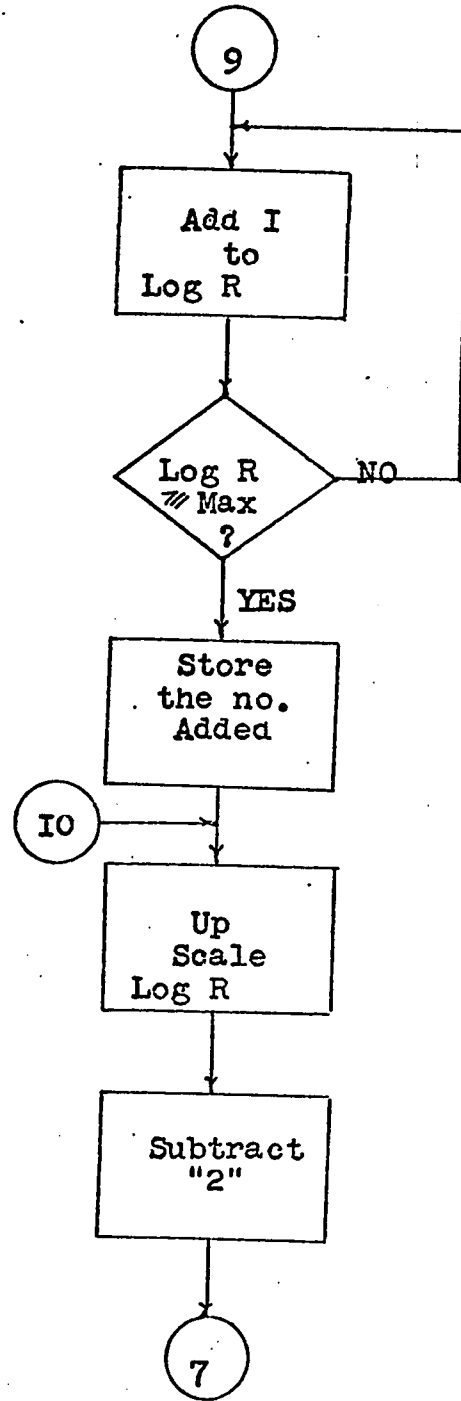
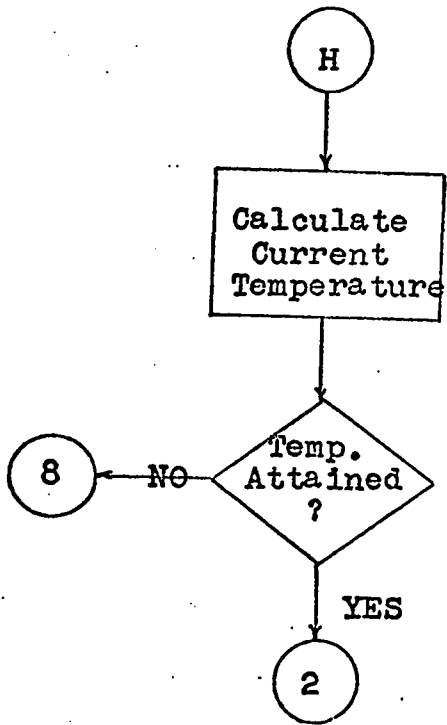
10. FLOW CHARTS : Program I.

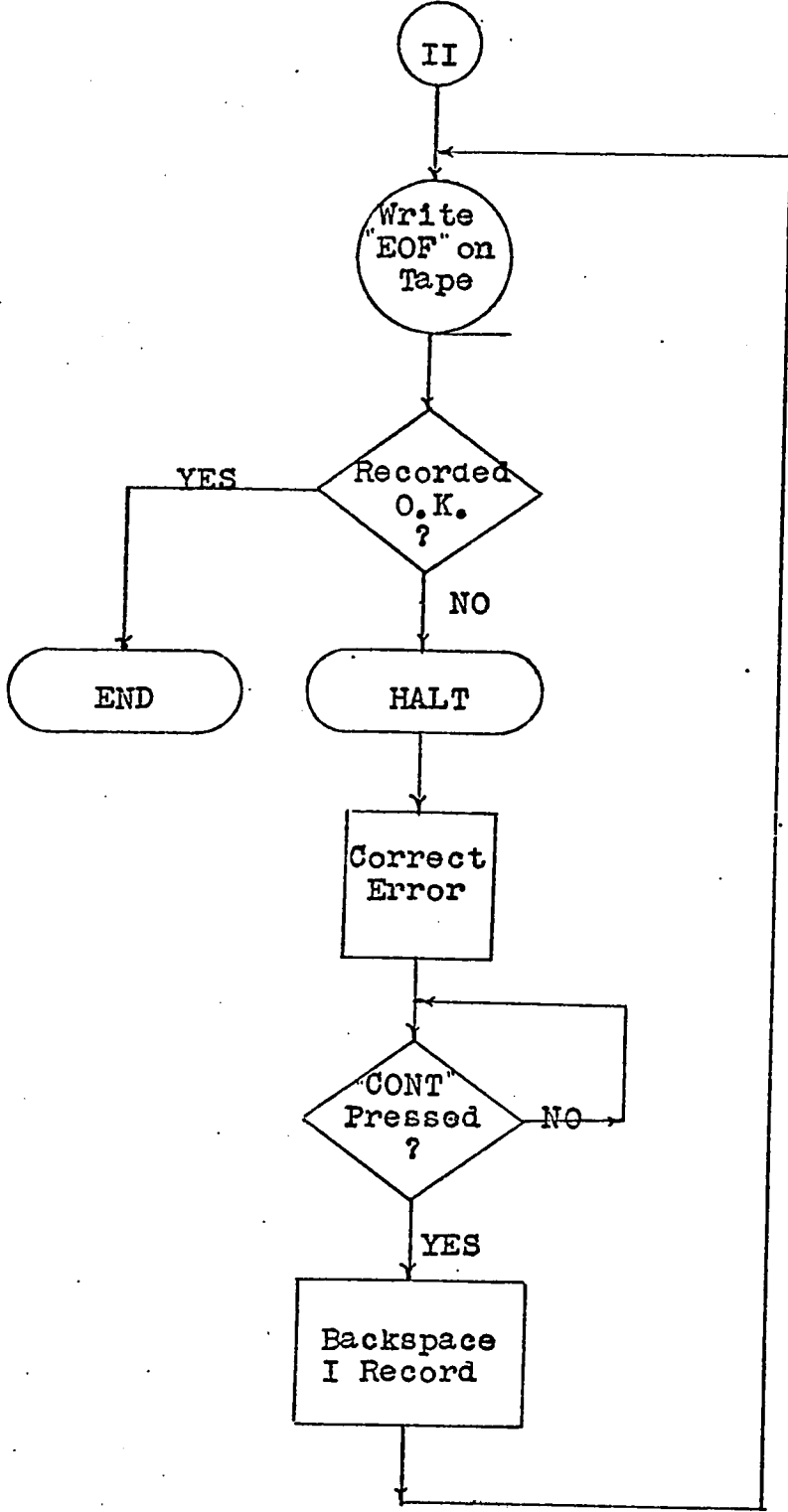




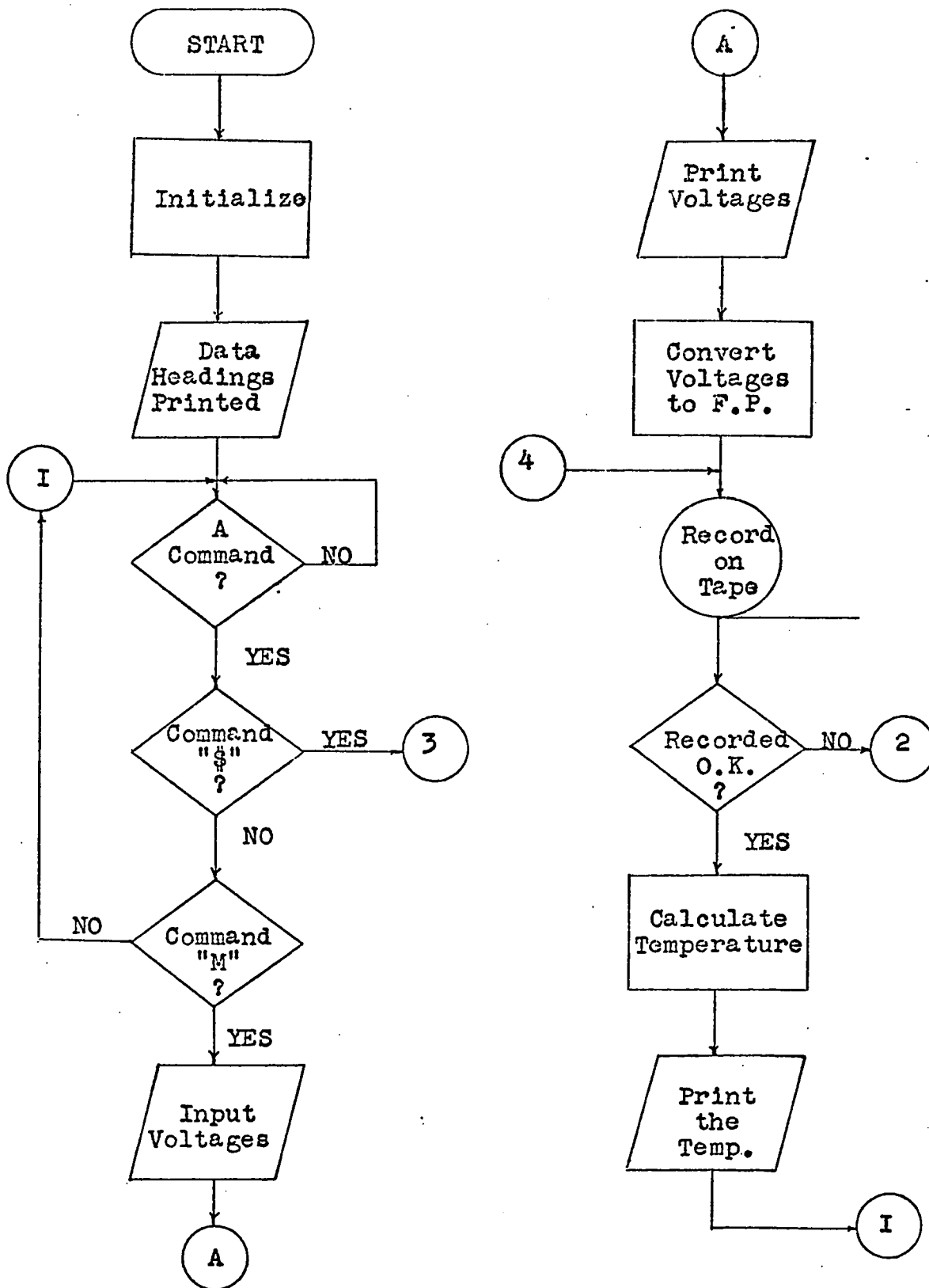


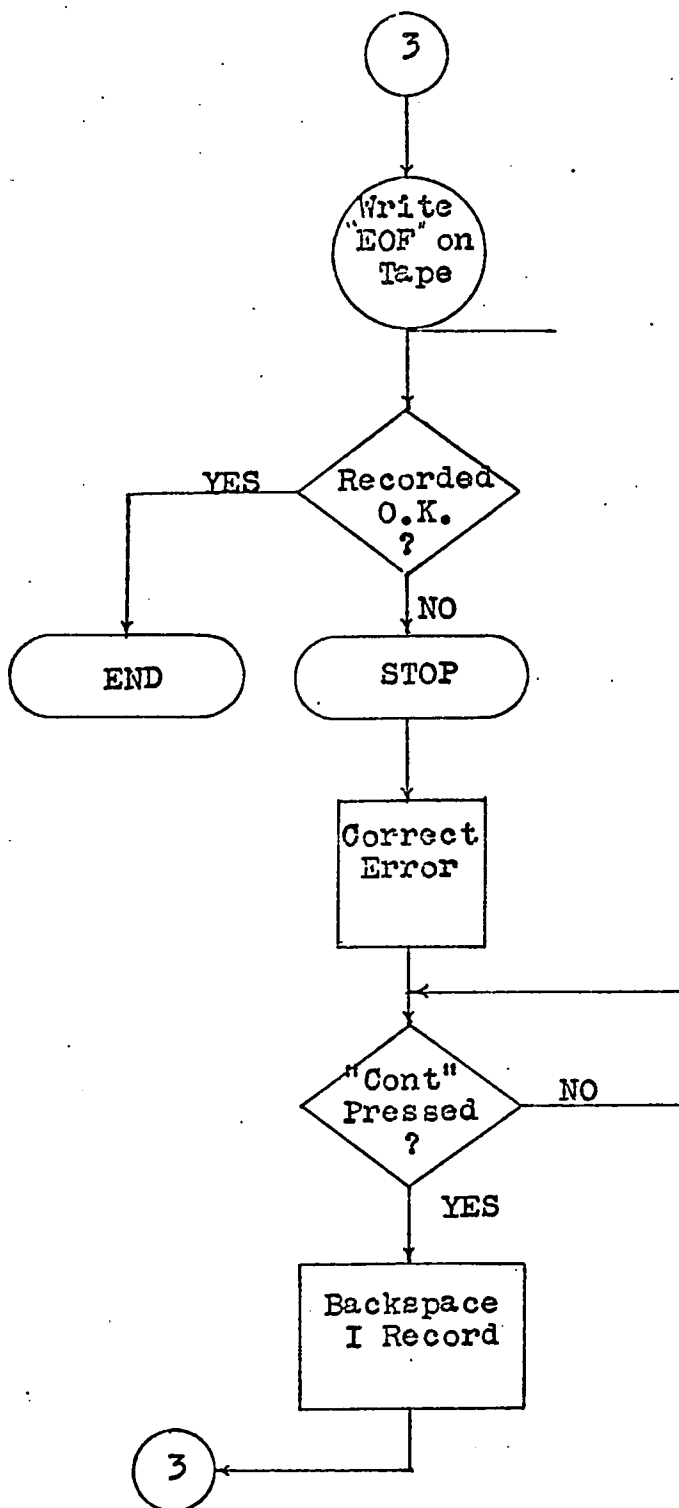
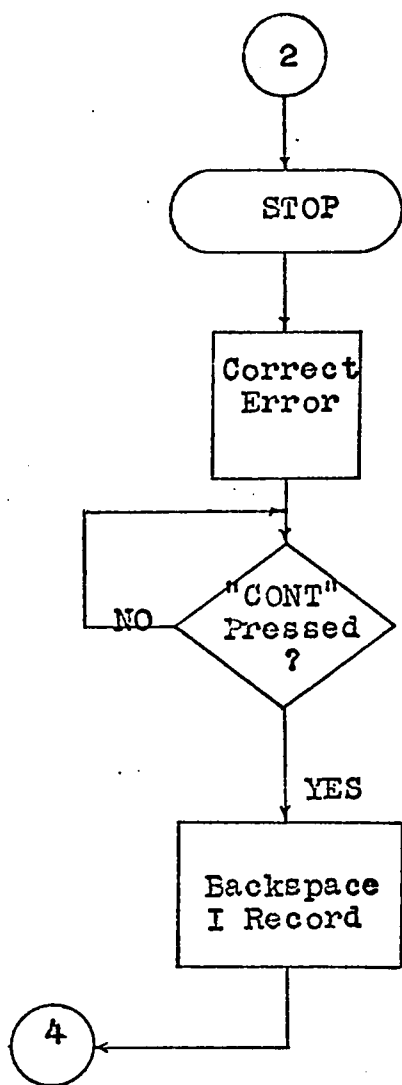






FLOW CHARTS : Program 2.





II. PROGRAM LISTING

/DATA ACQUISITION AND ANALYSIS
 /"THE TRANSPORT PROPERTIES OF S
 /DATA ACQUISITION FOR TEMPERATURE
 /PLOT OF LOG (RH) VS 1000/T

SQUARE=0001
 LOG =0007
 NEGATE=0010
 *5

0005	7400	7400	/POINTER TO INPUT ROUTINE
0006	7200	7200	/POINTER TO OUTPUT ROUTINE
0007	5600	5600	/POINTER TO INTERPRETER
		*200	
0200	7300	PHASE1, CLA CLL	
0201	1131	TAD C6000	/ALLOWS THE USE OF THE
0202	3530	DCA I L6554	/INTERPRETIVE COMMAND,
0203	7300	CLA CLL	/ "NEGATE"
0204	4420	JMS I CLEARP	/CLEAR ALL FLAGS
0205	4421	JMS I CRLEP	
0206	4422	JMS I DIMENP	/INPUT SAMPLE DIMENSION
0207	4421	JMS I CRLEP	
0210	4430	JMS I SCALEP	/INPUT SCALE FACTORS
0211	4421	JMS I CRLEP	
0212	4434	JMS I DELTP	/INPUT THE DESIRED TEMP.
0213	4421	JMS I CRLEP	/INCREMENT.
0214	4421	JMS I CRLEP	
0215	4436	JMS I FORMPR	/TYPE OUT HEADINGS
0216	4564	JMS I TRACEP	/TRACE OUT PLOT AREA.
0217	4512	JMS I LISNPR	/AT DESIRED TEMPERATURE
0220	1672	AGDAT1, TAD C3177	/"M" ON TTY TO START ACQUISITION
0221	3012	DCA 12	/B.C.D. VOLTAGES STORED
0222	1067	TAD M7	/UP
0223	4466	JMS I INPUTP	/READ 1ST. SET OF B.C.D.
0224	1072	TAD C3177	/INIT MEMORY
0225	3012	DCA 12	
0226	4470	JMS I OUTVPR	/PRINT OUT 1ST SET
0227	4512	JMS I LISNPR	/DEPRESS "M" WHEN MAG.
0230	1031	TAD C3224	/ FIELD ON.
0231	3012	DCA 12	
0232	1067	TAD M7	
0233	4466	JMS I INPUTP	/READ IN 2ND. SET OF VO
0234	1031	TAD C3224	
0235	3012	DCA 12	
0236	4470	JMS I OUTVPR	/PRINT OUT 2ND. SET
0237	1100	TAD M16	/CONVERT BOTH SETS OF V
0240	4473	JMS I FLOATP	/TO F.P. , STOPE
0241	4571	JMS I WRITEP	/WRITE F.P. VOLTAGES ON
0242	0052	0052	/NO. OF WORDS (OCTAL)
0243	3252	3252	/S.A. OF DATA IN CORE
0244	6731	6731	/ODD PARITY (BINARY CODE)
0245	5247	JMP +2	/ERROR RETURN
0246	5255	JMP +7	/NORMAL RETURN

0247	7402	HLT	/CORRECT ERROR; DEPRESS
0250	7300	CLA CLL	/ON CONSOLE
0251	6714	6714	/BACKSPACE 1 RECORD
0252	6701	6701	
0253	5252	JMP.-1	
0254	5241	JMP.-13	/TRY WRITING AGAIN
0255	7300	CLA CLL	/CONTINUE WITH PROGRAM
0256	4504	JMS I CALT1P	/CAL. TEMP. (FIELD OFF)
0257	4505	JMS I CALT2P	/CAL. TEMP. (FIELD ON)
0260	4526	JMS I MEANTP	/CAL. AVERAGE TEMP
0261	4527	JMS I PRINTP	/PRINT OUT AVERAGE TEMP
0262	4534	JMS I LOGRHP	/CALCULATE LOG(RH)
0263	4545	JMS I INVSTP	/CALCULATE 1000/T
0264	7300	CLA CLL	
0265	1156	TAD SW1	
0266	7650	SNA CLA	/FIRST PASS?
0267	5275	JMP.+6	/YES
0270	7300	CLA CLL	/NO
0271	1175	TAD SW1	/DOWN, OR UP
0272	7640	SZA CLA	/SCALING REQ'D?
0273	5330	JMP.+35	/DOWN SCALE
0274	5334	JMP.+40	/UP SCALE
0275	7300	CLA CLL	
0276	1153	TAD ONE	/RAISE SOFTWARE FLAG
0277	3156	DCA SW1	
0300	4565	JMS I OUTINP	/OUTPUT INDEX IN F4.2
0301	4407	JMS I 7	
0302	5552	FGET I MAXYPE	/CAL. MAX. CYCLE
0303	4532	FDIV I SCALYP	/PERMITTED.
0304	6573	FFUT I CYCLEP	
0305	0000	FEXT	
0306	7300	CLA CLL	
0307	4407	JMS I 7	
0310	5543	FGET I YVALP	
0311	0000	FEXT	
0312	7300	CLA CLL	/IS THE 1ST. VALUE
0313	1045	TAD 45	/OF LOG(RH) "-"?
0314	7700	SMA CLA	
0315	5317	JMP.+2	/NO, IT IS POSITIVE
0316	5332	JMP.+14	/YES
0317	4407	JMS I 7	
0320	5543	FGET I YVALP	
0321	2573	FSUB I CYCLEP	
0322	0000	FEXT	
0323	7300	CLA CLL	/IS THE 1ST. VALUE
0324	1045	TAD 45	/OF LOG(RH) > OR = MAX?
0325	7710	SPA CLA	
0326	5332	JMP.+4	/NO, UP SCALE
0327	4566	JMS I LOWINP	/YES, DOWN SCALE
0330	4567	JMS I SETINP	/RESCALE INDEX; STORE
0331	5335	JMP.+4	
0332	7300	CLA CLL	
0333	4576	JMS I UPINP	/UP SCALE
0334	4577	JMS I SETUPP	/RESCALE INDEX; STORE

0335	4551	JMS I STEPSF	/CONVERT X,Y VAL. TO STEP.
0336	4554	JMS I PLOTFR	/PLOT THE POINT
0337	4560	JMS I NEXTTP	/SELECT A TEMP. INCREMENT
0340	4561	JMS I EXAMTP	/IS THE TEMP. > OR = THE
0341	7300	CLA CLL	/DESIRED TEMP?
0342	1045	TAD 45	
0343	7710	SPA CLA	
0344	5340	JMP.-4	/NO, CHECK AGAIN
0345	7300	CLA CLL	/YES, OBTAIN NEXT SET
0346	5220	JMP A0DAT1	/OF DATA

/DATA ACQUISITION FOR FIELD VAR

	*400		
0400	7300	PHASE2, CLA CLL	
0401	1131	TAD C6000	
0402	3530	DCA I L6554	/ENABLES USE OF COMMAND
0403	7300	CLA CLL	/ "NEGATE"
0404	4420	JMS I CLEARP	/CLEAR ALL FLAGS
0405	4421	JMS I CRLFP	
0406	4421	JMS I CRLFP	
0407	4436	JMS I FORMPR	/TYPE OUT HEADINGS
0410	4512	A0DAT2, JMS I LISNPR	/LISTEN FOR COMMAND
0411	5213	JMP.+2	/COMMAND "M" GIVEN, CON.
0412	4572	JMS I ENDP	/COMMAND "S"; WRITE EOF
0413	7300	CLA CLL	
0414	1072	TAD C3177	
0415	3012	DCA 12	/READ A SET OF B.C.D. V
0416	1067	TAD M7	/INTO CORE
0417	4466	JMS I INPUTP	
0420	1072	TAD C3177	
0421	3012	DCA 12	/PRINT OUT VOLTAGES
0422	4470	JMS I OUTVPR	
0423	1067	TAD M7	/CONVERT B.C.D. VOLTAGE
0424	4473	JMS I FLOATP	/TO F.P. STORE
0425	4571	JMS I WRITEP	/RECORD ON MAGNETIC TAPE
0426	0025	0025	/NO. OF WORDS (OCTAL)
0427	3252	3252	/S.A. OF DATA IN CORE
0430	6731	6731	/ODD PARITY (BINARY CODE
0431	5233	JMP.+2	/ERROR RETURN
0432	5241	JMP.+7	/NORMAL RETURN
0433	7402	HLT	/CORRECT ERROR, DEPRESS
0434	7300	CLA CLL	/ON CONSOLE
0435	6714	6714	/BACKSPACE 1 RECORD
0436	6701	6701	
0437	5236	JMP.-1	
0440	5225	JMP.-13	/TRY WRITING AGAIN
0441	7300	CLA CLL	/CONTINUE ON WITH PROGR.
0442	4504	JMS I CALTIP	/CALCULATE TEMP. STORE
0443	4407	JMS I 7	
0444	5562	FGET I TIP	
0445	6433	FPUT I AVTP	

0446 0000
 0447 4527
 0450 4421
 0451 5210

FEXT
 JMS I PRINTP /PRINT OUT THE TEMPERAT.
 JMS I CRLFP
 JMP AGDAT2 /RECORD NEXT SET OF DATA

/MISCELLANEOUS SUBROUTINES

0600	0000	*600			
		OUTV,	0		/TYPE OUT 7 VOLTAGES
0601	1067			TAD M7	
0602	3071			DCA MCH	
0603	1111			TAD M2	
0604	4510			JMS I SKIPPR	
0605	1412			TAD I 12	
0606	3076			DCA WORD	/ENTER DATA WORD1
0607	4275			JMS SIGN	
0610	1076			TAD WORD	
0611	0102			AND MASKPW	
0612	1107			TAD M6	
0613	7440			SZA	/POWER(-6)
0614	5241			JMP DECPOS	
0615	1106			TAD PERIOD	
0616	4432			JMS I TYPEPR	
0617	1065			TAD M3	
0620	3274			DCA COUNTS	
0621	1412			TAD I 12	/DATA WORD2
0622	4310			JMS ROTATE	
0623	2274			ISZ COUNTS	
0624	5222			JMP.-2	
0625	7300			CLA CLL	
0626	1065			TAD M3	
0627	3274			DCA COUNTS	
0630	1412			TAD I 12	/DATA WORD3
0631	4310			JMS ROTATE	
0632	2274			ISZ COUNTS	
0633	5231			JMP.-2	
0634	7300			CLA CLL	
0635	2071			ISZ MCH	
0636	5203			JMP OUTV+3	
0637	4421			JMS I CRLFP	
0640	5600			JMP I OUTV	/EXIT SUBROUTINE
0641	3103	DECPOS,	DCA CNTRDP		
0642	1065			TAD M3	
0643	3274			DCA COUNTS	
0644	1412			TAD I 12	/WORD2
0645	4310			JMS ROTATE	
0646	2103			ISZ CNTRDP	
0647	5254			JMP.+5	
0650	3076			DCA WORD	
0651	1106			TAD PERIOD	
0652	4432			JMS I TYPEPR	
0653	1076			TAD WORD	
0654	2274			ISZ COUNTS	

0655	5245		JMP.-10	
0656	7300		CLA CLL	
0657	1065		TAD M3	
0660	3274		DCA COUNTS	
0661	1412		TAD I 12	
0662	4310		JMS ROTATE	
0663	2103		ISZ CNTRDP	
0664	5271		JMP.+5	
0665	3076		DCA WORD	
0666	1106		TAD PERIOD	
0667	4432		JMS I TYPEPR	
0670	1076		TAD WORD	
0671	2274		ISZ COUNTS	
0672	5262		JMP.-10	
0673	5234		JMP DECPOS-5	
0674	0000	COUNTS, 0		
0675	0000	SIGN, 0		
0676	1076		TAD WORD	
0677	0077		AND MASKSN	
0700	7640		SZA CLA	/-VE. VOLTAGE
0701	5305		JMP.+4	
0702	1114		TAD MINUS	
0703	4432		JMS I TYPEPR	
0704	5675		JMP I SIGN	
0705	1115		TAD PLUS	
0706	4432		JMS I TYPEPR	
0707	5675		JMP I SIGN	
0710	0000	ROTATE, 0		
0711	7006		RTL	
0712	7006		RTL	
0713	3323		DCA TEMP1	
0714	1323		TAD TEMP1	
0715	7004		RAL	
0716	0324		AND MASKSC	
0717	1325		TAD C260	
0720	4432		JMS I TYPEPR	
0721	1323		TAD TEMP1	
0722	5710		JMP I ROTATE	
0723	0000	TEMP1, 0		
0724	0017	MASKSC, 0017		
0725	0260	C260, 260		
0726	0000	EXAMT, 0		/CHECK TEMPERATURE CONTINUOUS.
0727	1072		TAD C3177	
0730	3012		DCA 12	
0731	1065		TAD M3	/READ INTO MEMORY THE V
0732	4466		JMS I INPUTP	/B.C.D. VOLTAGES RELATE
0733	1065		TAD M3	/THE TEMPERATURE
0734	4473		JMS I FLOATP	/FLOAT THESE VOLTAGES
0735	4504		JMS I CALTIP	/CALCULATE T, STORE IN
0736	4407		JMS I 7	
0737	5562		FGET I TIP	/SUBTRACT THE DESIRED T
0740	2343		FSUB NEWT	/FROM THE CURRENT TEMPE
0741	0000		FEXT	/EXIT WITH THE RESULT I
0742	5726		JMP I EXAMT	

0743	0000	NEWT,	0		
0744	0000			0	
0745	0000			0	
0746	0000	LISN,	0		
0747	6031			KSF	
0750	5347			JMP.-1	/LISTEN FOR A COMMAND
0751	6036			KRB	
0752	3024			DCA TEMP	/STORE THE COMMAND
0753	1024			TAD TEMP	
0754	1371			TAD MM	/WAS COMMAND "M" ISSUED
0755	7640			SZA CLA	
0756	5360			JMP.+2	/NO, SEARCH FOR NEXT LE.
0757	5746			JMP I LISN	/YES, EXIT
0760	1024			TAD TEMP	
0761	1372			TAD MDOLLA	
0762	7640			SZA CLA	/WAS COMMAND "S" ISSUED?
0763	5347			JMP LISN+1	/NO, WAIT FOR LEGAL COM.
0764	1024			TAD TEMP	/YES, ECHO IT
0765	6046			TLS	
0766	7200			CLA	
0767	2346			ISZ LISN	
0770	5746			JMP I LISN	/EXIT
0771	7463	MM,	-315		
0772	7534	MDOLLA,	-244		

		*1000			
1000	0000	DELTAT,	0		
1001	1224			TAD C4270	/LETTER STORAGE
1002	3010			DCA 10	/AUTO INDEX FOR
1003	1410			TAD I 10	
1004	3024			DCA TEMP	
1005	1024			TAD TEMP	
1006	1025			TAD MEQUAL	/TESTING FOR EQ
1007	7640			SZA CLA	
1010	7410			SKP	
1011	5215			JMP.+4	
1012	1024			TAD TEMP	
1013	4432			JMS I TYPEPR	
1014	5203			JMP DELTAT+3	
1015	1024			TAD TEMP	
1016	4432			JMS I TYPEPR	
1017	4405			JMS I 5	/INPUT, TERMINA
1020	4407			JMS I 7	/ENTER THE F.P.
1021	6435			FPUT I DTP	
1022	0000			FEXT	
1023	5600			JMP I DELTAT	
1024	4270	C4270,	4270		
1025	0000	FORMAT,	0		
1026	1315			TAD C4301	/LETTER STORAGE
1027	3010			DCA 10	/AUTO INDEX FOR
1030	1063			TAD M4	
1031	3023			DCA CNTR1	

1032	1316			TAD M42	
1033	4267			JMS SKIP	
1034	1410			TAD I 10	
1035	4432			JMS I TYPEPR	
1036	2023			ISZ CNTR1	/TYPES (DATA)
1037	5234			JMP.-3	
1040	4421			JMS I CRLFP	
1041	4421			JMS I CRLFP	
1042	4437			JMS I TABPR	
1043	4277			JMS HEAD	/TYPES (V(EX))
1044	1317			TAD M5	
1045	4267			JMS SKIP	
1046	4277			JMS HEAD	/TYPES (V(GE))
1047	1317			TAD M5	
1050	4267			JMS SKIP	
1051	4277			JMS HEAD	/TYPES (V(PT))
1052	4437			JMS I TABPR	
1053	4277			JMS HEAD	/TYPES (V(MAG))
1054	1065			TAD M3	
1055	4267			JMS SKIP	
1056	4277			JMS HEAD	/TYPES (V(SAM I))
1057	1065			TAD M3	
1060	4267			JMS SKIP	
1061	4277			JMS HEAD	/TYPES (V(RES))
1062	1317			TAD M5	
1063	4267			JMS SKIP	
1064	4277			JMS HEAD	/TYPES (V(HALL))
1065	4421			JMS I CRLFP	
1066	5625			JMP I FORMAT	
1067	0000	SKIP,	0		
1070	3276			DCA CNTRSK	
1071	1026			TAD SPACE	
1072	4432			JMS I TYPEPR	
1073	2276			ISZ CNTRSK	
1074	5271			JMP.-3	
1075	5667			JMP I SKIP	
1076	0000	CNTRSK,	0		
1077	0000	HEAD,	0		
1100	1410			TAD I 10	
1101	3024			DCA TEMP	
1102	1024			TAD TEMP	
1103	1064			TAD M251	/TESTING FOR CL
1104	7640			SZA CLA	
1105	7410			SKP	
1106	5312			JMP.+4	
1107	1024			TAD TEMP	
1110	4432			JMS I TYPEPR	
1111	5300			JMP HEAD+1	
1112	1024			TAD TEMP	
1113	4432			JMS I TYPEPR	
1114	5677			JMP I HEAD	
1115	4301	C4301,	4301		
1116	7736	M42,	-42		
1117	7773	M5,	-5		

1120	0000	INPUTV,	0		
1121	3071			DCA MCH	
1122	1343			TAD CW1	/STORE CONTROL WORD 1
1123	3345			DCA SAVE	
1124	1344	NEXTV,	TAD CW2		
1125	4347			JMS DIGITZ	/DIGITIZE VOLTAGE
1126	6542			RDCF	
1127	6544			BA	
1130	6542			RDCF	/INPUT THE VOLTAGE FROM
1131	6544			BA	/CHANNEL (7)
1132	6542			RDCF	/DO NOT STORE
1133	7300			CLA CLL	
1134	2345			ISZ SAVE	
1135	1345			TAD SAVE	
1136	4347			JMS DIGITZ	/DIGITIZE THE VOLTAGE T
1137	4746			JMS I VOLTP	/READ IN THE VOLTAGE, S
1140	2071			ISZ MCH	/ALL VOLTAGES READ IN?
1141	5324			JMP NEXTV	/NO
1142	5720			JMP I INPUTV	/YES, EXIT
1143	0677	CW1,	0677		
1144	0707	CW2,	0707		/C.W. FOR DUMMY VOLTAGE IN
1145	0000	SAVE,	0		
1146	1364	VOLTP,	VOLTIN		
1147	0000	DIGITZ,	0		/DIGITIZES A VOLTAGE AND PREPARE
1150	6531			CWRD	/IT FOR ENTRY INTO CORE
1151	6541			SDR	
1152	5351			JMP.-1	
1153	7300			CLA CLL	
1154	4362			JMS DELAY	
1155	6541			SDR	
1156	5355			JMP.-1	
1157	7300			CLA CLL	
1160	4362			JMS DELAY	
1161	5747			JMP I DIGITZ	
1162	0000	DELAY,	0		
1163	1372			TAD CONST	
1164	3373			DCA COUNT	
1165	2374			ISZ COUNT1	
1166	5365			JMP.-1	
1167	2373			ISZ COUNT	
1170	5365			JMP.-3	
1171	5762			JMP I DELAY	
1172	7770	CONST,	7770		/PROVIDES 150 MSEC. DELAY
1173	0000	COUNT,	0		
1174	0000	COUNT1,	0		

*1200

1200	0000	FLOATV,	0		
1201	3023			DCA CNTR1	/NO. OF VOLTAGES TO BE
1202	1072			TAD C3177	/B.C.D. VOLTAGES IN LOC
1203	3012			DCA 12	/AUTO-INDEX FOR B.C.D.
1204	1271			TAD C3252	/F.P. VOLTAGES IN LOC.

1205	3013			DCA 13	
1206	1412	NEXT,	TAD I 12		
1207	3076			DCA WORD	/STORE DATA WORD1
1210	1076			TAD WORD	
1211	0077			AND MASKSN	/SIGN TEST
1212	7650			SNA CLA	/+VE. VOLTAGE
1213	5216			JMP.+3	/-VE. VOLTAGE
1214	1101			TAD ZERO	
1215	3272			DCA SW	
1216	1076			TAD WORD	
1217	0102			AND MASKPW	/POWER TEST
1220	7041			CIA	
1221	3103			DCA CNTRDP	
1222	2012			ISZ 12	/ADDRESS OF NEXT DATA W
1223	1012			TAD 12	
1224	3226			DCA HAD	
1225	4474			JMS I DPBCDB	/CONVERT WORDS2,3 INTO
1226	0000	HAD,	0		
1227	3045			DCA 45	/STORE IN H.O. MANTISSA
1230	1475			TAD I LOWPR	
1231	3046			DCA 46	/STORE IN L.O. MANTISSA
1232	1273			TAD C27	
1233	3044			DCA 44	/SET EXP=23(10)
1234	4407			JMS I 7	/ENTER THE F.P. PACKAGE
1235	7000			FNOR	
1236	0000			FEXT	
1237	4407			JMS I 7	
1240	4274			FDIV TEN	/ACCOUNT FOR THE DECIMAL
1241	0000			FEXT	
1242	2103			ISZ CNTRDP	
1243	5237			JMP.-4	
1244	7300			CLA CLL	
1245	1272			TAD SW	
1246	7640			SZA CLA	/+VE. VOLTAGE
1247	5254			JMP.+5	/-VE. VOLTAGE
1250	4407			JMS I 7	
1251	6413			FPUT I 13	/STORE F.P. VOLTAGE
1252	0000			FEXT	
1253	5260			JMP.+5	
1254	4407			JMS I 7	
1255	0010			NEGATE	
1256	6413			FPUT I 13	
1257	0000			FEXT	
1260	1277			TAD C7777	/PREPARE FOR THE NEXT V
1261	3272			DCA SW	
1262	2012			ISZ 12	
1263	2013			ISZ 13	
1264	2013			ISZ 13	
1265	2013			ISZ 13	
1266	2023			ISZ CNTR1	
1267	5206			JMP NEXT	
1270	5600			JMP I FLOATV	
1271	3252	C3252,	3252		
1272	7777	SW,	7777		

1273	0027	C27,	27	
1274	0004	TEN,	4	
1275	2400			2400
1276	0000			0
1277	7777	C7777,	7777	
1300	0000	NEXTT,	0	/PROVIDES FOR INCREMENTAL T'S
1301	4421			JMS I CRLFP /OR FINALIZES THE ENTIR
1302	1106			TAD PERIOD /(:) INDICATES THE PROG.
1303	4432			JMS I TYPEPR /(COMMAND) MODE
1304	6031			KSF
1305	5304			JMP.-1 /ONLY VALID COMMANDS WI
1306	6036			KRB /ON THE TTY
1307	3361			DCA BUFFER
1310	1361			TAD BUFFER
1311	1362			TAD MD
1312	7640			SZA CLA /WAS COMMAND (D) GIVEN?
1313	5330			JMP.+15 /NO, SEARCH FOR OTHER L
1314	1361			TAD BUFFER /YES, ECHO ON TTY
1315	6046			TLS
1316	7200			CLA
1317	4421			JMS I CRLFP
1320	4434			JMS I DELTP /INPUT NEW DELTA T , ST
1321	4407			JMS I 7
1322	5433			FGET I AVTP
1323	1435			FADD I DTP
1324	6563			FPUT I NEWTP /NEWT=AVT+DTEMP
1325	0000			FEXT
1326	7300			CLA CLL
1327	5700			JMP I NEXTT /EXIT
1330	1361			TAD BUFFER
1331	1113			TAD MC /WAS COMMAND(C) GIVEN?
1332	7640			SZA CLA
1333	5347			JMP.+14 /NO, SEARCH FOR OTHER L
1334	1361			TAD BUFFER /YES, ECHO ON TTY
1335	6046			TLS
1336	7200			CLA
1337	4421			JMS I CRLFP
1340	4407			JMS I 7
1341	5433			FGET I AVTP
1342	1435			FADD I DTP
1343	6563			FPUT I NEWTP
1344	0000			FEXT
1345	7300			CLA CLL
1346	5700			JMP I NEXTT /EXIT
1347	1361			TAD BUFFER /WAS COMMAND (S) GIVEN?
1350	1363			TAD MDOLL
1351	7640			SZA CLA
1352	5304			JMP NEXTT+4 /NO. WAIT FOR A LEGAL C
1353	1361			TAD BUFFER /YES, ECHO ON TTY
1354	6046			TLS
1355	7200			CLA
1356	4421			JMS I CRLFP
1357	4572			JMS I ENDP /WRITE "EOF" ON MAGNETI
1360	5700			JMP I NEXTT /TERMINATE THE PROGRAM

1361	0000	BUFFER,	0		
1362	7474	MD,		-304	
1363	7534	MDOLL,		-244	
1364	0000	VOLTIN,	0		
1365	6542			RDCF	
1366	3412			DCA I 12	/STORE DATA WORD 1
1367	6544			BA	
1370	6542			RDCF	
1371	3412			DCA I 12	/STORE DATA WORD 2
1372	6544			BA	
1373	6542			RDCF	
1374	3412			DCA I 12	/STORE DATA WORD 3
1375	5764			JMP I VOLTIN	
		*1400			
1400	0000	CLEAR,	0		
1401	6032			KCC	/INITIALIZE HARD.
1402	6046			TLS	/FLAGS
1403	6502			PLCF	
1404	6504			PLPU	
1405	4574			JMS I DOPR	
1406	1101			TAD ZERO	/INITIALIZE SOFT.
1407	3156			DCA SW1	/FLAGS
1410	1101			TAD ZERO	
1411	3175			DCA SW2	
1412	5630			JMP I CLEAR	
1413	0000	CRLF,	0		
1414	1221			TAD CR	
1415	4223			JMS TYPE	
1416	1222			TAD LF	
1417	4223			JMS TYPE	
1420	5613			JMP I CRLF	
1421	0215	CR,		215	
1422	0212	LF,		212	
1423	0000	TYPE,	0		
1424	6041			TSF	
1425	5224			JMP.-1	
1426	6046			TLS	
1427	7200			CLA	
1430	5623			JMP I TYPE	
1431	0000	DIMEN,	0		
1432	1306			TAD C4177	/LETTERS IN LOG
1433	3010			DCA 10	/AUTO INDEX FOR
1434	1307			TAD C3400	/CONSTANTS IN L
1435	3011			DCA 11	
1436	1065			TAD M3	
1437	3023			DCA CNTR1	
1440	1410	DIMEN1,		TAD I 10	
1441	3024			DCA TEMP	
1442	1024			TAD TEMP	
1443	1064			TAD M251	/TESTING FOR CL
1444	7640			SZA CLA	
1445	7410			SKP	

1446	5252			JMP.+4	
1447	1024			TAD TEMP	
1450	4223			JMS TYPE	
1451	5240			JMP DIMEN1	
1452	1024			TAD TEMP	
1453	4223			JMS TYPE	
1454	4213			JMS CRLF	
1455	4310			JMS TAB	
1456	1410	DIMEN2,	TAD I 10		
1457	3024			DCA TEMP	
1460	1024			TAD TEMP	
1461	1025			TAD MEQUAL	/TESTING FOR EQ
1462	7640			SZA CLA	
1463	7410			SKP	
1464	5270			JMP.+4	
1465	1024			TAD TEMP	
1466	4223			JMS TYPE	
1467	5256			JMP DIMEN2	
1470	1024			TAD TEMP	
1471	4223			JMS TYPE	
1472	4405			JMS I 5	/INPUT, TERMINAL
1473	4407			JMS I 7	/ENTER THE F.P.
1474	6411			FPUT I 11	
1475	0000			FEXT	
1476	2023			ISZ CNTR1	
1477	7410			SKP	
1500	5305			JMP.+5	
1501	2011			ISZ 11	
1502	2011			ISZ 11	
1503	2011			ISZ 11	
1504	5255			JMP DIMEN2-1	
1505	5631			JMP I DIMEN	
1506	4177	C4177,	4177		
1507	3400	C3400,	3400		
1510	0000	TAB,	0		
1511	1063			TAD M4	
1512	3027			DCA CNTR2	
1513	1026			TAD SPACE	
1514	4223			JMS TYPE	
1515	2027			ISZ CNTR2	
1516	5313			JMP.-3	
1517	5710			JMP I TAB	
1520	0000	SCALE,	0		
1521	1375			TAD C4230	/LETTER STORAGE
1522	3010			DCA 10	/AUTO INDEX FOR
1523	1376			TAD C3411	/CONSTANTS STORE
1524	3011			DCA 11	
1525	1111			TAD M2	
1526	3023			DCA CNTR1	
1527	1410	SCALE1,	TAD I 10		
1530	3024			DCA TEMP	
1531	1024			TAD TEMP	
1532	1064			TAD M251	/TESTING FOR CL
1533	7640			SZA CLA	

1534	7410			SKP	
1535	5341			JMP.+4	
1536	1024			TAD TEMP	
1537	4223			JMS TYPE	
1540	5327			JMP SCALE1	
1541	1024			TAD TEMP	
1542	4223			JMS TYPE	
1543	4213			JMS CRLF	
1544	4310			JMS TAB	
1545	1410	SCALE2,	TAD I 10		
1546	3024			DCA TEMP	
1547	1024			TAD TEMP	
1550	1377			TAD MCOLON	
1551	7640			SZA CLA	/TESTING FOR CO
1552	7410			SKP	
1553	5357			JMP.+4	
1554	1024			TAD TEMP	
1555	4223			JMS TYPE	
1556	5345			JMP SCALE2	
1557	1024			TAD TEMP	
1560	4223			JMS TYPE	
1561	4405			JMS I 5	/INPUT
1562	4407			JMS I 7	/ENTER THE F.P.
1563	6411			FPUT I 11	
1564	0000			FEXT	
1565	2023			ISZ CNTR:	
1566	7410			SKP	
1567	5374			JMP.+5	
1570	2011			ISZ 11	
1571	2011			ISZ 11	
1572	2011			ISZ 11	
1573	5344			JMP SCALE2-1	
1574	5720			JMP I SCALE	
1575	4230	C4230,	4230		
1576	3411	C3411,	3411		
1577	7506	MCOLON,	-272		

		*1600			
1600	0000	CALT1,	0		/FIELD OFF
1601	4407			JMS I 7	/ENTER THE F.P. PACKAGE
1602	5516			FGET I GE1P	
1603	3540			FMPY I R3P	/R(GE)=V(GE)/V(EX)/R3
1604	4520			FDIV I EX1P	
1605	6270			FPUT RES	/STORE THE VALUE OF THE
1606	2301			FSUB MINRGE	/SUBTRACT 21.13 OHMS
1607	0000			FEXT	
1610	7300			CLA CLL	/IS THE RESISTANCE OF T.
1611	1045			TAD 45	/> OR =21.13 OHMS?
1612	7710			SPA CLA	/I.E. IS T<38 OR =38 DEG?
1613	5216			JMP.+3	/NO, T>38, USE PT. THER.
1614	4304			JMS GRANGE	/YES, USE GE. THERMOMET
1615	5227			JMP.+12	

1616	4407			JMS I 7	
1617	5522			FGET I PT1P	/CALCULATE R(PT)
1620	3540			FMPY I R3P	
1621	4520			FDIV I EX1P	
1622	0000			FEXT	
1623	7300			CLA CLL	/OBTAIN T BY EVALUATING
1624	4570			JMS I POLYP	/PT. TEMP. POLY.
1625	0006			0006	/DEGREE OF POLY.
1626	2671			2671	/S.A. OF COEFFICIENTS I
1627	4407			JMS I 7	
1630	6273			FPUT T1	/STORE T
1631	0000			FEXT	
1632	7300			CLA CLL	
1633	5600			JMP I CALT1	/EXIT
1634	0000	CALT2,	0		/FIELD ON
1635	4407			JMS I 7	/ENTER THE F.P. PACKAGE
1636	5523			FGET I GE2P	
1637	3540			FMPY I R3P	/CALCULATE R(GE)
1640	4524			FDIV I EX2P	
1641	6270			FPUT RES	/STORE THE VALUE OF THE
1642	2301			FSUB MINRGE	/SUBTRACT 21.13 OHMS
1643	0000			FEXT	
1644	7300			CLA CLL	/IS THE RESISTANCE OF T
1645	1045			TAD 45	/> OR =21.13 OHMS?
1646	7710			SPA CLA	/I.E. IS T<38, OR=38 DE
1647	5252			JMP.+3	/NO, T>38, USE PT. THER
1650	4304			JMS GRANGE	/YES, USE GE. THERMOMET
1651	5263			JMP.+12	
1652	4407			JMS I 7	
1653	5525			FGET I PT2P	/CALCULATE R(PT)
1654	3540			FMPY I R3P	
1655	4524			FDIV I EX2P	
1656	0000			FEXT	
1657	7300			CLA CLL	/OBTAIN T BY EVALUATING
1660	4570			JMS I POLYP	/PT. TEMP. POLY.
1661	0006			0006	/DEGREE OF POLY.
1662	2671			2671	/S.A. OF "COEFFICIENTS"
1663	4407			JMS I 7	
1664	6276			FPUT T2	/STORE T
1665	0000			FEXT	
1666	7300			CLA CLL	
1667	5634			JMP I CALT2	/EXIT
1670	0000	RES,	0		
1671	0000			0	
1672	0000			0	
1673	0000	T1,	0		
1674	0000			0	
1675	0000			0	
1676	0000	T2,	0		
1677	0000			0	
1700	0000			0	
1701	0005	MINRGE,	0005		/21.13 OHMS
1702	2510			2510	
1703	2437			2437	

1704	0000	GRANGE, 0		
1705	4407		JMS I 7	
1706	5270		FGET RES	
1707	2365		FSUB MINRR1	/SUBTRACT 847.2 OHMS
1710	0000		FEXT	
1711	7300		CLA CLL	/IS GE. RES. > OR =847.
1712	1045		TAD 45	/I.E. IS T<2.75 OR =2.7
1713	7710		SPA CLA	/I.E. IN RANGE1?
1714	5325		JMP.+11	/NO, T DOES NOT FALL IN
1715	4407		JMS I 7	/YES, T IN RANGE1
1716	5270		FGET RES	
1717	0000		FEXT	
1720	7300		CLA CLL	/OBTAIN T BY EVALUATING
1721	4570		JMS I POLYP	/GE. RANGE1 TEMP. POLY.
1722	0004		0004	/DEGREE OF POLY.
1723	2600		2600	/S.A. OF "COEFFICIENTS"
1724	5704		JMP I GRANGE	/EXIT WITH T IN F.P. AC
1725	4407		JMS I 7	/CHECKING RANGE2
1726	5270		FGET RES	
1727	2370		FSUB MINRR2	/SUBTRACT 164.1 OHMS
1730	0000		FEXT	
1731	7300		CLA CLL	/IS RESISTANCE > OR =16
1732	1045		TAD 45	/I.E. IS T<12 OR =12 DEG.
1733	7710		SPA CLA	/I.E. IN RANGE2?
1734	5345		JMP.+11	/NO, CHECK RANGE3
1735	4407		JMS I 7	/YES, T IN RANGE2
1736	5270		FGET RES	
1737	0000		FEXT	/OBTAIN T BY EVALUATING
1740	7300		CLA CLL	/GE. RANGE2 TEMP. POLY.
1741	4570		JMS I POLYP	
1742	0006		0006	/DEGREE OF POLY.
1743	2617		2617	/S.A. OF "COEFFICIENTS"
1744	5704		JMP I GRANGE	/EXIT WITH T IN F.P. AC
1745	4407		JMS I 7	/CHECKING RANGE3
1746	5270		FGET RES	
1747	2301		FSUB MINRGE	/SUBTRACT 21.13 OHMS
1750	0000		FEXT	
1751	7300		CLA CLL	/IS GE. RESISTOR> OR =2
1752	1045		TAD 45	/I.E. IS T< OR =38 DEGR
1753	7710		SPA CLA	/I.E. IN RANGE3?
1754	7402		HLT	/ERROR IN SUB.
1755	4407		JMS I 7	/YES, T IN RANGE3
1756	5270		FGET RES	
1757	0000		FEXT	
1760	7300		CLA CLL	/OBTAIN T BY EVALUATING
1761	4570		JMS I POLYP	/GE. RANGE3 TEMP. POLY.
1762	0006		0006	/DEGREE OF POLY.
1763	2644		2644	/S.A. OF COEFFICIENTS I
1764	5704		JMP I GRANGE	/EXIT WITH T IN F.P. AC
1765	0012	MINRR1, 0012		/847.2 OHMS
1766	3236		3236	
1767	3147		3147	
1770	0010	MINRR2, 0010		/164.1 OHMS
1771	2440		2440	

1772	6315				
				6315	
		*2000			
2000	0000	LOGRH,	0		/SUBROUTINE TO CALCULATE THE
2001	4407			JMS I 7	/LOG. OF THE ABSOLUTE V
2002	5535			FGET I HALL2P	/THE HALL COEFFICIENT
2003	2536			FSUB I HALL1P	/OBTAIN HALL VOLTAGE, S
2004	6234			FPUT HALL	
2005	5537			FGET I SAMI2P	/CALCULATE SAMPLE CURRE
2006	4517			FDIV I RIP	/I(SAMPLE)=V(SAM I)/R1
2007	6237			FPUT C	
2010	0000			FEXT	
2011	4407			JMS I 7	/ B=F(MAG. V)
2012	5544			FGET I MAG2P	
2013	0000			FEXT	
2014	4570			JMS I POLYP	/EVALUATE THE POLYNOMIAL
2015	0005			0005	/DEGREE OF POLY. (BINARY)
2016	2716			2716	/S.A. OF COEFFICIENTS
2017	4407			JMS I 7	
2020	6242			FPUT B	/STORE
2021	5234			FGET HALL	/CALCULATE THE HALL COE.
2022	3541			FMPY I TPR	/RH=V(HALL)T/CB
2023	4237			FDIV C	
2024	4242			FDIV B	
2025	3645			FMPY I CONV	/CONVERTS TO CGSM UNITS
2026	0007			LOG	/OBTAIN LOG(E)RH
2027	3542			FMPY I CONV	/OBTAIN LOG(I)RH
2030	6543			FPUT I YVALP	/STORE THE VALUE OF LOG
2031	0000			FEXT	/IN YVALUE
2032	7300			CLA CLL	
2033	5600			JMP I LOGRH	
2034	0000	HALL,	0		/HALL VOLTAGE
2035	0000			0	
2036	0000			0	
2037	0000	C,	0		/SAMPLE CURRENT
2040	0000			0	
2041	0000			0	
2042	0000	B,	0		/MAGNETIC FIELD
2043	0000			0	
2044	0000			0	
2045	3452	CONVP,	CONV		/10**8 CONVERTS TO CGSM UNITS
2046	0000	MEANT,	0		/OBTAIN AVERAGE TEMPERATURE
2047	4407			JMS I 7	
2050	5562			FGET I T1P	/AVT=(T1+T2)/2
2051	1657			FADD I T2P	
2052	4533			FDIV I TWOPR	
2053	6260			FPUT AVT	/STORE IN AVT
2054	0000			FEXT	
2055	7300			CLA CLL	
2056	5646			JMP I MEANT	
2057	1676	T2P,	T2		
2060	0000	AVT,	0		
2061	0000			0	

2062	0000		0	
2063	0000	INVST,	0	
2064	4407			JMS I 7 /CALCULATION OF 1000/T
2065	5546			FGET I KILOP
2066	4260			FDIV AVT
2067	6547			FPUT I XVALP /STORE IN X VALUE THE V
2070	0000			FEXT /1000/T
2071	7300			CLA CLL
2072	5663			JMP I INVST
2073	0000	PRINTT,	0	/PRINT OUT AVERAGE TEMPERATURE
2074	1323			TAD CT
2075	4432			JMS I TYPEPR
2076	1026			TAD SPACE
2077	4432			JMS I TYPEPR
2100	1324			TAD EQUAL
2101	4432			JMS I TYPEPR
2102	1026			TAD SPACE
2103	4432			JMS I TYPEPR
2104	4407			JMS I 7 /ENTER THE F.P. PACKAGE
2105	5260			FGET AVT /PUT THE AVERAGE TEMPER
2106	0000			FEXT /IN THE F.P. AC
2107	7300			CLA CLL
2110	1325			TAD CFIVE
2111	3062			DCA 62
2112	1326			TAD K2 /OUTPUT TEMPERATURE IN
2113	4406			JMS I 6 /F5.2
2114	7300			CLA CLL
2115	1026			TAD SPACE
2116	4432			JMS I TYPEPR
2117	1327			TAD CK
2120	4432			JMS I TYPEPR
2121	4421			JMS I CRLFP
2122	5673			JMP I PRINTT
2123	0324	CT,	324	
2124	0275	EQUAL,	275	
2125	0005	CFIVE,	5	
2126	0002	K2,	2	
2127	0313	CK,	313	

/SUBROUTINE "POLYEV" WILL EVALU
/DEGREE POLYNOMIAL: (STORAGE L
/ACCOMODATE UP TO A 15TH. DEGRE

/CALLING SEQUENCE: VALUE OF IND
/
/ JMS POLYEV
/
/ DEGREE OF POL.
/
/ S. A. OF COE

/RETURN: RETURN WITH
/
/ DEPENDANT VA

2200	0000	POLYEV, 0	
2201	4407		JMS I 7
2202	6305		FPUT VAR /STORE VALUE OF INDP VA.
2203	0000		FEXT
2204	7300		CLA CLL
2205	1600		TAD I POLYEV /STORE DEGREE OF POLY.
2206	3310		DCA DEGREE /EVALUATED
2207	2200		ISZ POLYEV
2210	1600		TAD I POLYEV /STORE S.A. OF "COEFFIC.
2211	3010		DCA 10
2212	1312		TAD C2314 /STORE S.A. OF TERMS
2213	3011		DCA 11
2214	4407		JMS I 7
2215	5410		FGET I 10 /STORE THE INTERCEPT
2216	6411		FPUT I 11
2217	0000		FEXT
2220	7300		CLA CLL
2221	1310		TAD DEGREE
2222	7041		CIA
2223	3023		DCA CNTR1
2224	1101		TAD ZERO
2225	3311		DCA INDEX
2226	2311		ISZ INDEX
2227	1311		TAD INDEX
2230	7041		CIA
2231	3027		DCA CNTR2
2232	2010		ISZ 10
2233	2010		ISZ 10
2234	2010		ISZ 10
2235	2011		ISZ 11
2236	2011		ISZ 11
2237	2011		ISZ 11
2240	4407		JMS I 7 /GENERATE THE POWERS OF
2241	5305		FGET VAR /INDEPENDENT VARIABLE
2242	0000		FEXT
2243	2027		ISZ CNTR2
2244	5246		JMP.+2
2245	5252		JIP.+5
2246	4407		JMS I 7
2247	3305		FMPY VAR
2250	0000		FEXT
2251	5243		JMP.-6
2252	4407		JMS I 7
2253	3410		FMPY I 10 /STORE THE TERMS
2254	6411		FPUT I 11
2255	0000		FEXT
2256	7300		CLA CLL
2257	2023		ISZ CNTR1
2260	5226		JMP.-32
2261	7300		CLA CLL
2262	1312		TAD C2314
2263	3011		DCA 11
2264	1310		TAD DEGREE
2265	7041		CIA

2266	3023			DCA CNTR1	
2267	4407			JMS I 7	
2270	5411			FGET I 11	
2271	0000			FEXT	
2272	2011			ISZ 11	
2273	2011			ISZ 11	/ADD UP THE TERMS
2274	2011			ISZ 11	
2275	4407			JMS I 7	
2276	1411			FADD I 11	
2277	0000			FEXT	
2300	2023			ISZ CNTR1	
2301	5272			JMP.-7	/EXIT WITH VALUE OF DEP
2302	2200			ISZ POLYEV	/VARIABLE IN F.P. AC
2303	7300			CLA CLL	
2304	5600			JMP I POLYEV	
2305	0000	VAR,	0		
2306	0000			0	
2307	0000			0	
2310	0000	DEGREE,	0		
2311	0000	INDEX,	0		
2312	2314	C2314,	2314		/TERMS STORED IN LOCATION 231

		*2400			
		STEPNO,	0		/CONVERTS X,Y VALUES TO STEP NO.
2400	0000			JMS I 7	
2401	4407			FGET I SCALXP	/STEP NO. =(STEPS/UNIT)
2402	5550			FMPY I XVALP	
2403	3547			FPUT BUFF	
2404	6341			FSUB MAXX	
2405	2344			FEXT	
2406	0000			CLA CLL	/IS THE NO. OF STEPS IN
2407	7300			TAD 45	/DIRECTION >600?
2410	1045			SPA CLA	
2411	7710			JMP.+3	/NO
2412	5215			ISZ STEPNO	/YES, DO NOT PLOT POINT
2413	2200			JMP I STEPNO	
2414	5600			JMS I 7	
2415	4407			FGET BUFF	
2416	5341			FEXT	
2417	0000			CLA CLL	/IS THE NO. OF STEPS IN
2420	7300			TAD 45	/DIRECTION NEGATIVE?
2421	1045			SMA CLA	
2422	7700			JMP.+3	/NO
2423	5226			ISZ STEPNO	/YES, DO NOT PLOT THE P
2424	2200			JMP I STEPNO	
2425	5600			JMS FIX	
2426	4272			DCA XCORD	
2427	3267			JMS I 7	
2430	4407			FGET I SCALYP	
2431	5532			FMPY I YVALP	
2432	3543			FPUT BUFF	
2433	6341			FSUB MAXY	
2434	2347				

2435	0000			FEXT	
2436	7300			CLA CLL	/IS THE NO. OF STEPS IN
2437	1045			TAD 45	/DIRECTION >800?
2440	7710			SPA CLA	
2441	5244			JMP.+3	/NO
2442	2200			ISZ STEPNO	/YES, DO NOT PLOT POINT
2443	5600			JMP I STEPNO	
2444	4407			JMS I 7	
2445	5341			FGET BUFF	
2446	0000			FEXT	
2447	7300			CLA CLL	/IS THE NO. OF STEPS IN
2450	1045			TAD 45	/DIRECTION NEGATIVE?
2451	7700			SMA CLA	
2452	5255			JMP.+3	/NO
2453	2200			ISZ STEPNO	/YES, DO NOT PLOT POINT
2454	5600			JMP I STEPNO	
2455	4272			JMS FIX	
2456	3270			DCA YCORD	
2457	5600			JMP I STEPNO	
2460	0000	PLOTP,	0		
2461	4264			JMS MOVE	/MOVE THE PEN TO CORRECT
2462	4557			JMS I MARKP	/MARK THE POINT
2463	5660			JMP I PLOTP	
2464	0000	MOVE,	0		
2465	7201			CLA IAC	/PLOT WITH PEN UP
2466	4555			JMS I PLOT	
2467	0000	XCORD,	0		
2470	0000	YCORD,	0		
2471	5664			JMP I MOVE	
2472	0000	FIX,	0		
2473	7300			CLA CLL	
2474	1044			TAD 44	/IS STEP NO. >1/2 AND<1?
2475	7440			SZA	
2476	5301			JMP.+3	/NO
2477	1153			TAD ONE	/YES, ROUND OFF TO 1 ST
2500	5672			JMP I FIX	
2501	7500			SMA	/IS STEP NO. <1/2?
2502	5305			JMP.+3	/NO
2503	7300			CLA CLL	/YES, SET STEP NO. TO ZERO
2504	5672			JMP I FIX	
2505	1326			TAD M14	
2506	1153			TAD ONE	
2507	3044			DCA 44	/BINARIZE STEPNO.
2510	7100	GO,	CLL		
2511	1045			TAD 45	
2512	7510			SPA	
2513	7020			CML	
2514	7010			RAR	
2515	3045			DCA 45	
2516	2044			ISZ 44	
2517	5310			JMP GO	
2520	7420			SNL	
2521	5323			JMP.+2	
2522	1153			TAD ONE	

2523	1045			TAD 45	
2524	7100			CLL	
2525	5672			JMP I FIX	
2526	7764	M14,	-14		
2527	0000	END,	0		
2530	4521			JMS I EOFP	/WRITE "EOF" MARK
2531	5332			JMP.+1	/ERROR RETURN
2532	7402			HLT	/NORMAL RETURN, AC =2100
2533	7300			CLA CLL	
2534	6714			6714	/CORRECT ERROR SHOWN IN
2535	6701			6701	/PRESS CONT. ON CONSOLE
2536	5335			JMP.-1	/BACKSPACE "1" RECORD
2537	5330			JMP.-7	
2540	5727			JMP I END	/REWRITE "EOF" MARK.
2541	0000	BUFF,	0		/STORAGE LOCATION
2542	0000			0	
2543	0000			0	
2544	0012	MAXX,	0012		/600 STEPS
2545	2260			2260	
2546	0000			0000	
2547	0012	MAXY,	0012		/800 STEPS
2550	3100			3100	
2551	0000			0000	
2552	0000	CYCLE,	0		/NO. OF LOG. CYCLES
2553	0000			0	
2554	0000			0	

/POLYNOMIAL COEFFICIENTS STORED

*2600

2600	0003			0003	/GE. RANGE1 POLY. COEFF.
2601	2557			2557	/A0= 5.43593917E00
2602	4622			4622	
2603	7771			7771	/A1= -5.34824691E-03
2604	5205			5205	
2605	7732			7732	
2606	7756			7756	/A2=3.36378859E-06
2607	3415			3415	
2610	7273			7273	
2611	7743			7743	/A3=-1.03966165E-09
2612	5610			5610	
2613	7026			7026	
2614	7726			7726	/A4=1.22283738E-13
2615	2115			2115	
2616	3362			3362	

*2617

2617	0010			0010	/GE. RANGE2 POLY. COEFF.
2620	2003			2003	/A0=1.28462098E02
2621	5442			5442	
2622	0001			0001	/A1= -1.73994671E00
2623	4412			4412	
2624	2273			2273	
2625	7772			7772	/A2=1.02044332E-02

2626	2471	2471	
2627	4076	4076	
2630	7762	7762	/A3=-3.15441609E-05
2631	5735	5735	
2632	4333	4333	
2633	7750	7750	/A4=5.37189186E-08
2634	3465	3465	
2635	6107	6107	
2636	7736	7736	/A5=-4.76352185E-11
2637	4563	4563	
2640	7703	7703	
2641	7723	7723	/A6=1.71679668E-14
2642	2325	2325	
2643	0516	0516	
	*2644		
2644	0006	0006	/GE. RANGE3 POLY. COEFF.
2645	3525	3525	/AC=5.86765111E01
2646	5137	5137	
2647	0001	0001	/A1= -1.44787668E00
2650	5065	5065	
2651	3000	3000	
2652	7773	7773	/A2=2.83238556E-02
2653	3500	3500	
2654	1667	1667	
2655	7765	7765	/A3=-3.24488008E-04
2656	5256	5256	
2657	7772	7772	
2660	7756	7756	/A4= 2.06888465E-06
2661	2126	2126	
2662	5624	5624	
2663	7745	7745	/A5=-6.80186941E-09
2664	4262	4262	
2665	2435	2435	
2666	7734	7734	/A6=8.74920244E-12
2667	2317	2317	
2670	2561	2561	
	*2671		
2671	0005	0005	/PT. POLY. COEFF.
2672	3371	3371	/A0=2.79057782E01
2673	7603	7603	
2674	7776	7776	/A1=2.22663494E-01
2675	3440	3440	
2676	0360	0360	
2677	7764	7764	/A2=-1.91322374E-04
2700	4673	4673	
2701	0446	0446	
2702	7753	7753	/A3=3.09260185E-07
2703	2460	2460	
2704	2062	2062	
2705	7741	7741	/A4=-2.44356257E-10
2706	5715	5715	
2707	2366	2366	
2710	7725	7725	/A5=9.50338067E-14
2711	3257	3257	

2712	7640		7640	
2713	7711		7711	/A6=-1.44777235E-17
2714	5723		5723	
2715	5671		5671	

*2716

2716	0006		0006	/FIELD POLY. COEFF.
2717	3675		3675	/A0=6.19089893E01
2720	0533		0533	
2721	0016		0016	/A1=1.16961558E04
2722	2666		2666	
2723	0115		0115	
2724	0014		0014	/A2=4.09160488E03
2725	3775		3775	
2726	6325		6325	
2727	0016		0016	/A3=-1.62317284E04
2730	4023		4023	
2731	0220		0220	
2732	0017		0017	/A4=2.45611509E04
2733	2777		2777	
2734	0446		0446	
2735	0016		0016	/A5=-1.32107778E04
2736	4614		4614	
2737	5166		5166	

*3000

3000	0000	LOWIND,	0	
3001	7300			CLA CLL
3002	1153			TAD ONE
3003	3175			DCA SW2
3004	4407			JMS I 7
3005	2223			FSUB CONE
3006	0000			FEXT
3007	2226			ISZ ONES
3010	7300			CLA CLL
3011	1045			TAD 45
3012	7700			SMA CLA
3013	5204			JMP.-7
3014	7300			CLA CLL
3015	1226			TAD ONES
3016	1227			TAD K1
3017	3230			DCA STORE
3020	1101			TAD ZERO
3021	3226			DCA ONES
3022	5600			JMP I LOWIND
3023	0001	CONE,	0001	/1 IN F.P. FORMAT
3024	2000			2000
3025	0000			0000
3026	0000	ONES,	0	
3027	0001	K1,	1	
3030	0000	STORE,	0	
3031	0000	SETIND,	0	
3032	7300			CLA CLL
3033	1230			TAD STORE

3034	7041		CIA	
3035	3023		DCA CNTRI	
3036	4407		JMS I 7	
3037	5543		FGET I YVALP	/SUBTRACT 1 FROM
3040	0000		FEXT	/LOG(RH) THE
3041	4407		JMS I 7	/CORRECT NO. OF
3042	2223		FSUB CONE	/TIMES
3043	0000		FEXT	
3044	2023		ISZ CNTRI	
3045	5241		JMP.-4	
3046	4407		JMS I 7	
3047	6543		FPUT I YVALP	/STORE THE NEW
3050	0000		FEXT	/VALUE OF LOG(RH)
3051	7300		CLA CLL	
3052	5631		JMP I SETIND	
3053	0000	UPIND,		0
3054	7300		CLA CLL	
3055	4407		JMS I 7	
3056	5543		FGET I YVALP	
3057	6307		FPUT SAVEY	/SAVE Y VALUE
3060	0000		FEXT	
3061	4407		JMS I 7	
3062	5307		FGET SAVEY	
3063	1223		FADD CONE	/ADD 1
3064	6307		FPUT SAVEY	
3065	0000		FEXT	
3066	2226		ISZ ONES	
3067	4407		JMS I 7	
3070	5307		FGET SAVEY	
3071	2573		FSUB I CYCLEP	
3072	0000		FEXT	
3073	7300		CLA CLL	
3074	1045		TAD 45	/IS LOG(RH) > MAX.?
3075	7700		SMA CLA	
3076	5300		JMP.+2	/YES
3077	5261		JMP.-16	/NO, ADD 1 AGAIN
3100	7300		CLA CLL	
3101	1226		TAD ONES	
3102	3230		DCA STORE	/STORE THE NO.
3103	1101		TAD ZERO	/OF TIMES 1 WAS
3104	3226		DCA ONES	/ADDED
3105	7300		CLA CLL	
3106	5653		JMP I UPIND	
3107	0000	SAVEY,		0
3110	0000			0
3111	0000			0
3112	0000	SETUP,		0
3113	7300		CLA CLL	
3114	1230		TAD STORE	
3115	7041		CIA	
3116	3023		DCA CNTRI	
3117	4407		JMS I 7	
3120	5543		FGET I YVALP	
3121	0000		FEXT	

3122	4407	JMS I 7	/ADD 1 TO LOG(RH)
3123	1223	FADD CONE	/THE CORRECT NO.
3124	0000	FEXT	/OF TIMES
3125	2023	ISZ CNTR1	
3126	5322	JMP.-4	
3127	4407	JMS I 7	
3130	2223	FSUB CONE	
3131	2223	FSUB CONE	
3132	6543	FPUT I YVALP	/STORE THE NEW
3133	0000	FEXT	/VAL. OF LOG(RH)
3134	7300	CLA CLL	
3135	5712	JMP I SETUP	

/VOLTAGE STORAGE (FLOATING POINT)
 /CORRESPONDING B.C.D. VOLTAGES
 /LOCATIONS, 3200-3251

		*3252		
3252	0000	EX1,	0	0
3253	0000			0
3254	0000			0
3255	0000	GE1,	0	0
3256	0000			0
3257	0000			0
3260	0000	PT1,	0	0
3261	0000			0
3262	0000			0
3263	0000	MAG1,	0	0
3264	0000			0
3265	0000			0
3266	0000	SAM11,	0	0
3267	0000			0
3270	0000			0
3271	0000	RES1,	0	0
3272	0000			0
3273	0000			0
3274	0000	HALL1,	0	0
3275	0000			0
3276	0000			0
3277	0000	EX2,	0	0
3300	0000			0
3301	0000			0
3302	0000	GE2,	0	0
3303	0000			0
3304	0000			0
3305	0000	PT2,	0	0
3306	0000			0
3307	0000			0
3310	0000	MAG2,	0	0
3311	0000			0
3312	0000			0

.3313	0000	SAMT2,	0	
3314	0000			0
3315	0000			0
3316	0000	RES2,	0	
3317	0000			0
3320	0000			0
3321	0000	HALL2,	0	
3322	0000			0
3323	0000			0

/SUBROUTINE "EOF" WILL WRITE "F
/MAGNETIC TAPE... DSA-S-390-4

/CALLING SEQUENCE:
/ JMS EOF

/RETURN: ERROR RETURN: STATUS R
/ LINK SE
/RETURN: NORMAL RETURN: NO ERROR

.3324	0000	*3324 EOF,	0	
3325	7300			CLA CLL
3326	6704			6704 /READ STATUS REGISTER I
3327	0347			AND K0200
3330	7650			SNA CLA /IS WRITE ENABLE RING C?
3331	5334			JMP.+3 /NO
3332	7120			STL /YES
3333	5724			JMP I EOF /ERROR RETURN
3334	6722			6722 /WRITE FILE GAP
3335	6701			6701
3336	5335			JMP.-1
3337	7300			CLA CLL
3340	6704			6704 /READ STATUS REGISTER I
3341	7004			RAL
3342	7430			SZL /ANY OTHER ERRORS?
3343	5345			JMP.+2 /YES
3344	2324			ISZ EOF /NO
3345	7110			CLL RAR /STATUS REGISTER IN AC
3346	5724			JMP I EOF
.3347	0200	K0200,	0200	

/CONSTANTS STORED IN F.P. FORMAT

3400	0000	*3400 W,	0	/WIDTH
3401	0000		0	
3402	0000		0	
3403	0000	T,	0	/THICKNESS
3404	0000		0	
3405	0000		0	

3406	0000	D,	0	/DEPTH
3407	0000		0	
3410	0000		0	
3411	0000	SCALEX,	0	
3412	0000		0	
3413	0000		0	
3414	0000	SCALEY,	0	
3415	0000		0	
3416	0000		0	
3417	0000	DTEMP,	0	
3420	0000		0	
3421	0000		0	
3422	0000	XVALUE,	0	
3423	0000		0	
3424	0000		0	
3425	0000	YVALUE,	0	
3426	0000		0	
3427	0000		0	
3430	0007	R1,	0007	/SAMPLE CURRENT RESISTOR (
3431	3100		3100	
3432	0000		0000	
3433	0016	R3,	0016	/SENSOR CURRENT RESISTOR(1
3434	2342		2342	
3435	0000		0000	
3436	7777	CONVF,	7777	/(.43429) CONVERTS FROM NATUE.
3437	3362		3362	/TO COMMON LOG.
3440	6642		6642	
3441	0002	TWO,	0002	/2(10)
3442	2000		2000	
3443	0000		0000	
3444	0003	FOUR,	0003	/4(10)
3445	2000		2000	
3446	0000		0000	
3447	0012	KILO,	0012	/1000(10)
3450	3720		3720	
3451	0000		0000	
3452	0033	CONV,	0033	/10**8, CONVERTS TO CGSM UNI
3453	2765		2765	
3454	7020		7020	

/SUBROUTINE "WRITE" WILL WRITE
/ON THE MAGNETIC TAPE ... DSA-S

/CALLING SEQUENCE:
/
/ JMS WRITE
/
/ NO. OF WORDS TO BE WRIT
/
/ STARTING ADDRESS OF DAT
/
/ INSTRUCTION WHICH SELEC

/RETURN:ERROR RETURN: STATUS RE
/
/ IF LINK SET, THE WRITE
/RETURN:NORMAL RETURN: NO ERROR

3455	0000	WRITE,	0	
3456	7300			CLA CLL
3457	1655			TAD I WRITE
3460	7041			CIA
3461	3757			DCA I PWCNT
3462	2255			ISZ WRITE
3463	7240			CLA CMA
3464	1655			TAD I WRITE
3465	3760			DCA I PADD
3466	2255			ISZ WRITE
3467	1655			TAD I WRITE
3470	3301			DCA.+11
3471	2255			ISZ WRITE
3472	6704			6704
3473	0361			AND M0200
3474	7650			SNA CLA
3475	5300			JMP.+3
3476	7120			STL
3477	5655			JMP I WRITE
3500	7200			CLA
3501	0000			0
3502	6721			6721
3503	6701			6701
3504	5303			JMP.-1
3505	6704			6704
3506	7104			CLL RAL
3507	7430			SZL
3510	5313			JMP.+3
3511	2255			ISZ WRITE
3512	5655			JMP I WRITE
3513	7110			CLL RAR
3514	5655			JMP I WRITE

/SUBROUTINE "READ" WILL READ "0"
/FROM THE MAGNETIC TAPE INTO CO
/DSA-S-390-3

/CALLING SEQUENCE:
/
/ JMS READ
/
/ NO. OF WORDS TO BE READ
/
/ STARTING ADDRESS OF THE
/
/ INSTRUCTION WHICH SELEC

/RETURN: ERROR RETURN, STATUS R
/RETURN: NORMAL RETURN, NO ERRO

		*3515		
3515	0000	READ,	0	
3516	7300			CLA CLL
3517	1715			TAD I READ
3520	7041			CIA
3521	3757			DCA I PWCNT
3522	2315			ISZ READ
3523	7240			CLA CMA

3524	1715			TAD I READ	/INPUT SA-1 INTO AC
3525	3760			DCA I PADD	/LOAD STARTING ADDRESS
3526	2315			ISZ READ	
3527	1715			TAD I READ	/INPUT SELECTED PARITY
3530	3342			DCA.+12	/LOAD SELECTED PARITY
3531	2315			ISZ READ	/ADDRESS OF ERROR RETUR
3532	7300			CLA CLL	
3533	6704			6704	/READ STATUS REGISTER I
3534	7006			RTL	
3535	7420			SNL	
3536	5342			JMP.+4	
3537	7012			RTR	
3540	7120			STL	/LINK SET, IF IN WRITE
3541	5715			JMP I READ	/EXIT WITH ERROR IN AC
3542	0000			0	/SELECTED PARITY
3543	6712			6712	/READ FORWARD
3544	6701			6701	
3545	5344			JMP.-1	
3546	7200			CLA	
3547	6704			6704	/READ STATUS REGISTER I
3550	7104			CLL RAL	/HARDWARE INCLUSIVE OR,
3551	7430			SZL	/NO ERROR
3552	5355			JMP.+3	
3553	2315			ISZ READ	
3554	5715			JMP I READ	/NORMAL RETURN
3555	7110			CLL RAR	
3556	5715			JMP I READ	/ERROR RETURN, STATUS I
3557	7576	PWCNT,	7576		/AUTO-INDEX REGISTER
3560	7577	PADD,	7577		/AUTO-INDEX REGISTER
3561	0200	M0200,	0200		

		*3600			
3600	0000	TRACE,	0		/TRACE OUT A STANDARD PLOTTIN
3601	7300			CLA CLL	/AREA, (6X8) INCHES
3602	6502			PLCF	/INITIALIZE PLOT SUBROU
3603	6504			PLPU	
3604	4266			JMS DO	/RAISE PEN
3605	1227			TAD M310	
3606	4232			JMS PENL	/MOVES THE PEN 200(10)
3607	1227			TAD M310	
3610	4241			JMS DRUMD	/MOVES THE DRUM 203(10)
3611	6524			PLPD	/LOWER PEN
3612	4266			JMS DO	
3613	1230			TAD M1130	/TRACE POSITIVE X AXIS
3614	4241			JMS DRUMD	/MOVES DRUM 600(10) STE
3615	1231			TAD M1440	/TRACE POSITIVE Y AXIS
3616	4232			JMS PENL	/MOVES PEN 800(10) STEP
3617	1230			TAD M1130	/TRACE NEGATIVE X AXIS
3620	4250			JMS DRUMU	/MOVES DRUM 600(10) STE
3621	1231			TAD M1440	/TRACE NEGATIVE Y AXIS
3622	4257			JMS PENR	/MOVES THE PEN 800(10)
3623	7240			CLA CMA	/RAISES PEN, INITIALIZE

3624	4555		JMS I PLOT	/PLOT SUBROUTINE
3625	7300		CLA CLL	
3626	5600		JMP I TRACE	
3627	7470	M310,	-310	/-200(10)
3630	6650	M1130,	-1130	/-600(10)
3631	6340	M1440,	-1440	/-800(10)
3632	0000	PENL,	0	/MOVES THE PEN A SPECIFIED
3633	3023		DCA CNTR1	/NO. OF STEPS TO THE LE
3634	6521		PLPL	
3635	4266		JMS DO	
3636	2023		ISZ CNTR1	
3637	5234		JMP.-3	
3640	5632		JMP I PENL	
3641	0000	DRUMD,	0	/MOVES THE DRUM A SPECIFIED
3642	3023		DCA CNTR1	/NO. OF STEPS DOWN
3643	6514		PLDD	
3644	4266		JMS DO	
3645	2023		ISZ CNTR1	
3646	5243		JMP.-3	
3647	5641		JMP I DRUMD	
3650	0000	DRUMU,	0	/MOVES THE DRUM A SPECIFIED
3651	3023		DCA CNTR1	/NO. OF STEPS, UP
3652	6522		PLUD	
3653	4266		JMS DO	
3654	2023		ISZ CNTR1	
3655	5252		JMP.-3	
3656	5650		JMP I DRUMU	
3657	0000	PENR,	0	/MOVES THE PEN A SPECIFIED
3660	3023		DCA CNTR1	/NO. OF STEPS RIGHT
3661	6511		PLPR	
3662	4266		JMS DO	
3663	2023		ISZ CNTR1	
3664	5261		JMP.-3	
3665	5657		JMP I PENR	
3666	0000	DO,	0	
3667	6501		PLSF	/WAIT FOR DONE FLAG
3670	5267		JMP.-1	/NOT YET
3671	6502		PLCF	/CLEAR FLAG
3672	5666		JMP I DO	/EXIT
3673	0000	MARK,	0	/MARK THE POINT, ENCIRCLE
3674	7300		CLA CLL	
3675	6502		PLCF	
3676	6524		PLPD	/MARK POINT
3677	4266		JMS DO	
3700	6504		PLPU	/ RAISE THE PEN
3701	4266		JMS DO	
3702	1063		TAD M4	/MOVE THE DRUM 4(10) ST
3703	4250		JMS DRUMU	
3704	1063		TAD M4	
3705	4257		JMS PENR	/MOVE THE PEN 4(10) STE
3706	6524		PLPD	/LOWER PEN
3707	4266		JMS DO	
3710	1334		TAD M10	/DRAW A SQUARE AROUND T
3711	4241		JMS DRUMD	/(8X8) STEPS

3712	1334		TAD M10	
3713	4232		JMS PENL	
3714	1334		TAD M10	
3715	4253		JMS DRUMU	
3716	1334		TAD M10	
3717	4257		JMS PENR	
3720	6534		PLPU	/REPOSITION PEN
3721	4266		JMS DO	
3722	1063		TAD M4	
3723	4232		JMS PENL	
3724	1063		TAD M4	
3725	4241		JMS DRUMD	
3726	6524		PLPD	
3727	4266		JMS DO	
3730	6534		PLPU	
3731	4266		JMS DO	
3732	7300		CLA CLL	
3733	5673		JMP I MARK	
3734	7770	M10,	-10	/-8(10)

```

/PLOT SUBROUTINE          DIGITAL-8-12-U
/CALLING SEQUENCE
/  C(AC)=-1; INITIALIZE
/  C(AC)= 0; PLOT WITH PEN DOWN
/  C(AC)= 1; PLOT WITH PEN UP
/    JMS PLOTX
/    X CO-ORDINATE (IN STEPS) (RETURN IF AC=-1)
/    Y CO-ORDINATE (IN STEPS)

```

```

*4000
4000  3000  PLOTX,  0
4001  7510
4002  5220
4003  1361
4004  7112
4005  7710
4006  5227
4007  7620
4010  5214
4011  3361
4012  6504
4013  5216
4014  2361
4015  6524
4016  4370
4017  5227
4020  7200  PLOTA,  CLA
4021  6504
4022  3361
4023  3362
4024  3363
4025  4370
4026  5600

SPA
JMP PLOTA
TAD PLOTPN
CLL RTR
SPA CLA
JMP PLOT1
SNL CLA
JMP .+4
DCA PLOTPN
PLPU
JMP .+3
ISZ PLOTPN
PLPD
JMS PLOTWT
JMP PLOT1

PLPU
DCA PLOTPN
DCA PLOTNX
DCA PLOTNY
JMS PLOTWT
JMP I PLOTX

/NO: CONTINUE
/ADD PEN STATUS
/ANY CHANGE?
/NO: CONTINUE
/LOWER THE PEN
/RAISE THE PEN
/LOWER THE PEN
/WAIT FOR FLAG
/CONTINUE
/RAISE THE PEN
/0 TO X CO-ORDINATE
/0 TO Y CO-ORDINATE

```

```

/PICK UP ARGUMENTS
4027 1362 PLOT1, TAD PLOTNX /FETCH PREVIOUS X CO-ORDINATE
4030 7141 CIA CLL
4031 1600 TAD I PLOTX /FORM NX-NPX
4032 7420 SNL /L=0: NX<NPX
4033 7041 CIA
4034 3364 DCA PLOTDX /ABSOLUTE VALUE OF DIFF
4035 7004 RAL
4036 3367 DCA PLOTMV /SAVE SIGN BIT
4037 1600 TAD I PLOTX /SET NEW
4040 3362 DCA PLOTNX /PREVIOUS X
4041 2200 ISZ PLOTX /INCREMENT POINTER
4042 1363 TAD PLOTNY /FETCH PREVIOUS Y CO-OR
4043 7141 CIA CLL
4044 1600 TAD I PLOTX /FORM NY-NPY
4045 7420 SNL /<=0: NPY<NY
4046 7041 CIA
4047 3365 DCA PLOTDY /ABSOLUTE VALUE OF DIFF
4050 1367 TAD PLOTMV /SAVE SIGN BIT
4051 7004 RAL /BIT 10(1)= DRUM-DOWN(P
4052 3367 DCA PLOTMV /BIT 11(1)=PEN-LEFT (PO
4053 1600 TAD I PLOTX /SET NEW
4054 3363 DCA PLOTNY /PREVIOUS Y
4055 2200 ISZ PLOTX /INCREMENT POINTER
4056 1364 TAD PLOTDX
4057 7141 CIA CLL
4060 1365 TAD PLOTDY
4061 7620 SNL CLA /L=0: DELTA Y <
4062 5275 JMP PLOT2
4063 1364 TAD PLOTDX /REVERSE NUMBERS
4064 3366 DCA PLOTNA
4065 1365 TAD PLOTDY
4066 3364 DCA PLOTDX
4067 1366 TAD PLOTNA
4070 3365 DCA PLOTDY
4071 7001 IAC
4072 0367 AND PLOTMV /SET MAJOR MOTION
4073 1342 TAD PLOTT1 /INSTRUCTION
4074 5300 JMP .+4
4075 1367 PLOT2, TAD PLOTMV
4076 7110 CLL RAR
4077 1345 TAD PLOTT2
4100 3366 DCA PLOTNA
4101 1766 TAD I PLOTNA
4102 3340 DCA PLOT4
4103 1367 TAD PLOTMV /SET COMBINED MOTION
4104 1350 TAD PLOTT3
4105 3367 DCA PLOTMV
4106 1767 TAD I PLOTMV
4107 3331 DCA PLOTDB
4110 1364 TAD PLOTDX
4111 7110 CLL RAR
4112 3366 DCA PLOTNA
4113 1364 TAD PLOTDX

```

4114	7040			CMA	
4115	3367			DCA PLOTMV	
4116	2367	PLOT3,	ISZ	PLOTMV	
4117	7410			SKP	
4120	5600			JMP I PLOTX	/ALL DONE
4121	1366			TAD PLOTNA	
4122	1365			TAD PLOTDY	
4123	3366			DCA PLOTNA	
4124	1366			TAD PLOTNA	
4125	7141			CIA CLL	
4126	1364			TAD PLOTDX	
4127	7630			SZL CLA	
4130	5340			JMP PLOT4	/SINGLE MOTION
4131	0000	PLOTDB,	0		/COMBINED MOTION
4132	1364			TAD PLOTDX	
4133	7041			CIA	
4134	1366			TAD PLOTNA	
4135	3366			DCA PLOTNA	
4136	4370			JMS PLOTWT	
4137	5316			JMP PLOT3	
4140	0000	PLOT4,	0		
4141	5336			JMP --3	
4142	4143	PLOTT1,	++1		
4143	6511			PLPR	/PEN-RIGHT
4144	6521			PLPL	/PEN-LEFT
4145	4146	PLOTT2,	++1		
4146	6512			PLDU	/DRUM-UP
4147	6514			PLDD	/DRUM-DOWN
4150	4151	PLOTT3,	++1		
4151	6513			PLDU PLFR	/UP-RIGHT
4152	6523			PLUD PLPL	/UP-LEFT
4153	6515			PLDD PLPR	/DOWN-RIGHT
4154	4355			JMS ++1	/DOWN-LEFT
4155	0000			0	
4156	6514			PLDD	
4157	6521			PLPL	
4160	5755			JMP I --3	
4161	0000	PLOTPN,	0		
4162	0000	PLOTNX,	0		
4163	0000	PLOTNY,	0		
4164	0000	PLOTDX,	0		
4165	0000	PLOTDY,	0		
4166	0000	PLOTNA,	0		
4167	0000	PLOTMV,	0		
4170	0000	PLOTWT,	0		
4171	6501			PLSF	/WAIT FOR DONE FLAG
4172	5371			JMP --1	/NOT YET
4173	6502			PLCF	/CLEAR FLAG
4174	5770			JMP I PLOTWT	/EXIT

*4200

4200 0323

323 /S

4201	0301	301	/A
4202	0315	315	/M
4203	0320	320	/P
4204	0314	314	/L
4205	0305	305	/E
4206	0240	240	/SPACE
4207	0304	304	/D
4210	0311	311	/I
4211	0315	315	/M
4212	0256	256	/PERIOD
4213	0240	240	/SPACE
4214	0250	250	/OPEN BRACKET
4215	0303	303	/C
4216	0315	315	/M
4217	0251	251	/CLOSED BRACKET
4220	0327	327	/W
4221	0240	240	/SPACE
4222	0275	275	/EQUAL
4223	0324	324	/T
4224	0240	240	/SPACE
4225	0275	275	/EQUAL
4226	0304	304	/D
4227	0240	240	/SPACE
4230	0275	275	/EQUAL
4231	0323	323	/S
4232	0303	303	/C
4233	0301	301	/A
4234	0314	314	/L
4235	0305	305	/E
4236	0240	240	/SPACE
4237	0250	250	/OPEN BRACKET
4240	0323	323	/S
4241	0324	324	/T
4242	0305	305	/E
4243	0320	320	/P
4244	0323	323	/S
4245	0257	257	/SLASH
4246	0325	325	/U
4247	0316	316	/N
4250	0311	311	/I
4251	0324	324	/T
4252	0251	251	/CLOSED BRACKET
4253	0330	330	/X
4254	0240	240	/SPACE
4255	0301	301	/A
4256	0330	330	/X
4257	0311	311	/I
4260	0323	323	/S
4261	0272	272	/COLON
4262	0331	331	/Y
4263	0240	240	/SPACE
4264	0301	301	/A
4265	0330	330	/X
4266	0311	311	/I

4267	0323	323	/S
4270	0272	272	/COLON
4271	0304	304	/D
4272	0305	305	/E
4273	0314	314	/L
4274	0324	324	/T
4275	0301	301	/A
4276	0240	240	/SPACE
4277	0324	324	/T
4300	0240	240	/SPACE
4301	0275	275	/EQUAL
4302	0304	304	/D
4303	0301	301	/A
4304	0324	324	/T
4305	0301	301	/A
4306	0326	326	/V
4307	0250	250	/OPEN BRACKET
4310	0305	305	/E
4311	0330	330	/X
4312	0251	251	/CLOSED BRACKET
4313	0326	326	/V
4314	0250	250	/OPEN BRACKET
4315	0307	307	/G
4316	0305	305	/E
4317	0251	251	/CLOSED BRACKET
4320	0326	326	/V
4321	0250	250	/OPEN BRACKET
4322	0320	320	/P
4323	0324	324	/T
4324	0251	251	/CLOSED BRACKET
4325	0326	326	/V
4326	0250	250	/OPEN BRACKET
4327	0315	315	/M
4330	0301	301	/A
4331	0307	307	/G
4332	0251	251	/CLOSED BRACKET
4333	0326	326	/V
4334	0250	250	/OPEN BRACKET
4335	0323	323	/S
4336	0301	301	/A
4337	0315	315	/M
4340	0240	240	/SPACE
4341	0311	311	/I
4342	0251	251	/CLOSED BRACKET
4343	0326	326	/V
4344	0250	250	/OPEN BRACKET
4345	0322	322	/R
4346	0305	305	/E
4347	0323	323	/S
4350	0251	251	/CLOSED BRACKET
4351	0326	326	/V
4352	0250	250	/OPEN BRACKET
4353	0310	310	/H
4354	0301	301	/A

4355	0314	314	/L
4356	0314	314	/L
4357	0251	251	/CLOSED BRACKET

/DOUBLE PRECISION BCD TO BINARY CONVERSION- DIGITAL-8-1
/CALLING SEQUENCE:

/ JMS DOUBLE
/ ADDRESS OF HIGH ORDER ARGUMENT
/ RETURN: C(AC)=HIGH ORDER PART
/ C(LOW) = LOW ORDER PART

/ALSO CONTAINS SINGLE PRECISION BCD TO BINARY

/CALLING SEQUENCE:

/ C(AC) = 3 BCD CHARACTERS
/ JMS BCDBIN
/ RETURN: ANSWER IN C(AC)

*4400

4400	0000	DOUBLE, 0	
4401	7300		CLA CLL
4402	1600		TAD I DOUBLE /FETCH ADDRESS
4403	3271		DCA LOW1 /STORE
4404	2200		ISZ DOUBLE /INCREMENT RETU
4405	1671		TAD I LOW1 /FETCH HIGH ORDER
4406	4275		JMS BCDBIN /CONVERT IT
4407	3272		DCA HIGH1 /STORE
4410	2271		ISZ LOW1 /INCREMENT POINT
4411	1671		TAD I LOW1 /FETCH LOW ORDER
4412	4275		JMS BCDBIN /CONVERT IT
4413	3271		DCA LOW1 /STORE IT
4414	1272		TAD HIGH1
4415	7112		CLL RTR
4416	7012		RTR
4417	7010		RAR /MULTIPLY HIGH ORDER
4420	3275		DCA BCDBIN /PART BY 128
4421	1275		TAD BCDBIN
4422	0327		AND K177
4423	3274		DCA HIGH
4424	1275		TAD BCDBIN
4425	7010		RAR
4426	0325		AND K7600
4427	3273		DCA LOW
4430	1272		TAD HIGH1 /MULTIPLY HIGH
4431	7104		CLL RAL /BY THREE
4432	1272		TAD HIGH1 /FORM 128*HIGH-
4433	7141		CIA CLL
4434	1273		TAD LOW
4435	3273		DCA LOW
4436	7420		SNL
4437	7040		CMA
4440	1274		TAD HIGH
4441	3274		DCA HIGH /125*HIGH
4442	1274		TAD HIGH /NOW MULTIPLY B

4443	7106			CLL RTL	
4444	7004			RAL	
4445	0326			AND K7770	/MASK 9 BITS
4446	3274			DCA HIGH	
4447	1273			TAD LOW	
4450	7106			CLL RTL	
4451	7004			RAL	
4452	3273			DCA LOW	
4453	1273			TAD LOW	
4454	7004			RAL	
4455	0324			AND K7	/3 ITS
4456	1274			TAD HIGH	
4457	3274			DCA HIGH	
4460	1273			TAD LOW	
4461	0326			AND K7770	/9 BITS
4462	7100			CLL	
4463	1271			TAD LOW1	/ADD LOW ORDER
4464	3273			DCA LOW	/STORE LOW ORDER PART
4465	1274			TAD HIGH	
4466	7430			SZL	
4467	7001			IAC	/CARRY
4470	5600			JMP J DOUBLE	
4471	0000	LOW1,	0		
4472	0000	HIGH1,	0		
4473	0000	LOW,	0		
4474	0000	HIGH,	0		
		/SINGLE PRECISION CONVERSION			
4475	0000	BCDBIN,	0		
4476	3274			DCA HIGH	
4477	1274			TAD HIGH	
4500	0330			AND K7400	/LEFT DIGIT
4501	7112			CLL RTR	
4502	3273			DCA LOW	
4503	1273			TAD LOW	
4504	7010			RAR	
4505	1273			TAD LOW	
4506	7041			CIA	
4507	1274			TAD HIGH	
4510	3274			DCA HIGH	
4511	1274			TAD HIGH	
4512	0323			AND K7760	
4513	7112			CLL RTR	
4514	3273			DCA LOW	
4515	1273			TAD LOW	
4516	7010			RAR	
4517	1273			TAD LOW	
4520	7041			CIA	
4521	1274			TAD HIGH	
4522	5675			JMP I BCDBIN	
4523	7760	K7760,	7760		
4524	0007	K7,	7		
4525	7600	K7600,	7600		
4526	7770	K7770,	7770		
4527	0177	K177,	177		

4530	7400	K7400,	7400	
4531	0000	OUTIND,	0	/OUTPUT INDEX IN
4532	4421			JMS I CRLFP /FORMAT F4.2
4533	1352			TAD STAR
4534	4432			JMS I TYPEPR
4535	1026			TAD SPACE
4536	4432			JMS I TYPEPR
4537	4407			JMS I 7
4540	5543			FGET I YVALP
4541	0000			FEXT
4542	7300			CLA CLL
4543	1353			TAD CFOUR
4544	3062			DCA 62
4545	1354			TAD CTWO
4546	4406			JMS I 6 /OUTPUT
4547	7300			CLA CLL
4550	4421			JMS I CRLFP
4551	5731			JMP I OUTIND
4552	0252	STAR,	252	
4553	0004	CFOUR,	4	
4554	0002	CTWO,	2	

/POINTER ADDRESSES STORED ON PA

		*20	
0020	1400	CLEARP,	CLEAR
0021	1413	CRLFP,	CRLF
0022	1431	DIMENP,	DIMEN
0023	0000	CNTR1,	0
0024	0000	TEMP,	0
0025	7503	MEQUAL,	-275
0026	0240	SPACE,	240
0027	0000	CNTR2,	0
0030	1520	SCALEP,	SCALE
0031	3224	C3224,	3224
0032	1423	TYPEPR,	TYPE
0033	2060	AVTP,	AVT
0034	1000	DELTP,	DELTAT
0035	3417	DTP,	DTEMP
0036	1025	FORMPR,	FORMAT
0037	1510	TABPR,	TAB
		*63	
0063	7774	M4,	-4
0064	7527	M251,	-251
0065	7775	M3,	-3
0066	1120	INPUTP,	INPUTV
0067	7771	M7,	-7
0070	0600	OUTVPR,	OUTV
0071	0000	MCH,	0
0072	3177	C3177,	3177
0073	1200	FLOATP,	FLOATV
0074	4400	DPCDB,	DOUPLE
0075	4473	LOWPR,	LOW

0076	0000	WORD,	0
0077	0020	MASKSN,	0020
0100	7762	M16,	-16
0101	0000	ZERO,	0
0102	0007	MASKPW,	0007
0103	0000	CNTRDP,	0
0104	1600	CALT1P,	CALT1
0105	1634	CALT2P,	CALT2
0106	0256	PERIOD,	256
0107	7772	M6,	-6
0110	1067	SKIPPR,	SKIP
0111	7776	M2,	-2
0112	0746	LISNPR,	LISN
0113	7475	MC,	-303
0114	0255	MINUS,	255
0115	0253	PLUS,	253
0116	3255	GE1P,	GE1
0117	3430	R1P,	R1
0120	3252	EX1P,	EX1
0121	3324	EOFP,	EOF
0122	3260	PT1P,	PT1
0123	3302	GE2P,	GE2
0124	3277	EX2P,	EX2
0125	3305	PT2P,	PT2
0126	2046	MEANTP,	MEANT
0127	2073	PRINTP,	PRINTT
0130	6554	L6554,	6554
0131	6000	C6000,	6000
0132	3414	SCALYP,	SCALEY
0133	3441	TWOPR,	TWO
0134	2000	LOGRHP,	LOGRH
0135	3321	HALL2P,	HALL2
0136	3274	HALL1P,	HALL1
0137	3313	SAMI2P,	SAMI2
0140	3433	R3P,	R3
0141	3403	TPR,	T
0142	3436	CONVFP,	CONVF
0143	3425	YVALP,	YVALUE
0144	3310	MAG2P,	MAG2
0145	2063	INVSTP,	INVST
0146	3447	KILOP,	KILO
0147	3422	XVALP,	XVALUE
0150	3411	SCALXP,	SCALEX
0151	2400	STEPSP,	STEPNO
0152	2547	MAXYPR,	MAXY
0153	0001	ONE,	1
0154	2460	PLOTPR,	PLOTP
0155	4000	PLOT,	PLOTX
0156	0000	SW1,	0
0157	3673	MARKP,	MARK
0160	1300	NEXTTP,	NEXTT
0161	0726	EXAMTP,	EXAMT
0162	1673	T1P,	T1
0163	0743	NEWTTP,	NEWT

0164	3600	TRACEP,	TRACE
0165	4531	OUTINP,	OUTIND
0166	3000	LOWINP,	LOWIND
0167	3031	SETINP,	SETIND
0170	2200	POLYP,	POLYEV
0171	3455	WRITEP,	WRITE
0172	2527	ENDP,	END
0173	2552	CYCLEP,	CYCLE
0174	3666	DOPR,	DO
0175	0000	SW2,	0
0176	3053	UPINP,	UPIND
0177	3112	SETUPP,	SETUP

/"FINIS"

/MNEMONICS USED

PLSF=6501
 PLCF=6502
 PLPU=6504
 PLPR=6511
 PLDU=6512
 PLUD=6522
 PLDD=6514
 PLPL=6521
 PLPD=6524
 CWRD=6531
 SDR=6541
 RDCF=6542
 BA=6544
 ICD=6532

T1 0220
 T2 0410
 2060
 0033
 2042
 6544
 IN 4475
 2541
 ER 1361
 2037
 I 1600
 IP 0104
 2 1634
 2P 0105
 E 2125
 R 4553
 2127
 R 1400
 RP 0020
 DP 0103

APPENDIX B

1. IDENTIFICATION

1.1 Phys - 8L - YYB - D

1.2 Off-Line Data Processing and Display Package

2. ABSTRACT

This software package, along with the Floating-Point Package (DEC-08-YQ4A-PB), will process the data obtained from the experiment on semiconductor crystals and will provide a graphical display of some of their more important electrical characteristics.

The package consists of two independent programs:

Program 1 reads data from the magnetic tape into core memory, processes this data, and plots the common logarithm of the resistivity as a function of the reciprocal of the absolute temperature.

Program 2 reads data from the magnetic tape into core memory, processes this data, and plots the common logarithm of the Hall mobility versus the common logarithm of the absolute temperature.

3. REQUIREMENTS

3.1 Equipment

Computer, DEC PDP-8/L with 4K memory

Teletype, ASR-33

Plotter, Houston DP-1-1

Magnetic Tape Unit, PEC 3520-7

3.2 Storage

	Locations	Registers
Data Processing and Display Package (Phys-8L-YYB-PB)	0-4556	1718
Floating-Point Package (DEC-08-YQ4A-PB)	4557-7577	1553

A total of 3,271 registers are required.

4. USAGE

4.1 The Data Processing and Display Package (Phys-8L-YYYB-PB) and the Floating-Point Package (DEC-08-YQ4A-PB) are loaded individually into the computer core memory by means of the Binary Loader. For proper loading procedure refer to FDP-8/L User's Handbook.

4.2 Start Up and/or Entry

To execute Program 1 set the switch register on the computer console to 0200, depress LOAD ADD and then START. Program 2 starts in location 0400.

4.3 Errors in Usage and Recovery from Such Errors.

4.3.1 Program 1

A) An error committed while typing in a parameter may be corrected by the use of one special input character, "Rubout". If this character is struck before the input delimiter, "Return", the input routine is restarted and the previous number deleted. The user then re-types the parameter on the same line. For further information refer to Floating-Point System Programming Manual.

B) The program will halt if the data has been incorrectly read from the magnetic tape into the computer core memory. The error code will be displayed in the accumulator.

Remedy: Correct the error, then depress the CONT key on the computer console. The program will cause the magnetic tape unit to backspace one record, re-read the data into core memory and continue execution.

N.B. A discussion of errors which may be committed while reading data from magnetic tape into core memory and their correction is given in DSA Operating Instructions Manual.

C) The error message, "INCREASE THE CYCLE RANGE", typed out on the teletype printer indicates that the value of the y coordinate of the point to be plotted is less than the minimum value allowed by the scale factor. The point is not plotted and execution of the program is terminated. The user must re-initiate program execution and provide for an adequate range along the ordinate.

4.3.2 For errors in usage and recovery from such errors incurred in Program 2 refer to section 4.3.1

5. RESTRICTIONS

The plotting area is confined to six (6) inches along the abscissa and eight (8) inches along the ordinate. Recalling that the plotter pen moves one hundred (100) steps per inch, it is imperative that the user establish the proper scale factors. The scale factor in this context is defined as the number of steps per logical unit.

A point having its y-value (in steps) greater than the maximum allowed value (800 steps) will not be plotted. The next data record is then entered and processed. A point having a negative number of steps in the y-direction will cause an error message to be printed. Execution of the program is terminated (as described in section 4.3.1C).

5.1 Program 1

5.1.1 Scaling of the Abscissa

Values of $1000/T$ will be plotted along the abscissa. The user inputs the maximum number of inverse temperature units expected along with the number of divisions desired on this axis.

5.1.2 Scaling of the Ordinate

Since the common logarithm of the resistivity will be plotted along the ordinate, the user inputs the number of logarithmic cycles along with the number of divisions desired.

5.2 Program 2

5.2.1 Scaling of the Abscissa

Since the common logarithm of the absolute temperature will be plotted along this axis, the user must input the number of cycles and divisions required.

5.2.2 Scaling of the Ordinate

The common logarithm of the Hall mobility will be plotted along the y-axis. The user inputs the number of logarithmic cycles and divisions desired.

6. DESCRIPTION

6.1 Both programs consist of three stages:

- 1) Parameter Input
- 2) Data Transfer
- 3) Data Processing and Display

6.1.1 Parameter Input

The computer types out appropriate comments, and when it is ready to receive a parameter it enters a waiting loop. This loop is signalled by the computer typing an "=" or a ":". The user then inputs the parameter in either the fixed or the floating-point notation. Input is terminated by typing a delimiting character. "Return" typed on the keyboard will terminate the input and provide a CRLF (carriage return and line feed).

This dialogue between computer and user permits the input of sample dimensions and scaling parameters. Upon termination of the dialogue, the plotting phase is initialized and program control enters the second stage.

N.B. As mentioned in section 5 two scaling parameters, separated by an arbitrary delimiter (";" most often used), must be provided for each axis. The delimiter "Return" must be used to terminate input of the second parameter.

6.1.2 Data Transfer

One record of data is read from magnetic tape into the core memory of the computer. Each record consists of forty-two (42_{10}) 12-bit words. Program control is transferred to stage 3.

N.B. A record containing an EOF (End of File) mark indicates that the last record has been read and results in the

termination of the execution of the program.

6.1.3 Data Processing and Display

The computer calculates the x and y values, scales these values, and plots the point (providing its coordinates fall within the plotting area). Having plotted the point, program control reverts to the second stage.

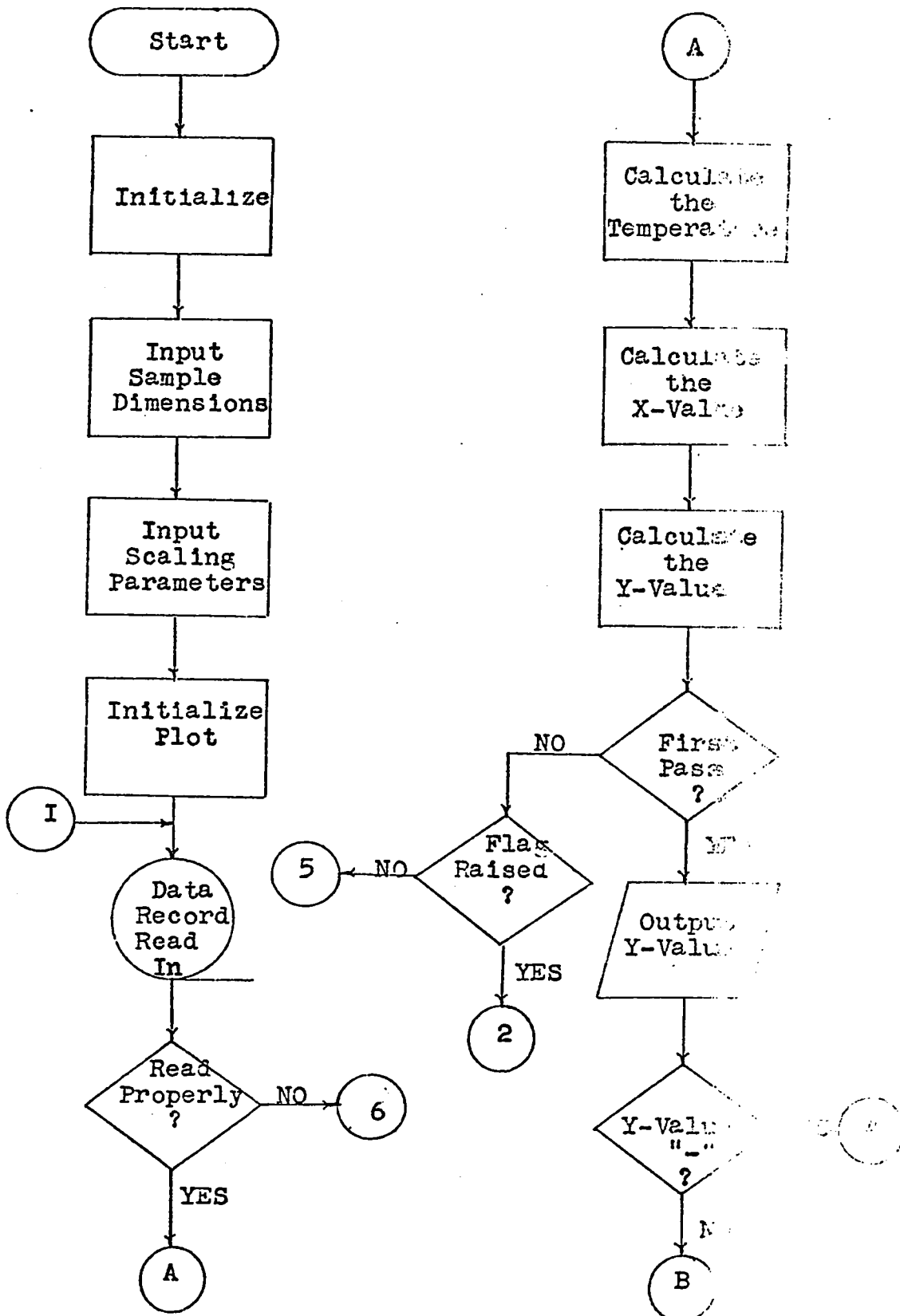
N.B. The y-value is printed only for the first pass. This enables the user to assign the correct value to each cycle.

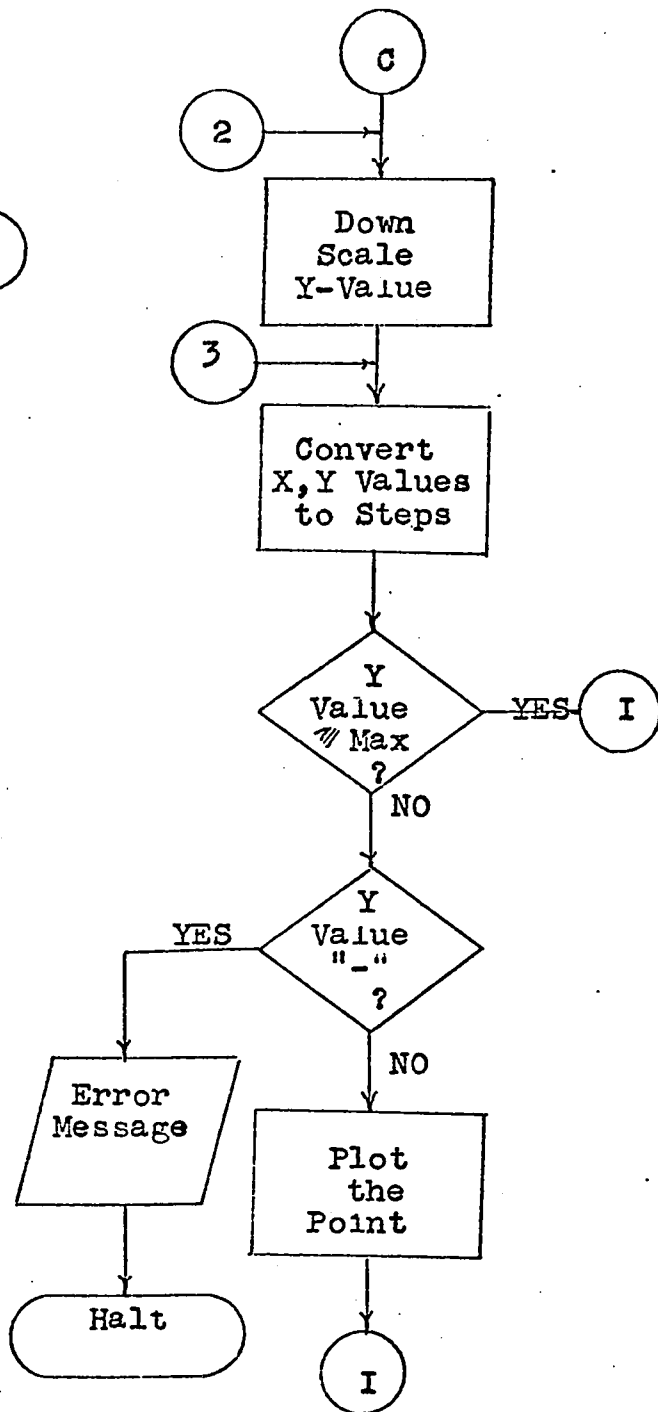
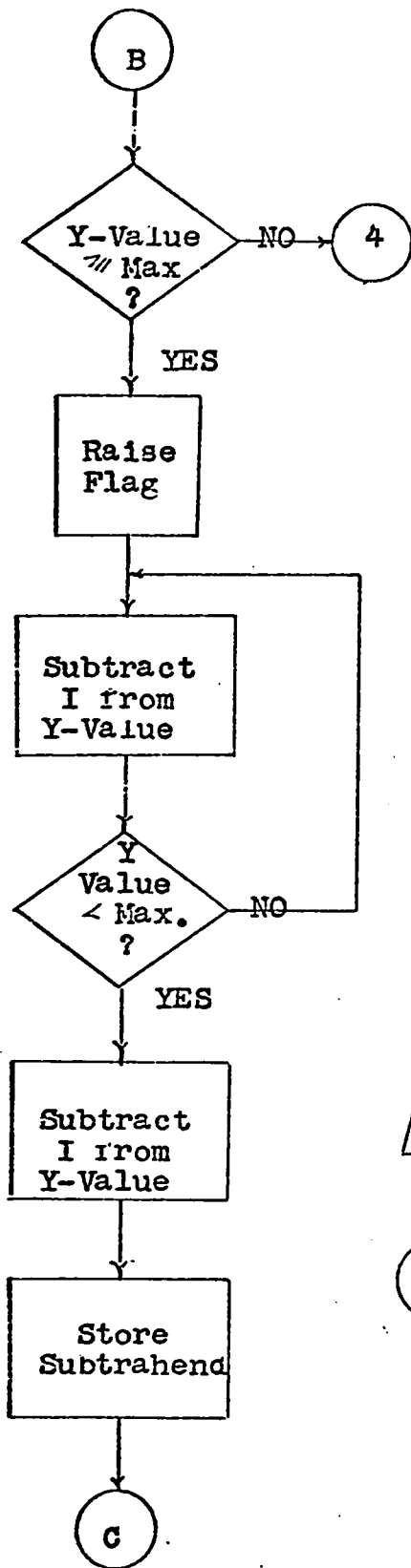
7. EXECUTION TIME

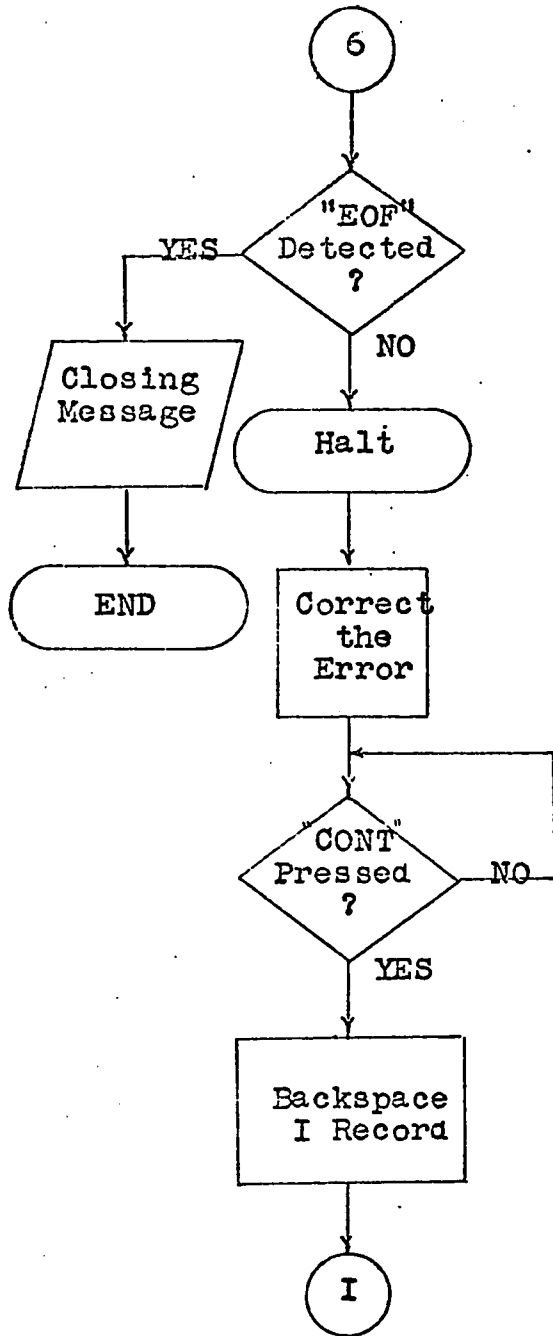
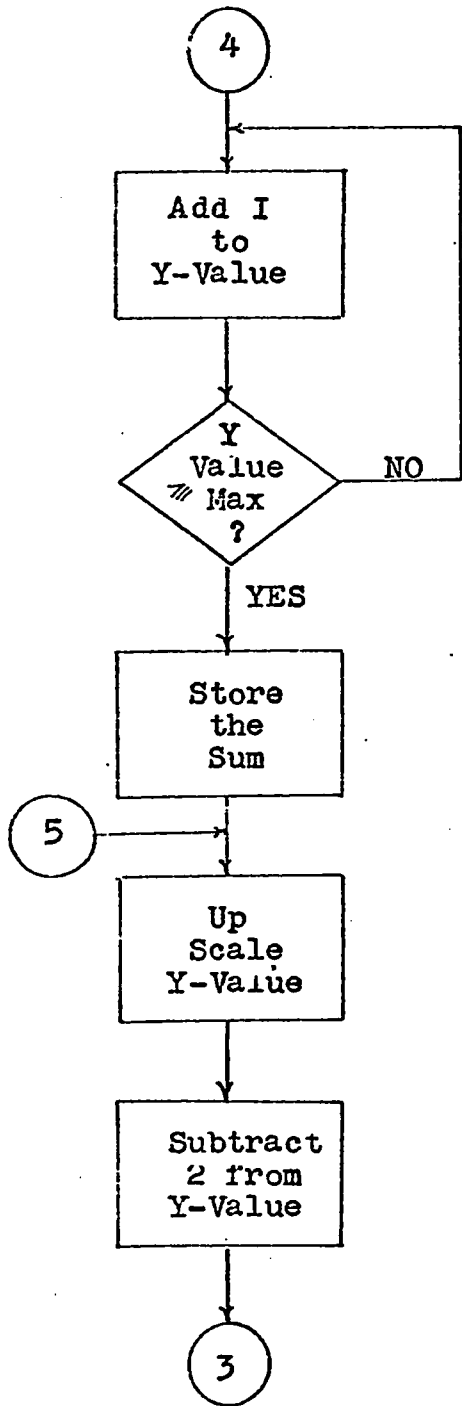
The processing and display of data is limited by the speed of peripheral devices.

8. PROGRAM LISTING AND FLOW CHARTS ARE PROVIDED.

9. FLOW CHARTS







IO. PROGRAM LISTING

/DATA PROCESSING AND DISPLAY PA
 /"THE TRANSPORT PROPERTIES
 /OF SEMICONDUCTORS"
 /PLOT OF LOG(RES) VS 1000/T

SQUARE=0001
 LOG =0007
 NEGATE=0010
 *5

0005	7400		7400	/POINTER TO INPUT
0006	7200		7200	/POINTER TO OUTPUT
0007	5600		5600	/POINTER TO INTERPRETER
		*200		
0200	7300	PROG1,	CLA CLL	
0201	1020		TAD C6000	/ALLOWS USE OF
0202	3421		DCA I L6554	/COMMAND "NEGATE"
0203	4422		JMS I CLEARP	/INITIALIZE ALL FLAGS
0204	4426		JMS I CRLFP	
0205	4427		JMS I DIMENP	/INPUT SAMPLE
0206	7300		CLA CLL	/DIMENSIONS
0207	4426		JMS I CRLFP	
0210	4463		JMS I SCALEP	/INPUT SCALING
0211	7300		CLA CLL	/PARAMETERS
0212	4426		JMS I CRLFP	
0213	4426		JMS I CRLFP	/CAL. SCALE FACTORS;
0214	4465		JMS I TRACEP	/SCALE OFF AXES
0215	4511	DATA1,	JMS I READP	/READ IN DATA RECORD
0216	0052		0052	/42 WORDS LONG
0217	4200		4200	/STORE IN 4200,UP
0220	6731		6731	/READ IN BINARY MODE
0221	5223		JMP.+2	/ERROR RETURN;SR. IN AC
0222	5240		JMP PROC1	/NORMAL RETURN, PROCESS
0223	3112		DCA ERROR	/DATA
0224	1513		TAD I C4200	
0225	1114		TAD M17	
0226	7640		SZA CLA	/ERROR DUE TO "EOF"?
0227	5231		JMP.+2	/NO. ERROR IN READING
0230	4515		JMS I ENDP	/YES, FINALIZE PROGRAM
0231	1112		TAD ERROR	
0232	7402		HLT	/ERROR CODE IN AC
0233	7300		CLA CLL	/PRESS "CONT"
0234	6714		6714	/BACKSPACE 1 RECORD
0235	6701		6701	
0236	5235		JMP.-1	
0237	5215		JMP DATA1	/RE-READ RECORD
0240	7300	PROC1,	CLA CLL	
0241	4521		JMS I CALTIP	/CALCULATE TEMP.
0242	4407		JMS I 7	
0243	5523		FGET I TIP	
0244	6525		FPUT I AVTP	/STORE
0245	0000		FEXT	
0246	7300		CLA CLL	

0247	4527	JMS I INVSTP	/CAL. 1000/T; STORE
0250	4531	JMS I LOGRP	/CALCULATE LOGR; STORE
0251	7300	CLA CLL	
0252	1024	TAD SW1	
0253	7650	SNA CLA	/FIRST PASS?
0254	5262	JMP.+6	/YES
0255	7300	CLA CLL	/NO
0256	1025	TAD SW2	/FIRST VALUE OF LOGR
0257	7640	SZA CLA	/> OR=MAX. VAL.
0260	5306	JMP.+26	/YES, DOWN SCALE LOGR
0261	5312	JMP.+31	/NO, UP SCALE LOGR
0262	7300	CLA CLL	
0263	1120	TAD ONE	/RAISE SOFTWARE FLAG
0264	3024	DCA SW1	
0265	4542	JMS I CUTINP	/OUTPUT LOGR IN
0266	4407	JMS I 7	/F4.2 FORMAT
0267	5541	FGET I YVALP	
0270	0000	FEXT	
0271	7300	CLA CLL	
0272	1045	TAD 45	/VALUE OF LOGR
0273	7700	SMA CLA	/NEGATIVE?
0274	5276	JMP.+2	/NO
0275	5310	JMP.+13	/YES, UP SCALE
0276	4407	JMS I 7	
0277	2472	FSUB I FULLYP	
0300	0000	FEXT	
0301	7300	CLA CLL	
0302	1045	TAD 45	/LOGR > OR =MAX.
0303	7710	SPA CLA	/ALLOWED VALUE?
0304	5310	JMP.+4	/NO, UP SCALE
0305	4543	JMS I DNINP	/YES, DOWN SCALE
0306	4544	JMS I SETDNP	/RESCALE INDEX, STORE
0307	5313	JMP.+4	
0310	7300	CLA CLL	/UP SCALE
0311	4545	JMS I UPINP	/RE-SCALE INDEX
0312	4546	JMS I SETUPP	/STORE
0313	4547	JMS I STEPP	/CONVERT X,Y VALUES
0314	7300	CLA CLL	/TO STEPS
0315	1550	TAD I YCORDP	
0316	1151	TAD M1440	/DOES Y CORD. EXCEED
0317	7710	SPA CLA	/PLOTING LIMITS?
0320	5322	JMP.+2	/NO
0321	5215	JMP DATA1	/YES, DO "NOT" PLOT
0322	7300	CLA CLL	/POINT
0323	1550	TAD I YCORDP	/IS Y CO-ORD.
0324	7700	SMA CLA	/NEGATIVE?
0325	5327	JMP.+2	/NO, PLOT POINT
0326	4552	JMS I MESSP	/YES, END EXECUTION
0327	4553	JMS I PLOTPR	/PLOT THE POINT
0330	5215	JMP DATA1	/READ IN NEXT RECORD

/LOG-LOG PLOT OF "HALL MOBILITY"

0400	7300	PROG2,	CLA CLL		
0401	1020		TAD C6000		/ALLOWS USE OF
0402	3421		DCA I L6554		/COMMAND "NEGATE"
0403	4422		JMS I CLEARP		/INITIALIZE ALL
0404	4426		JMS I CRLFP		/FLAGS
0405	4427		JMS I DIMENP		/INPUT SAMPLE
0406	7300		CLA CLL		/DIMENSIONS
0407	4426		JMS I CRLFP		
0410	4463		JMS I SCALEP		/INPUT SCALING
0411	7300		CLA CLL		/PARAMETERS
0412	4426		JMS I CRLFP		
0413	4426		JMS I CRLFP		/CAL. SCALE FACTORS;
0414	4465		JMS I TRACEP		/SCALE OFF AXES
0415	4511	DATA2,	JMS I READP	/READ	IN DATA RECORD
0416	0052		0052		/42 WORDS LONG
0417	4200		4200		/STORE IN 4200, UP
0420	6731		6731		/READ IN BINARY MODE
0421	5223		JMP.+2		/ERROR RETURN, S. IN AC.
0422	5240		JMP PROC2		/NORMAL RETURN
0423	3112		DCA ERROR		/PROCESS DATA
0424	1513		TAD I C4200		
0425	1114		TAD M17		
0426	7640		SZA CLA		/ERROR DUE TO "EOF"?
0427	5231		JMP.+2		/NO, ERROR IN READING
0430	4515		JMS I ENDP		/YES, FINALIZE PROGRAM
0431	1112		TAD ERROR		/ERROR CODE IN AC
0432	7402		HLT		/PRESS "CONT"
0433	7300		CLA CLL		
0434	6714		6714		/BACKSPACE 1 RECORD
0435	6701		6701		
0436	5235		JMP.-1		
0437	5215		JMP DATA2		/RE-READ RECORD
0440	7300	PROC2,	CLA CLL		
0441	4521		JMS I CALT1P		/CAL. TEMP. (FIELD OFF)
0442	4554		JMS I CALT2P		/CAL. TEMP. (FIELD ON)
0443	4555		JMS I MEANTP		/CAL. AVERAGE TEMP.
0444	4556		JMS I LOGTP		/CAL. LOG(T); STORE
0445	4557		JMS I LOGMUP		/CAL. LOG(MU); STORE
0446	7300		CLA CLL		
0447	1024		TAD SW1		
0450	7650		SNA CLA		/FIRST PASS?
0451	5257		JMP.+6		/YES
0452	7300		CLA CLL		/NO
0453	1025		TAD SW2		/1ST. VALUE OF LOG(MU)
0454	7640		SZA CLA		/> OR = MAX. VAL.?
0455	5303		JMP.+26		/YES, DOWN SCALE
0456	5307		JMP.+31		/NO, UP SCALE
0457	7300		CLA CLL		
0460	1120		TAD ONE		/RAISE SOFTWARE FLAG
0461	3024		DCA SW1		
0462	4542		JMS I OUTINP		/OUTPUT LOG(MU) IN
0463	4407		JMS I 7		/F4.2 FORMAT
0464	5541		FGET I YVALP		
0465	0000		FEXT		

0466	7300	CLA CLL	
0467	1045	TAD 45	/VALUE OF LOG(MU)
0470	7700	SMA CLA	/NEGATIVE?
0471	5273	JMP.+2	/NO
0472	5305	JMP.+13	/YES, UP SCALE
0473	4407	JMS I 7	
0474	2472	FSUB I FULLYP	
0475	0000	FEXT	
0476	7300	CLA CLL	
0477	1045	TAD 45	/LOG(MU) > OR = MAX.
0500	7710	SPA CLA	/ALLOWED VALUE?
0501	5305	JMP.+4	/NO, UP SCALE
0502	4543	JMS I DNINP	/YES, DOWN SCALE
0503	4544	JMS I SETDNP	/RE-SCALE INDEX; STORE
0504	5310	JMP.+4	
0505	7300	CLA CLL	/UP SCALE
0506	4545	JMS I UPINP	/RE-SCALE INDEX
0507	4546	JMS I SETUPP	/STORE
0510	4547	JMS I STEPSP	/CONVERT X,Y VALUES
0511	7300	CLA CLL	/TO STEPS
0512	1550	TAD I YCORDP	/DOES THE Y CO-ORD.
0513	1151	TAD M1440	/EXCEED THE LIMIT?
0514	7710	SPA CLA	
0515	5317	JMP.+2	/NO
0516	5215	JMP DATA2	/YES, DO "NOT" PLOT
0517	7300	CLA CLL	
0520	1550	TAD I YCORDP	/IS Y CO-ORD.
0521	7700	SMA CLA	/NEGATIVE?
0522	5324	JMP.+2	/NO, PLOT THE POINT
0523	4552	JMS I MESSP	/YES, END EXECUTION
0524	4553	JMS I PLOTPR	/PLOT THE POINT
0525	5215	JMP DATA2	/READ IN NEXT RECORD

/MISCELLANEOUS SUBROUTINES

0600	0000	*600 CLEAR,	0		
0601	6032			KCC	/INITIALIZE HARDWARE
0602	6046			TLS	/FLAGS
0603	6502			PLCF	
0604	6504			PLPU	
0605	4510			JMS I DOPR	
0606	1023			TAD ZERO	/INITIALIZE SOFTWARE
0607	3024			DCA SW1	/FLAGS
0610	1023			TAD ZERO	
0611	3025			DCA SW2	
0612	5600			JMP I CLEAR	
0613	0000	CRLF,	0		
0614	1221			TAD CR	
0615	4223			JMS TYPE	
0616	1222			TAD LF	
0617	4223			JMS TYPE	
0620	5613			JMP I CRLF	

0621	0215	CR,	215	
0622	0212	LF,	212	
0623	0000	TYPE,	0	
0624	6041			TSF
0625	5224			JMP.-1
0626	6046			TLS
0627	7200			CLA
0630	5623			JMP I TYPE
0631	0000	DIMEN,	0	
0632	1306			TAD C4377
0633	3010			DCA 10
0634	1307			TAD C4300
0635	3011			DCA 11
0636	1030			TAD M3
0637	3031			DCA CNTR1
0640	1410	DIMEN1,	TAD I 10	
0641	3032			DCA TEMP
0642	1032			TAD TEMP
0643	1033			TAD M251
0644	7640			SZA CLA
0645	7410			SKP
0646	5252			JMP.+4
0647	1032			TAD TEMP
0650	4223			JMS TYPE
0651	5240			JMP DIMEN1
0652	1032			TAD TEMP
0653	4223			JMS TYPE
0654	4213			JMS CRLF
0655	4310			JMS TAB
0656	1410	DIMEN2,	TAD I 10	
0657	3032			DCA TEMP
0660	1032			TAD TEMP
0661	1034			TAD MEQUAL
0662	7640			SZA CLA
0663	7410			SKP
0664	5270			JMP.+4
0665	1032			TAD TEMP
0666	4223			JMS TYPE
0667	5256			JMP DIMEN2
0670	1032			TAD TEMP
0671	4223			JMS TYPE
0672	4405			JMS I 5
0673	4407			JMS I 7
0674	6411			FPUT I 11
0675	0000			FEXT
0676	2031			ISZ CNTR1
0677	7410			SKP
0700	5305			JMP.+5
0701	2011			ISZ 11
0702	2011			ISZ 11
0703	2011			ISZ 11
0704	5255			JMP DIMEN2-1
0705	5631			JMP I DIMEN
0706	4377	C4377,	4377	

/LETTERS STORED IN
/LOC. 4400, UP
/CONSTANTS STORED IN
/LOC. 4300, UP

/INPUT SAMPLE
/DIMENSIONS;
/TERMINATE INPUT
/WITH "CR"

0707	4300	C4300,	4300		
0710	0000	TAB,	0		
0711	1035			TAD M4	
0712	3036			DCA CNTR2	
0713	1037			TAD SPACE	
0714	4223			JMS TYPE	
0715	2036			ISZ CNTR2	
0716	5313			JMP.-3	
0717	5710			JMP I TAB	
0720	0000	SCALE,	0		
0721	1106			TAD C4430	/LETTERS STORED IN
0722	3010			DCA 10	/LOC. 4431, UP
0723	1107			TAD C4311	/CONSTANTS STORED IN
0724	3011			DCA 11	/LOC. 4311, UP
0725	1064			TAD M2	
0726	3031			DCA CNTR1	
0727	1410	SCALE1,	TAD I 10		
0730	3032			DCA TEMP	
0731	1032			TAD TEMP	
0732	1377			TAD M272	
0733	7640			SZA CLA	
0734	7410			SKP	
0735	5341			JMP.+4	
0736	1032			TAD TEMP	
0737	4223			JMS TYPE	
0740	5327			JMP SCALE1	
0741	1032			TAD TEMP	
0742	4223			JMS TYPE	
0743	4213			JMS CRLF	
0744	4310			JMS TAB	
0745	1410	SCALE2,	TAD I 10		
0746	3032			DCA TEMP	
0747	1032			TAD TEMP	
0750	1377			TAD M272	
0751	7640			SZA CLA	
0752	7410			SKP	
0753	5357			JMP.+4	
0754	1032			TAD TEMP	
0755	4223			JMS TYPE	
0756	5345			JMP SCALE2	
0757	1032			TAD TEMP	
0760	4223			JMS TYPE	
0761	1064			TAD M2	
0762	3036			DCA CNTR2	
0763	4405			JMS I 5	/INPUT THE FULL SCALE
0764	4407			JMS I 7	/AND THE NO. OF
0765	6411			FPUT I 11	/DIVISIONS ON THE
0766	0000			FEXT	/X,Y AXIS
0767	2011			ISZ 11	
0770	2011			ISZ 11	
0771	2011			ISZ 11	
0772	2036			ISZ CNTR2	
0773	5363			JMP.-10	
0774	2031			ISZ CNTR1	

```

0775 5344      JMP SCALE2-1
0776 5720      JMP I SCALE
0777 7506 M272, -272

```

```

*1000
1000 0000 TRACE, 0
1001 4407      JMS I 7          /ENTER INTERPRETER
1002 5466      FGET I MAXXPR   /CALCULATE STEPS/UNIT
1003 4467      FDIV I FULLXP  /ON THE X AXIS
1004 6470      FPUT I SCALXP   /CALCULATE STEPS/UNIT
1005 5471      FGET I MAXYPR   /ON THE Y AXIS
1006 4472      FDIV I FULLYP  /CALCULATE STEPS/UNIT
1007 6473      FPUT I SCALYP   /ON THE Y AXIS
1010 5466      FGET I MAXXPR
1011 4474      FDIV I XDIVSP
1012 0000      FEXT
1013 7300      CLA CLL          /CALCULATE
1014 4475      JMS I FIXPR     /STEPS/DIVISION
1015 3102      DCA XINTST    /ON THE X AXIS
1016 4407      JMS I 7
1017 5474      FGET I XDIVSP
1020 0000      FEXT
1021 7300      CLA CLL          /STORE THE NO. OF
1022 4475      JMS I FIXPR     /DIVISIONS IN
1023 3103      DCA XTICKS    /FIXED POINT FORMAT
1024 4407      JMS I 7
1025 5471      FGET I MAXYPR
1026 4476      FDIV I YDIVSP
1027 0000      FEXT
1030 7300      CLA CLL          /CALCULATE
1031 4475      JMS I FIXPR     /STEPS/DIVISION
1032 3104      DCA YINTST    /ON THE Y AXIS
1033 4407      JMS I 7
1034 5476      FGET I YDIVSP
1035 0000      FEXT
1036 7300      CLA CLL          /STORE THE NO. OF
1037 4475      JMS I FIXPR     /DIVISIONS IN FIXED
1040 3105      DCA YTICKS    /POINT FORMAT
1041 6504      PLPU          /RAISE PEN
1042 4372      JMS DO
1043 1101      TAD M310
1044 4336      JMS PENL
1045 1101      TAD M310
1046 4345      JMS DRUMD     /POSITION PEN
1047 6524      PLPD          /LOWER PEN
1050 4372      JMS DO
1051 7300      CLA CLL
1052 1103      TAD XTICKS
1053 7041      CIA
1054 3031      DCA CNTR1
1055 1102      TAD XINTST    /SCALE OFF THE
1056 7041      CIA          /POSITIVE X AXIS
1057 4345      JMS DRUMD

```


1060	1100	TAD M14	
1061	4336	JMS PENL	
1062	1100	TAD M14	
1063	4363	JMS PENR	
1064	2031	ISZ CNTR1	
1065	5255	JMP.-10	
1066	1105	TAD YTICKS	
1067	7041	CIA	
1070	3031	DCA CNTR1	
1071	1104	TAD YINTST	
1072	7041	CIA	
1073	4336	JMS PENL	/SCALE OFF THE
1074	1100	TAD M14	/POSITIVE Y AXIS
1075	4354	JMS DRUMU	
1076	1100	TAD M14	
1077	4345	JMS DRUMD	
1100	2031	ISZ CNTR1	
1101	5271	JMP.-10	
1102	1103	TAD XTICKS	
1103	7041	CIA	
1104	3031	DCA CNTR1	
1105	1102	TAD XINTST	
1106	7041	CIA	/SCALE OFF THE
1107	4354	JMS DRUMU	/NEGATIVE X AXIS
1110	1100	TAD M14	
1111	4363	JMS PENR	
1112	1100	TAD M14	
1113	4336	JMS PENL	
1114	2031	ISZ CNTR1	
1115	5305	JMP.-10	
1116	1105	TAD YTICKS	
1117	7041	CIA	
1120	3031	DCA CNTR1	
1121	1104	TAD YINTST	
1122	7041	CIA	/SCALE OFF THE
1123	4363	JMS PENR	/NEGATIVE Y AXIS
1124	1100	TAD M14	
1125	4345	JMS DRUMD	
1126	1100	TAD M14	
1127	4354	JMS DRUMU	
1130	2031	ISZ CNTR1	
1131	5321	JMP.-10	
1132	7240	CLA CMA	
1133	4477	JMS I PLOT	/RAISE PEN, INITIALIZE
1134	7300	CLA CLL	/PLOT SUBROUTINE
1135	5600	JMP I TRACE	/EXIT
1136	0000	PENL,	0
1137	3036		
1140	6521	DCA CNTR2	/MOVES THE PEN
1141	4372	PLPL	/A SPECIFIED NO.
1142	2036	JMS DO	/OF STEPS LEFT
1143	5340	ISZ CNTR2	
1144	5736	JMP.-3	
1145	0000	JMP I PENL	
		DRUMD,	0

1146	3036			DCA CNTR2	/MOVES THE DRUM
1147	6514			PLDD	/A SPECIFIED NO.
1150	4372			JMS DO	/OF STEPS DOWN
1151	2036			ISZ CNTR2	
1152	5347			JMP.-3	
1153	5745			JMP I DRUMD	
1154	0000	DRUMU,	0		
1155	3036			DCA CNTR2	/MOVES THE DRUM
1156	6522			PLUD	/A SPECIFIED NO.
1157	4372			JMS DO	/OF STEPS UP
1160	2036			ISZ CNTR2	
1161	5356			JMP.-3	
1162	5754			JMP I DRUMU	
1163	0000	PENR,	0		
1164	3036			DCA CNTR2	/MOVES THE PEN
1165	6511			PLPR	/A SPECIFIED NO.
1166	4372			JMS DO	/OF STEPS RIGHT
1167	2036			ISZ CNTR2	
1170	5365			JMP.-3	
1171	5763			JMP I PENR	
1172	0000	DO,	0		
1173	6501			PLSF	/SKIP ON "DONE"
1174	5373			JMP.-1	/FLAG
1175	6502			PLCF	/CLEAR FLAG
1176	5772			JMP I DO	

/SUBROUTINE "READ" WILL READ
/"ONE" RECORD FROM THE MAGNETIC
/TAPE INTO CORE MEMORY
/DSA-S-390-3

/CALLING SEQUENCE:
/JMS READ
/NO. OF WORDS TO BE READ (BINARY)
/S.A. OF THE BUFFER IN CORE
/INSTRUCTION WHICH SELECTS PARITY

/RETURN: ERROR RETURN, SR IN AC
/RETURN: NORMAL RETURN, NO ERROR

		*1200			
1200	0000	READ,	0		
1201	7300			CLA CLL	
1202	1600			TAD I READ	/INPUT NO. OF WORDS
1203	7041			CIA	
1204	3642			DCA I PWCNT	/LOAD WORD COUNT
1205	2200			ISZ READ	
1206	7240			CLA CMA	
1207	1600			TAD I READ	/INPUT SA-1 INTO AC
1210	3643			DCA I PADD	/LOAD SA-1
1211	2200			ISZ READ	
1212	1600			TAD I READ	/INPUT SELECTED PARITY
1213	3225			DCA.+12	/LOAD SELECTED PARITY
1214	2200			ISZ READ	/ADDRESS OF ERROR

1215	7300			CLA CLL	/RETURN
1216	6704			6704	/READ SR INTO AC
1217	7006			RTL	
1220	7420			SNL	
1221	5225			JMP.+4	
1222	7012			RTR	
1223	7120			STL	/LINK SET, IF IN WRITE
1224	5600			JMP I READ	/MODE. EXIT
1225	0000			0	/SELECTED PARITY
1226	6712			6712	/READ FORWARD
1227	6701			6701	
1230	5227			JMP.-1	
1231	7200			CLA	
1232	6704			6704	/READ SR INTO AC
1233	7104			CLL RAL	/HARDWARE OR, BITS 6-11
1234	7430			SZL	/NO ERRORS
1235	5240			JMP.+3	
1236	2200			ISZ READ	
1237	5600			JMP I READ	/NORMAL RETURN
1240	7110			CLL RAR	
1241	5600			JMP I READ	/ERROR RETURN, SR IN AC
1242	7576	PWCNT,	7576		/AUTO INDEX REGISTER
1243	7577	PADD,	7577		/AUTO INDEX REGISTER
1244	0000	END,	0		
1245	1266			TAD C4471	/LETTERS STORED IN LOC.
1246	3010			DCA 10	/4472, UP
1247	1410			TAD I 10	
1250	3032			DCA TEMP	
1251	1032			TAD TEMP	
1252	1116			TAD M256	
1253	7640			SZA CLA	/IS IT A PERIOD?
1254	7410			SKP	/NO
1255	5261			JMP.+4	/YES
1256	1032			TAD TEMP	
1257	4517			JMS I TYPEPR	
1260	5247			JMP END+3	
1261	1032			TAD TEMP	
1262	4517			JMS I TYPEPR	
1263	4426			JMS I CRLFP	
1264	7402			HLT	/END OF PROGRAM
1265	5644			JMP I END	/AC=0
1266	4471	C4471,	4471		
1267	0000	FIX,	0		
1270	7300			CLA CLL	
1271	1044			TAD 44	/IS NO. >OR=1/2 AND
1272	7440			SZA	/ <1 ?
1273	5276			JMP.+3	/NO
1274	1120			TAD ONE	/YES, ROUND OFF TO
1275	5667			JMP I FIX	/"ONE", EXIT
1276	7500			SMA	/IS NO. $<1/2$?
1277	5302			JMP.+3	/NO
1300	7300			CLA CLL	/YES, SET NO. TO 0
1301	5667			JMP I FIX	/EXIT
1302	1100			TAD M14	

1303	1120			TAD ONE	
1304	3044			DCA 44	/BINARIZE THE NO.
1305	7100	GO,		CLL	
1306	1045			TAD 45	
1307	7510			SPA	
1310	7020			CML	
1311	7010			RAR	
1312	3045			DCA 45	
1313	2044			ISZ 44	
1314	5305			JMP 60	
1315	7420			SNL	
1316	5320			JMP.+2	
1317	1120			TAD ONE	
1320	1045			TAD 45	
1321	7100			CLL	
1322	5667			JMP I FIX	
1323	0000	MEANT,	0		/OBTAIN AVERAGE TEMP.
1324	4407			JMS I 7	
1325	5334			FGET T1	
1326	1337			FADD T2	
1327	4526			FDIV I TWOPR	/AVT= (T1+T2)/2
1330	6525			FPUT I AVTP	
1331	0000			FEXT	
1332	7300			CLA CLL	
1333	5723			JMP I MEANT	
1334	0000	T1,	0		
1335	0000			0	
1336	0000			0	
1337	0000	T2,	0		
1340	0000			0	
1341	0000			0	
1342	0000	INVST,	0		
1343	4407			JMS I 7	
1344	5352			FGET KILO	/CALCULATE 1000/T
1345	4525			FDIV I AVTP	
1346	6530			FPUT I XVALP	/STORE IN XVALUE
1347	0000			FEXT	
1350	7300			CLA CLL	
1351	5742			JMP I INVST	
1352	0012	KILO,	0012		/1000.
1353	3720			3720	
1354	0000			0000	
1355	0000	LOGR,	0		/SUB. CALCULATES THE
1356	4407			JMS I 7	/COMMON LOG OF THE
1357	5532			FGET I SAMIIP	/ABS. VALUE OF RES.
1360	4533			FDIV I RIP	
1361	6375			FPUT C	
1362	5534			FGET I RESIP	
1363	3535			FMPY I TPR	/RES=V(RES)TW/CD
1364	3536			FMPY I WPR	
1365	4375			FDIV C	
1366	4537			FDIV I DPR	
1367	0007			LOG	/TAKE THE NATURAL LOG
1370	3540			FMPY I CONVFP	/CONVERT TO COMMON LOG

1371	6541		FPUT I YVALP	/STORE
1372	0000		FEXT	
1373	7300		CLA CLL	
1374	5755		JMP I LOGR	
1375	0000	C,	0	/CURRENT
1376	0000		0	
1377	0000		0	
		*1400		
1400	0000	CALT1,	0	
1401	4407		JMS I 7	
1402	5751		FGET I GE1P	/R(GE)=V(GE)/V(EX)/R3
1403	3752		FMPY I R3P	
1404	4753		FDIV I EX1P	
1405	6371		FPUT RES	/STORE
1406	2360		FSUB MINRGE	/SUBTRACT 21.13 OHMS
1407	0000		FEXT	
1410	7300		CLA CLL	/RES. OF GE. SENSOR
1411	1045		TAD 45	/> OR = 21.13 OHMS?
1412	7710		SPA CLA	/I.E. T <38 OR =38 DEG.
1413	5216		JMP.+3	/NO, USE PT. SENSOR
1414	4270		JMS GRANGE	/YES, USE GE. SENSOR
1415	5227		JMP.+12	
1416	4407		JMS I 7	
1417	5754		FGET I PT1P	/CALCULATE R(P.T)
1420	3752		FMPY I R3P	
1421	4753		FDIV I EX1P	
1422	0000		FEXT	
1423	7300		CLA CLL	/OBTAIN T BY EVAL-
1424	4522		JMS I POLYP	/UATING PT. TEMP.
1425	0006		0006	/POLY.
1426	4071		4071	
1427	4407		JMS I 7	
1430	6523		FPUT I TIP	/STORE T
1431	0000		FEXT	
1432	7300		CLA CLL	
1433	5600		JMP I CALT1	/EXIT
1434	0000	CALT2,	0	
1435	4407		JMS I 7	
1436	5755		FGET I GE2P	
1437	3752		FMPY I R3P	/CALCULATE R(GE)
1440	4756		FDIV I EX2P	
1441	6371		FPUT RES	/STORE
1442	2360		FSUB MINRGE	/SUBTRACT 21.13 OHMS.
1443	0000		FEXT	
1444	7300		CLA CLL	
1445	1045		TAD 45	/RES. OF GE.
1446	7710		SPA CLA	/> OR = 21.13 OHMS?
1447	5252		JMP.+3	/NO, USE PT. SENSOR
1450	4270		JMS GRANGE	/YES, USE GE. SENSOR
1451	5263		JMP.+12	
1452	4407		JMS I 7	
1453	5757		FGET I PT2P	/CALCULATE R(P.T)
1454	3752		FMPY I R3P	

1455	4756	FDIV I EX2P	
1456	0000	FEXT	
1457	7300	CLA CLL	/OBTAIN T BY EVAL-
1460	4522	JMS I POLYP	/UATING PT. TEMP.
1461	0006	0006	/POLY.
1462	4071	4071	
1463	4407	JMS I 7	
1464	6524	FPUT I T2P	/STORE T
1465	0000	FEXT	
1466	7300	CLA CLL	
1467	5634	JMP I CALT2	/EXIT
1470	0000	- GRANGE, 0	
1471	4407	JMS I 7	
1472	5371	FGET RES	
1473	2363	FSUB MINRR1	/SUBTRACT 847.2 OHMS
1474	0000	FEXT	
1475	7300	CLA CLL	
1476	1045	TAD 45	/IS T < OR = 2.75 DEG.?
1477	7710	SPA CLA	/I.E. IN RANGE1?
1500	5311	JMP.+11	/NO
1501	4407	JMS I 7	/YES
1502	5371	FGET RES	
1503	0000	FEXT	
1504	7300	CLA CLL	
1505	4522	JMS I POLYP	/OBTAIN T BY EVAL-
1506	0004	0004	/RANGE1 POLY.
1507	4000	4000	
1510	5670	JMP I GRANGE	/EXIT, T IN FP. AC.
1511	4407	JMS I 7	
1512	5371	FGET RES	
1513	2366	FSUB MINRR2	/SUBTRACT 164.1 OHMS
1514	0000	FEXT	
1515	7300	CLA CLL	/IS T < OR =12 DEG.?
1516	1045	TAD 45	/I.E. IN RANGE2?
1517	7710	SPA CLA	
1520	5331	JMP.+11	/NO
1521	4407	JMS I 7	/YES, T IN RANGE2
1522	5371	FGET RES	
1523	0000	FEXT	/OBTAIN T BY EVAL-
1524	7300	CLA CLL	/UATING RANGE2 POLY.
1525	4522	JMS I POLYP	
1526	0006	0006	
1527	4017	4017	
1530	5670	JMP I GRANGE	/EXIT, T IN FP. AC.
1531	4407	JMS I 7	
1532	5371	FGET RES	
1533	2360	FSUB MINRGE	/SUBTRACT 21.13 OHMS
1534	0000	FEXT	
1535	7300	CLA CLL	
1536	1045	TAD 45	/IS T < OR = 38 DEG.?
1537	7710	SPA CLA	/I.E. IN RANGE3?
1540	7402	HLT	/NO, ERROR IN SUB.
1541	4407	JMS I 7	/YES
1542	5371	FGET RES	

```

1543 0000 FEXT
1544 7300 CLA CLL /OBTAIN T BY EVAL-
1545 4522 JMS I POLYP /UATING RANGE3 POLY.
1546 0006 0006
1547 4044 4044
1550 5670 JMP I GRANGE /EXIT, T IN FP. AC.
1551 4203 GE1P, GE1
1552 4341 R3P, R3
1553 4200 EX1P, EX1
1554 4206 PT1P, PT1
1555 4230 GE2P, GE2
1556 4225 EX2P, EX2
1557 4233 PT2P, PT2
1560 0005 MINRGE, 0005 /21.13 OHMS
1561 2510 2510
1562 2437 2437
1563 0012 MINRRI, 0012 /847.2 OHMS
1564 3236 3236
1565 3147 3147
1566 0010 MINRR2, 0010 /164.1 OHMS
1567 2440 2440
1570 6315 6315
1571 0000 RES, 0 /SENSOR RESISTANCE
1572 0000 0
1573 0000 0

```

```

/SUBROUTINE "POLYEV" WILL EVALU
/AN "NTH" DEGREE POLYNOMIAL
/(STORAGE LOCATIONS ACCOMODATE
/UP TO A 15TH. DEGREE POLYNOMIAL
/CALLING SEQUENCE:

```

```

/ VAR. IN F.P.
/ JMS POLYEV
/ DEGREE OF POL.
/ S.A. OF COEF

```

```

/RETURN: RETURN WITH
/ OF DEPENDENT
/ IN F.P. AC.

```

```

*1600
POLYEV, 0

```

```

1600 0000 JMS I 7
1601 4407 FPUT VAR /STORE VALUE OF INDP.
1602 6305 FEXT /VARIABLE
1603 0000 CLA CLL
1604 7300 TAD I POLYEV /STORE DEGREE OF POLY.
1605 1600 DCA DEGREE /TO BE EVALUATED
1606 3310 ISZ POLYEV
1607 2200 TAD I POLYEV /STORE S.A. OF
1610 1600 DCA 10 /"COEFFICIENTS"
1611 3010 TAD C1714 /STORE SA OF TERMS
1612 1312 DCA 11
1613 3011

```

1614	4407	JMS I 7	
1615	5410	FGET I 10	/STORE THE INTERCEPT
1616	6411	FPUT I 11	
1617	0000	FEXT	
1620	7300	CLA CLL	
1621	1310	TAD DEGREE	
1622	7041	CIA	
1623	3031	DCA CNTR1	
1624	1023	TAD ZERO	
1625	3311	DCA INDEX	
1626	2311	ISZ INDEX	
1627	1311	TAD INDEX	
1630	7041	CIA	
1631	3036	DCA CNTR2	
1632	2010	ISZ 10	
1633	2010	ISZ 10	
1634	2010	ISZ 10	
1635	2011	ISZ 11	
1636	2011	ISZ 11	
1637	2011	ISZ 11	
1640	4407	JMS I 7	/GENERATE POWERS
1641	5305	FGET VAR	/OF INDP. VAR.
1642	0000	FEXT	
1643	2036	ISZ CNTR2	
1644	5246	JMP.+2	
1645	5252	JMP.+5	
1646	4407	JMS I 7	
1647	3305	FMPY VAR	
1650	0000	FEXT	
1651	5243	JMP.-6	
1652	4407	JMS I 7	
1653	3410	FMPY I 10	/STORE THE TERMS
1654	6411	FPUT I 11	
1655	0000	FEXT	
1656	7300	CLA CLL	
1657	2031	ISZ CNTR1	
1660	5226	JMP.-32	
1661	7300	CLA CLL	
1662	1312	TAD C1714	
1663	3011	DCA 11	
1664	1310	TAD DEGREE	
1665	7041	CIA	
1666	3031	DCA CNTR1	
1667	4407	JMS I 7	
1670	5411	FGET I 11	
1671	0000	FEXT	
1672	2011	ISZ 11	
1673	2011	ISZ 11	/ADD UP THE TERMS
1674	2011	ISZ 11	
1675	4407	JMS I 7	
1676	1411	FADD I 11	
1677	0000	FEXT	
1700	2031	ISZ CNTR1	
1701	5272	JMP.-7	/EXIT WITH VALUE

1702	2200			ISZ POLYEV	/OF DEP. VAR. IN FP AC.
1703	7300			CLA CLL	
1704	5600			JMP I POLYEV	
1705	0000	VAR,	0		
1706	0000			0	
1707	0000			0	
1710	0000	DEGREE,	0		
1711	0000	INDEX,	0		
1712	1714	C1714,	1714		/TERMS IN LOC. 1714, UP
		*2000			
2000	0000	OUTIND,	0		/OUTPUT INDEX IN
2001	4426			JMS I CRLFP	/F4.2 FORMAT
2002	1221			TAD STAR	
2003	4517			JMS I TYPEPR	
2004	1037			TAD SPACE	
2005	4517			JMS I TYPEPR	
2006	4407			JMS I 7	
2007	5541			FGET I YVALP	
2010	0000			FEXT	
2011	7300			CLA CLL	
2012	1222			TAD CFOUR	
2013	3062			DCA 62	
2014	1223			TAD CTWO	
2015	4406			JMS I 6	
2016	7300			CLA CLL	
2017	4426			JMS I CRLFP	
2020	5600			JMP I OUTIND	
2021	0252	STAR,	252		
2022	0004	CFOUR,	4		
2023	0002	CTWO,	2		
2024	0000	DNIND,	0		/SCALE DOWN THE INDEX:
2025	7300			CLA CLL	
2026	1120			TAD ONE	/RAISE SOFTWARE FLAG
2027	3025			DCA SW2	
2030	4407			JMS I 7	
2031	2250			FSUB CONE	/SUBTRACT 1
2032	0000			FEXT	
2033	2253			ISZ ONES	
2034	7300			CLA CLL	
2035	1045			TAD 45	
2036	7700			SMA CLA	/Y VAL. < MAX. VAL.?
2037	5230			JMP.-7	/NO.
2040	7300			CLA CLL	
2041	1253			TAD ONES	/YES
2042	1255			TAD K1	
2043	3254			DCA STORE	/STORE SUBTRAHEND
2044	1023			TAD ZERO	
2045	3253			DCA ONES	
2046	7300			CLA CLL	
2047	5624			JMP I DNIND	/EXIT
2050	0001	CONE,	0001		/1
2051	2000			2000	

2052	0000			0000	
2053	0000	ONES,	0		
2054	0000	STORE,	0		
2055	0001	K1,	1		
2056	0000	SETDN,	0		
2057	7300			CLA CLL	
2060	1254			TAD STORE	
2061	7041			CIA	
2062	3031			DCA CNTR1	
2063	4407			JMS I 7	
2064	5541			FGET I YVALP	/SUBTRACT 1 FROM
2065	0000			FEXT	/Y VAL THE CORRECT
2066	4407			JMS I 7	/NO. OF TIMES
2067	2250			FSUB CONE	
2070	0000			FEXT	
2071	2031			ISZ CNTR1	
2072	5266			JMP.-4	
2073	4407			JMS I 7	/STORE THE NEW
2074	6541			FPUT I YVALP	/Y VALUE
2075	0000			FEXT	
2076	7300			CLA CLL	
2077	5656			JMP I SETDN	
2100	0000	UPIND,	0		
2101	7300			CLA CLL	
2102	4407			JMS I 7	
2103	5541			FGET I YVALP	
2104	6334			FPUT SAVEY	/SAVE Y VALUE
2105	0000			FEXT	
2106	4407			JMS I 7	
2107	5334			FGET SAVEY	
2110	1250			FADD CONE	/ADD 1
2111	6334			FPUT SAVEY	
2112	0000			FEXT	
2113	2253			ISZ ONES	
2114	4407			JMS I 7	
2115	5334			FGET SAVEY	
2116	2472			FSUB I FULLYP	
2117	0000			FEXT	
2120	7300			CLA CLL	
2121	1045			TAD 45	/IS Y VAL. > MAX.?
2122	7700			SMA CLA	
2123	5325			JMP.+2	/YES
2124	5306			JMP.-16	/NO, ADD 1 AGAIN
2125	7300			CLA CLL	
2126	1253			TAD ONES	
2127	3254			DCA STORE	/STORE THE NO.
2130	1023			TAD ZERO	/OF TIMES 1 WAS
2131	3253			DCA ONES	/ADDED
2132	7300			CLA CLL	
2133	5700			JMP I UPIND	
2134	0000	SAVEY,	0		
2135	0000			0	
2136	0000			0	
2137	0000	SETUP,	0		

2140	7300	CLA CLL	
2141	1254	TAD STORE	
2142	7041	CIA	
2143	3031	DCA CNTR1	
2144	4407	JMS I 7	
2145	5541	FGET I YVALP	
2146	0000	FEXT	
2147	4407	JMS I 7	/ADD 1 TO Y VAL.THE
2150	1250	FADD CONE	/CORRECT NO. OF TIMES
2151	0000	FEXT	
2152	2031	ISZ CNTR1	
2153	5347	JMP.-4	
2154	4407	JMS I 7	
2155	2250	FSUB CONE	
2156	2250	FSUB CONE	
2157	6541	FPUT I YVALP	/STORE THE NEW VALUE
2160	0000	FEXT	
2161	7300	CLA CLL	
2162	5737	JMP I SETUP	

		*2200	
2200	0000	MARK,	0
2201	7300		
2202	6502		
2203	6524		
2204	4510		
2205	6504		
2206	4510		
2207	1241		
2210	4642		
2211	1241		
2212	4643		
2213	6524		
2214	4510		
2215	1244		
2216	4645		
2217	1244		
2220	4646		
2221	1244		
2222	4642		
2223	1244		
2224	4643		
2225	6504		
2226	4510		
2227	1241		
2230	4646		
2231	1241		
2232	4645		
2233	6524		
2234	4510		
2235	6504		
2236	4510		
2237	7300		

2200	0000	CLA CLL	
2201	7300	PLCF	
2202	6502	PLPD	/MARK POINT
2203	6524	JMS I DOPR	
2204	4510	PLPU	/RAISE PEN
2205	6504	JMS I DOPR	
2206	4510	TAD MIN4	
2207	1241	JMS I DRUMUP	
2210	4642	TAD MIN4	
2211	1241	JMS I PENRP	
2212	4643	PLPD	
2213	6524	JMS I DOPR.	
2214	4510	TAD M10	/DRAW A SQUARE AROUND
2215	1244	JMS I DRUMDP	/POINT, (8X8) STEPS
2216	4645	TAD M10	
2217	1244	JMS I PENLP	
2220	4646	TAD M10	
2221	1244	JMS I DRUMUP	
2222	4642	TAD M10	
2223	1244	JMS I PENRP	
2224	4643	PLPU	
2225	6504	JMS I DOPR	
2226	4510	TAD MIN4	
2227	1241	JMS I PENLP	
2230	4646	TAD MIN4	
2231	1241	JMS I DRUMDP	
2232	4645	PLPD	
2233	6524	JMS I DOPR	
2234	4510	PLPU	/REPOSITION PEN
2235	6504	JMS I DOPR	
2236	4510	CLA CLL	
2237	7300		

2240	5600			JMP I MARK	
2241	7774	MIN4,	-4		
2242	1154	DRUMUP,	DRUMU		
2243	1163	PENRP,	PENR		
2244	7770	M10,	-10		
2245	1145	DRUMDP,	DRUMD		
2246	1136	PENLP,	PENL		
2247	0000	MESS,	0		
2250	7300			CLA CLL	
2251	1272			TAD C4511	/LETTERS STORED IN
2252	3010			DCA 10	/LOC. 4512, UP
2253	1410			TAD I 10	
2254	3032			DCA TEMP	
2255	1032			TAD TEMP	
2256	1116			TAD M256	
2257	7640			SZA CLA	/TESTING FOR PERIOD
2260	7410			SKP	
2261	5265			JMP.+4	
2262	1032			TAD TEMP	
2263	4517			JMS I TYPEPR	
2264	5253			JMP MESS+4	
2265	1032			TAD TEMP	
2266	4517			JMS I TYPEPR	
2267	4426			JMS I CRLFP	
2270	7402			HLT	/EXECUTION OF PROGRAM
2271	5647			JMP I MESS	/ABORTED.
2272	4511	C4511,	4511		
2273	0000	STEPNO,	0		
2274	4407			JMS I 7	
2275	5470			FGET I SCALXP	/STEP NO. =
2276	3530			FMPY I XVALP	/(STEPS/UNIT)(UNITS)
2277	0000			FEXT	
2300	4475			JMS I FIXPR	/CONVERT STEP NO. TO
2301	3320			DCA XCORD	/FIXED POINT NOTATION
2302	4407			JMS I 7	
2303	5473			FGET I SCALYP	
2304	3541			FMPY I YVALP	
2305	0000			FEXT	
2306	4475			JMS I FIXPR	
2307	3321			DCA YCORD	
2310	5673			JMP I STEPNO	
2311	0000	PLOTP,	0		
2312	4315			JMS MOVE	/POSITION PEN
2313	4200			JMS MARK	/MARK THE POINT
2314	5711			JMP I PLOTP	
2315	0000	MOVE,	0		
2316	7201			CLA IAC	/PLOT WITH PEN UP
2317	4477			JMS I PLOT	
2320	0000	XCORD,	0		
2321	0000	YCORD,	0		
2322	5715			JMP I MOVE	
2323	0000	LOGT,	0		
2324	4407			JMS I 7	
2325	5525			FGET I AVTP	/CALCULATE THE

2326	0007			LOG	/COMMON LOG.
2327	3540			FMPY I CONVFP	/OF THE TEMP.
2330	6530			FPUT I XVALP	/STORE THIS VAL.
2331	0000			FEXT	
2332	7300			CLA CLL	
2333	5723			JMP I LOGT	
2334	0000	LOGMU,	0		
2335	4407			JMS I 7	
2336	5560			FGET I MAG2P	/OBTAIN THE
2337	0000			FEXT	/VALUE OF THE
2340	4522			JMS I POLYP	/MAG. FIELD
2341	0005			0005	
2342	4116			4116	
2343	4407			JMS I 7	
2344	6366			FPUT B	
2345	5561			FGET I HALL2P	/CALCULATE THE
2346	2562			FSUB I HALL1P	/HALL VOLTAGE
2347	6371			FPUT HALL	
2350	0000			FEXT	
2351	4407			JMS I 7	/CALCULATE MU
2352	5371			FGET HALL	/MU=V(HALL)D/V(RES)BW
2353	3537			FMPY I DPR	
2354	4534			FDIV I RES1P	
2355	4366			FDIV B	
2356	4536			FDIV I WPR	
2357	3563			FMPY I CONVFP	/CONVERT TO
2360	0007			LOG	/CGSM UNITS
2361	3540			FMPY I CONVFP	/TAKE LOG. MU
2362	6541			FPUT I YVALP	
2363	0000			FEXT	/STORE THIS VALUE
2364	7300			CLA CLL	
2365	5734			JMP I LOGMU	
2366	0000	B,	0		/STORAGE FOR MAG.
2367	0000		0		/FIELD
2370	0000		0		
2371	0000	HALL,	0		/STORAGE FOR HALL
2372	0000		0		/VOLTAGE
2373	0000		0		

```

/PLOT SUBROUTINE          DIGITAL-8-12-U
/CALLING SEQUENCE
/  C(AC)=-1; INITIALIZE
/  C(AC)= 0; PLOT WITH PEN DOWN
/  C(AC)= 1; PLOT WITH PEN UP
/    JMS PLOTX
/    X CO-ORDINATE (IN STEPS) (RETURN IF AC=-1)
/    Y CO-ORDINATE (IN STEPS)

```

	*2400				
2400	0000	PLOTX,	0		
2401	7510			SPA	/MOVE THE PEN?
2402	5220			JMP PLOTA	/NO: CONTINUE
2403	1361			TAD PLOTPN	/ADD PEN STATUS

2404	7112		CLL RTR	
2405	7710		SPA CLA	/ANY CHANGE?
2406	5227		JMP PLOT1	/NO: CONTINUE
2407	7620		SNL CLA	
2410	5214		JMP.+4	/LOWER THE PEN
2411	3361		DCA PLOTPN	/RAISE THE PEN
2412	6504		PLPU	
2413	5216		JMP .+3	
2414	2361		ISZ PLOTPN	/LOWER THE PEN
2415	6524		PLPD	
2416	4370		JMS PLOTWT	/WAIT FOR FLAG
2417	5227		JMP PLOT1	/CONTINUE
2420	7200	PLOTA,		
2421	6504	CLA		
2422	3361		PLPU	/RAISE THE PEN
2423	3362		DCA PLOTPN	
2424	3363		DCA PLOTNX	/0 TO X CO-ORDINATE
2425	4370		DCA PLOTNY	/0 TO Y CO-ORDINATE
2426	5600		JMS PLOTWT	
			JMP I PLOTX	
			/PICK UP ARGUMENTS	
2427	1362	PLOT1,	TAD PLOTNX	/GET PREVIOUS X CO-ORD.
2430	7141		CIA CLL	
2431	1600		TAD I PLOTX	/FORM NX-NPX
2432	7420		SNL	/L=0: NX<NPX
2433	7041		CIA	
2434	3364		DCA PLOTDX	/ABS. VALUE OF DIFF.
2435	7004		RAL	
2436	3367		DCA PLOTMV	/SAVE SIGN BIT
2437	1600		TAD I PLOTX	/SET NEW
2440	3362		DCA PLOTNX	/PREVIOUS X
2441	2200		ISZ PLOTX	/INCREMENT POINTER
2442	1363		TAD PLOTNY	/GET PREVIOUS Y CO-ORD.
2443	7141		CIA CLL	
2444	1600		TAD I PLOTX	/FORM NY-NPY
2445	7420		SNL	/<=0: NPY<NPY
2446	7041		CIA	
2447	3365		DCA PLOTDY	/ABS. VALUE OF DIFF.
2450	1367		TAD PLOTMV	/SAVE SIGN BIT
2451	7004		RAL	
2452	3367		DCA PLOTMV	
2453	1600		TAD I PLOTX	/SET NEW
2454	3363		DCA PLOTNY	/PREVIOUS Y
2455	2200		ISZ PLOTX	/INCREMENT POINTER
2456	1364		TAD PLOTDX	
2457	7141		CIA CLL	
2460	1365		TAD PLOTDY	
2461	7620		SNL CLA	
2462	5275		JMP PLOT2	
2463	1364		TAD PLOTDX	/REVERSE NUMBERS
2464	3366		DCA PLOTNA	
2465	1365		TAD PLOTDY	
2466	3364		DCA PLOTDX	
2467	1366		TAD PLOTNA	
2470	3365		DCA PLOTDY	

2471	7001		IAC	/SET MAJOR MOTION
2472	0367		AND PLOTMV	/INSTRUCTION
2473	1342		TAD PLOTT1	
2474	5300		JMP .+4	
2475	1367	PLOT2,	TAD PLOTMV	
2476	7110		CLL RAR	
2477	1345		TAD PLOTT2	
2500	3366		DCA PLOTNA	
2501	1766		TAD I PLOTNA	
2502	3340		DCA PLOT4	
2503	1367		TAD PLOTMV	/SET COMBINED MOTION
2504	1350		TAD PLOTT3	
2505	3367		DCA PLOTMV	
2506	1767		TAD I PLOTMV	
2507	3331		DCA PLOTDB	
2510	1364		TAD PLOTDX	
2511	7110		CLL RAR	
2512	3366		DCA PLOTNA	
2513	1364		TAD PLOTDX	
2514	7040		CMA	
2515	3367		DCA PLOTMV	
2516	2367	PLOT3,	ISZ PLOTMV	
2517	7410		SKP	
2520	5600		JMP I PLOTX	/ALL DONE
2521	1366		TAD PLOTNA	
2522	1365		TAD PLOTDY	
2523	3366		DCA PLOTNA	
2524	1366		TAD PLOTNA	
2525	7141		CIA CLL	
2526	1364		TAD PLOTDX	
2527	7630		SZL CLA	
2530	5340		JMP PLOT4	/SINGLE MOTION
2531	0000	PLOTDB, 0		/COMBINED MOTION
2532	1364		TAD PLOTDX	
2533	7041		CIA	
2534	1366		TAD PLOTNA	
2535	3366		DCA PLOTNA	
2536	4370		JMS PLOTWT	
2537	5316		JMP PLOT3	
2540	0000	PLOT4, 0		
2541	5336		JMP .-3	
2542	2543	PLOTT1, .+1		
2543	6511		PLPR	/PEN-RIGHT
2544	6521		PLPL	/PEN-LEFT
2545	2546	PLOTT2, .+1		
2546	6512		PLDU	/DRUM-UP
2547	6514		PLDD	/DRUM-DOWN
2550	2551	PLOTT3, .+1		
2551	6513		PLDU PLPR	/UP-RIGHT
2552	6523		PLUD PLPL	/UP-LEFT
2553	6515		PLDD PLPR	/DOWN-RIGHT
2554	4355		JMS .+1	/DOWN-LEFT
2555	0000		0	
2556	6514		PLDD	

2557	6521		PLPL	
2560	5755		JMP I	--3
2561	0000	PLOTPN,	0	
2562	0000	PLOTNX,	0	
2563	0000	PLOTNY,	0	
2564	0000	PLOTDX,	0	
2565	0000	PLOTDY,	0	
2566	0000	PLOTNA,	0	
2567	0000	PLOTMV,	0	
2570	0000	PLOTWT,	0	
2571	6501		PLSF	/WAIT FOR DONE FLAG
2572	5371		JMP --1	/NOT YET
2573	6502		PLCF	/CLEAR FLAG
2574	5770		JMP I PLOTWT	/EXIT

/POLYNOMIAL COEFFICIENTS STORED
/IN F.P. FORMAT

*4000

4000	0003	0003	/GE. RANGE1 POLY. COEFF.
4001	2557	2557	/A0= 5.43593917E00
4002	4622	4622	
4003	7771	7771	/A1= -5.34824691E-03
4004	5205	5205	
4005	7732	7732	
4006	7756	7756	/A2=3.36378859E-06
4007	3415	3415	
4010	7273	7273	
4011	7743	7743	/A3=-1.03966165E-09
4012	5610	5610	
4013	7026	7026	
4014	7726	7726	/A4=1.22283738E-13
4015	2115	2115	
4016	3362	3362	

*4017

4017	0010	0010	/GE. RANGE2 POLY. COEFF.
4020	2003	2003	/A0=1.28462098E02
4021	5442	5442	
4022	0001	0001	/A1= -1.73994671E00
4023	4412	4412	
4024	2273	2273	
4025	7772	7772	/A2=1.02044332E-02
4026	2471	2471	
4027	4076	4076	
4030	7762	7762	/A3=-3.15441609E-05
4031	5735	5735	
4032	4333	4333	
4033	7750	7750	/A4=5.37189186E-08
4034	3465	3465	
4035	6107	6107	
4036	7736	7736	/A5=-4.76352185E-11
4037	4563	4563	
4040	7703	7703	
4041	7723	7723	/A6=1.71679668E-14

4042	2325		2325	
4043	0516		0516	
		*4044		
4044	0006		0006	/GE. RANGE3 POLY. COEFF.
4045	3525		3525	/A0=5.86765111E01
4046	5137		5137	
4047	0001		0001	/A1= -1.44787668E00
4050	5065		5065	
4051	3000		3000	
4052	7773		7773	/A2=2.83238556E-02
4053	3500		3500	
4054	1667		1667	
4055	7765		7765	/A3=-3.24488008E-04
4056	5256		5256	
4057	7772		7772	
4060	7756		7756	/A4= 2.06888465E-06
4061	2126		2126	
4062	5624		5624	
4063	7745		7745	/A5=-6.80186941E-09
4064	4262		4262	
4065	2435		2435	
4066	7734		7734	/A6=8.74920244E-12
4067	2317		2317	
4070	2561		2561	
		*4071		
4071	0005		0005	/PT. POLY. COEFF.
4072	3371		3371	/A0=2.79057782E01
4073	7603		7603	
4074	7776		7776	/A1=2.22663494E-01
4075	3440		3440	
4076	0360		0360	
4077	7764		7764	/A2=-1.91322374E-04
4100	4673		4673	
4101	0446		0446	
4102	7753		7753	/A3=3.09260185E-07
4103	2460		2460	
4104	2062		2062	
4105	7741		7741	/A4=-2.44356257E-10
4106	5715		5715	
4107	2366		2366	
4110	7725		7725	/A5=9.50338067E-14
4111	3257		3257	
4112	7640		7640	
4113	7711		7711	/A6=-1.44777235E-17
4114	5723		5723	
4115	5671		5671	
		*4116		
4116	0006		0006	/FIELD POLY. COEFF.
4117	3675		3675	/A0=6.19089893E01
4120	0533		0533	
4121	0016		0016	/A1=1.16961558E04
4122	2666		2666	
4123	0115		0115	
4124	0014		0014	/A2=4.09160488E03

4125	3775	3775	
4126	6325	6325	
4127	0016	0016	/A3=-1.62317284E04
4130	4023	4023	
4131	0220	0220	
4132	0017	0017	/A4=2.45611509E04
4133	2777	2777	
4134	0446	0446	
4135	0016	0016	/A5=-1.32107778E04
4136	4614	4614	
4137	5166	5166	

/DATA STORAGE (FLOATING-POINT F.)

		*4200	
4200	0000	EX1,	0
4201	0000		0
4202	0000		0
4203	0000	GE1,	0
4204	0000		0
4205	0000		0
4206	0000	PT1,	0
4207	0000		0
4210	0000		0
4211	0000	MAG1,	0
4212	0000		0
4213	0000		0
4214	0000	SAMI1,	0
4215	0000		0
4216	0000		0
4217	0000	RES1,	0
4220	0000		0
4221	0000		0
4222	0000	HALL1,	0
4223	0000		0
4224	0000		0
4225	0000	EX2,	0
4226	0000		0
4227	0000		0
4230	0000	GE2,	0
4231	0000		0
4232	0000		0
4233	0000	PT2,	0
4234	0000		0
4235	0000		0
4236	0000	MAG2,	0
4237	0000		0
4240	0000		0
4241	0000	SAMI2,	0
4242	0000		0
4243	0000		0
4244	0000	RES2,	0
4245	0000		0
4246	0000		0

4247	0000	HALL2,	0		
4250	0000			0	
4251	0000			0	
					/CONSTANTS STORAGE .
					/(FLOATING-POINT FORMAT)
		*4300			
4300	0000	W,		0	/WIDTH
4301	0000			0	
4302	0000			0	
4303	0000	T,		0	/THICKNESS
4304	0000			0	
4305	0000			0	
4306	0000	D,		0	/DEPTH
4307	0000			0	
4310	0000			0	
4311	0000	FULLX,	0		/FULL SCALE VALUE
4312	0000			0	/ON THE X AXIS
4313	0000			0	
4314	0000	XDIVS,	0		/NO. OF DIVISIONS
4315	0000			0	/ON THE X AXIS
4316	0000			0	
4317	0000	FULLY,	0		/FULL SCALE VALUE
4320	0000			0	/ON THE Y AXIS
4321	0000			0	
4322	0000	YDIVS,	0		/NO. OF DIVISIONS
4323	0000			0	/ON THE Y AXIS
4324	0000			0	
4325	0000	SCALEX,	0		/STEPS/UNIT
4326	0000			0	/ON THE X AXIS
4327	0000			0	
4330	0000	SCALEY,	0		/STEPS/UNIT
4331	0000			0	/ON THE Y AXIS
4332	0000			0	
4333	0012	MAXX,	0012		/600 STEPS
4334	2260			2260	
4335	0000			0000	
4336	0012	MAXY,	0012		/800 STEPS
4337	3100			3100	
4340	0000			0000	
4341	0016	R3,		0016	/SENSOR CURRENT
4342	2342			2342	/RESISTOR (10K OHMS)
4343	0000			0000	
4344	0007	R1,		0007	/SAMPLE CURRENT
4345	3100			3100	/RESISTOR (100 OHMS)
4346	0000			0000	
4347	0002	TWO,		0002	/2
4350	2000			2000	
4351	0000			0000	
4352	7777	CONVF,	7777		/(.43429) CONVERTS
4353	3362			3362	/FROM NATURAL TO
4354	6642			6642	/COMMON LOG
4355	0000	AVT,	0		/AVERAGE TEMP.
4356	0000			0	
4357	0000			0	

4360	0000	XVALUE,	0		
4361	0000			0	
4362	0000			0	
4363	0000	YVALUE,	0		
4364	0000			0	
4365	0000			0	
4366	0033	CONV,	0033		/10**8 CONVERTS
4367	2765			2765	/TO CGSM UNITS
4370	7020			7020	

/LETTER STORAGE

*4400

4400	0323			323	/S
4401	0301			301	/A
4402	0315			315	/M
4403	0320			320	/P
4404	0314			314	/L
4405	0305			305	/E
4406	0240			240	/SPACE
4407	0304			304	/D
4410	0311			311	/I
4411	0315			315	/M
4412	0256			256	/PERIOD
4413	0240			240	/SPACE
4414	0250			250	/OPEN BRACKET
4415	0303			303	/C
4416	0315			315	/M
4417	0251			251	/CLOSED BRACKET
4420	0327			327	/W
4421	0240			240	/SPACE
4422	0275			275	/EQUAL
4423	0324			324	/T
4424	0240			240	/SPACE
4425	0275			275	/EQUAL
4426	0304			304	/D
4427	0240			240	/SPACE
4430	0275			275	/EQUAL
4431	0323			323	/S
4432	0303			303	/C
4433	0301			301	/A
4434	0314			314	/L
4435	0311			311	/I
4436	0316			316	/N
4437	0307			307	/G
4440	0240			240	/SPACE
4441	0320			320	/P
4442	0301			301	/A
4443	0322			322	/R
4444	0301			301	/A
4445	0315			315	/M
4446	0305			305	/E
4447	0324			324	/T
4450	0305			305	/E

4451	0322	322	/R
4452	0323	323	/S
4453	0272	272	/COLON
4454	0330	330	/X
4455	0240	240	/SPACE
4456	0301	301	/A
4457	0330	330	/X
4460	0311	311	/I
4461	0323	323	/S
4462	0272	272	/COLON
4463	0331	331	/Y
4464	0240	240	/SPACE
4465	0301	301	/A
4466	0330	330	/X
4467	0311	311	/I
4470	0323	323	/S
4471	0272	272	/COLON
4472	0252	252	/STAR
4473	0240	240	/SPACE
4474	0312	312	/J
4475	0317	317	/O
4476	0302	302	/B
4477	0240	240	/SPACE
4500	0303	303	/C
4501	0317	317	/O
4502	0315	315	/M
4503	0320	320	/P
4504	0314	314	/L
4505	0305	305	/E
4506	0324	324	/T
4507	0305	305	/E
4510	0304	304	/D
4511	0256	256	/PERIOD
4512	0252	252	/STAR
4513	0240	240	/SPACE
4514	0311	311	/I
4515	0316	316	/N
4516	0303	303	/C
4517	0322	322	/R
4520	0305	305	/E
4521	0301	301	/A
4522	0323	323	/S
4523	0305	305	/E
4524	0240	240	/SPACE
4525	0324	324	/T
4526	0310	310	/H
4527	0305	305	/E
4530	0240	240	/SPACE
4531	0303	303	/C
4532	0331	331	/Y
4533	0303	303	/C
4534	0314	314	/L
4535	0305	305	/E
4536	0240	240	/SPACE

4537	0322	322	/R
4540	0301	301	/A
4541	0316	316	/N
4542	0307	307	/G
4543	0305	305	/E
4544	0256	256	/PERIOD

/POINTER ADDRESSES STORED ON PA

		*20	
0020	6000	C6000,	6000
0021	6554	L6554,	6554
0022	0600	CLEARP,	CLEAR
0023	0000	ZERO,	0
0024	0000	SW1,	0
0025	0000	SW2,	0
0026	0613	CRLF,	CRLF
0027	0631	DIMENP,	DIMEN
0030	7775	M3,	-3
0031	0000	CNTR1,	0
0032	0000	TEMP,	0
0033	7527	M251,	-251
0034	7503	MEQUAL,	-275
0035	7774	M4,	-4
0036	0000	CNTR2,	0
0037	0240	SPACE,	240
		*63	
0063	0720	SCALEP,	SCALE
0064	7776	M2,	-2
0065	1000	TRACEP,	TRACE
0066	4333	MAXXPR,	MAXX
0067	4311	FULLXP,	FULLX
0070	4325	SCALXP,	SCALEX
0071	4336	MAXYPR,	MAXY
0072	4317	FULLYP,	FULLY
0073	4330	SCALYP,	SCALEY
0074	4314	XDIVSP,	XDIVS
0075	1267	FIXPR,	FIX
0076	4322	YDIVSP,	YDIVS
0077	2400	PLOT,	PLOTX
0100	7764	M14,	-14
0101	7470	M310,	-310
0102	0000	XINTST,	0
0103	0000	XTICKS,	0
0104	0000	YINTST,	0
0105	0000	YTICKS,	0
0106	4430	C4430,	4430
0107	4311	C4311,	4311
0110	1172	DOPR,	DO
0111	1200	READP,	READ
0112	0000	ERROR,	0
0113	4200	C4200,	4200
0114	6100	M17,	-1700
0115	1244	ENDP,	END

0116	7522	M256,	-256
0117	0623	TYPEPR,	TYPE
0120	0001	ONE,	1
0121	1400	CALT1P,	CALT1
0122	1600	POLYP,	POLYEV
0123	1334	T1P,	T1
0124	1337	T2P,	T2
0125	4355	AVTP,	AVT
0126	4347	TWOPR,	TWO
0127	1342	INVSTP,	INVST
0130	4360	XVALP,	XVALUE
0131	1355	LOGRP,	LOGR
0132	4214	SAMI1P,	SAMI1
0133	4344	R1P,	R1
0134	4217	RES1P,	RES1
0135	4303	TPR,	T
0136	4300	WPR,	W
0137	4306	DPR,	D
0140	4352	CONVFP,	CONVF
0141	4363	YVALP,	YVALUE
0142	2000	OUTINP,	OUTIND
0143	2024	DNINP,	DNIND
0144	2056	SETDNP,	SETDN
0145	2100	UPINP,	UPIND
0146	2137	SETUPP,	SETUP
0147	2273	STEPSP,	STEPNO
0150	2321	YCORDP,	YCORD
0151	6340	M1440,	-1440
0152	2247	MESSP,	MESS
0153	2311	PLOTPR,	PLOTP
0154	1434	CALT2P,	CALT2
0155	1323	MEANTP,	MEANT
0156	2323	LOGTP,	LOGT
0157	2334	LOGMUP,	LOGMU
0160	4236	MAG2P,	MAG2
0161	4247	HALL2P,	HALL2
0162	4222	HALL1P,	HALL1
0163	4366	CONVP,	CONV

/FINIS
/MNEMONICS USED

PLSF=6501
PLCF=6502
PLPU=6504
PLPR=6511
PLDU=6512
PLUD=6522
PLDD=6514
PLPL=6521
PLPD=6524

4355
0125