CALCULATOR - AIDED MICROWAVE NETWORK ANALYSIS

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THESIS

CALCULATOR - AIDED
MICROWAVE NETWORK ANALYSIS

by

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The HP-8410S Microwave Network Analyzer System and the Wang 600 Programmable Calculating and Plotting System are discussed. An interface Between the two is described and the feasibility of microwave network analysis under program control is demonstrated. Four calculator programs which implement S-parameter sampling and data reduction are described and documented.

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Calculator - Aided

Microwave Network Analysis

by

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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December 1974

ABSTRACT

The HP-8410S Microwave Network Analyzer System and the Wang 600 Programmable Calculating and Plotting System are discussed. An interface between the two is described and the feasibility of microwave network analysis under program control is demonstrated. Four calculator programs which implement S-parameter sampling and data reduction are described and documented.

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I. INTRODUCTION

The HP-8410S Microwave Network Analyzer System enables rapid characterization of microwave network components by determining complex scattering parameters, commonly referred to as S parameters. It provides a large amount of raw data by displaying these parameters in a continuous analog plot over octave bandwidths. Even though a large amount of data is provided, recording and interpretation must still be done manually. This is time consuming, and the accuracy provided by the network analyzer can be diminished by recording and reduction errors.

With this in mind, it was felt that the network analyzer system could be enhanced by the addition of a peripheral system to automatically sample the displayed S parameters at discrete frequencies, perform data reduction, plot and list the results. The purpose of this study was to demonstrate the feasibility of such a system by interfacing the Wang 600 Programmable Calculator System and the HP-8410S Microwave Network Analyzer System and developing several software programs.

II. S PARAMETERS

A. DESCRIPTION

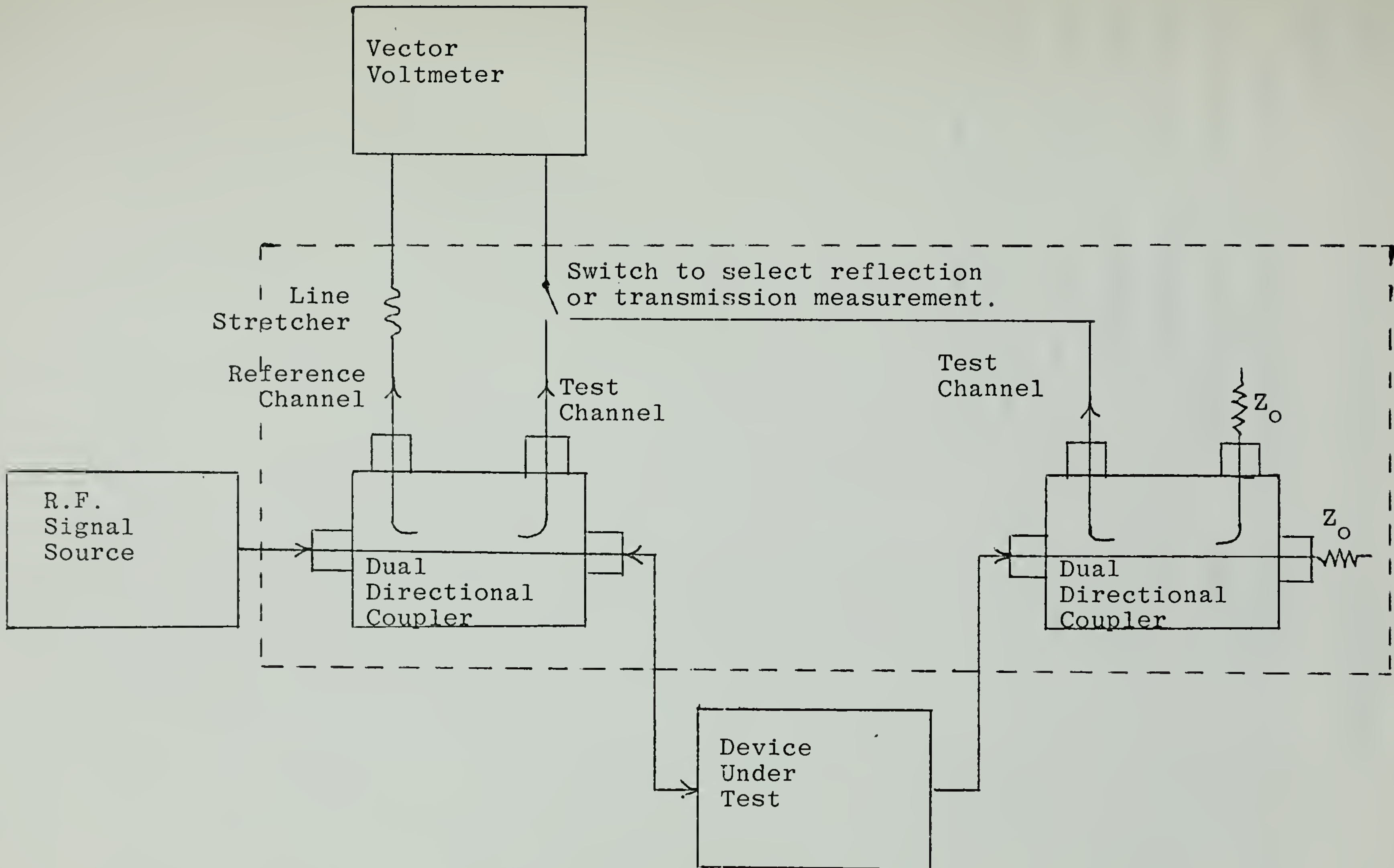
S parameters are obtained from reflection and transmission measurements of voltage waves incident on a test device. They are the ratios of complex signal voltages and contain both amplitude and phase information.

S parameters are preferred at microwave frequencies because they are measured with the device under test terminated in the characteristic impedance of the transmission line in which it is inserted. As a result, stray capacitance and lead inductance caused by open and short circuit terminations are eliminated. Also, semiconductor devices do not oscillate under test.

B. MEASUREMENT TECHNIQUE

A means of determining S parameters is by use of two dual directional couplers with the device to be tested inserted between and the system fed by a high frequency signal source. This technique is shown in block diagram form in Figure 1.

The ratio of the reference and test channel signals is obtained with a vector voltmeter. The characteristic impedance terminations on the second directional coupler prevent reflections. With this arrangement, S_{11} and S_{21} can be determined. To obtain S_{22} and S_{12}, the two



S - Parameter Measurement Technique

Figure 1

port device is turned around and the measurements repeated.

The part of the block diagram enclosed by dotted lines is referred to as a transducer. It splits the incoming signal into a reference and test channel, and provides the capability of extending the electrical length of the reference channel so that the reference and test signals travel the same electrical distance. This preserves the phase relationship between the two.

III. SYSTEM DESCRIPTION

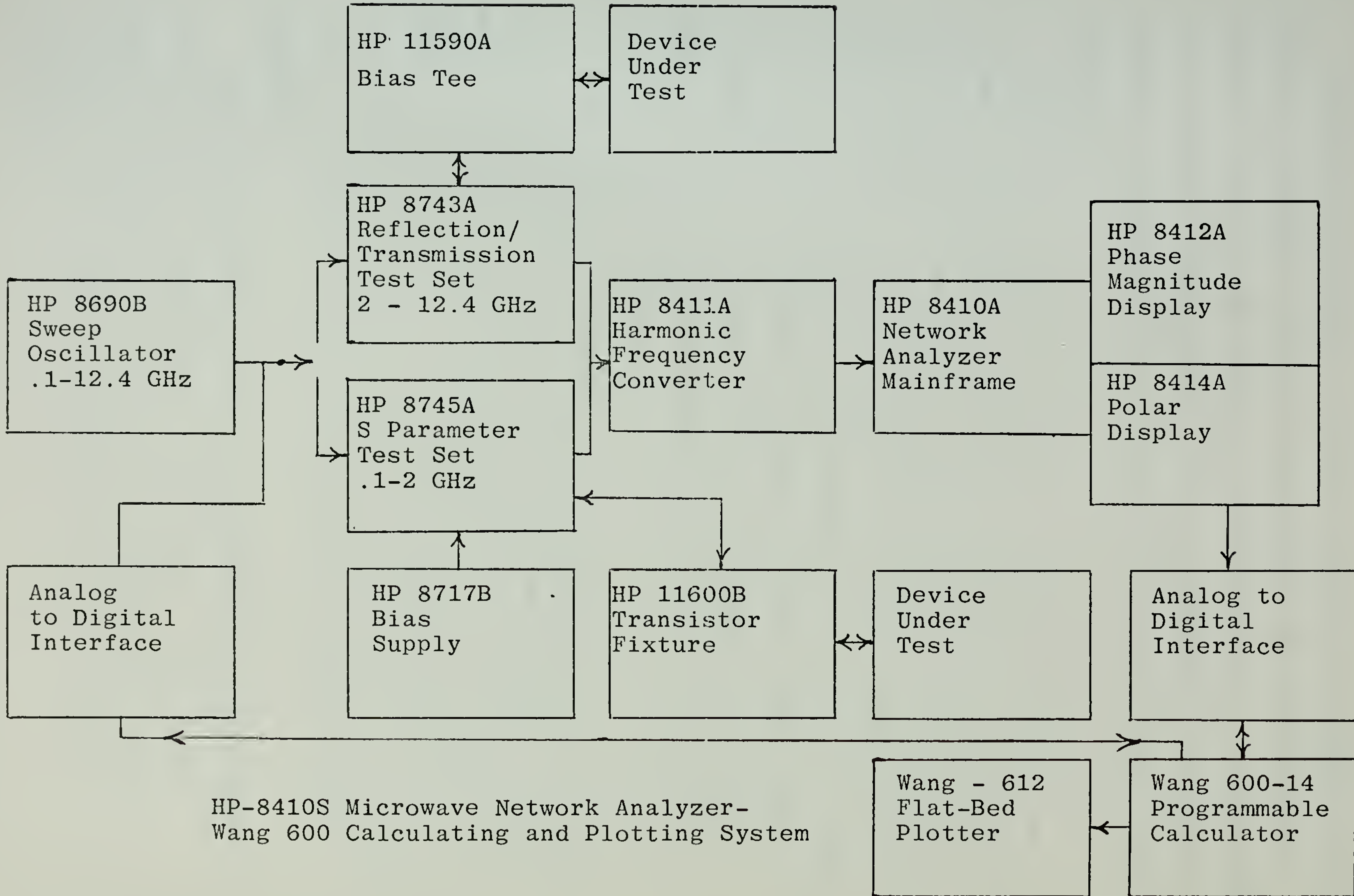
Figure 2 is a block diagram of the HP-8410S Microwave Network Analyzer - Wang 600 Calculating and Plotting System which is installed in the Naval Postgraduate School Microwave Laboratory.

A. MICROWAVE NETWORK ANALYZER

The HP-8690B Sweep Oscillator with the HP-8690B series RF plug-ins serves as the signal source for one of two transducers, either the HP-8743A Reflection-Transmission Test Unit or the HP-8745A S-Parameter Test Set, depending on the frequency range of operation desired.

These transducers are capable of both reflection and transmission measurements. They use dual directional couplers to split the incoming signal into reference and test channels. The device under test is connected to the front panel. Coaxial switches, operated by pushbuttons, connect the system correctly for the type measurement desired.

Available with the transducers are the HP-11600B Transistor Fixture, HP-8717B bias Supply and HP-11590A Bias Tee, which allow S parameter characterization of active semiconductor devices. Bipolar Transistors, FET's, diodes, negative resistance transferred electron devices, etc. can be easily and quickly analyzed for any specified bias condition.



HP-8410S Microwave Network Analyzer-
Wang 600 Calculating and Plotting System

Figure 2

The HP-8411A Harmonic Frequency Converter receives the test and reference channel signals from the transducer and converts them over a range of 0.11 to 12.4 GHz to a 20.278 MHz IF. Since the conversion is linear, the test and reference channel IF signals maintain their same relative amplitudes and phases.

Comparison of the two signals is accomplished by low frequency circuitry in the displays mounted in the HP-8410A Network Analyzer Mainframe. The mainframe provides phase-lock circuitry over an octave bandwidth to maintain the 20.278 MHz IF while frequency is being swept. It takes the ratio of the test and reference signals and then converts down to a second IF of 278 KHz. It has a precision 0 to 69 dB attenuator for accurate measurement of gain or attenuation of test channel amplitude.

The measured S parameters are displayed on the HP-8414A Polar Display or HP-8412A Phase-Magnitude Display. If the polar display is used, the parameters are read directly as magnitude and angle. If the phase-magnitude display is used, the parameters are in the form of return loss in dB, insertion loss or insertion gain in dB and phase in degrees versus frequency.

The polar display is most often used for measurement of reflection and transmission coefficients. The phase-magnitude display is effective for determining filter response such as skirt steepness and phase response linearity.

Smith Chart overlays are available with the polar display. These allow direct reading of normalized impedance in the case of reflection measurements since the Smith Chart is defined by $\frac{Z}{Z_o} = \frac{1 + \Gamma}{1 - \Gamma}$ where Γ is the reflection coefficient of the device under test and Z_o is the characteristic impedance of the transmission line in which the device is inserted.

B. CALCULATOR - PLOTTER

The Wang 600-14 Programmable Calculator has a programmable memory which allows program control of any operation which the calculator is capable of manually. It has a decision-making capability which allows branching and looping in programs. To write a program, the calculator is placed in the "Learn" mode and the sequence of operations desired is keyed. This results in the generation of four digit codes which are stored sequentially in memory. Each four digit code corresponds to a specific keyboard operation or a specific function selection and its corresponding register number. For example, the code 0815 means to take the number in the display register, invert it and put the result back in the display register. The code 0405 means to multiply the number in register five by the number in the display register and place the result back in register five.

To execute a program, the calculator is placed in the "Run" mode and the program is initiated by the operator. If the program has "Bugs," the calculator is again placed in the "Learn" mode and the program is stepped through. Each

program instruction is displayed as it is reached and is checked for correctness by the operator. When an incorrect code is found, the correct code is merely keyed in at the same location.

Programs can be recorded on magnetic tape for storage and future use. When a program which is on tape is needed, it is loaded directly into memory from the tape.

There are sixteen basic registers available for data storage. If only these sixteen are used, then programs up to 1,848 steps can be written. If the need arises for more than sixteen data storage registers, the calculator adapts by changing program step storage area into data storage registers. This is accomplished by taking eight program steps and grouping them together to form one register. If the entire memory is used for data storage registers, then there are 247 available.

The Wang Model 612 Flat-Bed Plotter provides line or point plotting and alphanumeric labeling. Format and content of the labeling is controlled by the calculator.

IV. ANALOG TO DIGITAL INTERFACE

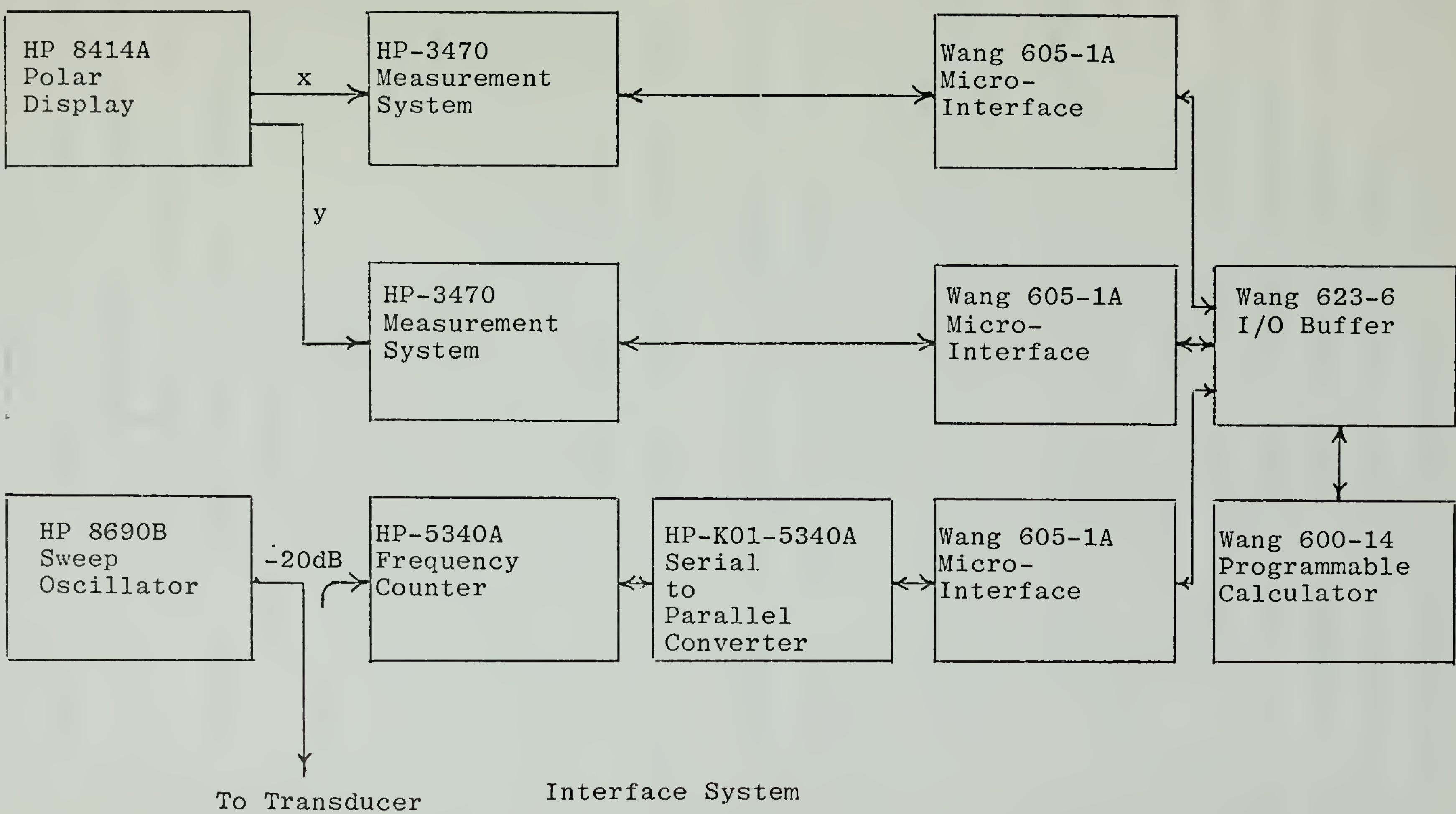
The analog to digital interfaces shown in Figure 2 were implemented by the author. A block diagram of the interface system is shown in Figure 3.

In the rear of the polar display, horizontal and vertical voltages directly proportional to the CRT deflection voltages are available. They are fed into two HP-3470 Measurement Systems where they are converted from analog to bit parallel character parallel 8421 BCD. After transfer to Wang 605-1A Micro Interfaces, these voltages are further converted to serial hexadecimal.

A portion of the output from the sweep oscillator is routed to a HP-5340A Frequency Counter by a -20dB directional coupler. After passing through the counter and a K01-5340A Serial to Parallel Converter, the frequency enters a micro-interface as bit parallel character parallel 8421 BCD and is converted to serial hexadecimal.

Since three micro-interfaces are used, they are connected to a Wang 623-6 I/O Buffer to alleviate fan-out problems. The micro-interfaces transfer the voltages and frequency in serial hexadecimal form through the I/O buffer into the calculator's display register.

To implement the interface, it was necessary to compare connector diagrams of a micro-interface, a BCD module and the serial to parallel converter. These are shown in Figures



Interface System

Figure 3

4, 5, and 6. As a result of comparison, the connectors were wired as listed in Tables I and II. Logic level switches on the micro-interfaces were set as follows. For connection to BCD module; sign, down; print, up; execute, down; logic level, down. For connection to serial to parallel converter; sign, doesn't matter; print, up; execute, up; logic level, down.

A description of each interface component and control signal interaction is given in the following section.

A. INTERFACE COMPONENT AND CONTROL SIGNAL DESCRIPTION

The Wang 605-1A Micro-Interface is an input-only interface which accepts up to seven digits plus sign of bit parallel character parallel 8421 BCD and converts it into serial hexadecimal for input to the calculator's display register.

Input logic levels are TTL/DTL compatible with nominal values of zero volts for "O" state and +5 volts for "1" state. One output and one input control signal are provided and are respectively "Execute" and "Print." "Execute" is a switch selectable d.c. condition of zero volts or +5 volts, and indicates that the micro-interface is ready to receive data. "Print" is an input strobe of 5 microsecond minimum duration which can be positive or negative. A switch allows the micro-interface to adapt to either polarity. "Print" indicates that the peripheral to which the micro-interface is attached is about to transfer data.

Two 36 wire cables are used for data input and output. The output cable is factory wired to a 36 pin male Amphenol

Micro-Interface Connector Diagram

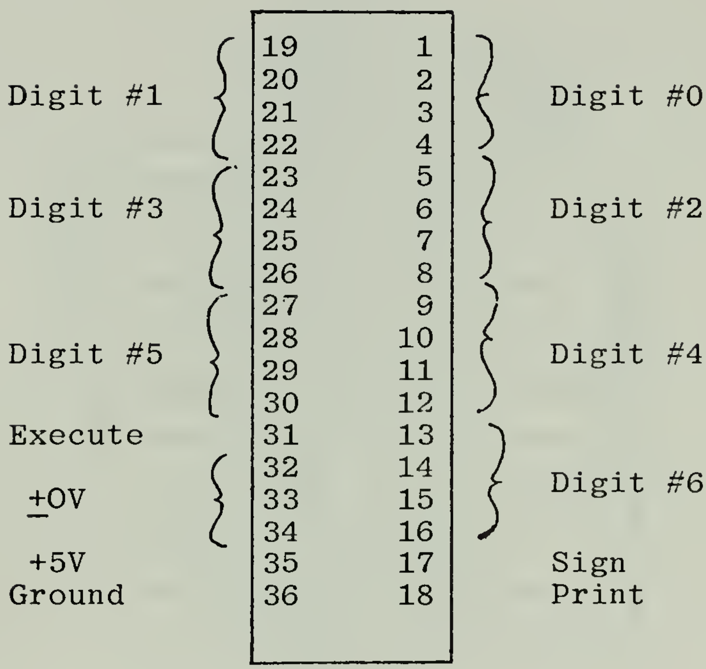


Figure 4

BCD Module Connector Diagram

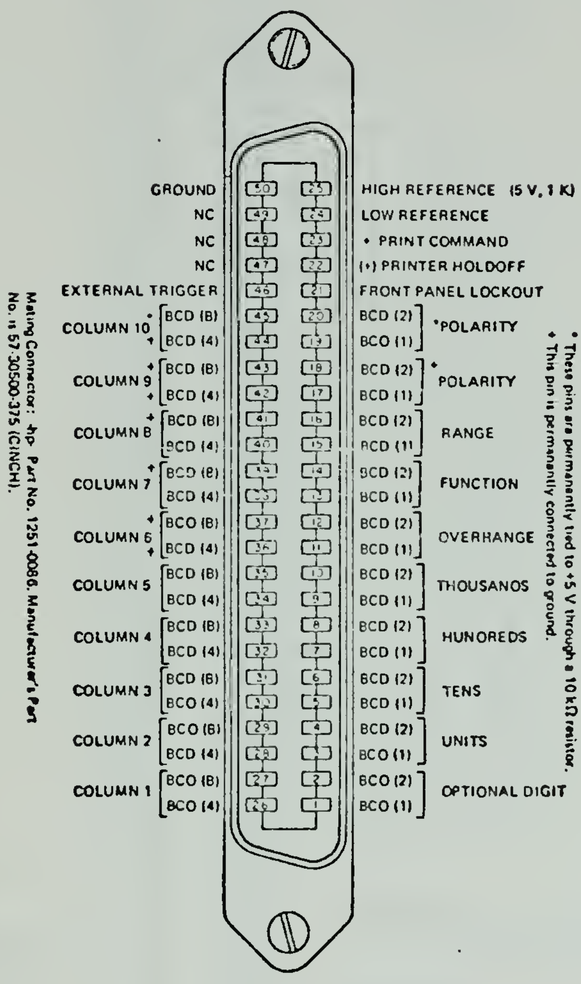


Figure 5

Serial to Parallel Converter Connector Diagram

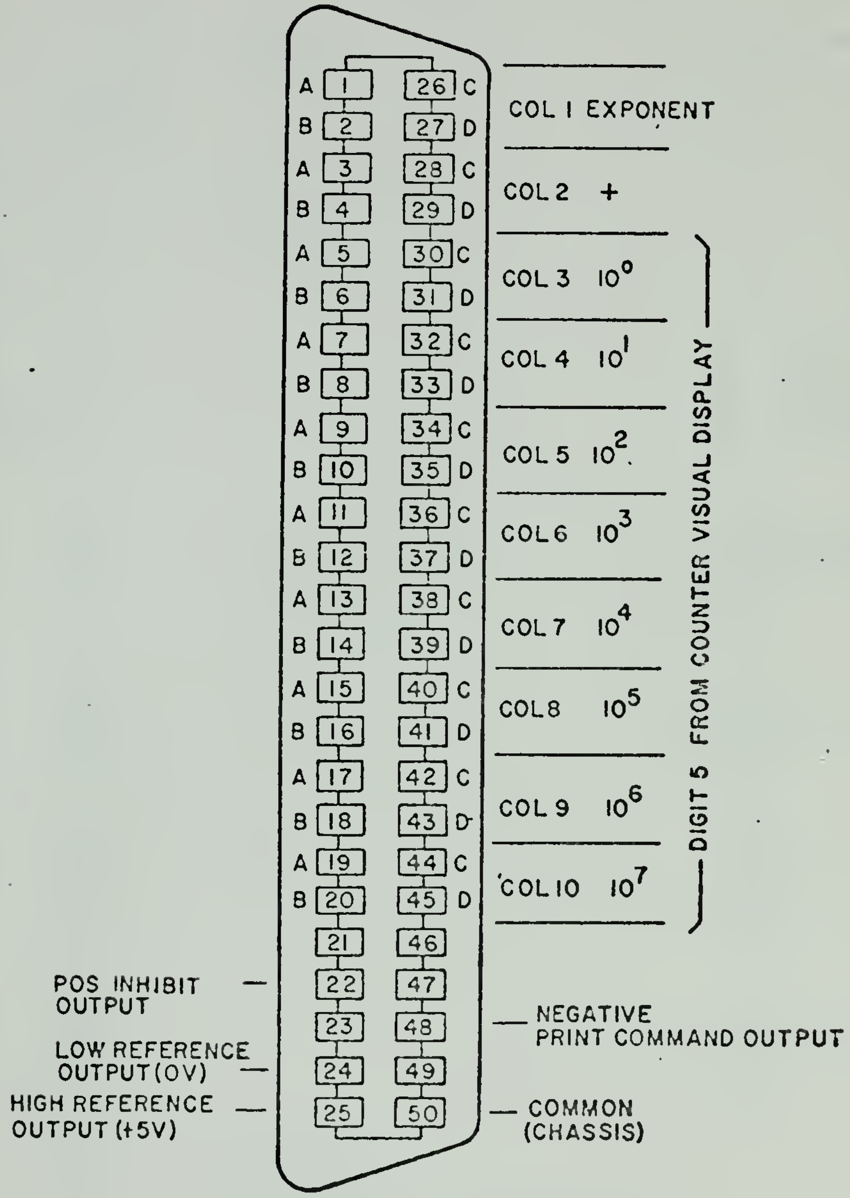


Figure 6

MICRO-INTERFACE-BCD MODULE WIRING LIST

Micro-Interface Wire Numbers				BCD Module Connector Pin Numbers	
Digit #0	1	bundle		24 ±0 Volts	
	2	bundle			
	3	bundle			
	4	bundle			
	5	bundle			
	7	bundle			
	32	bundle			
	33	bundle			
	34	bundle			
	6	unconnected			
	8	"			
Ground	36	"			
Sign	17			19	Polarity
Print	18			23	Print
Execute	31			46	External Trigger
+5 Volts	35			25	+5 Volts
Digit #6	13			1	Optional Digit
	14			2	
	15			26	
	16			27	
Digit #5	27			3	Units
	28			4	
	29			28	
	30			29	
Digit #4	9			5	Tens
	10			6	
	11			30	
	12			31	
Digit #3	23			7	Hundreds
	24			8	
	25			32	
	26			33	
Digit #2	5	to bundle	Generates Decimal Point		
	6	unconnected			
	7	to bundle			
	8	unconnected			
Digit #1	19			9	Thousands
	20			10	
	21			34	
	22			35	

TABLE I

MICRO-INTERFACE-SERIAL TO PARALLEL CONVERTER WIRING LIST

Micro-Interface	Wire Numbers		Serial to Parallel Converter Connector Pin Numbers	
±0 Volts	32, 33, 34	bundle	24	±0 Volts
Sign	17	unconnected		
Ground	36	"		
Print	18		48	Print
Execute	31		22	Inhibit
+5 Volts	35		25	+5 Volts
Digit #6	13, 14, 15, 16		1, 2, 26, 27	Exponent
Digit #5	27, 28, 29, 30		9, 10, 34, 35	10^2
Digit #4	9, 10, 11, 12		11, 12, 36, 37	10^3
Digit #3	23, 24, 25, 26		13, 14, 38, 39	10^4
Digit #2	5, 6, 7, 8		15, 16, 40, 41	10^5
Digit #1	19, 20, 21, 22		17, 18, 42, 43	10^6
Digit #0	1, 2, 3, 4		19, 20, 44, 45	10^7

TABLE II

connector and plugs into the I/O buffer. The input cable has one end factory wired to a 36 pin male Amphenol connector which plugs into the micro-interface. The other end consists of 36 exposed, numbered wires which can be wired to a suitable connector for attachment to a peripheral.

The HP-3470 Measurement System consists of a HP-34701A DC Voltmeter, a HP-34740A Display and a HP-34721 BCD Module. The d.c. voltmeter reads an analog voltage, the display converts it into character serial digital form and displays it. The BCD module converts the character serial data from the display into bit parallel character parallel 8421 BCD for input to a HP-5055A Digital Recorder or equivalent. In this case, the input is to a micro-interface rather than a digital recorder. BCD module output is through a 50 pin rear panel connector. Ten columns are available, five are for the digits in the Display, one for overrange, one for function, one for range and two for polarity.

The d.c. voltmeter has four voltage ranges of operation, 0 to ± 1, 0 to ± 10, 0 to ± 100, and 0 to ± 1000. The display has four digits plus and overrange digit which completes the readout on measurements above full scale up to 100% overrange. When 100% overrange is reached, all digits except the overrange digit are blanked.

The maximum useable x or y output from the polar display is ± 2.1 volts. Therefore, the 0 to ± 1 volt range on the d.c. voltmeter cannot be used because even with the overrange digit feature on the display, the maximum voltage which can

be displayed is 1.9999 volts. Any larger voltage yields 1.____. Thus, the 0 to ± 10 volt range is used. This range gives a digital output adequate to cover the x and y voltage range with three decimal point accuracy.

The logic level of the BCD module is the same as that of the micro-interface. It allows for three input control signals, "Front Panel Lockout," "(+) Printer Hold-off," and "External Trigger," and provides one output control signal, "Print." The input control signal of consequence here is "External Trigger," which is a +5 volt d.c. pulse of one microsecond minimum duration.

With the front panel output rate switch in the hold position, the display will be sampled by the BCD module only when the "External Trigger" pin is at +5 volts or the "Manual" pushbutton is pressed. When the micro-interface sends its "Execute" command to the external trigger pin on the BCD module connector, it responds by sequentially transferring the data in the display into output data registers. During this transfer, conversion from bit parallel character serial 8421 BCD to bit parallel character parallel 8421 BCD occurs.

The BCD module next sends its "Print" command, followed by the parallel transfer of the number in its output data registers to the micro-interface. Once there, this number is converted to serial hexadecimal and transferred into the display register of the calculator. When transfer is complete, the "Execute" command from the micro-interface is returned to its original d.c. state of 0 volts and control is returned to the calculator.

The HP-5340A Frequency Counter provides a digital display of measured frequency and outputs bit parallel character serial "1" state negative ASCII to a 24 pin rear panel connector. A HP-K01-5340A Serial to Parallel Converter is used to convert this into bit parallel, character parallel 8421 BCD for input to a HP-5050A/B or HP-5055A Digital Recorder with the counter functioning as "Talker" and the recorder as "Listener." In this case, the input is to a micro-interface rather than a digital recorder.

The serial to parallel converter has as input from the frequency counter a 24 wire cable and as output a 50 pin connector which outputs ten columns of bit parallel character parallel 8421 BCD. Eight columns are for the digits displayed in the window of the frequency counter, and two columns are for a positive single digit exponent. The exponent is used to designate decimal point location with hertz as the measurement unit. Blanked zeros in the frequency counter's display are output as zeros by the serial to parallel converter. The 50 pin connector provides one input command, "Inhibit," and one output command, "Print." Logic levels are the same as those of the micro-interface.

Unlike the BCD module, which can have its sample and output rate controlled by "External Trigger," the converter was designed to enable the frequency counter to operate in the "Talk Always" mode to a digital recorder. This means that no "External Trigger" input is available to control sample and output rate. The frequency counter samples its

display window and issues a "Print" command at the rate determined by its internal rate generator. However, the converter provides a means by which the frequency counter will not output data until a record cycle is complete. When the frequency counter samples a frequency and generates a BCD output, the converter issues a "Print" command to the digital recorder. The recorder responds with an "Inhibit" command which causes the converter to prevent any further frequency sampling by the counter. The recorder removes the "Inhibit" command when recording is complete. The converter then allows another count-record cycle to be started.

In order to control sample and output rate of the frequency counter, the "Execute" command line from the micro-interface is connected to the "Inhibit" pin on the converter and has its logic level set so that when the micro-interface is not requesting data from the frequency counter, +5 volts are applied to the "Inhibit" pin of the converter. When the micro-interface sends its "Execute" command to the converter, the +5 volts are removed. This causes the converter to allow the frequency counter to function and send data to the converter which issues a "Print" command and transfers the data to the micro-interface. After the data is transferred to the calculator's display register, the "Execute" command is removed and +5 volts are again applied to the "Inhibit" pin of the converter, thus preventing any further sampling by the counter.

B. DIGIT WIRING

Any one of the seven input digits to the micro-interface can be wired to generate a decimal. Since four significant digits are transferred from the BCD module to the micro-interface, and since the voltages measured are always within the 10 volt range of the d.c. voltmeter, the micro-interface is wired to generate a decimal which follows the most significant digit of the input voltage. This was accomplished by wiring digit #2 on the micro-interface as a decimal. The least significant digit of the input voltage is wired to digit #5, the most significant to digit #1. The other digits are wired in order between. Digit #0 is unused and digit #6 is wired to the optional digit input from the BCD module.

If the HP-34750A Display were used instead of the HP-34740A Display, the optional digit would give another decimal point of accuracy. Since the HP-34740A Display is used, the optional digit always appears as a zero when transferred to the calculator's display register.

Eight digits, a plus sign and an exponent are output by the serial to parallel converter. The micro-interface can only accept seven digits. Therefore, only the six most significant digits of the frequency measurement and the exponent are wired to the micro-interface connector. The plus sign which preceeds the exponent is unnecessary. The exponent digit is wired to digit #6 on the micro-interface and the most significant digit of the frequency is wired to digit #0. The other digits are wired in order between.

Since two digits of the frequency are not sent to the micro-interface, the exponent is in error and must have two added to it to give a correct reading when displayed in the calculator's display register. This is accomplished with a short calculator subroutine.

V. CALCULATOR PROGRAMMING

Four programs to demonstrate the feasibility of calculator-aided microwave network analysis were written by the author. In general terms they can be described as follows.

The x and y voltages from the polar display and the frequency of the sweep oscillator's output are called for sequentially by the calculator. Each micro-interface has a switch selectable address which can be any number from 00 through 15. When a calculator program requires raw data, the calculator transfers control to a micro-interface, which then interrogates the peripheral to which it is attached. The peripheral responds with the data to the micro-interface, which transfers it to the calculator's display register. Once in the display register, it is moved to a storage location.

When this cycle is complete, program control returns to the calculator and another micro-interface is given control, or if the data sampling desired by the program is finished, then data reduction proceeds in the calculator.

The reduced data is stored by the calculator and then plotted by the plotter under program control in the form desired. The data can also be listed beside the plot or printed out on the calculator's 21-column drum printer.

A. S_{11}/S_{22} - PRINTING

This program uses the calculator's 21-column drum printer to type out ten items derived from reflection measurements using the polar display. These are frequency, VSWR, Re Γ, Im Γ, $|\Gamma|$, $\angle\Gamma$, Re z, Im z, $|z|$, and $\angle z$. The Program is designed to be executed on a point by point basis i.e. a point is taken and the reduced data typed out before another point is taken.

Figure 7 shows a typical output.

B. SMITH CHART - PLOTTING AND LISTING

This program uses the plotter as the output device and is designed for reflection measurements on the polar display. A maximum of 41 data points can be taken. Forty-two or more will cause data to be stored in memory locations which contain program steps and will result in program errors. A simplified Smith Chart is drawn and the points plotted on it. Frequency and real and imaginary parts of normalized impedance of each point are listed beside the chart.

The program can be used for devices which exhibit a negative real part of impedance ($\Gamma > 1$), such as transferred electron devices, as well as devices which have a positive real part of impedance ($\Gamma \leq 1$). This flexibility results from a routine which tests each point before it is plotted to determine if $\Gamma > 1$ or if $\Gamma \leq 1$. If $\Gamma > 1$, the location of the point to be plotted on the Smith Chart is obtained from the inverse of the complex conjugate of the measured

Reflection measurement of input to a JAN2N3866 Transistor at .5004 GHz. Bias Conditions; V_{CE} = 5 Volts, I_E = 50 ma.

5,004 x 10^5 Hz

Frequency	50045.0000	D
VSWR	3.5573	D
Re Γ	-.3866	D
Im Γ	.4066	D
|Γ|	.5611	D
∠Γ	133.5558	D
Re z	.3280	D
Im z	.3894	D
|z|	.5092	D
∠z	-310.1091	D

Figure 7

reflection coefficient. The Smith Chart lines of constant resistance are then interpreted as negative and the impedance print out has its real part negative. If $\Gamma \leq 1$, the location of the point is obtained from the unchanged measured reflection coefficient, the lines of constant resistance are interpreted as positive and the impedance print out has its real part positive.

To measure $\Gamma > 1$, the display must be compressed to place the point on the CRT. This is accomplished by attenuating the test channel signal. The difference between the dB setting necessary to calibrate the network analyzer and the attenuation in dB's applied to the test channel is entered into the program by the operator via the keyboard. The program uses this value to plot the points correctly on the Smith Chart.

Figures 8 and 9 show typical outputs.

C. S_{12}/S_{21} POLAR COORDINATES - PLOTTING AND LISTING

This program is designed for transmission measurements using the polar display. A maximum of 36 data points can be taken. Thirty-seven or more will result in program errors. A polar coordinate system is drawn and the value of the outer circle radius is printed. Frequency and magnitude and angle of each transmission coefficient are listed beside the plot.

The program can be used for transmission coefficients either larger or smaller than one. To measure a transmission coefficient with magnitude greater than one, the display must be compressed. The dB difference between calibration setting

Negative Resistance Smith Chart Plot for a GD508A Gunn Diode between 8.1 and 9.0 GHz in 0.1 GHz Steps. Bias; 7 Volts. 10 dB's of attenuation have been applied to the test channel signal.

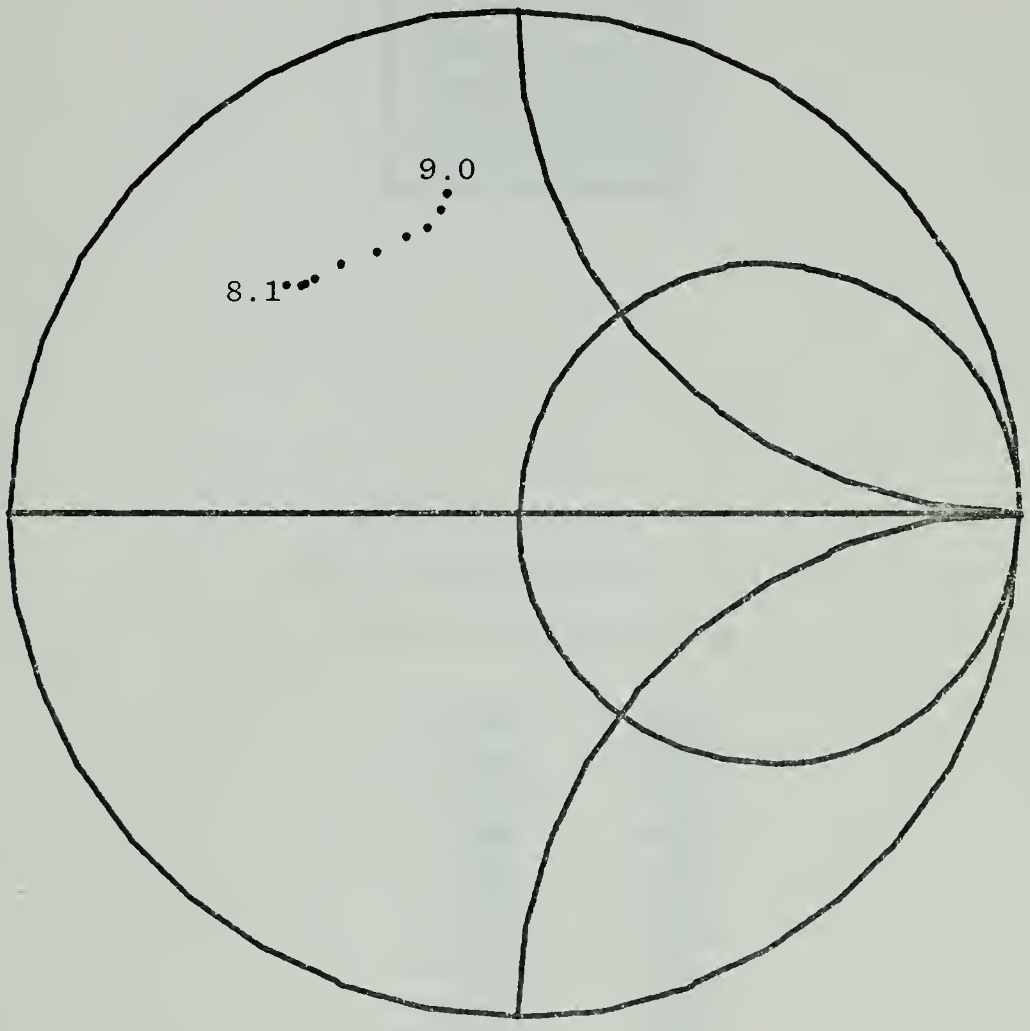


Figure 8a

Frequency in Hz

8.1012000000E08
8.2003000000E08
8.3001000000E08
8.4013000000E08
8.5007000000E08
8.6002000000E08
8.7028000000E08
8.8013000000E08
8.9012000000E08
9.0041000000E08

Real and Imaginary Parts

of Normalized Impedance.

-.246	.336
-.272	.410
-.278	.418
-.285	.437
-.307	.468
-.342	.557
-.380	.628
-.375	.681
-.353	.735
-.329	.768

Figure 8b

Normalized Input Impedance of a JAN2N3866 Transistor Between .5 and 1.0 GHz in .1 GHz Steps. Bias Conditions; V_{CE} = 5 Volts, I_E = 50 ma.

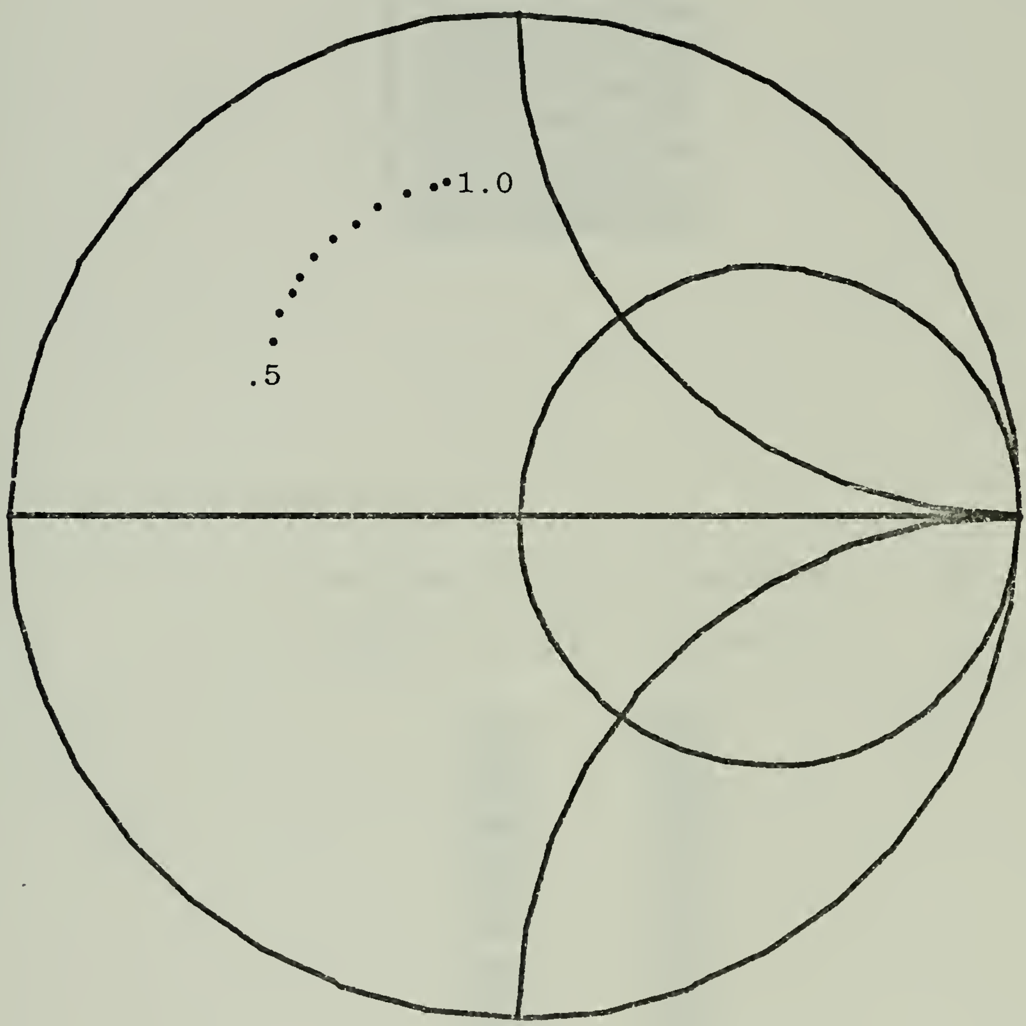


Figure 9a

Frequency in Hz
5.0070000000E03
5.5020000000E03
6.0320000000E03
6.5020000000E03
7.0020000000E03
7.5040000000E03
8.0020000000E03
8.5020000000E03
8.0020000000E03
8.5040000000E03
1.0023000000E03

Real and Imaginary Parts of

Normalized Input Impedance.

.274	.304
.282	.353
.262	.388
.258	.429
.254	.472
.237	.518
.287	.571
.263	.627
.277	.684
.283	.753
.287	.785

Figure 9b

and compressed setting is entered into the program by the operator. This is used to calculate the radius of the outer circle.

One other operator entry is required, the absolute value of the x voltage when the analyzer is calibrated to a short circuit. This is used to normalize x and y voltage readings to one so that 449 plotter increments will define maximum radius regardless of actual maximum radius value. Generally, this normalizing voltage is 2.1. It should be noted that regardless of the test channel dB setting, either before or after display compression or expansion, this voltage is always produced as the maximum useable x deflection voltage.

Figure 10 shows a typical output.

D. SCHOTTKY BARRIER CAPACITANCE - PLOTTING AND LISTING

This program calculates and plots the depletion capacitance of a Schottky diode as a function of reverse bias. The Smith Chart program is used to store and plot reflection measurement points of a reverse biased Schottky diode. The diode program is then loaded into memory where the Smith Chart program is located. This replaces the Smith Chart program with the diode program. The raw data stored in memory is not disturbed by this reloading.

The diode program draws and labels a rectangular coordinate system for quadrant II. The operator then enters the bias voltages in the order used. As a voltage is entered, depletion capacitance is calculated and stored with it. The program compares the voltages and uses the largest to scale

Forward Voltage Transfer Coefficient (S_{21}) of a JAN2N3866 Transistor Between .5 and 1.0 GHz in .1 GHz Steps. Bias conditions; V_{CE} = 5 Volts, I_E = 50 ma. 6 dB's of attenuation have been applied to the test channel signal.

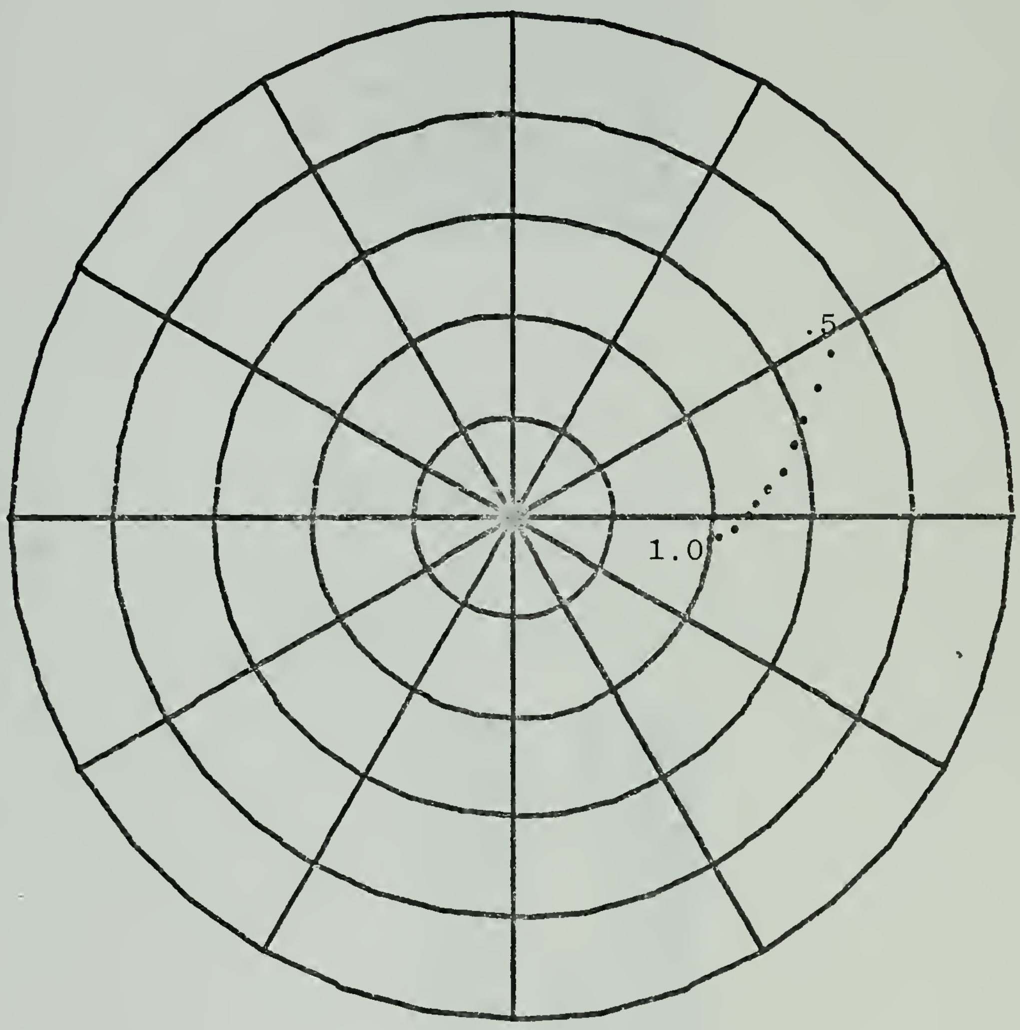


Figure 10a

Frequency in Hz

5.Ø34ØØØØØØØØE08
5.5Ø8ØØØØØØØØE08
6.Ø2ØØØØØØØØØE08
6.5Ø3ØØØØØØØØE08
7.Ø38ØØØØØØØØE08
7.5Ø2ØØØØØØØØE08
8.Ø28ØØØØØØØØE08
8.5Ø7ØØØØØØØØE08
9.Ø15ØØØØØØØØE08
9.5Ø4ØØØØØØØØE08
1.ØØ2ØØØØØØØØE09

Magnitude and Angle of S_{21}

1.433	27.58Ø
1.32Ø	23.171
1.218	18.83Ø
1.152	14.688
1.Ø78	9.47Ø
1.Ø24	6.138
.944	2.384
.9Ø7	358.75Ø
.854	355.6Ø1
.782	352.827
.734	351.Ø12

Figure 10b

the x axis. Likewise, the largest capacitance is used to scale the y axis to either 2.5 or 5 picofarads. The points are plotted and tabulated in the order taken.

Bias voltage can be applied to the diode in any order desired, but it must be entered into the program in that same order.

Figure 11 shows a typical output.

Reverse Biased Schottky Diode at 1.0 GHz. Bias; 0 to -5 Volts in .5 Volt Increments.

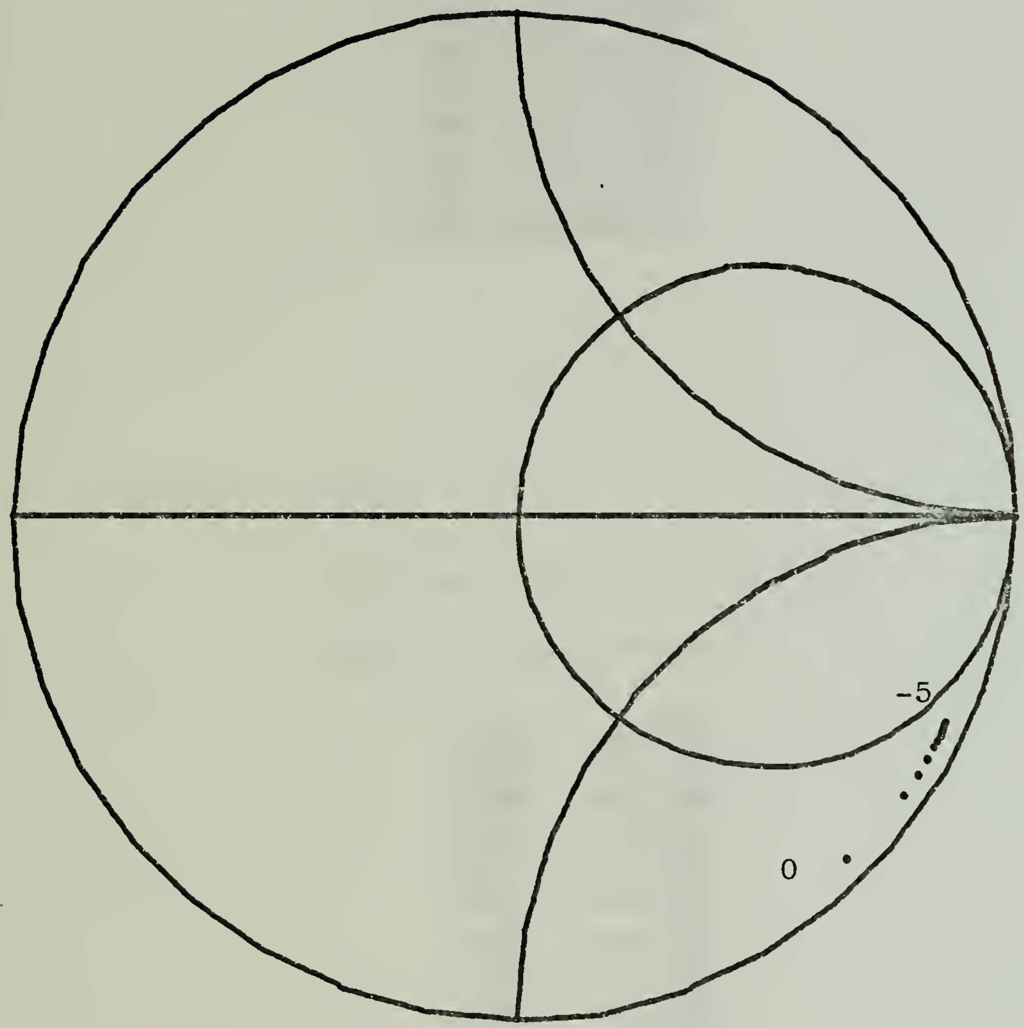


Figure 11a

Frequency in Hz

1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08
1.00170000000E08

Real and Imaginary Parts of

Normalized Impedance.

.180	-2.378
.259	-3.138
.302	-3.481
.348	-3.737
.381	-3.871
.415	-4.107
.440	-4.252
.467	-4.381
.488	-4.442
.503	-4.538
.510	-4.613

Figure 11b

Depletion Capacitance Versus Reverse Bias Voltage for Schottky Diode.

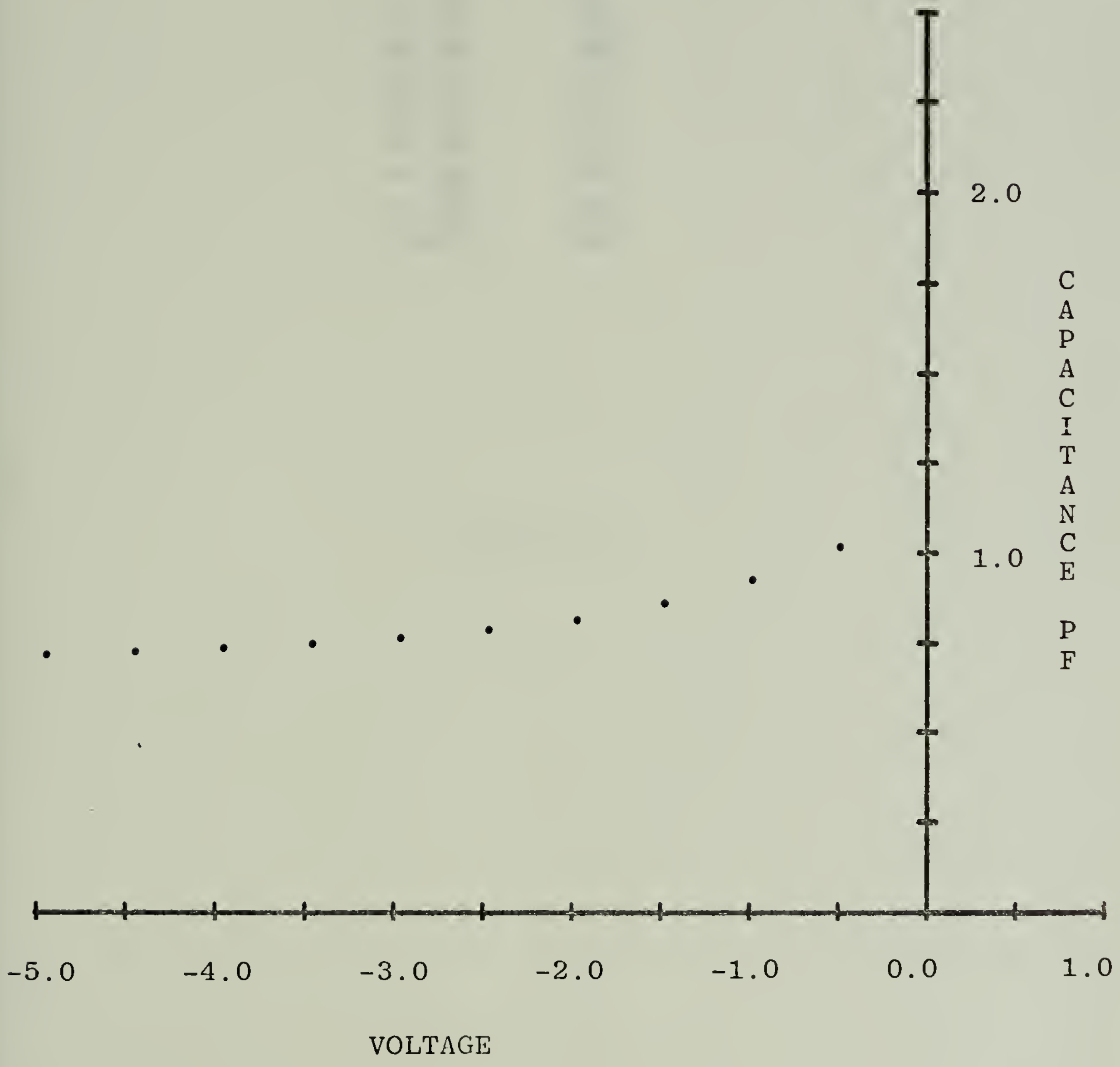


Figure 11c

VOLTS	PICOFARADS
0.00	1.33
-.50	1.01
-1.00	.81
-1.50	.85
-2.00	.80
-2.50	.77
-3.00	.74
-3.50	.72
-4.00	.71
-4.50	.69
-5.00	.68

Figure 11d

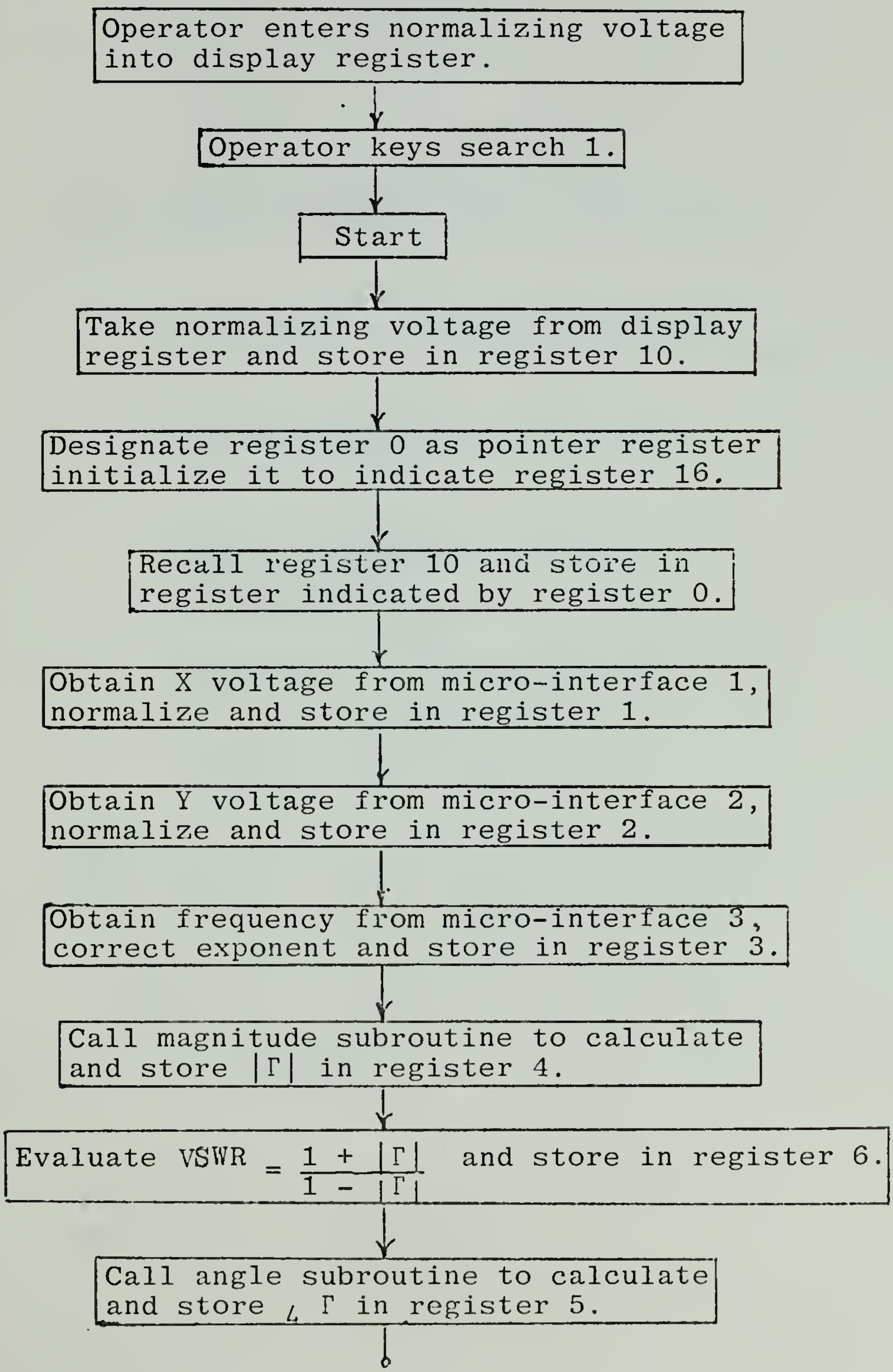
VI. CONCLUSIONS

The feasibility of calculator-aided microwave network analysis has been demonstrated. Data reduction program implementation requires more than casual familiarity with the programmable calculator.

VII. RECOMMENDATIONS

A digital to analog interface from the calculator to the sweep oscillator should be acquired. This would allow frequency selection under program control, thus making the analyzer-calculator system fully automatic.

APPENDIX A: S_{11}/S_{22}-PRINTING FLOWCHART



Relocate frequency, VSWR, Re Γ (x), Im Γ (y), |Γ|, and ∠ Γ in registers 17, 18, 19, 20, 21, and 22 respectively by storing indirectly through pointer register 0.

↓

Recall x from register 1 and store in register 6.

↓

Store 1 + x in register 1.

↓

Call magnitude subroutine to evaluate and store $|(1 + x) + j \cdot y|$ in register 4.

↓

Call angle subroutine to evaluate and store $\angle \{(1 + x) + j \cdot y\}$ in register 5.

↓

Recall register 4 and store in register 7.

↓

Recall register 5 and store in register 8.

↓

Store 1 - x in register 1.

↓

Store - y in register 2.

↓

Call magnitude subroutine to evaluate and store $|(1 - x) - j \cdot y|$ in register 4.

↓

Call angle subroutine to evaluate and store $\angle \{(1 - x) - j \cdot y\}$ in register 5.

↓

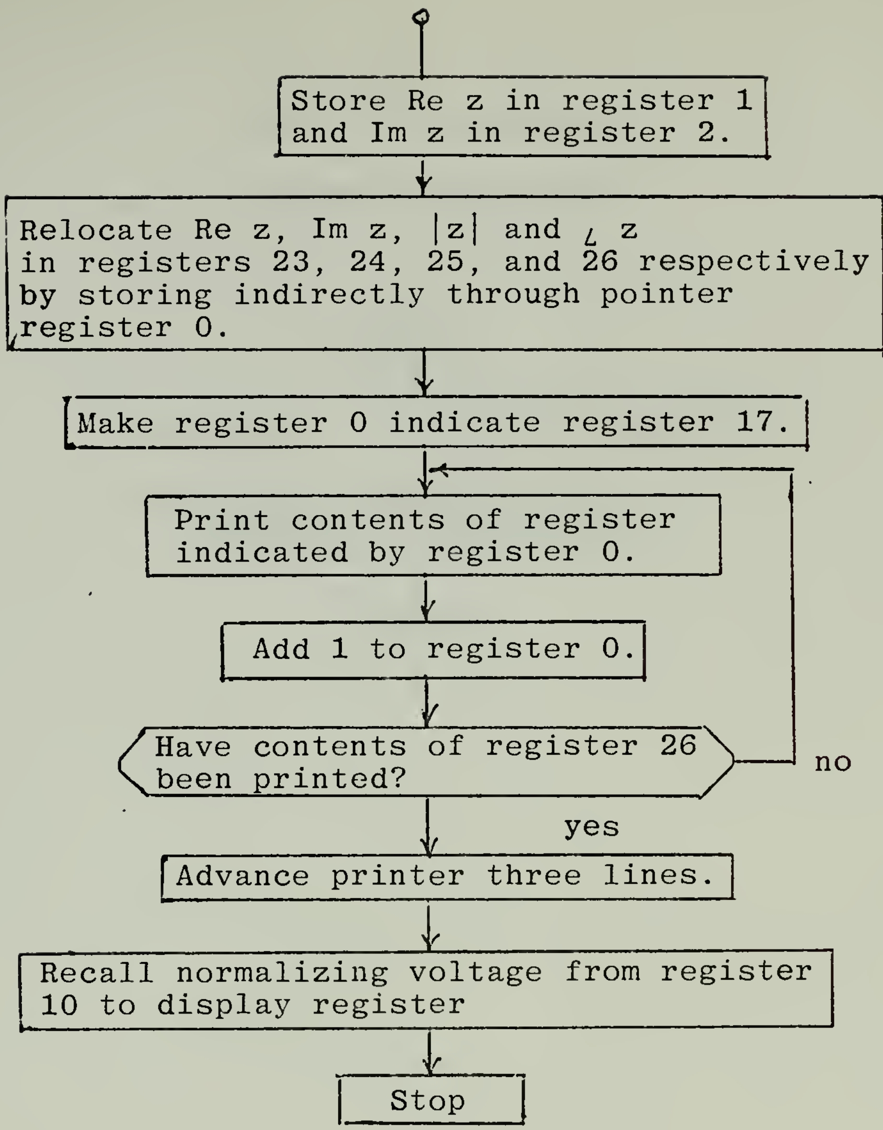
Evaluate $|z| = \frac{\text{Register 7}}{\text{Register 4}}$ and store in register 4.

↓

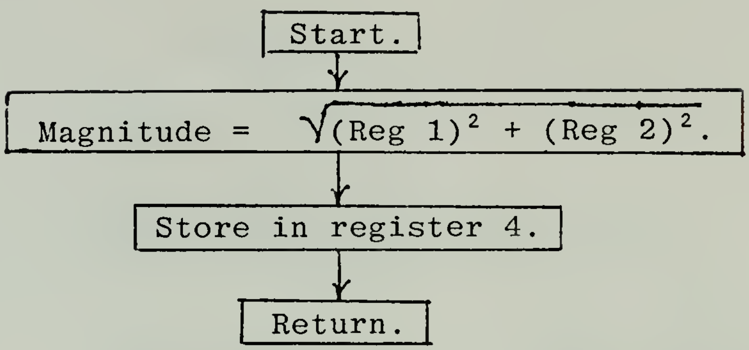
Evaluate $\angle z$ = Register 8 - Register 5 and store in register 5.

↓

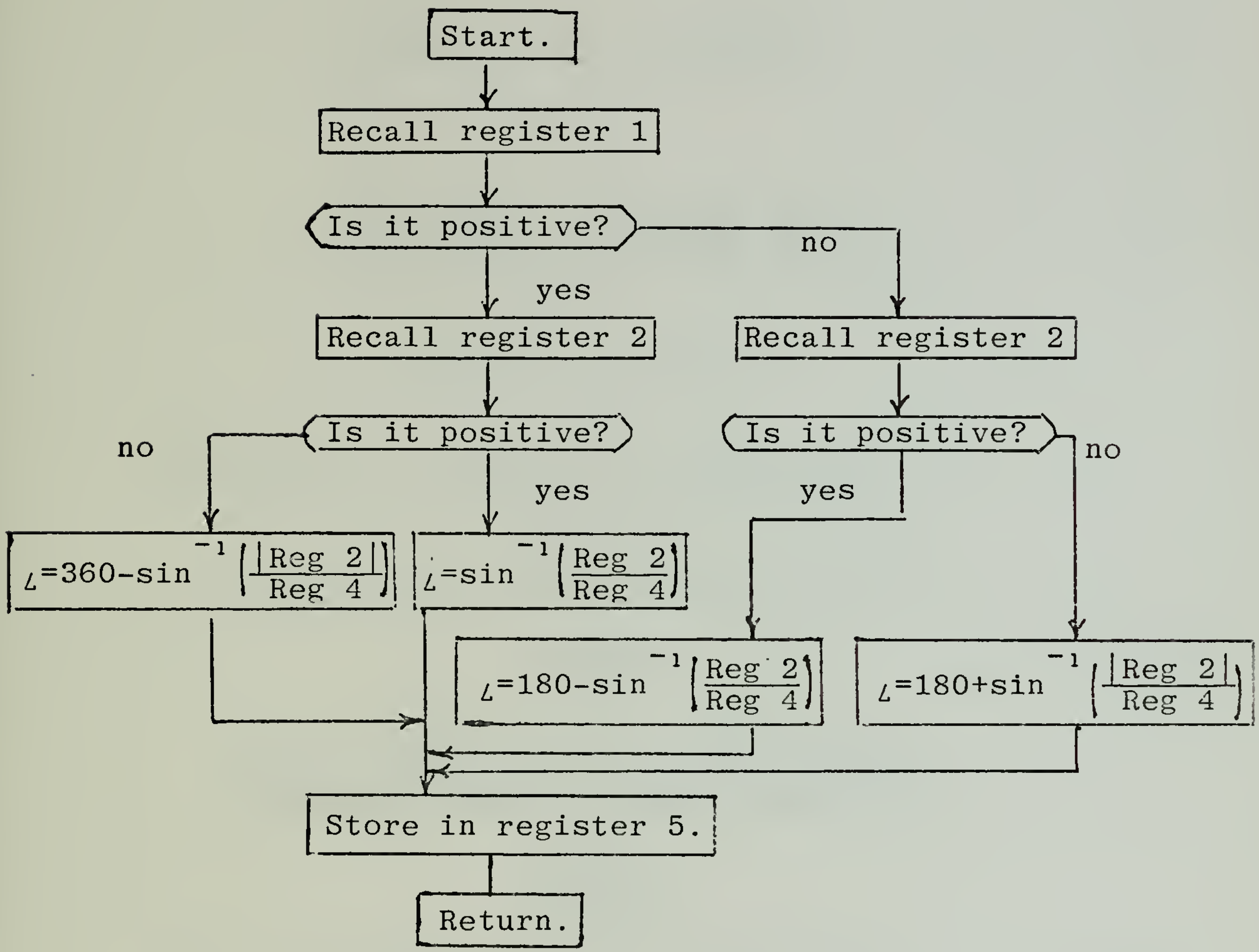
Evaluate $z = |z|\{\cos \angle z + j \cdot \sin \angle z\}$


Store Re z in register 1 and Im z in register 2.
Relocate Re z, Im z, |z| and ∠ z in registers 23, 24, 25, and 26 respectively by storing indirectly through pointer register 0.
Make register 0 indicate register 17.
Print contents of register indicated by register 0.
Add 1 to register 0.
Have contents of register 26 been printed?
no
yes
Advance printer three lines.
Recall normalizing voltage from register 10 to display register
Stop

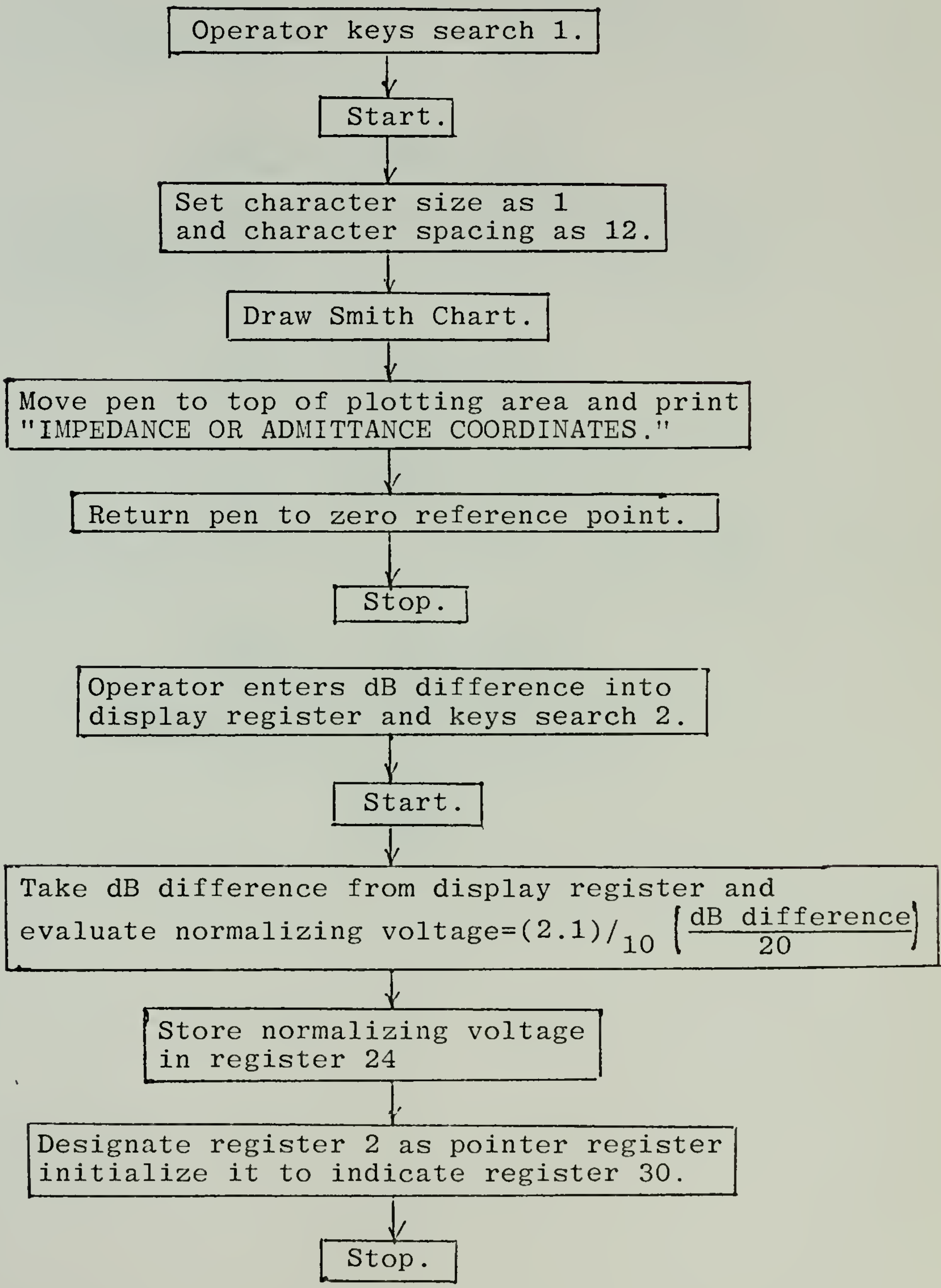
MAGNITUDE SUBROUTINE

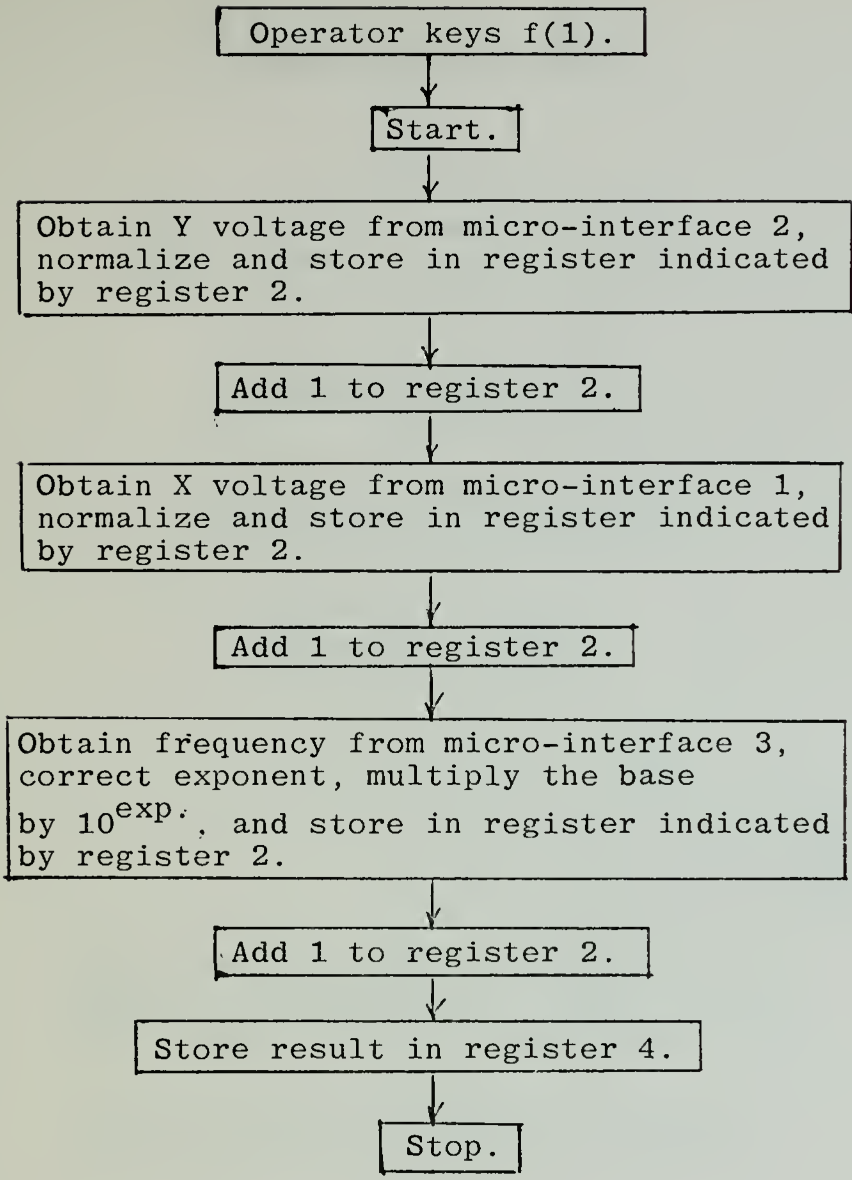


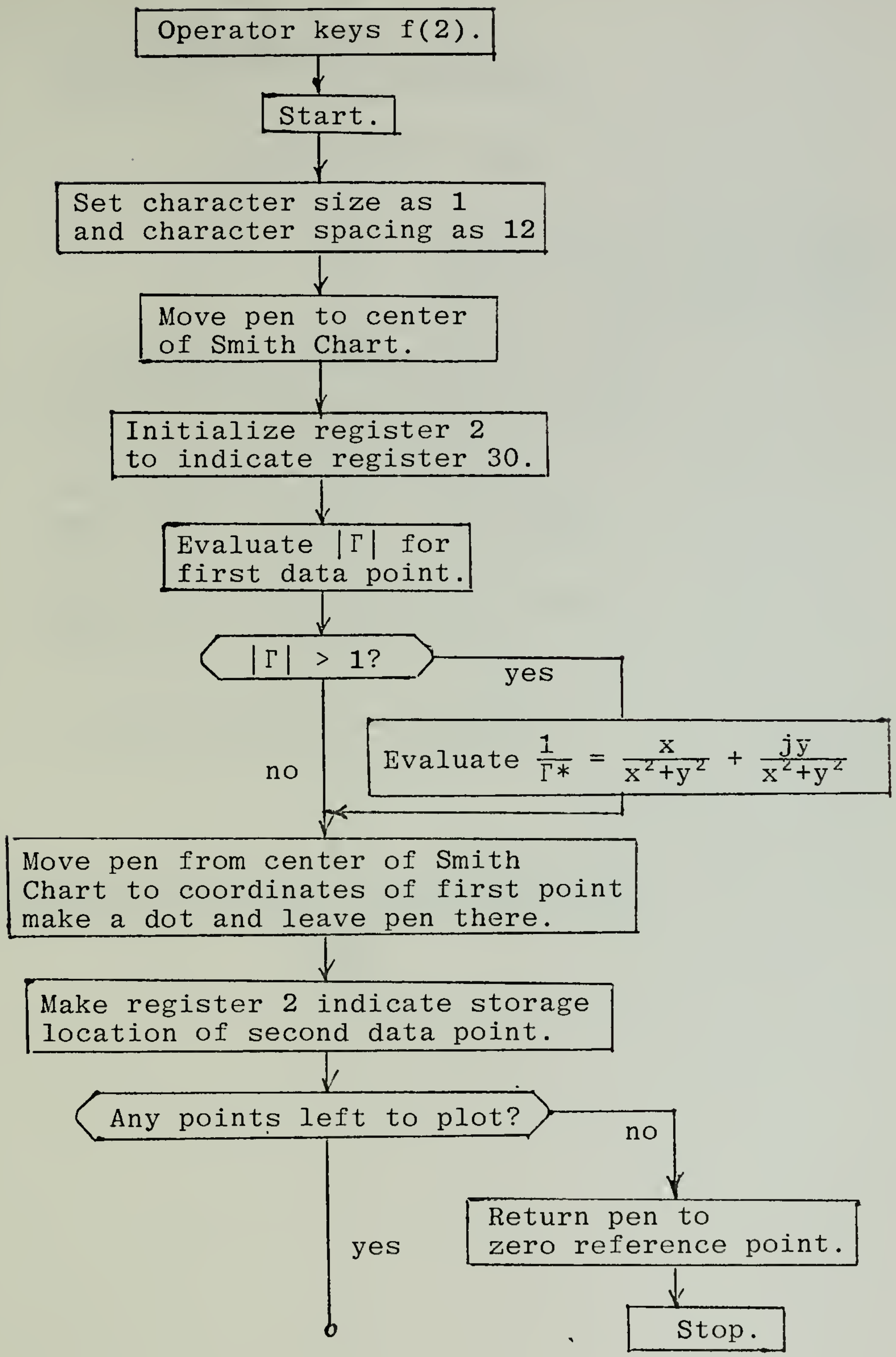
ANGLE SUBROUTINE

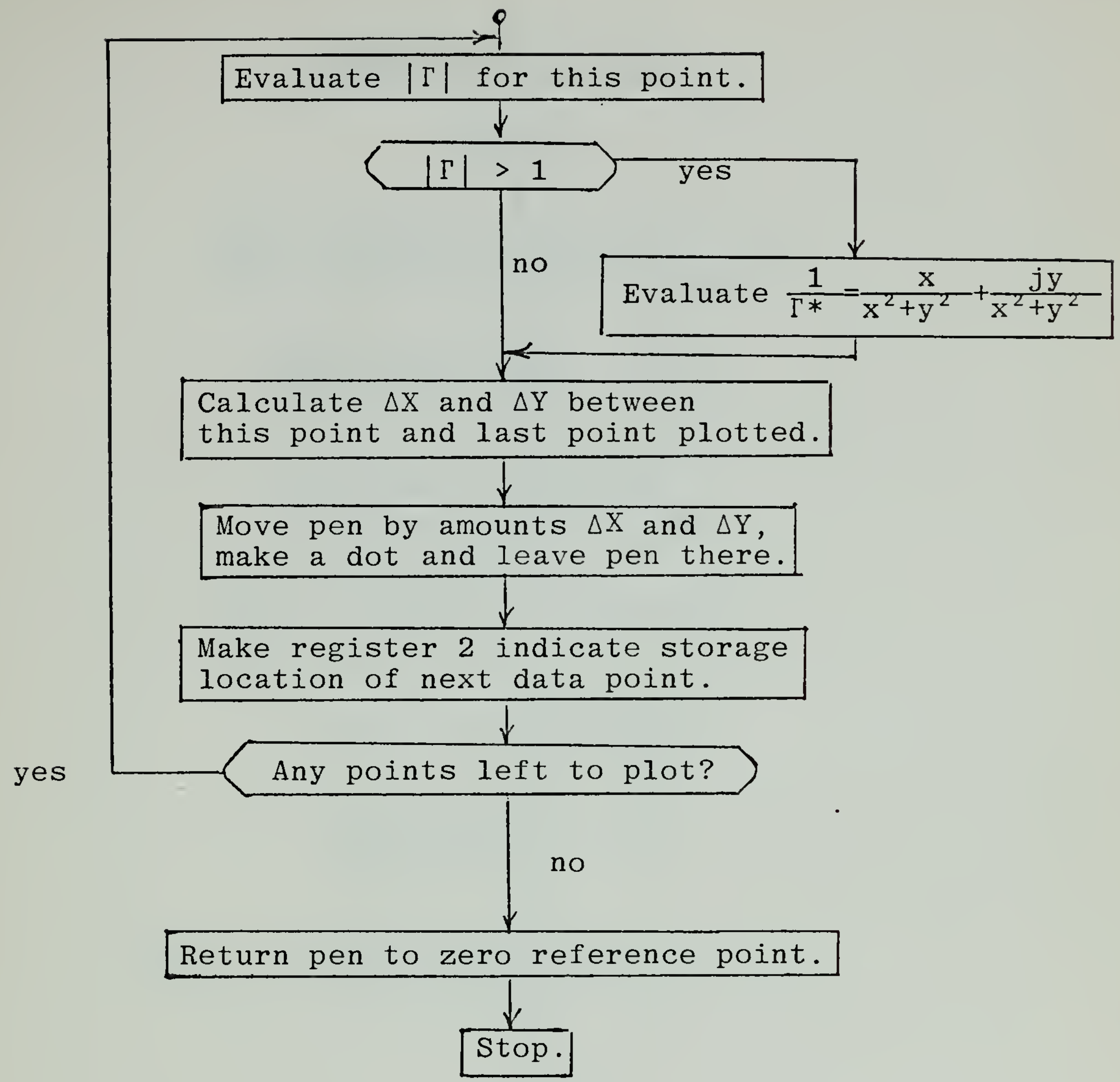


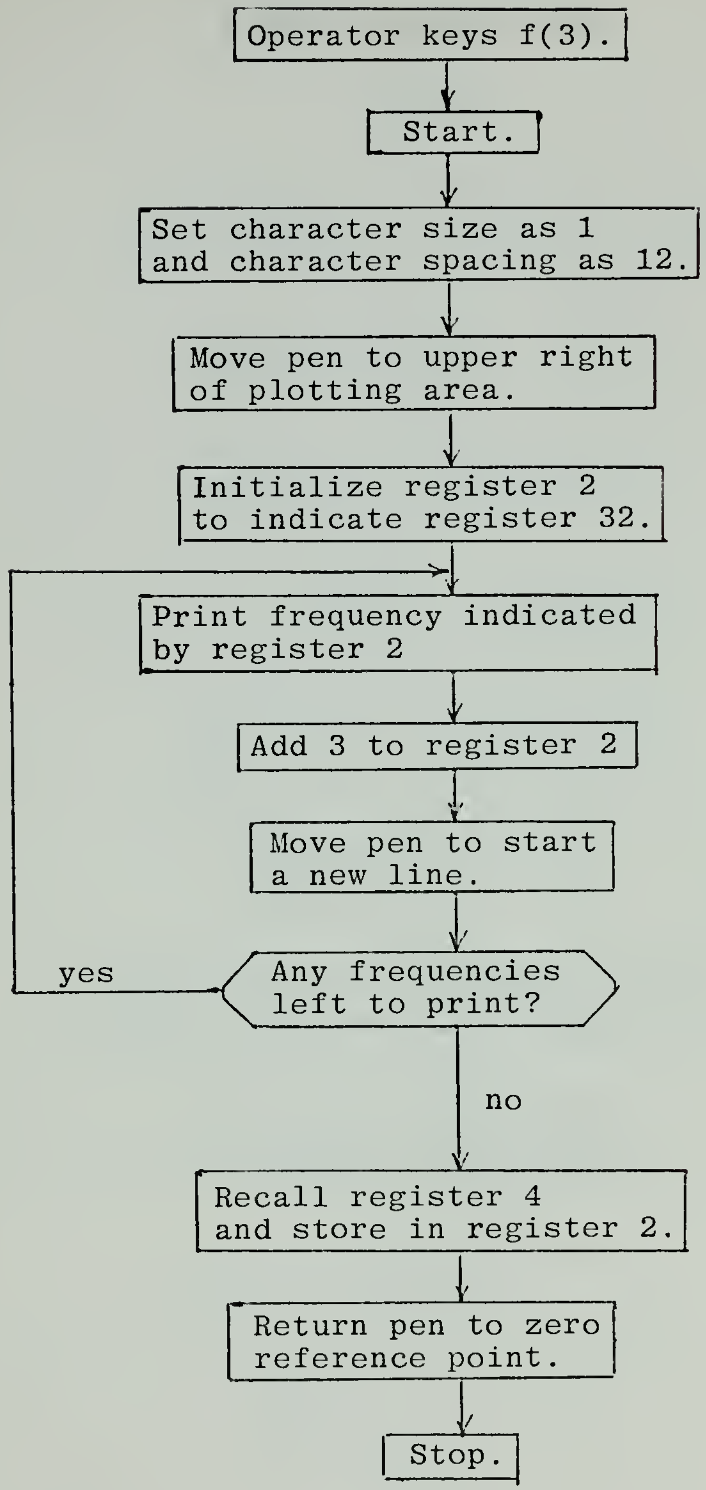
APPENDIX B: SMITH CHART-PLOTTING AND LISTING FLOWCHART

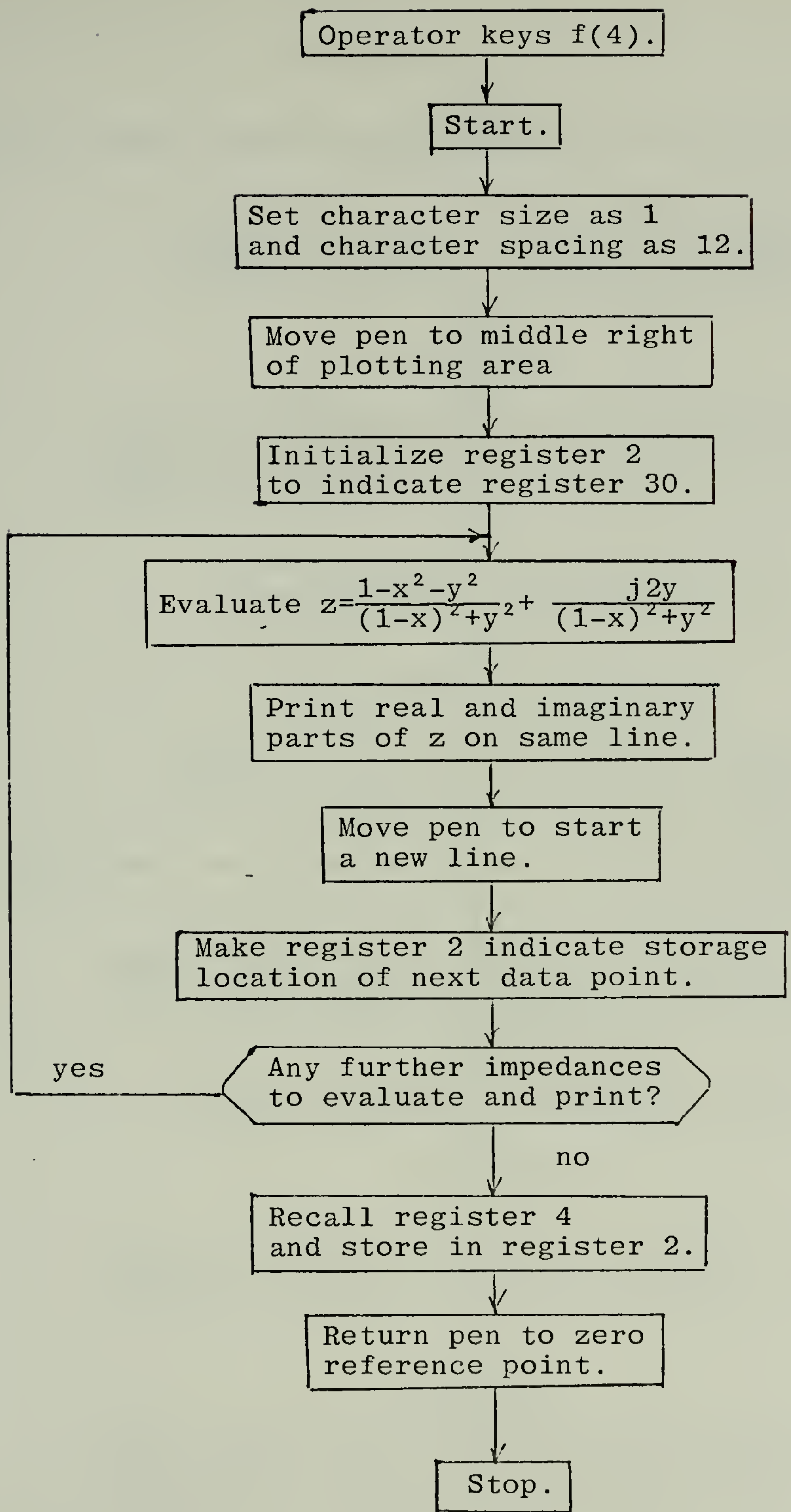



Operator keys f(1).
Start.
Obtain Y voltage from micro-interface 2, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain X voltage from micro-interface 1, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain frequency from micro-interface 3, correct exponent, multiply the base by 10exp., and store in register indicated by register 2.
Add 1 to register 2.
Store result in register 4.
Stop.


Operator keys f(2).
Start.
Set character size as 1 and character spacing as 12
Move pen to center of Smith Chart.
Initialize register 2 to indicate register 30.
Evaluate |Γ| for first data point.
|Γ| > 1?
yes
no
Evaluate $\frac{1}{\Gamma*} = \frac{x}{x^2+y^2} + \frac{jy}{x^2+y^2}$
Move pen from center of Smith Chart to coordinates of first point make a dot and leave pen there.
Make register 2 indicate storage location of second data point.
Any points left to plot?
no
yes
Return pen to zero reference point.
Stop.

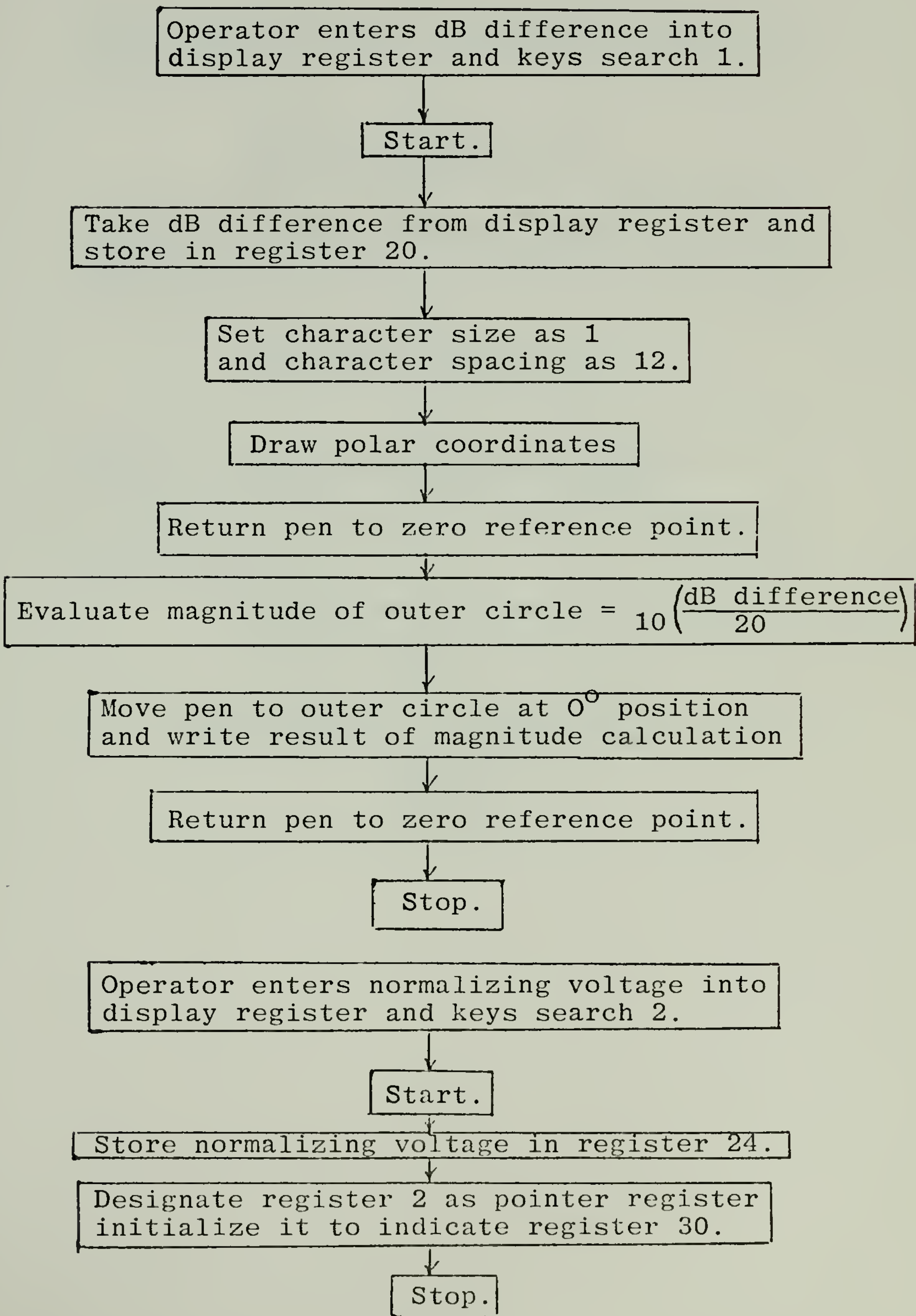

Evaluate |Γ| for this point.
|Γ| > 1
yes
no
Evaluate $\frac{1}{\Gamma^*} = \frac{x}{x^2+y^2} + \frac{jy}{x^2+y^2}$
Calculate ΔX and ΔY between this point and last point plotted.
Move pen by amounts ΔX and ΔY, make a dot and leave pen there.
Make register 2 indicate storage location of next data point.
yes
Any points left to plot?
no
Return pen to zero reference point.
Stop.

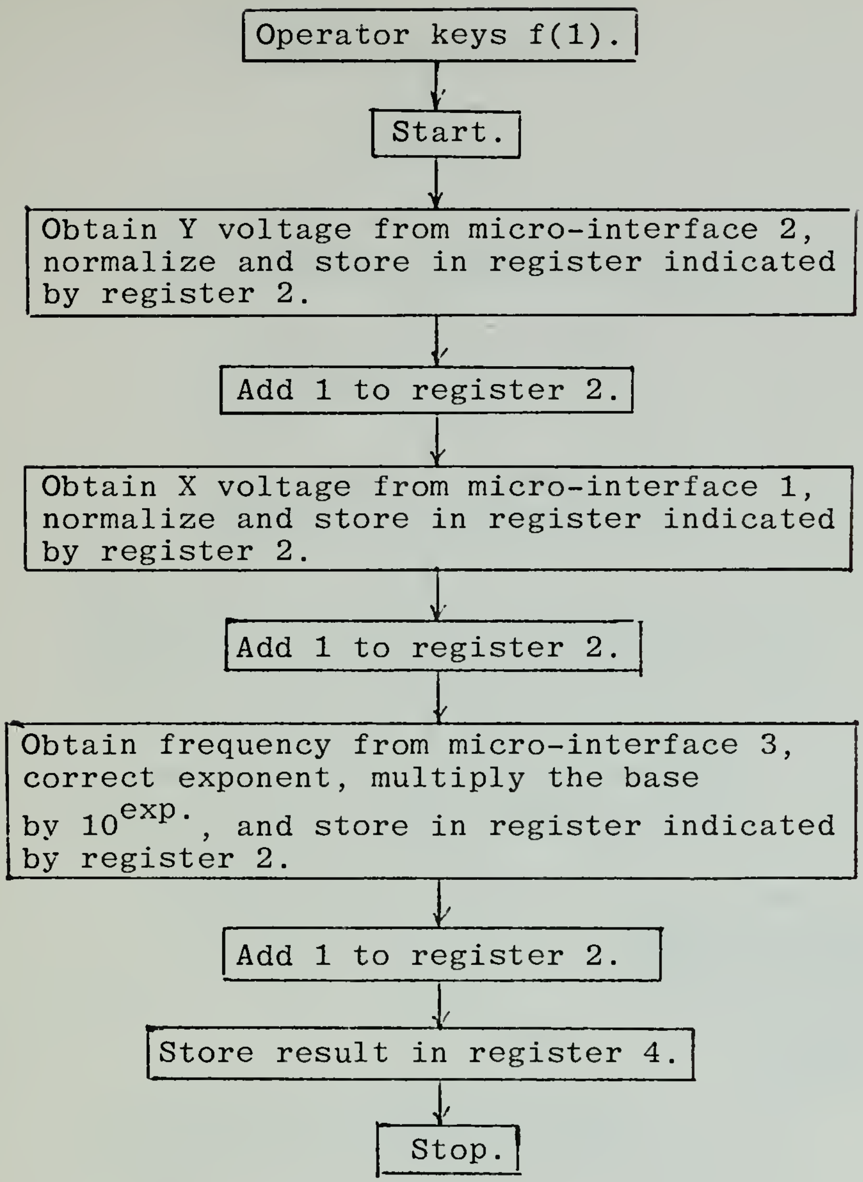

Operator keys f(3).
Start.
Set character size as 1 and character spacing as 12.
Move pen to upper right of plotting area.
Initialize register 2 to indicate register 32.
Print frequency indicated by register 2
Add 3 to register 2
Move pen to start a new line.
Any frequencies left to print?
yes
no
Recall register 4 and store in register 2.
Return pen to zero reference point.
Stop.

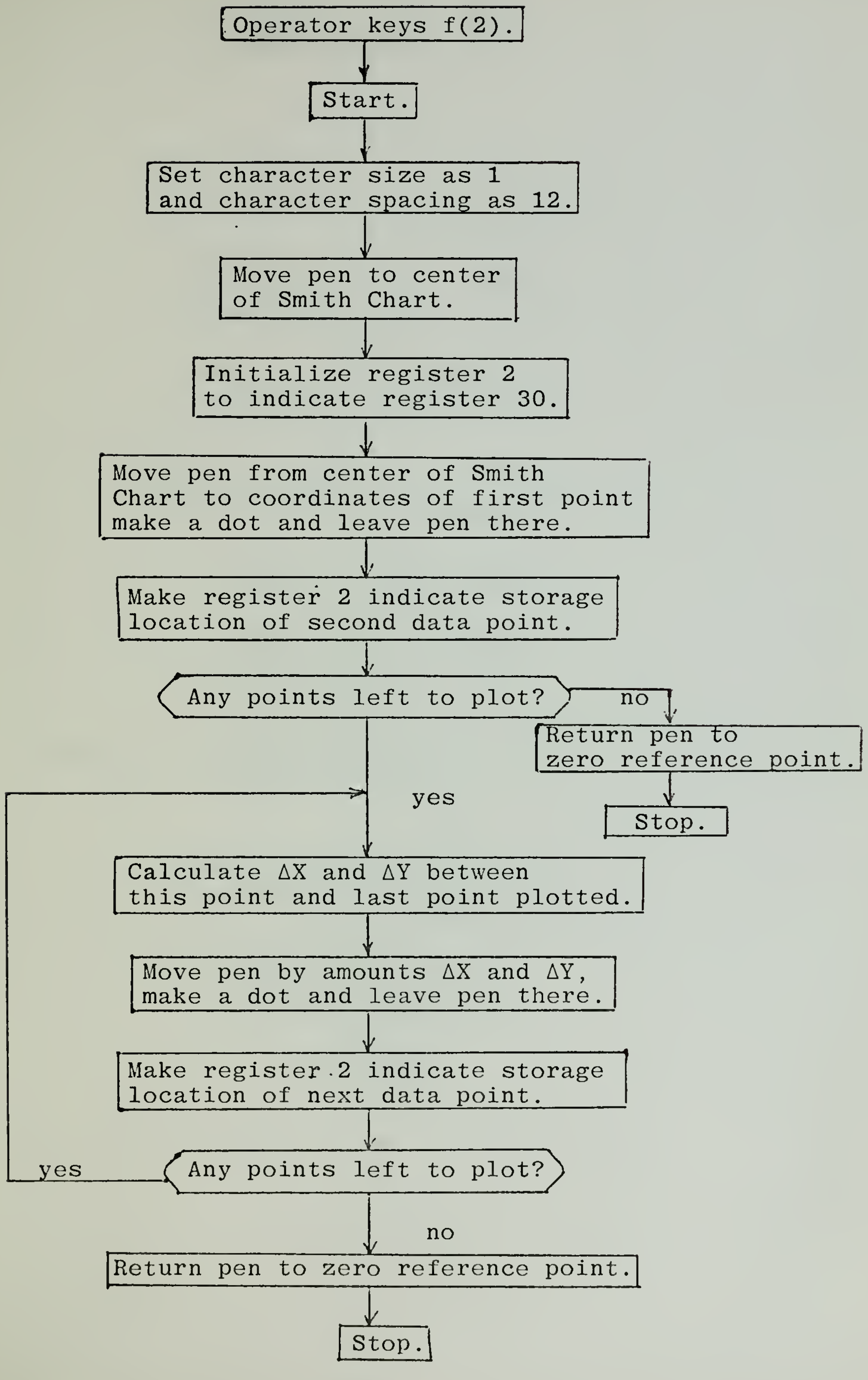

Operator keys f(4).
Start.
Set character size as 1 and character spacing as 12.
Move pen to middle right of plotting area
Initialize register 2 to indicate register 30.
Evaluate $z=\frac{1-x^2-y^2}{(1-x)^2+y^2}+\frac{j2y}{(1-x)^2+y^2}$
Print real and imaginary parts of z on same line.
Move pen to start a new line.
Make register 2 indicate storage location of next data point.
Any further impedances to evaluate and print?
yes
no
Recall register 4 and store in register 2.
Return pen to zero reference point.
Stop.

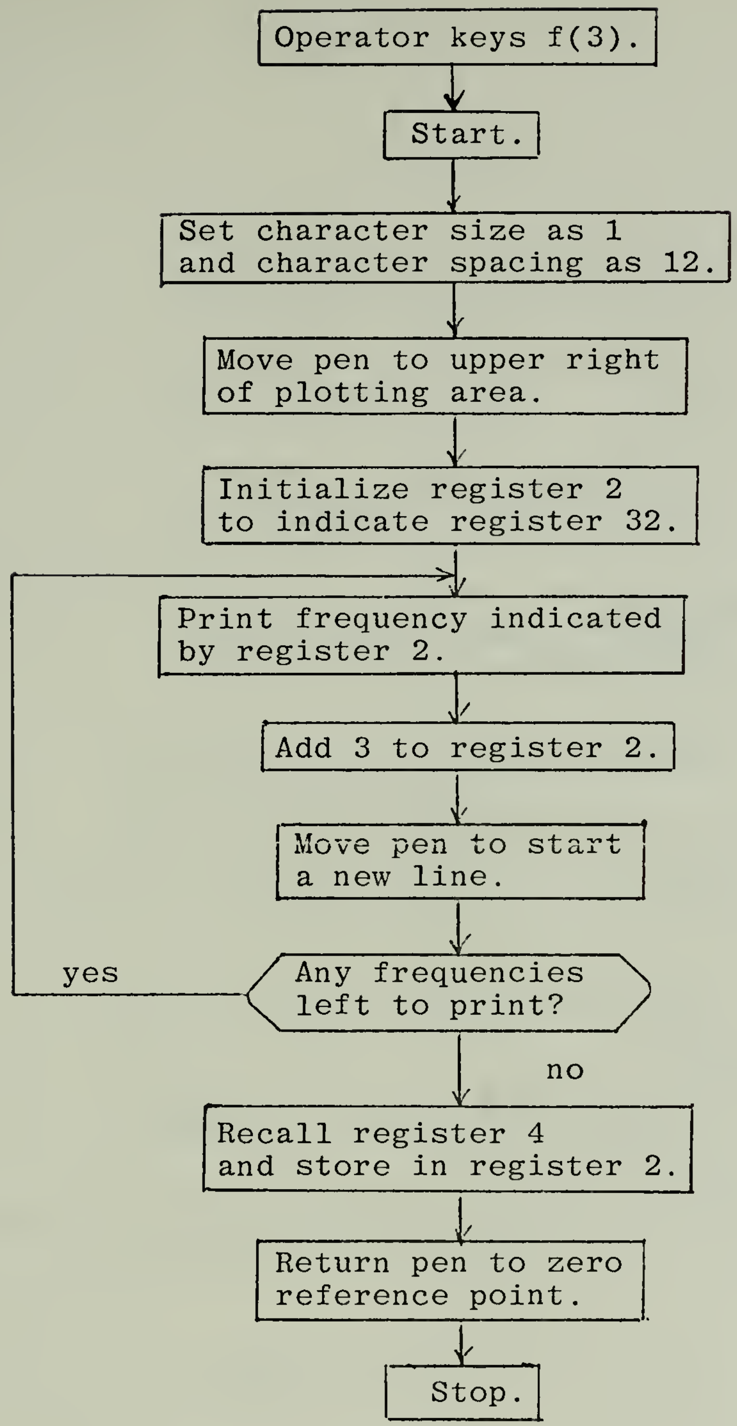
APPENDIX C

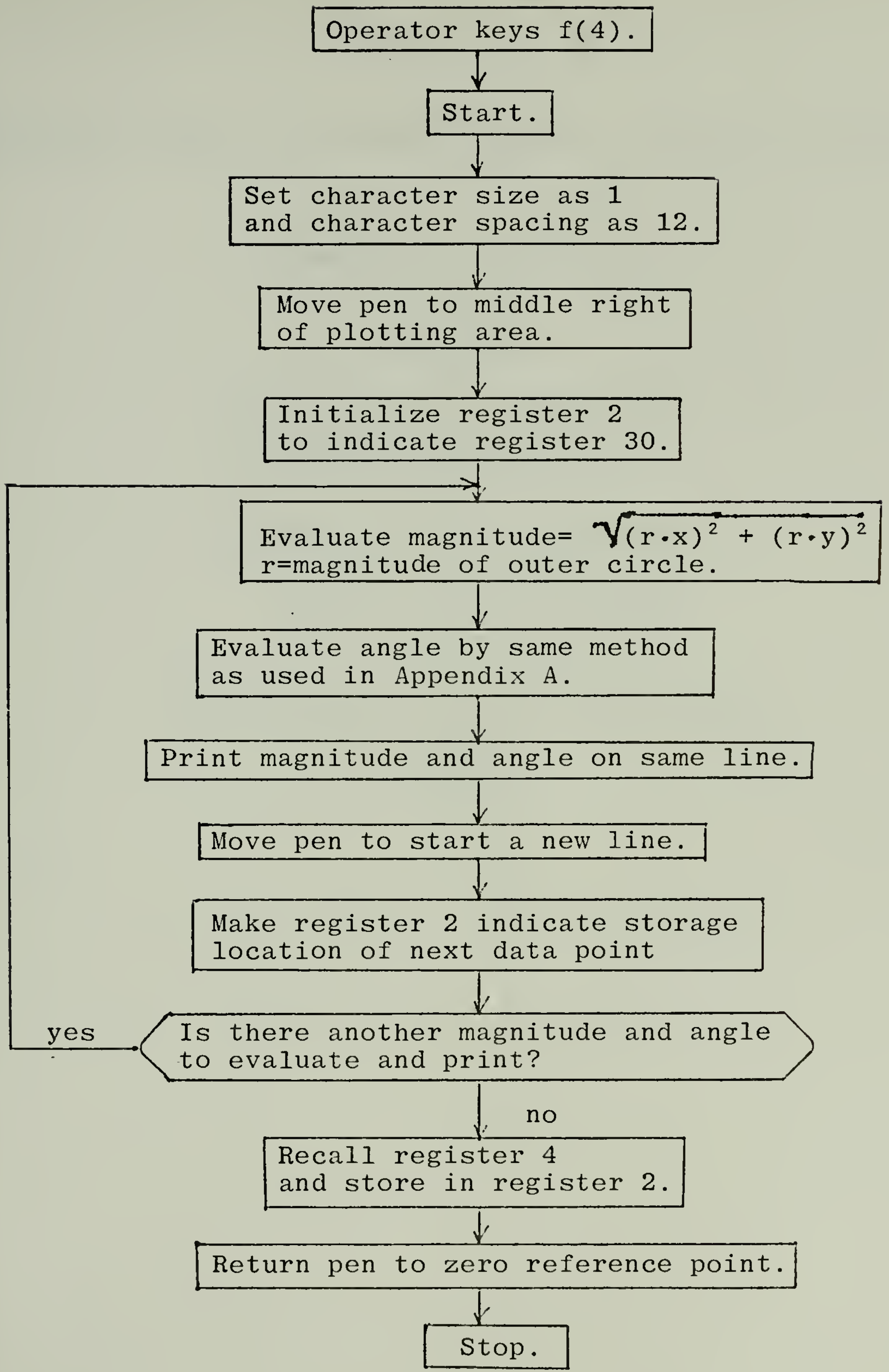
S_{12}/S_{21} POLAR COORDINATES-PLOTTING AND LISTING FLOWCHART




Operator keys f(1).
Start.
Obtain Y voltage from micro-interface 2, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain X voltage from micro-interface 1, normalize and store in register indicated by register 2.
Add 1 to register 2.
Obtain frequency from micro-interface 3, correct exponent, multiply the base by 10exp., and store in register indicated by register 2.
Add 1 to register 2.
Store result in register 4.
Stop.

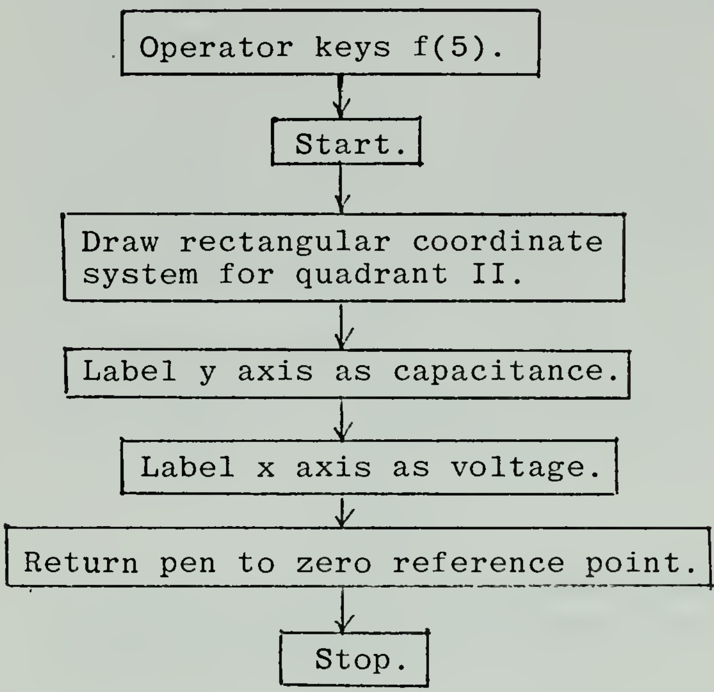

Operator keys f(2).
Start.
Set character size as 1 and character spacing as 12.
Move pen to center of Smith Chart.
Initialize register 2 to indicate register 30.
Move pen from center of Smith Chart to coordinates of first point make a dot and leave pen there.
Make register 2 indicate storage location of second data point.
Any points left to plot?
no
Return pen to zero reference point.
Stop.
yes
Calculate ΔX and ΔY between this point and last point plotted.
Move pen by amounts ΔX and ΔY, make a dot and leave pen there.
Make register 2 indicate storage location of next data point.
yes
Any points left to plot?
no
Return pen to zero reference point.
Stop.


Operator keys f(3).
Start.
Set character size as 1
and character spacing as 12.
Move pen to upper right
of plotting area.
Initialize register 2
to indicate register 32.
Print frequency indicated
by register 2.
Add 3 to register 2.
Move pen to start
a new line.
Any frequencies
left to print?
yes
no
Recall register 4
and store in register 2.
Return pen to zero
reference point.
Stop.


Operator keys f(4).
Start.
Set character size as 1 and character spacing as 12.
Move pen to middle right of plotting area.
Initialize register 2 to indicate register 30.
Evaluate magnitude= $\sqrt{(r\cdot x)^2 + (r\cdot y)^2}$
r=magnitude of outer circle.
Evaluate angle by same method as used in Appendix A.
Print magnitude and angle on same line.
Move pen to start a new line.
Make register 2 indicate storage location of next data point
Is there another magnitude and angle to evaluate and print?
yes
no
Recall register 4 and store in register 2.
Return pen to zero reference point.
Stop.

APPENDIX D

SCHOTTKY BARRIER CAPACITANCE-PLOTTING AND LISTING FLOWCHART



Operator keys f(6).

Start.

Designate register 2 as a pointer register. Initialize it to indicate register 30.

Designate register 3 as a pointer register. Recall register 4 and store in register 3. This makes register 3 indicate the first available register for bias voltage storage.

Designate register 5 to indicate the number of the bias voltage to be entered. Initialize it to 1.

Stop.

Operator enters bias voltage into display register and keys go.

Start.

Take bias voltage from display register and store in register indicated by register 3.

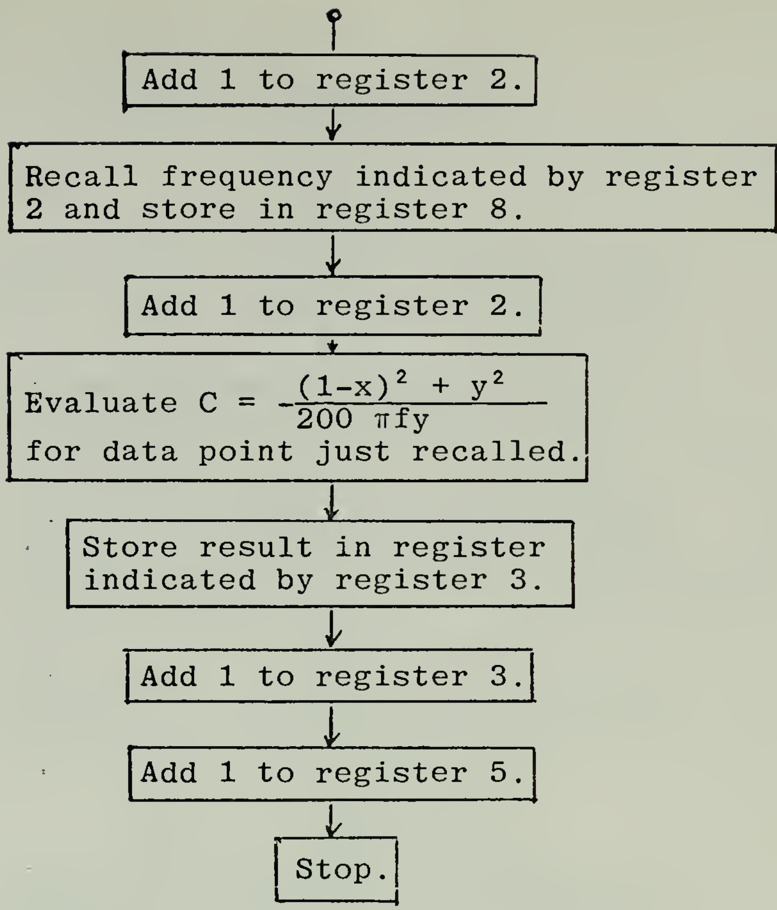
Add 1 to register 3

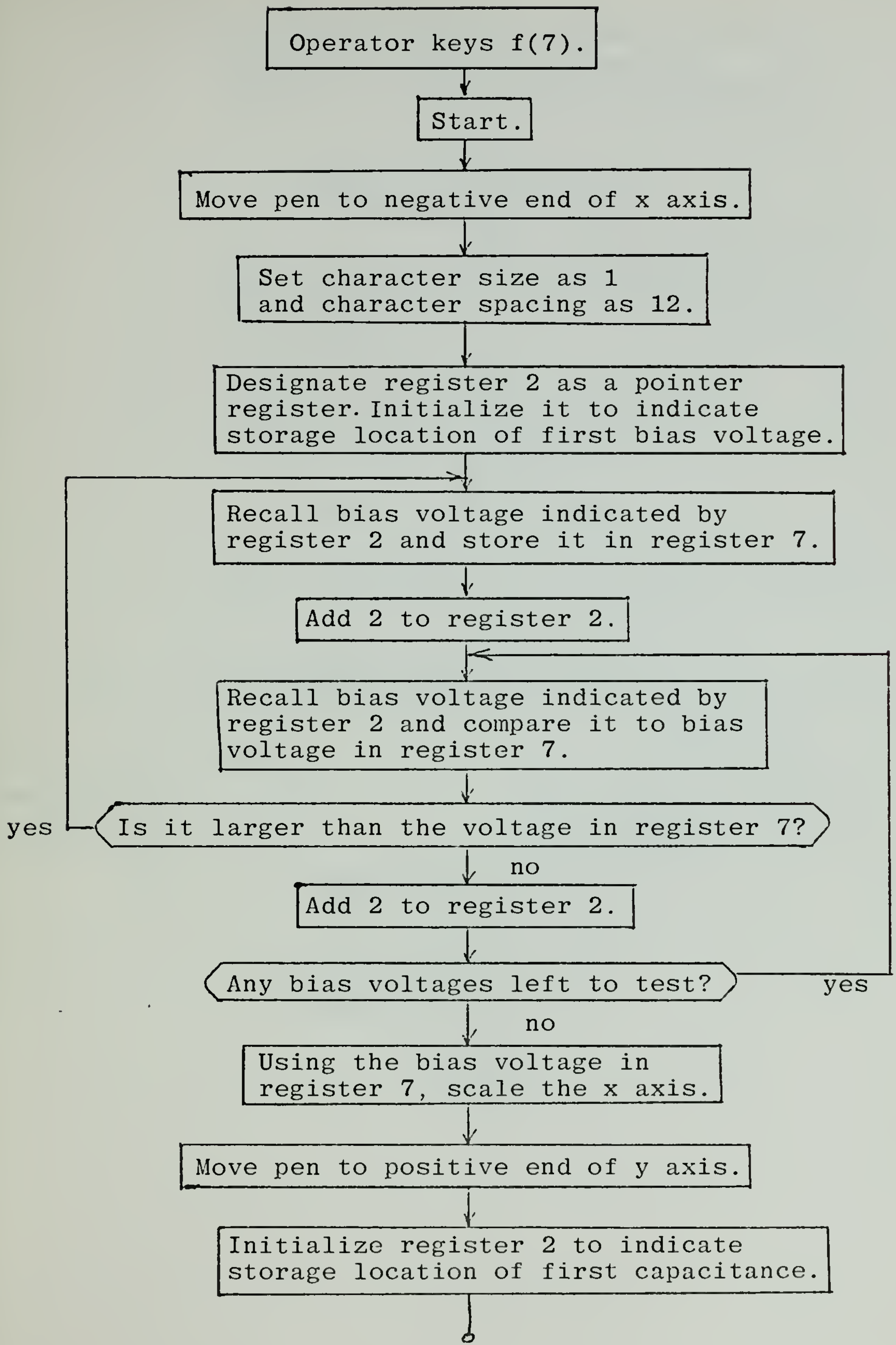
Recall y voltage indicated by register 2 and store in register 6.

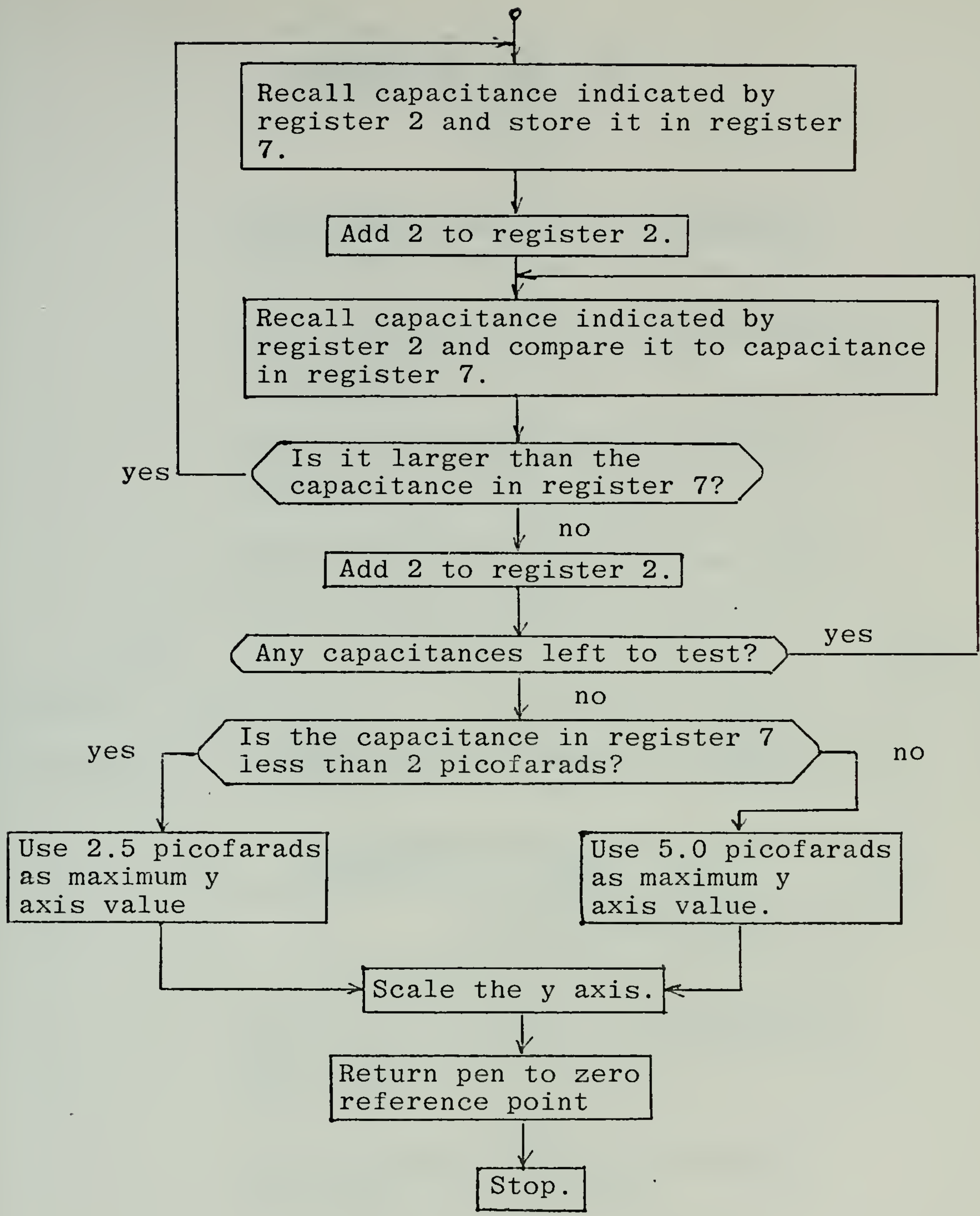
Add 1 to register 2.

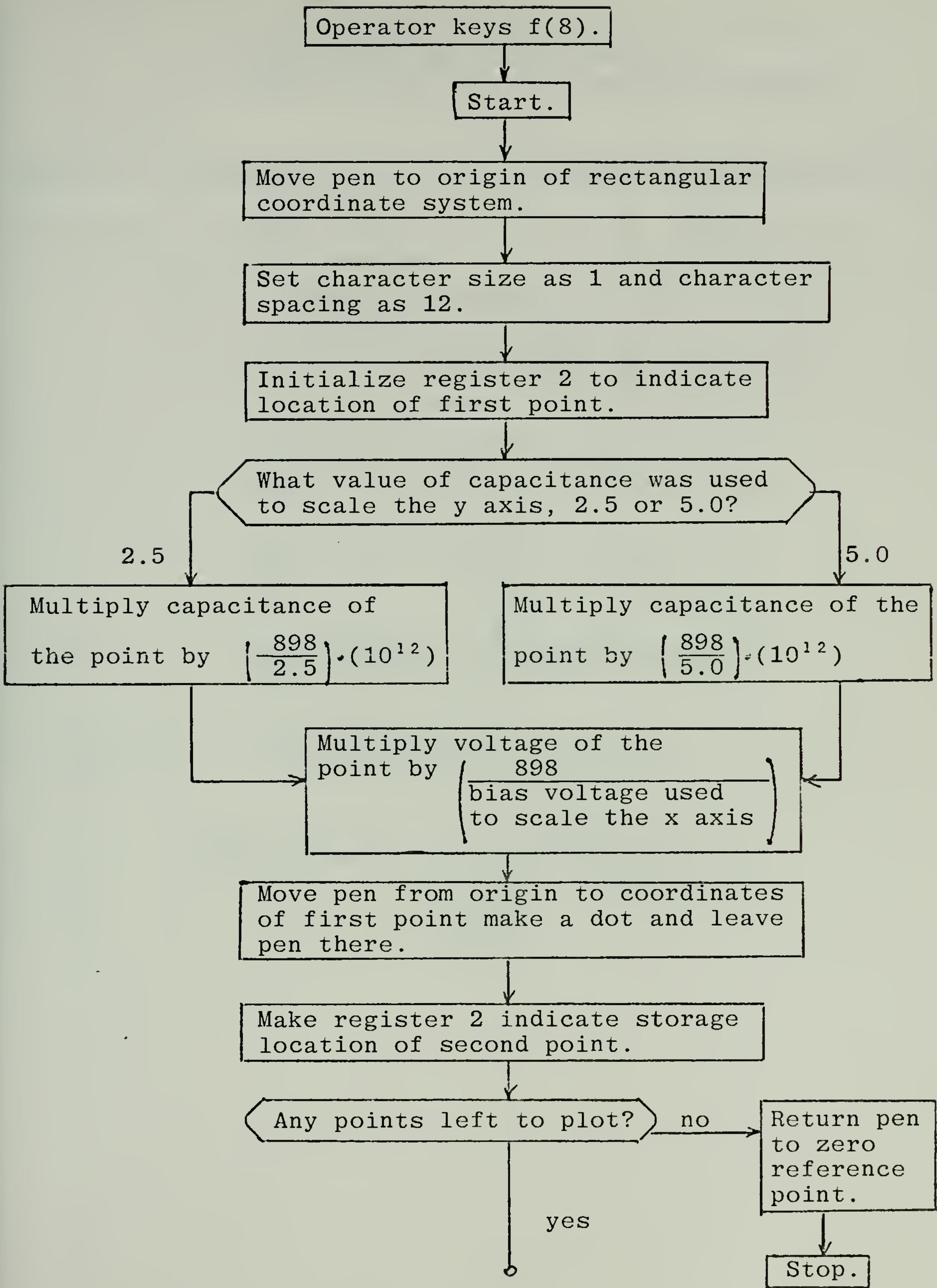
Recall x voltage indicated by register 2 and store in register 7.

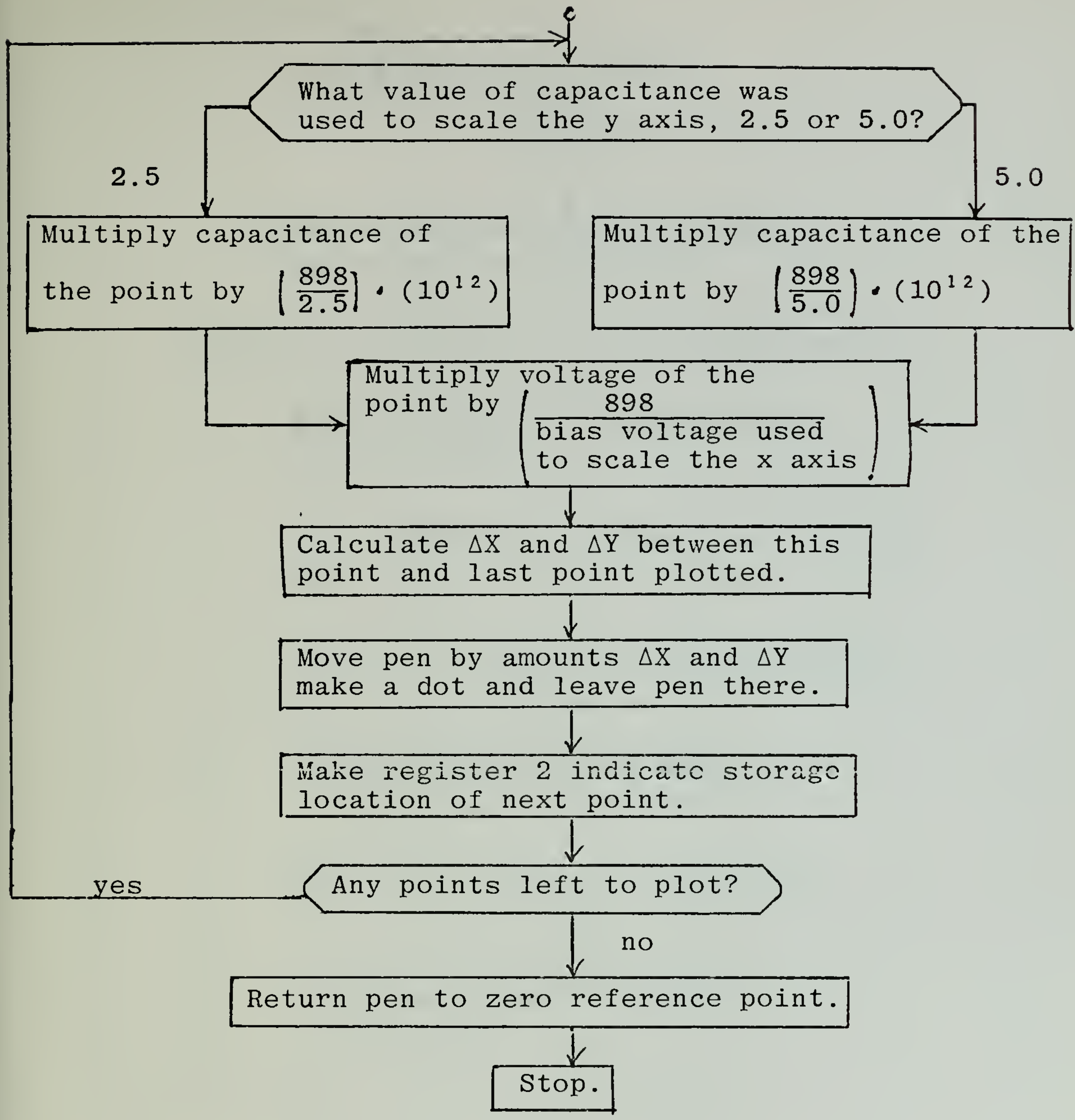
D

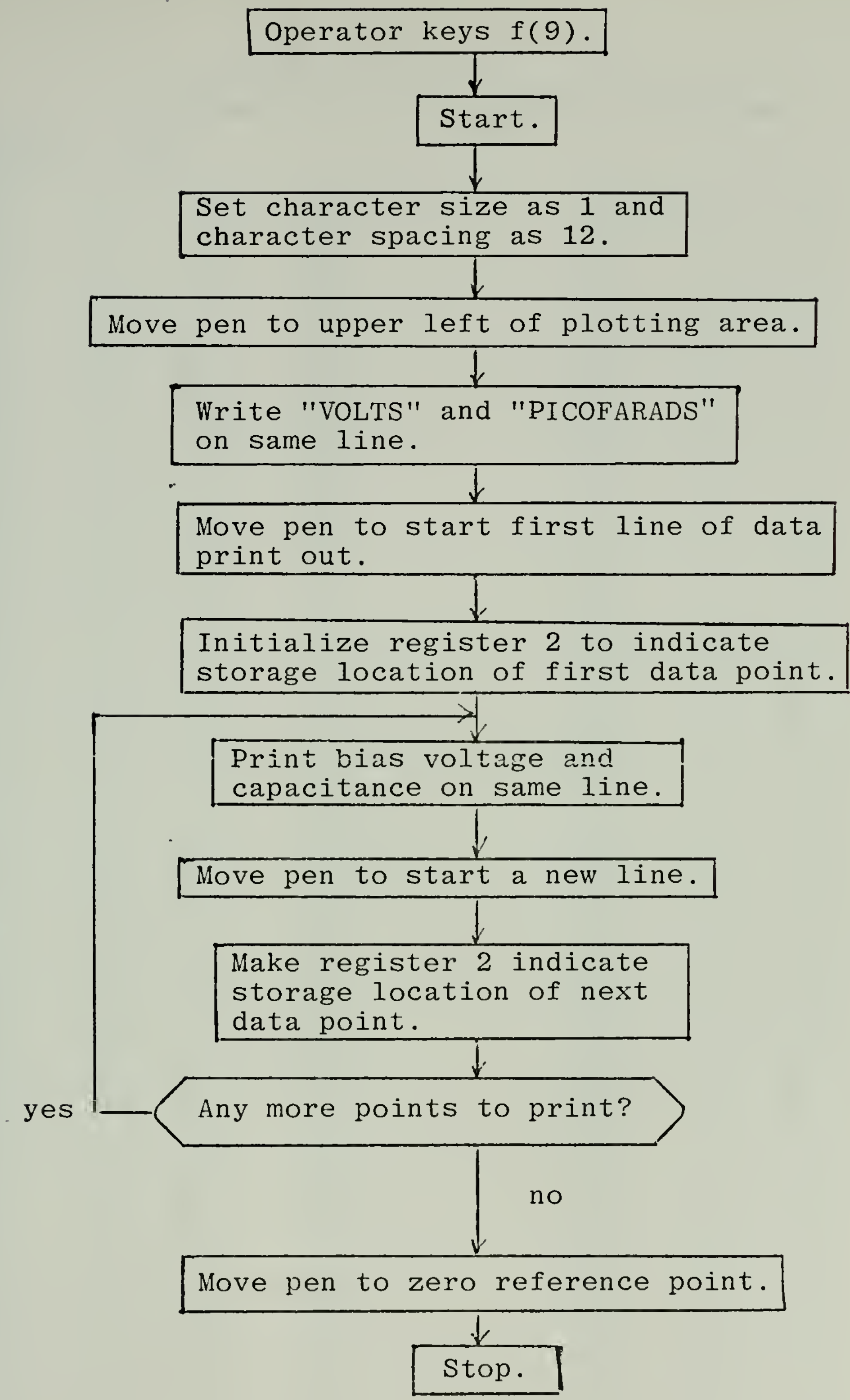

Add 1 to register 2.
Recall frequency indicated by register 2 and store in register 8.
Add 1 to register 2.
Evaluate $C = -\frac{(1-x)^2 + y^2}{200 \pi f y}$
for data point just recalled.
Store result in register indicated by register 3.
Add 1 to register 3.
Add 1 to register 5.
Stop.


Operator keys f(7).
Start.
Move pen to negative end of x axis.
Set character size as 1 and character spacing as 12.
Designate register 2 as a pointer register. Initialize it to indicate storage location of first bias voltage.
Recall bias voltage indicated by register 2 and store it in register 7.
Add 2 to register 2.
Recall bias voltage indicated by register 2 and compare it to bias voltage in register 7.
yes
Is it larger than the voltage in register 7?
no
Add 2 to register 2.
Any bias voltages left to test?
yes
no
Using the bias voltage in register 7, scale the x axis.
Move pen to positive end of y axis.
Initialize register 2 to indicate storage location of first capacitance.


Recall capacitance indicated by register 2 and store it in register 7.
Add 2 to register 2.
Recall capacitance indicated by register 2 and compare it to capacitance in register 7.
yes
Is it larger than the capacitance in register 7?
no
Add 2 to register 2.
Any capacitances left to test?
yes
no
yes
Is the capacitance in register 7 less than 2 picofarads?
no
Use 2.5 picofarads as maximum y axis value
Use 5.0 picofarads as maximum y axis value.
Scale the y axis.
Return pen to zero reference point
Stop.


Operator keys f(8).
Start.
Move pen to origin of rectangular coordinate system.
Set character size as 1 and character spacing as 12.
Initialize register 2 to indicate location of first point.
What value of capacitance was used to scale the y axis, 2.5 or 5.0?
2.5
5.0
Multiply capacitance of the point by (898/2.5)·(10^12)
Multiply capacitance of the point by (898/5.0)·(10^12)
Multiply voltage of the point by (898 / bias voltage used to scale the x axis)
Move pen from origin to coordinates of first point make a dot and leave pen there.
Make register 2 indicate storage location of second point.
Any points left to plot?
no
Return pen to zero reference point.
Stop.
yes


What value of capacitance was used to scale the y axis, 2.5 or 5.0?
2.5
5.0
Multiply capacitance of the point by (898/2.5) · (10¹²)
Multiply capacitance of the point by (898/5.0) · (10¹²)
Multiply voltage of the point by (898 / bias voltage used to scale the x axis)
Calculate ΔX and ΔY between this point and last point plotted.
Move pen by amounts ΔX and ΔY make a dot and leave pen there.
Make register 2 indicate storage location of next point.
yes
Any points left to plot?
no
Return pen to zero reference point.
Stop.


Operator keys f(9).
Start.
Set character size as 1 and character spacing as 12.
Move pen to upper left of plotting area.
Write "VOLTS" and "PICOFARADS" on same line.
Move pen to start first line of data print out.
Initialize register 2 to indicate storage location of first data point.
Print bias voltage and capacitance on same line.
Move pen to start a new line.
Make register 2 indicate storage location of next data point.
Any more points to print?
yes
no
Move pen to zero reference point.
Stop.

APPENDIX E: S_{11}/S_{22}-PRINTING PROGRAM

Verify = 3177

0000	09	00	* M
0001	00	01	E 1
0002	06	10	ST10
0003	00	01	E 1
0004	00	06	E 6
0005	06	00	ST 0
0006	07	10	RE10
0007	15	11	D11
0008	06	00	ST 0
0009	10	01	f 1
0010	10	02	f 2
0011	10	00	f 0
0012	10	03	f 3
0013	10	04	f 4
0014	10	07	f 7
0015	10	08	f 8
0016	10	10	f 10
0017	10	11	f 11
0018	09	03	* SP
0019	09	00	* M
0020	10	01	f 1
0021	15	13	D13
0022	07	01	RE 1
0023	06	01	ST 1
0024	15	11	D11
0025	07	00	RE 0
0026	05	01	÷ 1
0027	15	13	D13
0028	07	02	RE 2
0029	06	02	ST 2
0030	15	11	D11
0031	07	00	RE 0
0032	05	02	÷ 2
0033	15	13	D13
0034	07	03	RE 3
0035	15	13	D13
0036	07	03	RE 3
0037	06	03	ST 3
0038	00	02	E 2
0039	02	03	+ 3
0040	09	15	* RT
0041	09	00	* M
0042	10	02	f 2
0043	07	01	RE 1
0044	08	12	* x^2
0045	06	14	ST14
0046	07	02	RE 2
0047	08	12	* x^2
0048	02	14	+ 14
0049	08	13	* $\sqrt{x}$
0050	06	04	ST 4
0051	09	15	* RT
0052	09	00	* M
0053	10	03	f 3
0054	07	01	RE 1
0055	08	05	* J+
0056	08	00	* S
0057	00	02	E 2
0058	07	02	RE 2
0059	06	14	ST14
0060	08	05	* J+
0061	08	00	* S
0062	00	03	E 3
0063	07	04	RE 4
0064	05	14	÷ 14
0065	09	06	* S'
0066	06	05	ST 5
0067	09	15	* RT
0068	09	00	* M
0069	00	02	E 2
0070	07	02	RE 2
0071	06	14	ST14
0072	08	05	* J+
0073	08	00	* S
0074	00	04	E 4
0075	00	01	E 1
0076	00	08	E 8
0077	00	00	E 0
0078	06	05	ST 5
0079	07	04	RE 4

0080	05	14	÷14	
0081	09	06	*	S'
0082	03	05	-5	
0083	09	15	*	RT
0084	09	00	*	M
0085	00	03	E3	
0086	00	12	E12	
0087	06	14	ST14	
0088	00	03	E3	
0089	00	06	E6	
0090	00	00	E0	
0091	06	05	ST5	
0092	07	04	RE4	
0093	05	14	÷14	
0094	09	06	*	S'
0095	03	05	-5	
0096	09	15	*	RT
0097	09	00	*	M
0098	00	04	E4	
0099	00	12	E12	
0100	06	14	ST14	
0101	00	01	E1	
0102	00	08	E8	
0103	00	00	E0	
0104	06	05	ST5	
0105	07	04	RE4	
0106	05	14	÷14	
0107	09	06	*	S'
0108	02	05	+5	
0109	10	05	f5	
0110	09	15	*	RT
0111	09	00	*	M
0112	10	04	f4	
0113	10	06	f6	
0114	07	03	RE3	
0115	10	05	f5	
0116	10	06	f6	
0117	07	06	RE6	
0118	10	05	f5	
0119	10	06	f6	
0120	07	01	RE1	
0121	10	05	f5	
0122	10	06	f6	
0123	07	02	RE2	
0124	10	05	f5	
0125	10	06	f6	
0126	07	04	RE4	
0127	10	05	f5	
0128	10	06	f6	
0129	07	05	RE5	
0130	10	05	f5	
0131	09	15	*	RT
0132	09	00	*	M
0133	10	05	f5	
0134	15	11	D11	
0135	06	00	ST0	
0136	09	15	*	RT
0137	09	00	*	M
0138	10	06	f6	
0139	00	01	E1	
0140	02	00	+0	
0141	09	15	*	RT
0142	09	00	*	M
0143	10	07	f7	
0144	07	01	RE1	
0145	06	06	ST6	
0146	00	01	E1	
0147	02	01	+1	
0148	10	02	f2	
0149	10	03	f3	
0150	07	04	RE4	
0151	06	07	ST7	
0152	07	05	RE5	
0153	06	08	ST8	
0154	00	02	E2	
0155	04	06	×6	
0156	03	01	-1	
0157	07	02	RE2	
0158	00	12	E12	
0159	06	02	ST2	

0160	10	02	f 2
0161	10	03	f 3
0162	07	04	RE 4
0163	05	07	÷ 7
0164	06	04	ST 4
0165	07	05	RE 5
0166	03	08	− 8
0167	06	05	ST 5
0168	09	15	* RT
0169	09	00	* M
0170	10	08	f 8
0171	07	05	RE 5
0172	08	07	* CS
0173	06	01	ST 1
0174	07	04	RE 4
0175	04	01	× 1
0176	07	05	RE 5
0177	08	05	* J+
0178	10	09	f 9
0179	09	15	* RT
0180	08	06	* SN
0181	06	02	ST 2
0182	07	04	RE 4
0183	04	02	× 2
0184	09	15	* RT
0185	09	00	* M
0186	10	09	f 9
0187	00	12	E 12
0188	08	06	* SN
0189	06	02	ST 2
0190	00	01	E 1
0191	00	12	E 12
0192	04	02	× 2
0193	07	04	RE 4
0194	04	02	× 2
0195	09	15	* RT
0196	09	00	* M
0197	10	10	f 10
0198	10	06	f 6
0199	07	01	RE 1
0200	10	05	f 5
0201	10	06	f 6
0202	07	02	RE 2
0203	10	05	f 5
0204	10	06	f 6
0205	07	04	RE 4
0206	10	05	f 5
0207	10	06	f 6
0208	07	05	RE 5
0209	10	05	f 5
0210	09	15	* RT
0211	09	00	* M
0212	10	11	f 11
0213	07	00	RE 0
0214	06	01	ST 1
0215	00	01	E 1
0216	00	06	E 6
0217	06	00	ST 0
0218	09	00	* M
0219	00	05	E 5
0220	10	06	f 6
0221	10	12	f 12
0222	07	01	RE 1
0223	09	02	* α
0224	08	04	* Jo
0225	08	00	* S
0226	00	05	E 5
0227	08	02	* W
0228	06	15	ST 15
0229	08	02	* W
0230	06	15	ST 15
0231	08	02	* W
0232	06	15	ST 15
0233	07	10	RE 10
0234	09	15	* RT
0235	09	00	* M
0236	10	12	f 12
0237	15	11	D 11
0238	07	00	RE 0
0239	08	02	* W

0240	06	04	ST 4	
0241	09	15	*	XI
0242	09	00	*	M
0243	10	00	f 0	
0244	07	04	RE 4	
0245	06	06	ST 6	
0246	06	07	ST 7	
0247	00	01	E 1	
0248	00	12	E 12	
0249	04	07	× 7	
0250	00	01	E 1	
0251	02	06	+ 6	
0252	00	01	E 1	
0253	02	07	+ 7	
0254	05	06	÷ 6	
0255	09	15	*	RT
0256	09	03	*	SP
0257	09	14	*	EP

APPENDIX F: SMITH CHART-PLOTTING AND LISTING PROGRAM

Verify =.6980

0000	09	00	*	M
0001	00	01	E 1	
0002	00	00	E 0	
0003	06	00	ST 0	
0004	00	01	E 1	
0005	06	01	ST 1	
0006	09	02	*	α
0007	05	08	÷ 8	
0008	02	02	+ 2	
0009	00	01	E 1	
0010	00	02	E 2	
0011	06	01	ST 1	
0012	09	02	*	α
0013	05	10	÷ 10	
0014	02	02	+ 2	
0015	00	05	E 5	
0016	00	04	E 4	
0017	00	07	E 7	
0018	06	00	ST 0	
0019	00	05	E 5	
0020	00	06	E 6	
0021	00	03	E 3	
0022	06	01	ST 1	
0023	00	04	E 4	
0024	00	04	E 4	
0025	00	09	E 9	
0026	06	03	ST 3	
0027	09	02	*	α
0028	05	11	÷ 11	
0029	05	03	÷ 3	
0030	02	02	+ 2	
0031	00	00	E 0	
0032	06	00	ST 0	
0033	07	03	RE 3	
0034	06	01	ST 1	
0035	09	02	*	α
0036	05	03	÷ 3	
0037	02	02	+ 2	
0038	00	01	E 1	
0039	00	00	E 0	
0040	06	07	ST 7	
0041	00	03	E 3	
0042	00	07	E 7	
0043	00	00	E 0	
0044	06	08	ST 8	
0045	00	00	E 0	
0046	06	04	ST 4	
0047	06	05	ST 5	
0048	00	04	E 4	
0049	00	04	E 4	
0050	00	09	E 9	
0051	06	06	ST 6	
0052	00	00	E 0	
0053	06	10	ST 10	
0054	06	11	ST 11	
0055	09	00	*	M
0056	00	04	E 4	
0057	07	07	RE 7	
0058	08	06	*	SN
0059	06	00	ST 0	
0060	07	03	RE 3	
0061	04	00	× 0	
0062	06	12	ST 12	
0063	07	07	RE 7	
0064	08	07	*	CS
0065	06	01	ST 1	
0066	07	03	RE 3	
0067	04	01	× 1	
0068	06	13	ST 13	
0069	07	05	RE 5	
0070	03	00	− 0	
0071	07	06	RE 6	
0072	03	01	− 1	
0073	07	12	RE 12	
0074	06	05	ST 5	
0075	07	13	RE 13	
0076	06	06	ST 6	
0077	07	10	RE 10	
0078	02	00	+ 0	
0079	07	11	RE 11	

0080	02	01	+1
0081	09	02	* a
0082	05	02	÷2
0083	02	02	+2
0084	07	00	RE0
0085	06	14	ST14
0086	09	12	* I
0087	03	14	−14
0088	06	10	ST10
0089	07	01	RE1
0090	06	14	ST14
0091	09	12	* I
0092	03	14	−14
0093	06	11	ST11
0094	00	01	E1
0095	00	00	E0
0096	02	07	+7
0097	06	14	ST14
0098	07	08	RE8
0099	03	14	−14
0100	08	05	* J.
0101	08	00	* S
0102	00	04	E4
0103	00	01	E1
0104	02	04	+4
0105	00	02	E2
0106	06	14	ST14
0107	07	04	RE4
0108	03	14	−14
0109	09	04	* J.
0110	08	00	* S
0111	00	05	E5
0112	00	03	E3
0113	06	14	ST14
0114	07	04	RE4
0115	03	14	−14
0116	09	04	* J.
0117	08	00	* S
0118	00	06	E6
0119	00	04	E4
0120	06	14	ST14
0121	07	04	RE4
0122	03	14	−14
0123	09	04	* J.
0124	08	00	* S
0125	00	07	E7
0126	00	02	E2
0127	00	02	E2
0128	00	04	E4
0129	06	03	ST3
0130	00	01	E1
0131	00	00	E0
0132	06	07	ST7
0133	00	00	E0
0134	06	05	ST5
0135	00	02	E2
0136	00	02	E2
0137	00	04	E4
0138	06	06	ST6
0139	08	00	* S
0140	00	04	E4
0141	09	00	* M
0142	00	05	E5
0143	00	04	E4
0144	00	04	E4
0145	00	09	E9
0146	06	03	ST3
0147	00	01	E1
0148	00	00	E0
0149	00	00	E0
0150	06	07	ST7
0151	00	01	E1
0152	00	09	E9
0153	00	00	E0
0154	06	08	ST8
0155	00	04	E4
0156	00	04	E4
0157	00	09	E9
0158	06	05	ST5
0159	00	00	E0

0160	06	06	ST 6	
0161	08	00	*	S
0162	00	04	E 4	
0163	09	00	*	M
0164	00	06	E 6	
0165	00	08	E 8	
0166	00	09	E 9	
0167	00	08	E 8	
0168	06	00	ST 0	
0169	00	00	E 0	
0170	06	01	ST 1	
0171	09	02	*	α
0172	05	03	÷ 3	
0173	02	02	+ 2	
0174	00	04	E 4	
0175	00	04	E 4	
0176	00	09	E 9	
0177	06	03	ST 3	
0178	00	01	E 1	
0179	00	09	E 9	
0180	00	00	E 0	
0181	06	07	ST 7	
0182	00	02	E 2	
0183	00	08	E 8	
0184	00	00	E 0	
0185	06	08	ST 8	
0186	00	00	E 0	
0187	06	05	ST 5	
0188	00	12	E 12	
0189	00	04	E 4	
0190	00	04	E 4	
0191	00	09	E 9	
0192	06	06	ST 6	
0193	08	00	*	S
0194	00	04	E 4	
0195	09	00	*	M
0196	00	07	E 7	
0197	00	00	E 0	
0198	06	00	ST 0	
0199	00	12	E 12	
0200	00	08	E 8	
0201	00	09	E 9	
0202	00	08	E 6	
0203	06	01	ST 1	
0204	09	02	*	α
0205	05	02	÷ 2	
0206	02	02	+ 2	
0207	00	05	E 5	
0208	00	00	E 0	
0209	00	05	E 5	
0210	06	00	ST 0	
0211	00	02	E 2	
0212	00	05	E 5	
0213	00	00	E 0	
0214	06	01	ST 1	
0215	09	02	*	α
0216	05	03	÷ 3	
0217	02	02	+ 2	
0218	00	01	E 1	
0219	06	01	ST 1	
0220	09	02	*	α
0221	05	08	÷ 8	
0222	02	02	+ 2	
0223	00	00	E 0	
0224	06	00	ST 0	
0225	00	01	E 1	
0226	00	02	E 2	
0227	06	01	ST 1	
0228	09	02	*	α
0229	05	10	÷ 10	
0230	01	04	T 4	
0231	01	15	T 15	
0232	00	05	E 5	
0233	02	05	+ 5	
0234	02	13	+ 13	
0235	01	12	T 12	
0236	02	06	+ 6	
0237	02	12	+ 12	
0238	02	05	+ 5	
0239	05	03	÷ 3	

0240	01	09	T9
0241	01	13	T13
0242	05	03	÷3
0243	01	12	T12
0244	02	13	+13
0245	01	15	T15
0246	01	04	T4
0247	02	07	+7
0248	02	07	+7
0249	01	12	T12
0250	02	06	+6
0251	02	12	+12
0252	02	05	+5
0253	05	03	÷3
0254	02	12	+12
0255	01	09	T9
0256	01	09	T9
0257	01	13	T13
0258	02	13	+13
0259	01	04	T4
0260	02	06	+6
0261	01	12	T12
0262	02	07	+7
0263	02	05	+5
0264	01	01	T1
0265	05	11	÷11
0266	02	02	+2
0267	09	03	* SP

0268	09	00	*	M
0269	00	02	E2	
0270	06	15	ST15	
0271	00	02	E2	
0272	00	10	E10	
0273	00	01	E1	
0274	06	14	ST14	
0275	00	02	E2	
0276	00	00	E0	
0277	05	15	÷15	
0278	09	11	*	[illegible]
0279	09	01	*	ST
0280	01	09	T9	
0281	05	14	÷14	
0282	09	01	*	ST
0283	01	08	T8	
0284	00	03	E3	
0285	00	00	E0	
0286	06	02	ST2	
0287	09	03	*	SP

0288	09	00	* M
0289	10	01	f 1
0290	15	13	D13
0291	07	02	RE 2
0292	06	14	ST14
0293	08	01	* RE
0294	01	08	T 8
0295	05	14	÷14
0296	15	11	D11
0297	06	02	ST 2
0298	00	01	E 1
0299	02	02	+ 2
0300	15	13	D13
0301	07	01	RE 1
0302	06	14	ST14
0303	08	01	* RE
0304	01	08	T 8
0305	05	14	÷14
0306	15	11	D11
0307	06	02	ST 2
0308	00	01	E 1
0309	02	02	+ 2
0310	15	13	D13
0311	07	03	RE 3
0312	15	13	D13
0313	07	03	RE 3
0314	06	14	ST14
0315	09	02	* α
0316	11	01	F 1
0317	09	12	* I
0318	06	15	ST15
0319	09	02	* α
0320	10	01	f 1
0321	03	14	−14
0322	00	02	E 2
0323	02	14	+14
0324	09	00	* M
0325	08	06	* SN
0326	00	01	E 1
0327	03	14	−14
0328	00	01	E 1
0329	00	00	E 0
0330	04	15	×15
0331	07	14	RE14
0332	08	04	* Jo
0333	08	00	* S
0334	08	06	* SN
0335	07	15	RE15
0336	15	11	D11
0337	06	02	ST 2
0338	00	01	E 1
0339	02	02	+ 2
0340	06	04	ST 4
0341	09	15	* RT

0342	09	00	* M
0343	10	02	f 2
0344	00	00	E 0
0345	06	00	ST 0
0346	00	01	E 1
0347	06	01	ST 1
0348	09	02	* α
0349	05	08	÷ 8
0350	02	02	+ 2
0351	00	01	E 1
0352	00	02	E 2
0353	06	01	ST 1
0354	09	02	* α
0355	05	10	÷ 10
0356	02	02	+ 2
0357	00	05	E 5
0358	00	04	E 4
0359	00	07	E 7
0360	06	00	ST 0
0361	00	05	E 5
0362	00	06	E 6
0363	00	03	E 3
0364	06	01	ST 1
0365	00	03	E 3
0366	00	00	E 0
0367	06	02	ST 2
0368	00	04	E 4
0369	00	04	E 4
0370	00	09	E 9
0371	06	03	ST 3
0372	09	02	* α
0373	05	11	÷ 11
0374	05	03	÷ 3
0375	02	02	+ 2
0376	01	00	T 0
0377	01	01	T 1
0378	01	10	T 10
0379	01	11	T 11
0380	11	01	F 1
0381	08	05	* J+
0382	11	02	F 2
0383	08	05	* J+
0384	11	03	F 3
0385	08	03	* Go
0386	07	05	RE 5
0387	06	00	ST 0
0388	07	06	RE 6
0389	06	01	ST 1
0390	00	02	E 2
0391	02	02	+ 2
0392	09	02	* α
0393	05	03	÷ 3
0394	01	06	T 6
0395	02	02	+ 2
0396	10	10	f 10
0397	07	04	RE 4
0398	06	14	ST 14
0399	07	02	RE 2
0400	03	14	− 14
0401	08	04	* Jo
0402	08	00	* S
0403	00	03	E 3
0404	09	02	* α
0405	05	11	÷ 11
0406	02	02	+ 2
0407	09	03	* SP
0408	09	00	* M
0409	00	03	E 3
0410	07	10	RE 10
0411	02	00	+ 0
0412	07	11	RE 11
0413	02	01	+ 1
0414	07	00	RE 0
0415	00	12	E 12
0416	06	00	ST 0
0417	07	01	RE 1
0418	00	12	E 12
0419	06	01	ST 1
0420	11	01	F 1
0421	08	05	* J+

0422	11	02	F 2
0423	08	05	* J+
0424	11	03	F 3
0425	03	03	* bo
0426	07	05	RE 5
0427	02	00	+ 0
0428	07	06	RE 6
0429	02	01	+ 1
0430	09	02	* α
0431	05	03	÷ 3
0432	01	06	T 6
0433	02	02	+ 2
0434	10	10	f 10
0435	07	05	RE 5
0436	06	00	ST 0
0437	07	06	RE 6
0438	06	01	ST 1
0439	00	02	E 2
0440	02	02	+ 2
0441	07	04	RE 4
0442	06	14	ST 14
0443	07	02	RE 2
0444	03	14	− 14
0445	08	04	* Jo
0446	08	00	* S
0447	00	03	E 3
0448	09	02	* α
0449	05	11	÷ 11
0450	02	02	+ 2
0451	09	03	* SP
0452	09	00	* M
0453	10	10	f 10
0454	07	00	RE 0
0455	06	07	ST 7
0456	07	01	RE 1
0457	06	08	ST 8
0458	00	00	E 0
0459	06	00	ST 0
0460	00	01	E 1
0461	00	02	E 2
0462	00	12	E 12
0463	06	01	ST 1
0464	09	02	* α
0465	05	03	÷ 3
0466	02	02	+ 2
0467	07	07	RE 7
0468	06	00	ST 0
0469	07	08	RE 8
0470	06	01	ST 1
0471	09	15	* RT

0472	09	00	*	M
0473	10	03	f 3	
0474	09	02	*	α
0475	05	11	÷11	
0476	02	02	+2	
0477	00	09	E9	
0478	00	09	E9	
0479	00	09	E9	
0480	06	00	ST0	
0481	00	09	E9	
0482	00	09	E9	
0483	00	09	E9	
0484	06	01	ST1	
0485	06	01	ST1	
0486	09	02	*	α
0487	05	03	÷3	
0488	02	02	+2	
0489	00	00	E0	
0490	06	00	ST0	
0491	00	01	E1	
0492	06	01	ST1	
0493	09	02	*	α
0494	05	08	÷8	
0495	02	02	+2	
0496	00	00	E0	
0497	06	00	ST0	
0498	00	01	E1	
0499	00	02	E2	
0500	06	01	ST1	
0501	09	02	*	α
0502	05	10	÷10	
0503	02	02	+2	
0504	00	00	E0	
0505	06	00	ST0	
0506	00	04	E4	
0507	00	00	E0	
0508	06	01	ST1	
0509	09	02	*	α
0510	05	03	÷3	
0511	02	02	+2	
0512	00	03	E3	
0513	00	02	E2	
0514	06	02	ST2	
0515	09	00	*	M
0516	08	07	*	CS
0517	15	11	D11	
0518	07	02	RE2	
0519	15	02	D2	
0520	01	01	T1	
0521	00	03	E3	
0522	02	02	+2	
0523	00	02	E2	
0524	00	00	E0	
0525	00	12	E12	
0526	06	00	ST0	
0527	00	01	E1	
0528	00	09	E9	
0529	00	02	E2	
0530	00	12	E12	
0531	06	01	ST1	
0532	09	02	*	α
0533	05	03	÷3	
0534	02	02	+2	
0535	07	02	RE2	
0536	06	00	ST0	
0537	07	04	RE4	
0538	09	02	*	α
0539	08	05	*	J+
0540	08	00	*	S
0541	08	07	*	CS
0542	07	04	RE4	
0543	06	02	ST2	
0544	09	02	*	α
0545	05	11	÷11	
0546	02	02	+2	
0547	09	15	*	RT

0548	09	00	*	M
0549	10	04	f 4	
0550	09	02	*	α
0551	05	11	÷11	
0552	02	02	+2	
0553	00	05	E5	
0554	00	01	E1	
0555	00	00	E0	
0556	06	00	ST0	
0557	00	09	E9	
0558	00	09	E9	
0559	00	09	E9	
0560	06	01	ST1	
0561	09	02	*	α
0562	05	03	÷3	
0563	02	02	+2	
0564	00	00	E0	
0565	06	00	ST0	
0566	00	04	E4	
0567	00	00	E0	
0568	06	01	ST1	
0569	09	02	*	α
0570	05	03	÷3	
0571	02	02	+2	
0572	00	00	E0	
0573	06	00	ST0	
0574	00	01	E1	
0575	06	01	ST1	
0576	09	02	*	α
0577	05	08	÷8	
0578	02	02	+2	
0579	00	00	E0	
0580	06	00	ST0	
0581	00	01	E1	
0582	00	02	E2	
0583	06	01	ST1	
0584	09	02	*	α
0585	05	10	÷10	
0586	02	02	+2	
0587	00	03	E3	
0588	00	00	E0	
0589	06	02	ST2	
0590	09	00	*	M
0591	09	07	*	C'
0592	15	11	D11	
0593	07	02	RE2	
0594	06	05	ST5	
0595	00	01	E1	
0596	02	02	+2	
0597	15	11	D11	
0598	07	02	RE2	
0599	06	06	ST6	
0600	07	05	RE5	
0601	08	12	*	x^2
0602	06	14	ST14	
0603	07	06	RE6	
0604	00	12	E12	
0605	06	15	ST15	
0606	00	01	E1	
0607	02	15	+15	
0608	08	12	*	x^2
0609	02	14	+14	
0610	06	07	ST7	
0611	07	05	RE5	
0612	08	12	*	x^2
0613	00	12	E12	
0614	06	14	ST14	
0615	07	06	RE6	
0616	08	12	*	x^2
0617	00	12	E12	
0618	02	14	+14	
0619	00	01	E1	
0620	02	14	+14	
0621	07	07	RE7	
0622	05	14	÷14	
0623	06	08	ST8	
0624	07	05	RE5	
0625	06	14	ST14	
0626	00	02	E2	
0627	04	14	×14	

0628	07	07	RE 7
0629	05	14	÷14
0630	06	09	ST 9
0631	07	08	RE 8
0632	15	02	D 2
0633	03	03	−3
0634	00	00	E 0
0635	06	00	ST 0
0636	00	01	E 1
0637	00	02	E 2
0638	06	01	ST 1
0639	09	02	* α
0640	05	03	÷3
0641	02	02	+2
0642	07	09	RE 9
0643	15	02	D 2
0644	03	03	−3
0645	00	02	E 2
0646	00	00	E 0
0647	00	12	E 12
0648	06	00	ST 0
0649	00	02	E 2
0650	00	00	E 0
0651	00	04	E 4
0652	00	12	E 12
0653	06	01	ST 1
0654	09	02	* α
0655	05	03	÷3
0656	02	02	+2
0657	00	02	E 2
0658	02	02	+2
0659	07	04	RE 4
0660	06	14	ST 14
0661	07	02	RE 2
0662	03	14	−14
0663	08	04	* J_0
0664	08	00	* S
0665	09	07	* C'
0666	07	04	RE 4
0667	06	02	ST 2
0668	09	02	* α
0669	05	11	÷11
0670	02	02	+2
0671	09	15	* RT
0672	09	00	* M
0673	11	01	F 1
0674	15	11	D 11
0675	07	02	RE 2
0676	08	12	* x^2
0677	06	14	ST 14
0678	00	01	E 1
0679	02	02	+2
0680	15	11	D 11
0681	07	02	RE 2
0682	08	12	* x^2
0683	02	14	+14
0684	08	13	* $\sqrt{x}$
0685	06	15	ST 15
0686	00	01	E 1
0687	03	15	−15
0688	09	15	* RT
0689	09	00	* M
0690	11	02	F 2
0691	00	01	E 1
0692	03	02	−2
0693	15	11	D 11
0694	07	02	RE 2
0695	06	05	ST 5
0696	08	01	* RE
0697	01	08	T 8
0698	04	05	×5
0699	00	01	E 1
0700	02	02	+2
0701	15	11	D 11
0702	07	02	RE 2
0703	06	06	ST 6
0704	08	01	* RE
0705	01	08	T 8
0706	04	06	×6
0707	08	01	* RE

0708	01	09	T9	
0709	04	05	×5	
0710	08	01	*	RE
0711	01	09	T9	
0712	04	06	×6	
0713	00	02	E2	
0714	00	10	E10	
0715	00	01	E1	
0716	05	05	÷5	
0717	00	02	E2	
0718	00	10	E10	
0719	00	01	E1	
0720	05	06	÷6	
0721	07	03	RE3	
0722	04	05	×5	
0723	07	03	RE3	
0724	04	06	×6	
0725	00	01	E1	
0726	09	15	*	RT
0727	09	00	*	M
0728	11	03	F3	
0729	00	01	E1	
0730	03	02	−2	
0731	15	11	D11	
0732	07	02	RE2	
0733	06	15	ST15	
0734	07	14	RE14	
0735	05	15	÷15	
0736	06	05	ST5	
0737	00	01	E1	
0738	02	02	+2	
0739	15	11	D11	
0740	07	02	RE2	
0741	06	15	ST15	
0742	07	14	RE14	
0743	05	15	÷15	
0744	06	06	ST6	
0745	07	03	RE3	
0746	04	05	×5	
0747	07	03	RE3	
0748	04	06	×6	
0749	09	15	*	RT
0750	09	14	*	EP

APPENDIX G

S_{12}/S_{21} POLAR COORDINATES-PLOTTING AND LISTING PROGRAM

Verify = 7738

0000	09	00	*	M
0001	00	01	E1	
0002	09	01	*	SI
0003	01	04	T4	
0004	00	00	E0	
0005	06	00	ST0	
0006	00	01	E1	
0007	06	01	ST1	
0008	09	02	*	α
0009	05	08	÷8	
0010	02	02	+2	
0011	00	01	E1	
0012	00	02	E2	
0013	06	01	ST1	
0014	09	02	*	α
0015	05	10	÷10	
0016	02	02	+2	
0017	00	05	E5	
0018	00	04	E4	
0019	00	07	E7	
0020	06	00	ST0	
0021	00	05	E5	
0022	00	06	E6	
0023	00	03	E3	
0024	06	01	ST1	
0025	00	04	E4	
0026	00	04	E4	
0027	00	09	E9	
0028	06	03	ST3	
0029	09	02	*	α
0030	05	11	÷11	
0031	05	03	÷3	
0032	02	02	+2	
0033	00	00	E0	
0034	06	00	ST0	
0035	07	03	RE3	
0036	06	01	ST1	
0037	09	02	*	α
0038	05	03	÷3	
0039	02	02	+2	
0040	00	01	E1	
0041	00	00	E0	
0042	06	07	ST7	
0043	00	03	E3	
0044	00	07	E7	
0045	00	00	E0	
0046	06	08	ST8	
0047	00	00	E0	
0048	06	04	ST4	
0049	06	05	ST5	
0050	00	04	E4	
0051	00	04	E4	
0052	00	09	E9	
0053	06	06	ST6	
0054	00	00	E0	
0055	06	10	ST10	
0056	06	11	ST11	
0057	09	00	*	M
0058	00	04	E4	
0059	07	07	RE7	
0060	08	06	*	SI
0061	06	00	ST0	
0062	07	03	RE3	
0063	04	00	×0	
0064	06	12	ST12	
0065	07	07	RE7	
0066	08	07	*	CS
0067	06	01	ST1	
0068	07	03	RE3	
0069	04	01	×1	
0070	06	13	ST13	
0071	07	05	RE5	
0072	03	00	−0	
0073	07	06	RE6	
0074	03	01	−1	
0075	07	12	RE12	
0076	06	05	ST5	
0077	07	13	RE13	
0078	06	06	ST6	
0079	07	10	RE10	

0080	02	00	+0
0081	07	11	RE11
0082	02	01	+1
0083	09	02	* α
0084	05	02	÷2
0085	02	02	+2
0086	07	00	RE0
0087	06	14	ST14
0088	09	12	* I
0089	03	14	−14
0090	06	10	ST10
0091	07	01	RE1
0092	06	14	ST14
0093	09	12	* I
0094	03	14	−14
0095	06	11	ST11
0096	00	01	E1
0097	00	00	E0
0098	02	07	+7
0099	06	14	ST14
0100	07	08	RE8
0101	03	14	−14
0102	08	05	* J.
0103	08	00	* S
0104	00	04	E4
0105	00	00	E0
0106	06	00	ST0
0107	00	09	E9
0108	00	00	E0
0109	00	12	E12
0110	06	01	ST1
0111	09	02	* α
0112	05	03	÷3
0113	02	02	+2
0114	00	01	E1
0115	02	04	+4
0116	00	02	E2
0117	06	14	ST14
0118	07	04	RE4
0119	03	14	−14

0120	09	04	* J.
0121	08	00	* S
0122	00	05	E5
0123	00	03	E3
0124	06	14	ST14
0125	07	04	RE4
0126	03	14	−14
0127	09	04	* J.
0128	08	00	* S
0129	00	06	E6
0130	00	04	E4
0131	06	14	ST14
0132	07	04	RE4
0133	03	14	−14
0134	09	04	* J.
0135	08	00	* S
0136	00	07	E7
0137	00	05	E5
0138	06	14	ST14
0139	07	04	RE4
0140	03	14	−14
0141	09	04	* J.
0142	08	00	* S
0143	00	08	E8
0144	00	03	E3
0145	00	05	E5
0146	00	09	E9
0147	06	03	ST3
0148	00	01	E1
0149	00	00	E0
0150	06	07	ST7
0151	00	00	E0
0152	06	05	ST5
0153	00	03	E3
0154	00	05	E5
0155	00	09	E9
0156	06	06	ST6
0157	08	00	* S
0158	00	04	E4
0159	09	00	* M

0160	00	05	E5
0161	00	02	E2
0162	00	06	E6
0163	00	09	E9
0164	06	03	ST3
0165	00	01	E1
0166	00	00	E0
0167	06	07	ST7
0168	00	00	E0
0169	06	05	ST5
0170	00	02	E2
0171	00	06	E6
0172	00	09	E9
0173	06	06	ST6
0174	08	00	* S
0175	00	04	E4
0176	09	00	* M
0177	00	06	E6
0178	00	01	E1
0179	00	08	E8
0180	00	00	E0
0181	06	03	ST3
0182	00	01	E1
0183	00	00	E0
0184	06	07	ST7
0185	00	00	E0
0186	06	05	ST5
0187	00	01	E1
0188	00	08	E8
0189	00	00	E0
0190	06	06	ST6
0191	08	00	* S
0192	00	04	E4
0193	09	00	* M
0194	00	07	E7
0195	00	09	E9
0196	00	00	E0
0197	06	03	ST3
0198	00	01	E1
0199	00	00	E0
0200	06	07	ST7
0201	00	00	E0
0202	06	05	ST5
0203	00	09	E9
0204	00	00	E0
0205	06	06	ST6
0206	08	00	* S
0207	00	04	E4
0208	09	00	* M
0209	00	08	E8
0210	00	00	E0
0211	06	00	ST0
0212	00	04	E4
0213	00	04	E4
0214	00	09	E9
0215	06	01	ST1
0216	09	02	* α
0217	05	03	÷3
0218	02	02	+2
0219	00	08	E8
0220	00	09	E9
0221	00	08	E8
0222	00	12	E12
0223	06	01	ST1
0224	09	02	* α
0225	05	02	÷2
0226	02	02	+2
0227	00	04	E4
0228	00	04	E4
0229	00	09	E9
0230	06	00	ST0
0231	06	01	ST1
0232	09	02	* α
0233	05	03	÷3
0234	02	02	+2
0235	00	08	E8
0236	00	09	E9
0237	00	08	E8
0238	00	12	E12
0239	06	00	ST0

0240	00	00	E0		0280	06	00	ST0	
0241	06	01	ST1		0281	00	04	E4	
0242	09	02	*	α	0282	00	04	E4	
0243	05	02	÷2		0283	00	08	E8	
0244	02	02	+2		0284	00	12	E12	
0245	00	06	E6		0285	06	01	ST1	
0246	00	01	E1		0286	09	02	*	α
0247	06	00	ST0		0287	05	02	÷2	
0248	00	02	E2		0288	02	02	+2	
0249	00	02	E2		0289	00	01	E1	
0250	00	04	E4		0290	00	06	E6	
0251	06	01	ST1		0291	00	04	E4	
0252	09	02	*	α	0292	06	00	ST0	
0253	05	03	÷3		0293	00	01	E1	
0254	02	02	+2		0294	00	06	E6	
0255	00	07	E7		0295	00	04	E4	
0256	00	07	E7		0296	00	12	E12	
0257	00	06	E6		0297	06	01	ST1	
0258	06	00	ST0		0298	09	02	*	α
0259	00	04	E4		0299	05	03	÷3	
0260	00	04	E4		0300	02	02	+2	
0261	00	08	E8		0301	00	04	E4	
0262	00	12	E12		0302	00	04	E4	
0263	06	01	ST1		0303	00	08	E8	
0264	09	02	*	α	0304	06	00	ST0	
0265	05	02	÷2		0305	00	07	E7	
0266	02	02	+2		0306	00	07	E7	
0267	00	00	E0		0307	00	06	E6	
0268	06	00	ST0		0308	06	01	ST1	
0269	00	04	E4		0309	09	02	*	α
0270	00	04	E4		0310	05	02	÷2	
0271	00	08	E8		0311	02	02	+2	
0272	06	01	ST1		0312	00	04	E4	
0273	09	02	*	α	0313	00	04	E4	
0274	05	03	÷3		0314	00	08	E8	
0275	02	02	+2		0315	00	12	E12	
0276	00	07	E7		0316	06	00	ST0	
0277	00	07	E7		0317	00	00	E0	
0278	00	06	E6		0318	06	01	ST1	
0279	00	12	E12		0319	09	02	*	α

0320	05	03	÷3	
0321	02	02	+2	
0322	00	04	E4	
0323	00	04	E4	
0324	00	08	E8	
0325	06	00	ST0	
0326	00	07	E7	
0327	00	07	E7	
0328	00	06	E6	
0329	00	12	E12	
0330	06	01	ST1	
0331	09	02	*	α
0332	05	02	÷2	
0333	05	11	÷11	
0334	02	02	+2	
0335	08	01	*	RE
0336	01	04	T4	
0337	06	14	ST14	
0338	00	02	E2	
0339	00	00	E0	
0340	05	14	÷14	
0341	09	11	*	y^x
0342	06	14	ST14	
0343	00	05	E5	
0344	00	04	E4	
0345	00	07	E7	
0346	06	00	ST0	
0347	00	05	E5	
0348	00	06	E6	
0349	00	03	E3	
0350	06	01	ST1	
0351	09	02	*	α
0352	05	03	÷3	
0353	02	02	+2	
0354	00	00	E0	
0355	06	00	ST0	
0356	00	04	E4	
0357	00	06	E6	
0358	00	01	E1	
0359	06	01	ST1	
0360	09	02	*	α
0361	05	03	÷3	
0362	02	02	+2	
0363	07	14	RC14	
0364	15	02	D2	
0365	02	02	+2	
0366	09	02	*	α
0367	05	11	÷11	
0368	02	02	+2	
0369	09	03	*	SP

0370	09	00	*	M
0371	00	02	E2	
0372	09	01	*	ST
0373	01	08	T8	
0374	00	03	E3	
0375	00	00	E0	
0376	06	02	ST2	
0377	09	03	*	SP

0378	09	00	* M
0379	10	01	f 1
0380	15	13	D13
0381	07	02	RE 2
0382	06	14	ST14
0383	08	01	* RE
0384	01	08	T 8
0385	05	14	÷14
0386	15	11	D11
0387	06	02	ST 2
0388	00	01	E 1
0389	02	02	+ 2
0390	15	13	D13
0391	07	01	RE 1
0392	06	14	ST14
0393	08	01	* RE
0394	01	08	T 8
0395	05	14	÷14
0396	15	11	D11
0397	06	02	ST 2
0398	00	01	E 1
0399	02	02	+ 2
0400	15	13	D13
0401	07	03	RE 3
0402	15	13	D13
0403	07	03	RE 3
0404	06	14	ST14
0405	09	02	* α
0406	11	01	F 1
0407	09	12	* I
0408	06	15	ST15
0409	09	02	* α
0410	10	01	f 1
0411	03	14	−14
0412	00	02	E 2
0413	02	14	+14
0414	09	00	* M
0415	08	06	* JN
0416	00	01	E 1
0417	03	14	−14
0418	00	01	E 1
0419	00	00	E 0
0420	04	15	×15
0421	07	14	RE14
0422	08	04	* Jo
0423	08	00	* S
0424	08	06	* JN
0425	07	15	RE15
0426	15	11	D11
0427	06	02	ST 2
0428	00	01	E 1
0429	02	02	+ 2
0430	06	04	ST 4
0431	09	15	* RT

0432	09	00	*	M
0433	10	02	f 2	
0434	00	00	E 0	
0435	06	00	ST 0	
0436	00	01	E 1	
0437	06	01	ST 1	
0438	09	02	*	α
0439	05	08	÷ 8	
0440	02	02	+ 2	
0441	00	01	E 1	
0442	00	02	E 2	
0443	06	01	ST 1	
0444	09	02	*	α
0445	05	10	÷ 10	
0446	02	02	+ 2	
0447	00	05	E 5	
0448	00	04	E 4	
0449	00	07	E 7	
0450	06	00	ST 0	
0451	00	05	E 5	
0452	00	06	E 6	
0453	00	03	E 3	
0454	06	01	ST 1	
0455	00	03	E 3	
0456	00	00	E 0	
0457	06	02	ST 2	
0458	00	04	E 4	
0459	00	04	E 4	
0460	00	09	E 9	
0461	06	03	ST 3	
0462	09	02	*	α
0463	05	11	÷ 11	
0464	05	03	÷ 3	
0465	02	02	+ 2	
0466	01	00	T 0	
0467	01	01	T 1	
0468	01	10	T 10	
0469	01	11	T 11	
0470	15	11	D 11	
0471	07	02	RE 2	
0472	06	00	ST 0	
0473	07	03	RE 3	
0474	04	00	× 0	
0475	00	01	E 1	
0476	02	02	+ 2	
0477	15	11	D 11	
0478	07	02	RE 2	
0479	06	01	ST 1	
0480	07	03	RE 3	
0481	04	01	× 1	
0482	00	02	E 2	
0483	02	02	+ 2	
0484	09	02	*	α
0485	05	03	÷ 3	
0486	01	06	T 6	
0487	02	02	+ 2	
0488	10	10	f 10	
0489	07	04	RE 4	
0490	06	14	ST 14	
0491	07	02	RE 2	
0492	03	14	− 14	
0493	08	04	*	Jo
0494	08	00	*	S
0495	00	03	E 3	
0496	09	02	*	α
0497	05	11	÷ 11	
0498	02	02	+ 2	
0499	09	03	*	SP
0500	09	00	*	M
0501	00	03	E 3	
0502	07	10	RE 10	
0503	02	00	+ 0	
0504	07	11	RE 11	
0505	02	01	+ 1	
0506	07	00	RE 0	
0507	00	12	E 12	
0508	06	00	ST 0	
0509	07	01	RE 1	
0510	00	12	E 12	
0511	06	01	ST 1	

0512	15	11	D11	
0513	07	02	RE 2	
0514	06	14	ST14	
0515	07	03	RE 3	
0516	04	14	×14	
0517	02	00	+0	
0518	00	01	E 1	
0519	02	02	+2	
0520	15	11	D11	
0521	07	02	RE 2	
0522	06	14	ST14	
0523	07	03	RE 3	
0524	04	14	×14	
0525	02	01	+1	
0526	00	01	E 1	
0527	03	02	−2	
0528	09	02	*	α
0529	05	03	÷3	
0530	01	06	T 6	
0531	02	02	+2	
0532	10	10	f10	
0533	07	00	RE 0	
0534	06	14	ST14	
0535	09	12	*	I
0536	03	14	−14	
0537	06	10	ST10	
0538	07	01	RE 1	
0539	06	14	ST14	
0540	09	12	*	I
0541	03	14	−14	
0542	06	11	ST11	
0543	15	11	D11	
0544	07	02	RE 2	
0545	06	14	ST14	
0546	07	03	RE 3	
0547	04	14	×14	
0548	06	00	ST 0	
0549	00	01	E 1	
0550	02	02	+2	
0551	15	11	D11	
0552	07	02	RE 2	
0553	06	14	ST14	
0554	07	03	RE 3	
0555	04	14	×14	
0556	06	01	ST 1	
0557	00	02	E 2	
0558	02	02	+2	
0559	07	04	RE 4	
0560	06	14	ST14	
0561	07	02	RE 2	
0562	03	14	−14	
0563	08	04	*	Jo
0564	08	00	*	S
0565	00	03	E 3	
0566	09	02	*	α
0567	05	11	÷11	
0568	02	02	+2	
0569	09	03	*	SP
0570	09	00	*	M
0571	10	10	f10	
0572	07	00	RE 0	
0573	06	06	ST 6	
0574	07	01	RE 1	
0575	06	07	ST 7	
0576	00	00	E 0	
0577	06	00	ST 0	
0578	00	01	E 1	
0579	00	02	E 2	
0580	00	12	E12	
0581	06	01	ST 1	
0582	09	02	*	α
0583	05	03	÷3	
0584	02	02	+2	
0585	07	06	RE 6	
0586	06	00	ST 0	
0587	07	07	RE 7	
0588	06	01	ST 1	
0589	09	15	*	RI

0590	09	00	*	M
0591	10	03	f 3	
0592	09	02	*	α
0593	05	11	÷11	
0594	02	02	+2	
0595	00	09	E 9	
0596	00	09	E 9	
0597	00	09	E 9	
0598	06	00	ST 0	
0599	06	01	ST 1	
0600	09	02	*	α
0601	05	03	÷3	
0602	02	02	+2	
0603	00	00	E 0	
0604	06	00	ST 0	
0605	00	01	E 1	
0606	06	01	ST 1	
0607	09	02	*	α
0608	05	08	÷8	
0609	02	02	+2	
0610	00	00	E 0	
0611	06	00	ST 0	
0612	00	01	E 1	
0613	00	02	E 2	
0614	06	01	ST 1	
0615	09	02	*	α
0616	05	10	÷10	
0617	02	02	+2	
0618	00	00	E 0	
0619	06	00	ST 0	
0620	00	04	E 4	
0621	00	00	E 0	
0622	06	01	ST 1	
0623	09	02	*	α
0624	05	03	÷3	
0625	02	02	+2	
0626	00	03	E 3	
0627	00	02	E 2	
0628	06	02	ST 2	
0629	09	00	*	M
0630	08	07	*	ω
0631	15	11	D11	
0632	07	02	RE 2	
0633	15	02	D 2	
0634	01	01	T 1	
0635	00	03	E 3	
0636	02	02	+2	
0637	00	02	E 2	
0638	00	00	E 0	
0639	00	12	E12	
0640	06	00	ST 0	
0641	00	01	E 1	
0642	00	09	E 9	
0643	00	02	E 2	
0644	00	12	E12	
0645	06	01	ST 1	
0646	09	02	*	α
0647	05	03	÷3	
0648	02	02	+2	
0649	07	02	RE 2	
0650	06	00	ST 0	
0651	07	04	RE 4	
0652	09	02	*	α
0653	08	05	*	J+
0654	08	00	*	S
0655	08	07	*	ω
0656	07	04	RE 4	
0657	06	02	ST 2	
0658	09	02	*	α
0659	05	11	÷11	
0660	02	02	+2	
0661	09	15	*	NT

0662	09	00	*	M
0663	10	04	f 4	
0664	09	02	*	α
0665	05	11	÷11	
0666	02	02	+2	
0667	00	05	E5	
0668	00	01	E1	
0669	00	00	E0	
0670	06	00	ST0	
0671	00	09	E9	
0672	00	09	E9	
0673	00	09	E9	
0674	06	01	ST1	
0675	09	02	*	α
0676	05	03	÷3	
0677	02	02	+2	
0678	00	00	E0	
0679	06	00	ST0	
0680	00	04	E4	
0681	00	00	E0	
0682	06	01	ST1	
0683	09	02	*	α
0684	05	03	÷3	
0685	02	02	+2	
0686	00	00	E0	
0687	06	00	ST0	
0688	00	01	E1	
0689	06	01	ST1	
0690	09	02	*	α
0691	05	08	÷8	
0692	02	02	+2	
0693	00	00	E0	
0694	06	00	ST0	
0695	00	01	E1	
0696	00	02	E2	
0697	06	01	ST1	
0698	09	02	*	α
0699	05	10	÷10	
0700	02	02	+2	
0701	00	03	E3	
0702	00	00	E0	
0703	06	02	ST2	
0704	09	00	*	M
0705	09	07	*	C'
0706	15	11	D11	
0707	07	02	RE2	
0708	06	05	ST5	
0709	00	01	E1	
0710	02	02	+2	
0711	15	11	D11	
0712	07	02	RE2	
0713	06	06	ST6	
0714	07	05	RE5	
0715	08	12	*	x^2
0716	06	14	ST14	
0717	07	06	RE6	
0718	08	12	*	x^2
0719	02	14	+14	
0720	08	13	*	$\sqrt{x}$
0721	06	10	ST10	
0722	07	05	RE5	
0723	06	15	ST15	
0724	08	01	*	RE
0725	01	04	T4	
0726	06	14	ST14	
0727	00	02	E2	
0728	00	00	E0	
0729	05	14	÷14	
0730	09	11	*	U'
0731	09	01	*	ST
0732	01	05	T5	
0733	08	01	*	RE
0734	01	05	T5	
0735	04	15	×15	
0736	08	12	*	x^2
0737	06	14	ST14	
0738	07	06	RE6	
0739	06	15	ST15	
0740	08	01	*	RE
0741	01	05	T5	

0742	04	15	×15
0743	08	12	* x^2
0744	02	14	+14
0745	08	13	* $\sqrt{x}$
0746	06	08	ST8
0747	07	06	RE6
0748	08	05	* J+
0749	08	00	* S
0750	09	06	* S'
0751	07	05	RE5
0752	06	14	ST14
0753	08	05	* J+
0754	08	00	* S
0755	08	08	* IN
0756	07	10	RE10
0757	05	14	÷14
0758	09	06	* S'
0759	06	09	ST9
0760	08	00	* S
0761	08	11	* e^x
0762	09	00	* M
0763	09	06	* S'
0764	07	05	RE5
0765	06	14	ST14
0766	08	05	* J+
0767	08	00	* S
0768	09	08	* T'
0769	00	01	E1
0770	00	08	E8
0771	00	00	E0
0772	06	09	ST9
0773	07	10	RE10
0774	05	14	÷14
0775	09	06	* S'
0776	03	09	−9
0777	08	00	* S
0778	08	11	* e^x
0779	09	00	* M
0780	08	08	* IN
0781	00	12	E12

0782	06	14	ST14
0783	00	03	E3
0784	00	06	E6
0785	00	00	E0
0786	06	09	ST9
0787	07	10	RE10
0788	05	14	÷14
0789	09	06	* S'
0790	03	09	−9
0791	08	00	* S
0792	08	11	* e^x
0793	09	00	* M
0794	09	08	* T'
0795	00	12	E12
0796	06	14	ST14
0797	00	01	E1
0798	00	08	E8
0799	00	00	E0
0800	06	09	ST9
0801	07	10	RE10
0802	05	14	÷14
0803	09	06	* S'
0804	02	09	+9
0805	08	00	* S
0806	08	11	* e^x
0807	09	00	* M
0808	08	11	* e^x
0809	07	08	RE8
0810	15	02	D2
0811	03	03	−3
0812	00	00	E0
0813	06	00	ST0
0814	00	01	E1
0815	00	02	E2
0816	06	01	ST1
0817	09	02	* α
0818	05	03	÷3
0819	02	02	+2
0820	07	09	RE9
0821	15	02	D2

0822	03	03	-3	
0823	00	02	E2	
0824	00	00	E0	
0825	00	12	E12	
0826	06	00	ST0	
0827	00	02	E2	
0828	00	00	E0	
0829	00	04	E4	
0830	00	12	E12	
0831	06	01	ST1	
0832	09	02	*	α
0833	05	03	÷3	
0834	02	02	+2	
0835	00	02	E2	
0836	02	02	+2	
0837	07	04	RE4	
0838	06	14	ST14	
0839	07	02	RE2	
0840	03	14	-14	
0841	08	04	*	Jo
0842	08	00	*	S
0843	09	07	*	C'
0844	07	04	RE4	
0845	06	02	ST2	
0846	09	02	*	α
0847	05	11	÷11	
0848	02	02	+2	
0849	09	15	*	RT
0850	09	14	*	EP

APPENDIX H
SCHOTTKY BARRIER CAPACITANCE-PLOTTING AND LISTING PROGRAM

Verify = 7706

0000	09	00	* M
0001	10	05	f 5
0002	09	02	* α
0003	05	11	÷ 11
0004	02	02	+ 2
0005	00	09	E 9
0006	00	08	E 8
0007	06	00	ST 0
0008	00	01	E 1
0009	00	00	E 0
0010	00	01	E 1
0011	06	01	ST 1
0012	09	02	* α
0013	05	03	÷ 3
0014	02	02	+ 2
0015	00	01	E 1
0016	00	03	E 3
0017	06	02	ST 2
0018	09	00	* M
0019	08	13	* √x
0020	00	01	E 1
0021	00	00	E 0
0022	06	00	ST 0
0023	00	00	E 0
0024	06	01	ST 1
0025	09	02	* α
0026	05	02	÷ 2
0027	02	02	+ 2
0028	00	02	E 2
0029	00	00	E 0
0030	00	12	E 12
0031	06	00	ST 0
0032	09	02	* α
0033	05	02	÷ 2
0034	02	02	+ 2
0035	00	01	E 1
0036	00	00	E 0
0037	06	00	ST 0
0038	09	02	* α
0039	05	02	÷ 2
0040	02	02	+ 2
0041	00	01	E 1
0042	03	02	− 2
0043	09	04	* J.
0044	08	00	* S
0045	09	13	* ʌl
0046	00	00	E 0
0047	06	00	ST 0
0048	00	09	E 9
0049	00	00	E 0
0050	06	01	ST 1
0051	09	02	* α
0052	05	02	÷ 2
0053	02	02	+ 2
0054	08	00	* S
0055	08	13	* √x
0056	09	00	* M
0057	09	13	* |x|
0058	00	00	E 0
0059	06	00	ST 0
0060	00	01	E 1
0061	00	08	E 8
0062	00	00	E 0
0063	00	12	E 12
0064	06	01	ST 1
0065	09	02	* α
0066	05	02	÷ 2
0067	02	02	+ 2
0068	00	01	E 1
0069	00	01	E 1
0070	06	02	ST 2
0071	09	00	* M
0072	09	11	* v'
0073	00	00	E 0
0074	06	00	ST 0
0075	00	01	E 1
0076	00	00	E 0
0077	06	01	ST 1
0078	09	02	* α
0079	05	02	÷ 2

0080	02	02	+2	
0081	00	02	E2	
0082	00	00	E0	
0083	00	12	E12	
0084	06	01	ST1	
0085	09	02	*	α
0086	05	02	÷2	
0087	02	02	+2	
0088	00	01	E1	
0089	00	00	E0	
0090	06	01	ST1	
0091	09	02	*	α
0092	05	02	÷2	
0093	02	02	+2	
0094	00	01	E1	
0095	03	02	−2	
0096	09	04	*	J•
0097	08	00	* S	
0098	11	06	F6	
0099	00	09	E9	
0100	00	00	E0	
0101	06	00	ST0	
0102	00	00	E0	
0103	06	01	ST1	
0104	09	02	*	α
0105	05	02	÷2	
0106	02	02	+2	
0107	08	00	* S	
0108	09	11	*	r^x
0109	09	00	*	M
0110	11	06	F6	
0111	00	03	E3	
0112	00	07	E7	
0113	00	00	E0	
0114	00	12	E12	
0115	06	00	ST0	
0116	00	02	E2	
0117	00	00	E0	
0118	00	00	E0	
0119	06	01	ST1	
0120	09	02	*	α
0121	05	03	÷3	
0122	02	02	+2	
0123	00	01	E1	
0124	06	01	ST1	
0125	09	02	*	α
0126	05	08	÷8	
0127	02	02	+2	
0128	00	01	E1	
0129	00	05	E5	
0130	00	12	E12	
0131	06	00	ST0	
0132	00	00	E0	
0133	06	01	ST1	
0134	09	02	*	α
0135	05	10	÷10	
0136	02	12	+12	
0137	01	12	T12	
0138	00	05	E5	
0139	01	12	T12	
0140	02	12	+12	
0141	01	04	T4	
0142	02	07	+7	
0143	01	12	T12	
0144	02	06	+6	
0145	02	12	+12	
0146	02	05	+5	
0147	02	02	+2	
0148	00	04	E4	
0149	00	00	E0	
0150	00	00	E0	
0151	00	12	E12	
0152	06	00	ST0	
0153	00	06	E6	
0154	00	09	E9	
0155	00	00	E0	
0156	00	12	E12	
0157	06	01	ST1	
0158	09	02	*	α
0159	05	03	÷3	

0160	02	02	+2	
0161	00	00	E0	
0162	06	00	ST0	
0163	00	01	E1	
0164	00	02	E2	
0165	06	01	ST1	
0166	09	02	*	α
0167	05	10	÷10	
0168	05	03	÷3	
0169	01	14	T14	
0170	01	09	T9	
0171	03	15	−15	
0172	02	07	+7	
0173	01	12	T12	
0174	00	15	E15	
0175	02	05	+5	
0176	05	11	÷11	
0177	02	02	+2	
0178	09	03	*	SP

0179	09	00	* M
0180	10	06	f 6
0181	07	04	RE 4
0182	06	03	ST 3
0183	00	03	E 3
0184	00	00	E 0
0185	06	02	ST 2
0186	00	01	E 1
0187	06	05	ST 5
0188	09	03	* SP
0189	09	00	* M
0190	08	15	* 1/x
0191	15	11	D 11
0192	06	03	ST 3
0193	00	01	E 1
0194	02	03	+ 3
0195	15	11	D 11
0196	07	02	RE 2
0197	06	06	ST 6
0198	00	01	E 1
0199	02	02	+ 2
0200	15	11	D 11
0201	07	02	RE 2
0202	06	07	ST 7
0203	00	01	E 1
0204	02	02	+ 2
0205	15	11	D 11
0206	07	02	RE 2
0207	06	08	ST 8
0208	00	01	E 1
0209	02	02	+ 2
0210	07	06	RE 6
0211	08	12	* x^2
0212	06	14	ST 14
0213	00	01	E 1
0214	06	15	ST 15
0215	07	07	RE 7
0216	03	15	− 15
0217	08	12	* x^2
0218	02	14	+ 14
0219	07	06	RE 6
0220	06	15	ST 15
0221	00	02	E 2
0222	04	15	× 15
0223	07	14	RE 14
0224	05	15	÷ 15
0225	00	12	E 12
0226	08	15	* 1/x
0227	06	14	ST 14
0228	00	01	E 1
0229	00	00	E 0
0230	00	00	E 0
0231	05	14	÷ 14
0232	09	02	* α
0233	10	00	f 0
0234	05	14	÷ 14
0235	07	08	RE 8
0236	05	14	÷ 14
0237	15	11	D 11
0238	06	03	ST 3
0239	00	01	E 1
0240	02	03	+ 3
0241	00	01	E 1
0242	02	05	+ 5
0243	09	03	* SP
0244	08	00	* S
0245	08	15	* 1/x
0246	09	15	* RT

0247	09	00	* M	0287	07	15	RE15
0248	10	07	f 7	0288	06	09	ST 9
0249	09	02	* α	0289	15	02	D 2
0250	05	11	÷11	0290	02	02	+ 2
0251	02	02	+ 2	0291	00	10	E10
0252	00	08	E 8	0292	00	08	E 8
0253	00	01	E 1	0293	06	06	ST 6
0254	06	00	ST 0	0294	00	05	E 5
0255	00	06	E 6	0295	06	02	ST 2
0256	00	03	E 3	0296	09	00	* M
0257	06	01	ST 1	0297	11	10	F 10
0258	09	02	* α	0298	07	15	RE15
0259	05	03	÷ 3	0299	06	14	ST14
0260	02	02	+ 2	0300	07	06	RE 6
0261	00	01	E 1	0301	04	14	×14
0262	06	01	ST 1	0302	00	10	E10
0263	09	02	* α	0303	00	02	E 2
0264	05	08	÷ 8	0304	03	06	− 6
0265	02	02	+ 2	0305	00	01	E 1
0266	00	00	E 0	0306	03	02	− 2
0267	06	00	ST 0	0307	09	04	* J•
0268	00	01	E 1	0308	08	00	* S
0269	00	02	E 2	0309	11	11	F 11
0270	06	01	ST 1	0310	00	00	E 0
0271	09	02	* α	0311	06	00	ST 0
0272	05	10	÷10	0312	00	01	E 1
0273	02	02	+ 2	0313	00	00	E 0
0274	07	04	RE 4	0314	00	08	E 8
0275	06	02	ST 2	0315	06	01	ST 1
0276	15	11	D 11	0316	09	02	* α
0277	07	02	RE 2	0317	05	03	÷ 3
0278	06	07	ST 7	0318	02	02	+ 2
0279	09	13	* |x|	0319	07	14	RE14
0280	06	06	ST 6	0320	15	02	D 2
0281	00	02	E 2	0321	02	02	+ 2
0282	02	02	+ 2	0322	08	00	* S
0283	08	00	* S	0323	11	10	F 10
0284	11	12	F 12	0324	09	00	* M
0285	09	00	* M	0325	11	11	F 11
0286	11	04	F 4	0326	00	01	E 1

0327	00	03	E 3	
0328	00	00	E 0	
0329	06	01	ST 1	
0330	09	02	*	α
0331	05	03	÷ 3	
0332	03	01	− 1	
0333	01	06	T 6	
0334	03	01	− 1	
0335	03	01	− 1	
0336	02	02	+ 2	
0337	00	01	E 1	
0338	00	01	E 1	
0339	00	00	E 0	
0340	06	01	ST 1	
0341	09	02	*	α
0342	05	03	÷ 3	
0343	02	02	+ 2	
0344	07	15	RE 15	
0345	06	14	ST 14	
0346	00	10	E 10	
0347	00	02	E 2	
0348	04	14	× 14	
0349	00	12	E 12	
0350	15	02	D 2	
0351	02	02	+ 2	
0352	07	04	RE 4	
0353	06	02	ST 2	
0354	00	01	E 1	
0355	02	02	+ 2	
0356	15	11	D 11	
0357	07	02	RE 2	
0358	06	06	ST 6	
0359	06	07	ST 7	
0360	00	02	E 2	
0361	02	02	+ 2	
0362	09	00	*	M
0363	11	12	F 12	
0364	15	11	D 11	
0365	07	02	RE 2	
0366	09	13	*	|X|
0367	03	06	− 6	
0368	08	05	*	J+
0369	08	00	*	S
0370	11	13	F 13	
0371	07	07	RE 7	
0372	09	13	*	|X|
0373	06	06	ST 6	
0374	00	02	E 2	
0375	02	02	+ 2	
0376	07	03	RE 3	
0377	06	14	ST 14	
0378	07	02	RE 2	
0379	03	14	− 14	
0380	00	01	E 1	
0381	03	14	− 14	
0382	08	05	*	J+
0383	08	00	*	S
0384	11	14	F 14	
0385	08	00	*	S
0386	11	12	F 12	
0387	09	00	*	M
0388	11	13	F 13	
0389	15	11	D 11	
0390	07	02	RE 2	
0391	06	07	ST 7	
0392	09	13	*	|X|
0393	06	06	ST 6	
0394	00	02	E 2	
0395	02	02	+ 2	
0396	07	03	RE 3	
0397	06	14	ST 14	
0398	07	02	RE 2	
0399	03	14	− 14	
0400	00	01	E 1	
0401	03	14	− 14	
0402	08	05	*	J+
0403	08	00	*	S
0404	11	14	F 14	
0405	08	00	*	S
0406	11	12	F 12	

0407	09	00	*	M
0408	11	14	F 14	
0409	07	07	rE 7	
0410	06	15	ST 15	
0411	00	01	E 1	
0412	02	14	+ 14	
0413	09	04	*	Jo
0414	08	00	* S	
0415	11	04	F 4	
0416	09	00	*	M
0417	11	15	F 15	
0418	07	15	rE 15	
0419	09	12	*	I
0420	08	04	* Jo	
0421	08	00	* S	
0422	11	00	F 0	
0423	00	01	E 1	
0424	00	00	E 0	
0425	04	15	× 15	
0426	08	00	* S	
0427	11	15	F 15	
0428	09	00	*	M
0429	11	00	F 0	
0430	06	14	ST 14	
0431	07	15	rE 15	
0432	03	14	− 14	
0433	00	01	E 1	
0434	02	14	+ 14	
0435	02	15	+ 15	
0436	06	14	ST 14	
0437	00	10	E 10	
0438	00	08	E 8	
0439	06	02	ST 2	
0440	00	09	E 9	
0441	00	01	E 1	
0442	00	08	E 8	
0443	06	00	ST 0	
0444	00	02	E 2	
0445	00	00	E 0	
0446	00	00	E 0	
0447	00	12	E 12	
0448	06	01	ST 1	
0449	09	02	*	a
0450	05	03	÷ 3	
0451	02	02	+ 2	
0452	00	02	E 2	
0453	03	14	− 14	
0454	08	04	* Jo	
0455	08	00	* S	
0456	11	01	F 1	
0457	09	00	*	M
0458	11	02	F 2	
0459	00	02	E 2	
0460	00	10	E 10	
0461	00	05	E 5	
0462	06	14	ST 14	
0463	06	15	ST 15	
0464	06	08	ST 8	
0465	15	02	D 2	
0466	01	01	T 1	
0467	08	00	* S	
0468	11	03	F 3	
0469	09	00	*	M
0470	11	01	F 1	
0471	00	05	E 5	
0472	06	14	ST 14	
0473	06	15	ST 15	
0474	06	08	ST 8	
0475	15	02	D 2	
0476	01	01	T 1	
0477	09	00	*	M
0478	11	03	F 3	
0479	00	01	E 1	
0480	00	08	E 8	
0481	00	00	E 0	
0482	00	12	E 12	
0483	06	00	ST 0	
0484	00	04	E 4	
0485	00	08	E 8	
0486	00	12	E 12	

0487	06	01	ST 1	
0488	09	02	*	α
0489	05	03	÷ 3	
0490	02	02	+ 2	
0491	07	15	RE 15	
0492	06	14	ST 14	
0493	07	02	RE 2	
0494	04	14	× 14	
0495	15	02	D 2	
0496	01	01	T 1	
0497	00	10	E 10	
0498	00	02	E 2	
0499	03	02	− 2	
0500	09	04	*	J.
0501	08	00	* S	
0502	11	07	F 7	
0503	08	00	* S	
0504	11	03	F 3	
0505	09	00	*	M
0506	11	07	F 7	
0507	09	02	*	α
0508	05	11	÷ 11	
0509	02	02	+ 2	
0510	09	03	*	SP

0511	09	00	* M
0512	10	08	f 8
0513	00	01	E 1
0514	00	00	E 0
0515	00	01	E 1
0516	06	00	ST 0
0517	00	09	E 9
0518	00	09	E 9
0519	00	09	E 9
0520	06	01	ST 1
0521	09	02	* α
0522	05	03	÷ 3
0523	02	02	+ 2
0524	00	01	E 1
0525	06	01	ST 1
0526	09	02	* α
0527	05	08	÷ 8
0528	02	02	+ 2
0529	00	00	E 0
0530	06	00	ST 0
0531	00	01	E 1
0532	00	02	E 2
0533	06	01	ST 1
0534	09	02	* α
0535	05	10	÷ 10
0536	02	02	+ 2
0537	07	04	RE 4
0538	06	02	ST 2
0539	00	08	E 8
0540	00	09	E 9
0541	00	08	E 8
0542	06	10	ST 10
0543	05	08	÷ 8
0544	08	15	* 1/x
0545	06	08	ST 8
0546	00	01	E 1
0547	00	11	E 11
0548	00	01	E 1
0549	00	02	E 2
0550	04	08	× 8

0551	07	10	RE 10
0552	05	09	÷ 9
0553	08	15	* 1/x
0554	09	13	* |x|
0555	06	09	ST 9
0556	00	00	E 0
0557	06	00	ST 0
0558	06	01	ST 1
0559	06	10	ST 10
0560	06	11	ST 11
0561	15	11	D 11
0562	07	02	RE 2
0563	06	01	ST 1
0564	07	09	RE 9
0565	04	01	× 1
0566	00	01	E 1
0567	02	02	+ 2
0568	15	11	D 11
0569	07	02	RE 2
0570	06	00	ST 0
0571	07	08	RE 8
0572	04	00	× 0
0573	00	01	E 1
0574	02	02	+ 2
0575	09	02	* α
0576	05	03	÷ 3
0577	01	06	T 6
0578	02	02	+ 2
0579	11	09	F 9
0580	07	03	RE 3
0581	06	14	ST 14
0582	07	02	RE 2
0583	03	14	− 14
0584	08	04	* J_0
0585	08	00	* S
0586	11	08	F 8
0587	09	02	* α
0588	05	11	÷ 11
0589	02	02	+ 2
0590	09	03	* ℘

0591	09	00	*	M
0592	11	08	F 8	
0593	07	10	RE10	
0594	02	00	+ 0	
0595	07	11	RE11	
0596	02	01	+ 1	
0597	07	00	RE 0	
0598	00	12	E12	
0599	06	00	ST 0	
0600	07	01	RE 1	
0601	00	12	E12	
0602	06	01	ST 1	
0603	15	11	D11	
0604	07	02	RE 2	
0605	06	14	ST14	
0606	07	09	RE 9	
0607	04	14	×14	
0608	02	01	+ 1	
0609	00	01	E 1	
0610	02	02	+ 2	
0611	15	11	D11	
0612	07	02	RE 2	
0613	06	14	ST14	
0614	07	08	RE 8	
0615	04	14	×14	
0616	02	00	+ 0	
0617	00	01	E 1	
0618	03	02	− 2	
0619	09	02	*	α
0620	05	03	÷ 3	
0621	01	06	T 6	
0622	02	02	+ 2	
0623	11	09	F 9	
0624	07	00	RE 0	
0625	06	14	ST14	
0626	09	12	*	I
0627	03	14	−14	
0628	06	10	ST10	
0629	07	01	RE 1	
0630	06	14	ST14	
0631	09	12	*	I
0632	03	14	−14	
0633	06	11	ST11	
0634	15	11	D11	
0635	07	02	RE 2	
0636	06	14	ST14	
0637	07	09	RE 9	
0638	04	14	×14	
0639	06	01	ST 1	
0640	00	01	E 1	
0641	02	02	+ 2	
0642	15	11	D11	
0643	07	02	RE 2	
0644	06	14	ST14	
0645	07	08	RE 8	
0646	04	14	×14	
0647	06	00	ST 0	
0648	00	01	E 1	
0649	02	02	+ 2	
0650	07	03	RE 3	
0651	06	14	ST14	
0652	07	02	RE 2	
0653	03	14	−14	
0654	08	04	*	Jo
0655	08	00	*	S
0656	11	08	F 8	
0657	09	02	*	α
0658	05	11	÷11	
0659	02	02	+ 2	
0660	09	03	*	SP
0661	09	00	*	M
0662	11	09	F 9	
0663	07	00	RE 0	
0664	06	06	ST 6	
0665	07	01	RE 1	
0666	06	07	ST 7	
0667	00	00	E 0	
0668	06	00	ST 0	
0669	00	01	E 1	
0670	00	02	E 2	

0671	00	12	E12	
0672	06	01	ST 1	
0673	09	02	*	α
0674	05	03	÷3	
0675	02	02	+2	
0676	07	06	RE 6	
0677	06	00	ST 0	
0678	07	07	RE 7	
0679	06	01	ST 1	
0680	09	15	*	RT
0681	09	03	*	SP

0682	09	00	*	M
0683	10	09	f 9	
0684	09	02	*	α
0685	05	11	÷11	
0686	02	02	+ 2	
0687	00	09	E 9	
0688	00	09	E 9	
0689	00	09	E 9	
0690	06	00	ST 0	
0691	00	01	E 1	
0692	00	00	E 0	
0693	00	01	E 1	
0694	06	01	ST 1	
0695	09	02	*	α
0696	05	03	÷ 3	
0697	02	02	+ 2	
0698	00	00	E 0	
0699	06	00	ST 0	
0700	00	01	E 1	
0701	06	01	ST 1	
0702	09	02	*	α
0703	05	08	÷ 8	
0704	02	02	+ 2	
0705	00	01	E 1	
0706	00	02	E 2	
0707	06	01	ST 1	
0708	09	02	*	α
0709	05	10	÷10	
0710	01	14	T14	
0711	01	09	T 9	
0712	03	15	−15	
0713	02	07	+ 7	
0714	01	01	T 1	
0715	05	03	÷ 3	
0716	05	03	÷ 3	
0717	05	03	÷ 3	
0718	05	03	÷ 3	
0719	05	03	÷ 3	
0720	00	05	E 5	
0721	01	04	T 4	
0722	02	12	+12	
0723	01	09	T 9	
0724	00	14	E14	
0725	01	12	T12	
0726	01	13	T13	
0727	01	12	T12	
0728	02	13	+13	
0729	01	01	T 1	
0730	02	02	+ 2	
0731	00	02	E 2	
0732	00	00	E 0	
0733	00	12	E12	
0734	06	00	ST 0	
0735	00	02	E 2	
0736	00	04	E 4	
0737	00	00	E 0	
0738	00	12	E12	
0739	06	01	ST 1	
0740	09	02	*	α
0741	05	03	÷ 3	
0742	02	02	+ 2	
0743	07	04	RE 4	
0744	06	02	ST 2	
0745	09	00	*	M
0746	10	15	f 15	
0747	15	11	D11	
0748	07	02	RE 2	
0749	15	02	D 2	
0750	02	02	+ 2	
0751	00	00	E 0	
0752	06	00	ST 0	
0753	00	03	E 3	
0754	00	00	E 0	
0755	06	01	ST 1	
0756	09	02	*	α
0757	05	03	÷ 3	
0758	02	02	+ 2	
0759	00	01	E 1	
0760	02	02	+ 2	
0761	15	11	D11	

0762	07	02	RE 2
0763	06	14	ST 14
0764	00	01	E 1
0765	00	11	E 11
0766	00	01	E 1
0767	00	02	E 2
0768	04	14	× 14
0769	15	02	D 2
0770	01	02	T 2
0771	00	02	E 2
0772	00	00	E 0
0773	00	12	E 12
0774	06	00	ST 0
0775	00	01	E 1
0776	00	06	E 6
0777	00	02	E 2
0778	00	12	E 12
0779	06	01	ST 1
0780	09	02	* α
0781	05	03	÷ 3
0782	02	02	+ 2
0783	00	01	E 1
0784	02	02	+ 2
0785	06	14	ST 14
0786	07	03	RE 3
0787	03	14	− 14
0788	08	04	* Jo
0789	08	00	* S
0790	10	15	f 15
0791	09	02	* α
0792	05	11	÷ 11
0793	02	02	+ 2
0794	09	03	* SP
0795	09	14	* EP

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