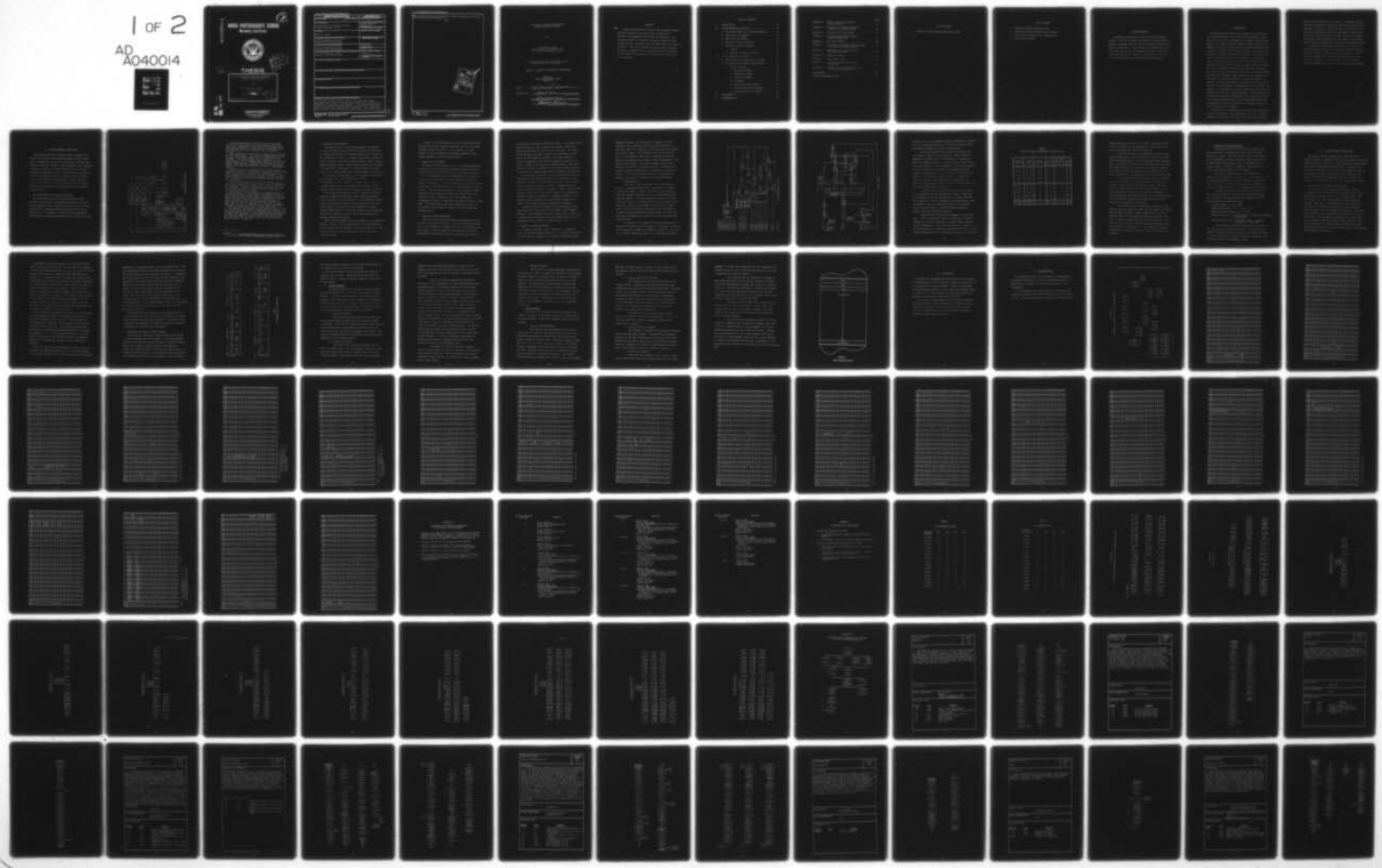
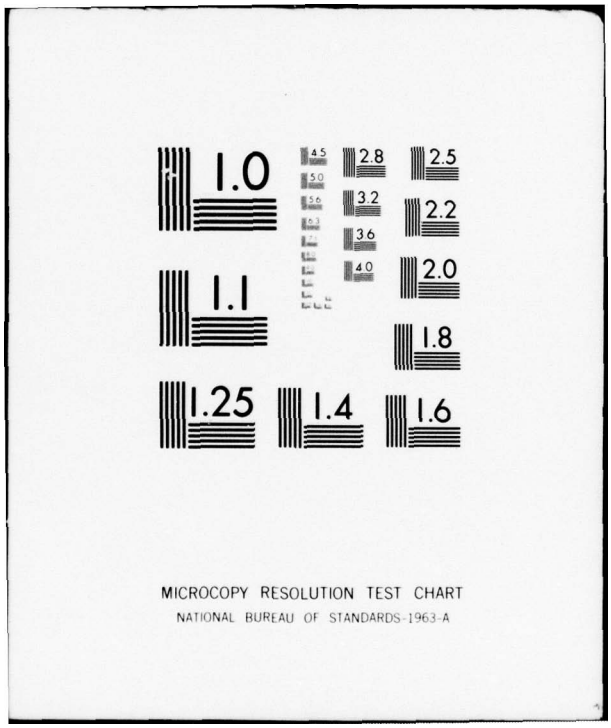
AD-A040 014 NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF F/G 17/2.1
A CALCULATOR CONTROLLED MICROWAVE NETWORK ANALYZER SYSTEM.(U)
MAR 77 D K YOUNG

UNCLASSIFIED NL

1 OF 2
AD A040014




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A040014

(2)

B.S.

NAVAL POSTGRADUATE SCHOOL

Monterey, California

DDC
RECEIVED
MAY 26 1977
C

(9) Master's THESIS

(6) A CALCULATOR CONTROLLED MICROWAVE NETWORK ANALYZER SYSTEM.

by

(10) David K. Young

(11) Mar[redacted]77 (12) 165 p.

Thesis Advisor: J. B. Knorr

AD No. ____
DDC FILE COPY

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

251 450

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Calculator Controlled Microwave Network Analyzer System		5. TYPE OF REPORT & PERIOD COVERED Masters Thesis; March 1977 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David K. Young		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1977 13. NUMBER OF PAGES 165
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A Hewlett Packard 8410S (Option 310) Microwave Network Analyzer System and the input/output interface to a Wang 600-14 Programmable Calculator are described. The original design of a digital to analog interface between the Wang 600-14 Calculator and a HP 8690B Sweep Oscillator is presented. Two system software programs which implement automatic S-parameter data collection

→ next page

DD FORM 1 JAN 73 1473 (Page 1)

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601 |

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

and either external data storage or data reduction and display are described and documented.

A Calculator Controlled Microwave Network Analyzer System

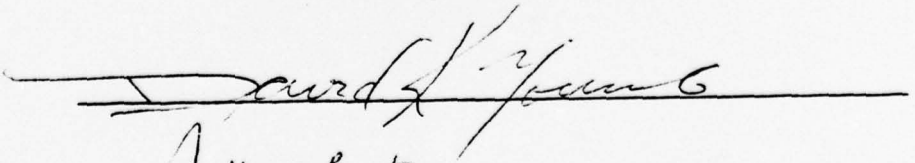
by

David Keith Young
Lieutenant, United States Navy
B.S., Purdue University, 1971

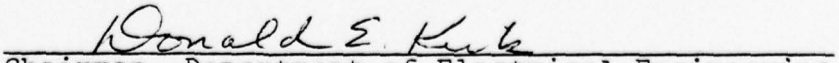
Submitted in partial fulfillment of the
requirements for the degree of

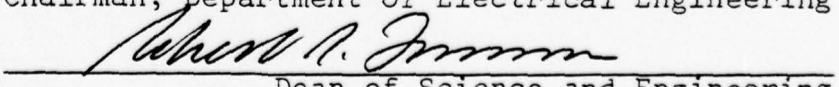
MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the
NAVAL POSTGRADUATE SCHOOL
March 1977

Author 

Approved by:
Thesis Advisor


Chairman, Department of Electrical Engineering


Dean of Science and Engineering

ABSTRACT

A Hewlett Packard 8410S (Option 310) Microwave Network Analyzer System and the input/output interface to a Wang 600-14 Programmable Calculator are described. The original design of a digital to analog interface between the Wang 600-14 Calculator and a HP 8690B Sweep Oscillator is presented. Two system software programs which implement automatic S-parameter data collection and either external data storage or data reduction and display are described and documented.

TABLE OF CONTENTS

I. INTRODUCTION 10

II. SYSTEM HARDWARE DESCRIPTION 12

A. HP 8410S (OPTION 310) NETWORK ANALYZER 12

B. WANG 600-14 CALCULATOR 15

C. WANG 623-6 I/O BUFFER 16

D. ANALOG TO DIGITAL INTERFACE 16

E. DIGITAL TO ANALOG INTERFACE 17

1. Control 18

2. Digital to Analog Converter 24

III. SYSTEM SOFTWARE DESCRIPTION 25

A. COLLECTION AND STORAGE SYSTEM PROGRAM 25

B. COLLECTION AND DISPLAY SYSTEM PROGRAM 27

1. System Programs 29

a. Bootstrap Program 29

b. Executive Programs 29

c. Display Programs 31

2. User Programs 31

a. S_{11}/S_{22} Printing Program 31

b. S_{11}/S_{22} Smith Chart Program 32

c. S_{12}/S_{21} Polar Plot Program 32

IV. CONCLUSIONS 35

V. RECOMMENDATIONS 36

		Page
Appendix A	Digital to Analog Interface Wiring Tables	37
Appendix B	Procedures for Using Collection and Storage System Program	58
Appendix C	Collection Job Code Tables	62
Appendix D	Collection and Storage System Program Memory Map	65
Appendix E	Data Tape Formats	66
Appendix F	Collection and Storage System Program Flow Charts and Descriptions	76
Appendix G	Procedures for Using Collection and Display System	107
Appendix H	Display Job Codes	109
Appendix I	User Program Table	110
Appendix J	Collection and Display System Memory Map	111
Appendix K	Collection and Display System Flow Charts and Descriptions	112
BIBLIOGRAPHY		164
INITIAL DISTRIBUTION LIST		165

LIST OF TABLES

1. Digital to Analog Interface Function Codes

LIST OF FIGURES

1. Microwave Network Analyzer System

2. Digital to Analog Interface Logic Diagram

3. Collection and Display Tape Organization

4. User Program Format

ACKNOWLEDGEMENTS

I gratefully acknowledge Captain Victor McCullough, USA-ret., for his invaluable assistance in transforming the digital to analog interface from its original prototype to a circuit board model. I also experss my appreciation to my wife Nancy for all her encouragement and help in putting this thesis in order. Finally, I would like to say a P.T.L., for without it none of this would have been possible.

I. INTRODUCTION

The Microwave Network Analyzer System, as configured at the Naval Postgraduate School Microwave Measurement Laboratory, has as its major components the Hewlett Packard 8410S (option 310) Network Analyzer System, the Wang 600-14TP Programmable Calculator, three Wang 605-1A Micro-Interfaces and a digital to analog (D/A) interface between the Wang 600-14 Calculator and a HP 8690B Sweep Oscillator. Two system software programs enable the Wang Calculator to automatically collect S-parameter data from the HP 8410S Network Analyzer System and either store the data on cassette tape or massage the data to produce characteristic parameters for display. The system is fully automated so that once the system program is loaded and initiated, user intervention is required only when called for by the calculator. User intervention is limited to providing pertinent information to the calculator in order for the program to accomplish the job requested. For example, in collecting and storing S-parameter data, the calculator will call for a start frequency, a stop frequency and a step size. Once this information is provided by the user, the system program will step the HP 8690B Sweep Oscillator as specified, collect the associated S-parameter data, and build a tape file of the data.

Initial work in establishing this system was carried out by John C. Carlton Jr. and documented in Ref. 1. The work consisted of the input interface from the HP 8410S Network

Analyzer to the Wang 600-14 Calculator. Frequency acquisition was accomplished manually and data collection for each frequency was manually initiated. Data reduction and display was accomplished without further manual intervention. Limitations encountered were the time involved in manually setting the sweep oscillator and the number of data points which could be processed due to memory storage restrictions.

The purpose of this thesis was to build a digital to analog interface to enable the Wang 600 Calculator to automatically control the HP 8690B Sweep Oscillator. System software programs were developed to maximize the control functions performed by the calculator and to minimize manual intervention involved in data collection and display.

II. SYSTEM HARDWARE DESCRIPTION

The Microwave Network Analyzer System is composed of the HP 8410S (option 310) Network Analyzer System, a Wang 600-14 Programmable Calculator, input/output interface and a Wang 612 Flat-Bed Plotter. These components are configured as shown in Figure 1. A brief description of the system components is presented below. A more detailed description of the characteristics and the operational theory can be found in the appropriate operating and service manuals listed in Ref. 2-8. A thorough description of the characteristics of the digital to analog interface is presented in Chapter II-E.

A. HP 8410S (OPTION 310) NETWORK ANALYZER

The HP 8410S (option 310) Network Analyzer System performs the function of a ratiometer between two signals and then displays these complex ratios on one of two output display units. Depending upon the configuration of the components, it is capable of measuring both transmission and reflection scattering parameters from .1 GHZ to 12.4 GHZ.

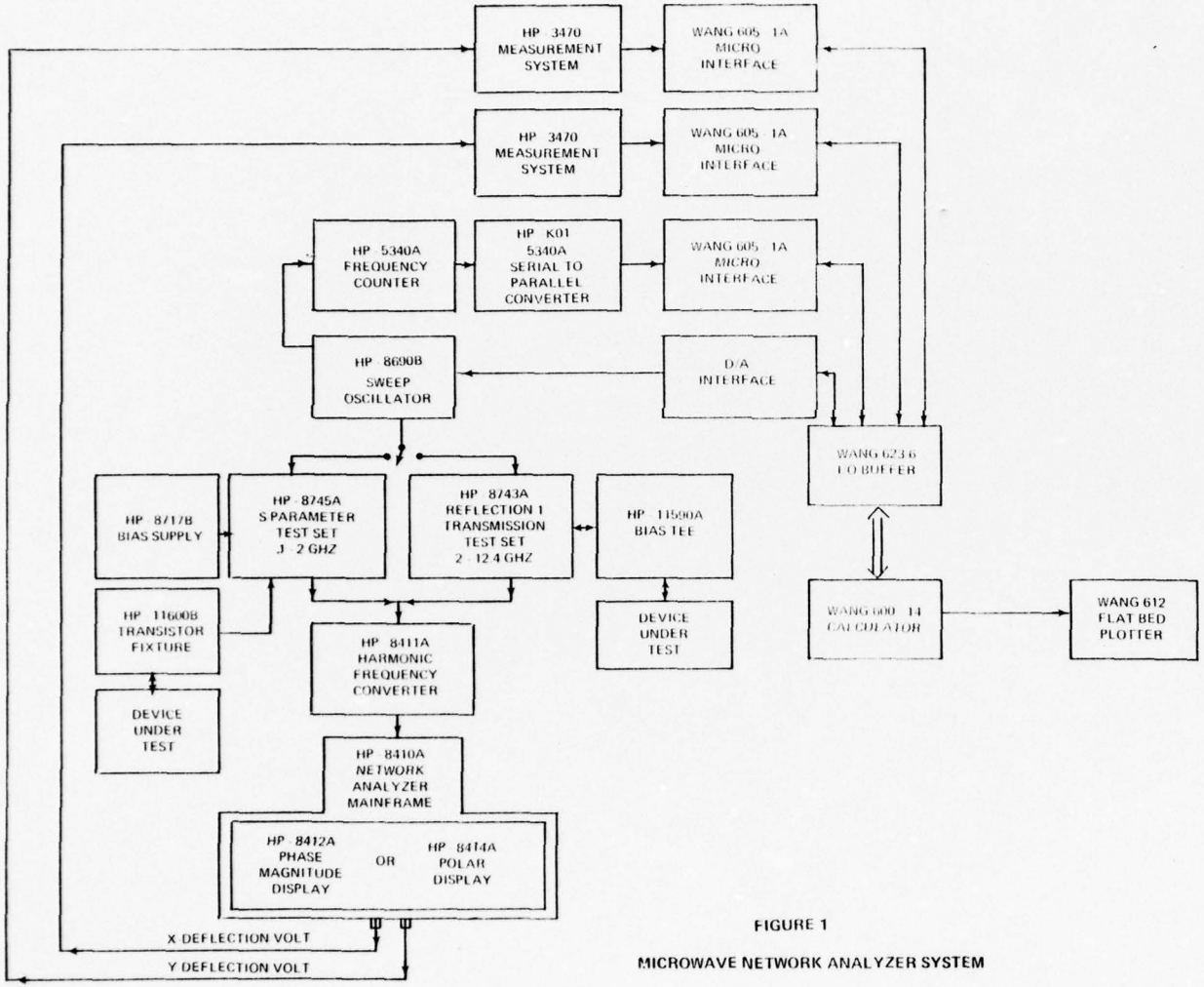


FIGURE 1

MICROWAVE NETWORK ANALYZER SYSTEM

"The HP 8690B Sweep Oscillator with the HP 8690B Series RF plug-ins serves as the RF 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.

Both transducers are capable of 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 of the transducer which operates over the frequency range desired. Pushbuttons located on the front panel of the transducer operate coaxial switches which connect the system correctly for the type of measurement desired.

Available with the transducers are the HP 11600B transistor fixture, HP 8717B bias supply and the HP 11590A Bias Tee, which allow S-parameter characterization of active Semiconductor devices. Bipolar Transistors, FET's diods, negative resistance transferred electron devices, etc. can be easily and quickly analyzed for any specific bias condition.

The HP 8411A Harmonic Frequency Converter receives the test and reference channel signals from the transducer and converts them over a range up 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 the 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."[1]

---

[1]CARLTON, J. C., Calculator-Aided Microwave Network Analysis P 13-15, MS Thesis, Naval Postgraduate School, 1974

B. WANG 600-14 CALCULATOR

The Wang 600-14 is a desktop programmable calculator. It has 1,848 memory locations (words) which are eight bits in length and are used for program storage, data storage, or any combination of both. A program instruction requires one word of storage, and a data storage register (DSR) requires eight contiguous words. Data storage registers are numbered 16 through 246. DRS number 16 occupies memory locations 1840 - 1847 and DSR number 246 occupies memory locations 0 - 7.

The range of numbers which can be represented and stored by the Wang 600-14 is $-9.999999999 \times 10^{-99}$ to $+9.999999999 \times 10^{+99}$. Numbers in either fixed point or floating point format, are represented in binary coded decimal (BCD) and are stored in memory, two digits per word.

The central processing unit (CPU) consists of sixteen registers numbered 00 through 15 and a display register which functions as the accumulator. All arithmetic/trigonometric instructions available on the Wang 600-14 are executed using the contents of the accumulator for single operand instructions, or using the contents of the accumulator and the contents of one of the 16 CPU registers for double operand instructions.

There are two external ports for connection of perpherial devices. One is a 36 pin input/output port connecting the CPU to a Wang 623-6 I/O Buffer. The second port is a 27 pin output only port which connects the CPU to a Wang 612 Flat-Bed Plotter.

Integral to the calculator is a 21-column drum printer for printing display register contents, as well as listing programs entered in memory. Also included is a tape cassette unit for loading or recording programs or data, either manually or under program control.

C. WANG 623-6 I/O BUFFER

The Wang 623-6 I/O Buffer is a 1 to 6 expander/isolator. It permits up to 6 peripheral interface devices to have on line access to the 36 pin I/O port of the Wang calculator

Due to irregularities in the manufacturer's design or wiring of the I/O buffer, all six interface ports do not function identically. All six output ports did not have pins 12 through 19 wired according to the manufacturer's specifications. The problem was brought to the attention of Wang Laboratories and corrective action was taken on only one of the six ports. Because of this, port number one (numbering from left to right) must be used for the D/A interface. The three Wang 605-1A Micro-Interface devices can be connected in any order to three of the five remaining interface ports.

D. ANALOG TO DIGITAL INTERFACE

There are three Wang 605-1A Micro-Interface devices connected to the 623-6 I/O Buffer. Two of the devices provide the X and Y deflection voltages taken from the HP 8410S Display Module. These voltages are fed through two HP 3470 Measurement Systems where they are converted from analog to

bit parallel, character parallel 8421 BCD. In the Wang 605-1A Micro-Interfaces, these voltages are further converted to serial hexadecimal for input to the I/O buffer. The third micro-interface provides a reading of the frequency output of the HP 8690B Sweep Oscillator. The sweep oscillator output is sampled by the HP 5340-A Frequency counter. The digital output of the counter is passed through a KOI 5340A Serial to Parallel Converter to the micro-interface where it is converted to serial hexadecimal and passed to the buffer.

The calculator initiates an input operation from one of the three micro-interface devices by the execution of the appropriate GROUP I - XXXX command sequence. The four digit address code which follows the GROUP I command specifies which interface device is to respond. A GROUP I 0701 command sequence causes the X deflection voltage to be sampled and passed to the display register. Likewise, a GROUP I 0702 command sequence samples the Y deflection voltage, and a GROUP I 0703 command sequence samples the frequency.

Calculator control is passed to the appropriate interface device by the execution of the GROUP I XXXX command sequence. The calculator does not regain control until the interface device returns a 0804 (GO) command and a 10 to 20 microsecond input strobe on connector pins 1 - 9.

E. DIGITAL TO ANALOG INTERFACE

The digital to analog (D/A) interface is designed to drive the HP 8690B Sweep Oscillator to a frequency specified by, and under the control of, a software subroutine called

FREQUENCY ACQUIRE. The interface is composed of three cascaded 4 bit synchronous up/down counters (N74191), a Burr-Brown DAC 80 (V) Digital to Analog Converter and extensive control logic. The interface counts up or down at one of five different clock rates, specified by the subroutine, and generates an output voltage proportional to the state of the counter. The output voltage is fed to the external FM input of the sweep oscillator. The algorithm used for frequency acquisition is described in Appendix F. Figure 2 is the logic diagram for the D/A interface and Appendix A contains the wiring cross reference tables.

1. Control Logic

The control logic performs four basic functions. First, it recognizes whether the I/O command is a GROUP I or GROUP II command. Second, the control logic returns a 0803 (GO) command along with a 10 to 20 microsecond input strobe on pins 1 - 9 to the calculator. Third, it either stops the counter or it gates one of the five clocks to the twelve bit counter and specifies the direction it should count. The fourth function the control logic performs is to insure that the counter does not recycle to an all zero state when counting up or recycle to an all one state when counting down.

All GROUP II I/O commands from the calculator are reserved for use by the D/A interface. The signal on pin 28, which designates a GROUP I or GROUP II command (I = +5 volts, II = 0 volts), along with the 15 to 25 microsecond output

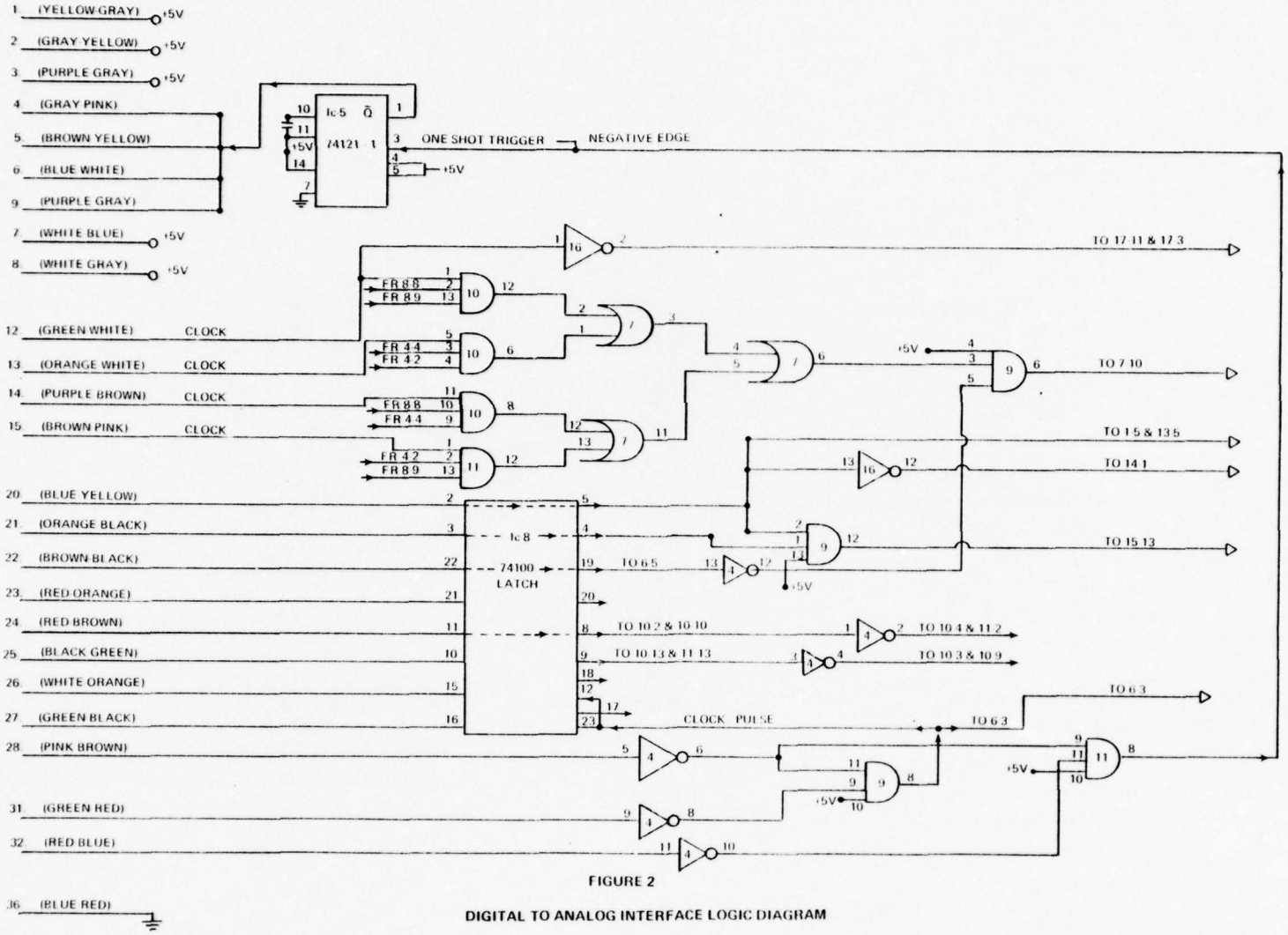


FIGURE 2

DIGITAL TO ANALOG INTERFACE LOGIC DIAGRAM

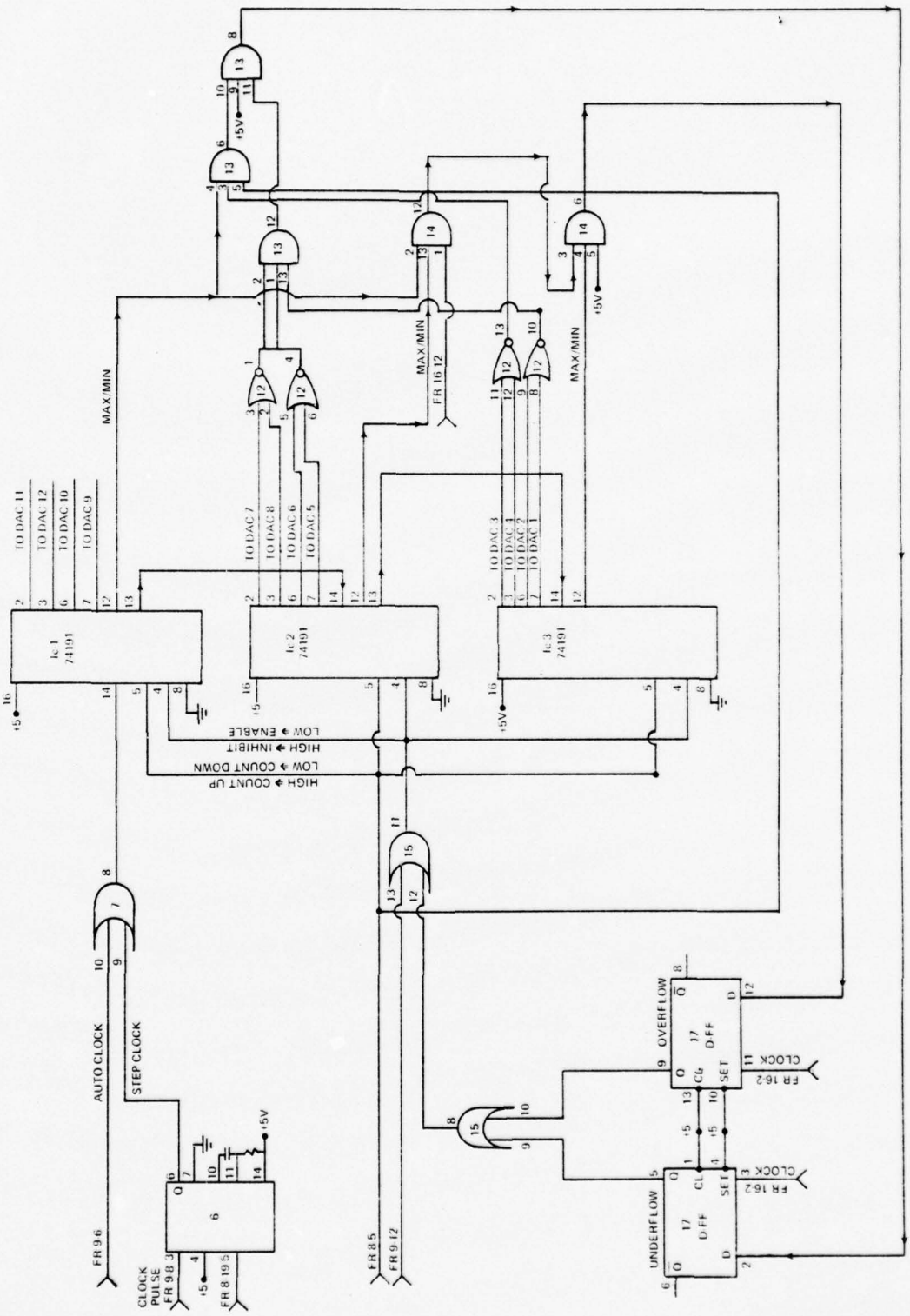


FIGURE 2 CONTINUED

strobe on Pin 31 are combined through an AND gate to produce a 15 to 25 microsecond pulse. This pulse is used to latch all GROUP II address codes into a N74100 latch.

Pins 1 through 8 of the 36 pin I/O port are used for external inputs to the calculator. When a GROUP II command is received by the D/A interface, it generates a 0803 (GO) command on pins 1 - 8 and an input strobe on pin 9 to return control to the calculator. The static condition of pins 1 through 9 is +5 volts. To generate the 0803 command requires pins 1, 2, 3, 7, 8 to be at +5 volts and pins 4, 5, 6 to be at 0 volts. Pins 4, 5, 6 and 9 are pulled 0 volts for approximately 15 microseconds by a GROUP II command signal on pin 28 and a 0 volt keyboard condition indicator signal on pin 32.

The GROUP II I/O address codes on pins 20 through 27 are latched into a N74100 eight bit latch. These four digit address codes are normally used to access different I/O interfaces. The D/A interface uses these address codes as function codes to control the counter. The function codes, listed in Table 1, either stop the counter or specify the count rate and direction.

There are five clock rates available to the interface. Four of these clock rates are available on pins 12 through 15 of the I/O connector at 724HZ, 362HZ, 181HZ and 90.5HZ, respectively. The firth clock rate is a single pulse generated by a monostable multivibrator (N74121). The combined signals sent to the interface on pins 22, 24 and 25,

TABLE I

DIGITAL TO ANALOG INTERFACE FUNCTION CODES

Function Code	Clock Rate	Count Direction	I/O Pin States						
			20	21	22	24	25	28
0406	724 HZ	Down	H	L	L	H	H	L
0306	362 HZ	Down	H	L	L	L	L	L
0206	181 HZ	Down	H	L	L	H	L	L
0106	90.5 HZ	Down	H	L	L	L	H	L
0702	STEP	Down	H	L	H	L	L	L
0405	724 HZ	Up	L	H	L	H	H	L
0305	362 HZ	Up	L	H	L	L	L	L
0205	181 HZ	Up	L	H	L	H	L	L
0105	90.5 HZ	Up	L	H	L	L	H	L
0701	STEP	Up	L	H	H	L	L	L
0704	STOP	-	H	H	L	L	L	L

specify which clock rate is to be used. The state of pins 20 and 21 specify the count direction. When pins 20 and 21 are both high the counter is disabled.

The function codes are overridden by control logic which automatically stop the counter at the all-one state while counting up and at the all-zero state while counting down. This logic ensures the D/A interface does not drive the sweep oscillator to one end of its frequency range or the other, and with one additional clock pulse force the sweep oscillator to the opposite end of its frequency range.

The all-one state of the three, four-bit, cascaded counters is detected by the simultaneous occurance of an overflow pulse from each individual counter. When this occurs a D-type Flip-Flop is set and its output is fed to the enable/disable inputs of the counter, disabling it. The counter will remain disabled until a count down function code is received, causing the overflow Flip-Flop to be reset and the counter to count down.

The all-zero state is detected by taking the eight outputs from the second and third 4-bit counters and running them through a NOR gate. When a HIGH occurs out of the NOR gate along with an underflow condition from the first 4-bit counter, an underflow D-type Flip-Flop is set. The output of the Flip-Flop is fed to the enable/disable inputs of the counter and disables it. The underflow Flip-Flop is reset when a count-up function code is received by the interface.

2. Digital to Analog Converter

The Burr-Brown DAC 80 (V) Digital to Analog (D/A) Converter accepts complimentary binary inputs from the twelve bit counter. The requirement of the D/A converter to use complimentary binary causes the interface to drive the HP 8690B Sweep Oscillator down in frequency when a count-up code is received. Likewise, a count-down code drives the sweep oscillator up in frequency.

The output voltage range of the converter, as wired for the interface, is 0 volts to 9.9976 volts $\pm$ 2.44 mv. An operational amplifier is used to increase the maximum output voltage to 13 volts which enables the interface to drive the sweep oscillator to its maximum output frequency.

Frequency resolution obtainable is a function of the frequency range of the RF plug-in module being used. The theoretical frequency resolution obtainable for the 8694A RF-Module is presented below.

Frequency Range = 8 - 12.4 GHZ

Counter Resolution = $2^{-12} = 2.441 \times 10^{-4}$

Input FM Voltage Range = 0 to 13 volts

Voltage Resolution = (Voltage range) x (counter resolution)
= 3.173 mvolts.

Frequency Resolution = (Frequency range) x (voltage resolution) = 13.96 MHZ.

The theoretical frequency resolution has proven to be poorer than is actually obtainable. The software subroutine, FREQUENCY ACQUIRE, will drive the sweep oscillator to within 900 KHZ of the desired frequency, based upon the output of the HP 5340A Frequency Counter.

III. SYSTEM SOFTWARE DESCRIPTION

Two system software programs have been developed to enable automatic S-parameter data collection from the HP 8410S Network Analyzer. The first program, Collection and Storage, will collect S-parameter data and build a cassette tape file of the collected data. The second program, Collection and Display, collects S-parameter data and displays the data or characteristic parameters derived from the data, either on the drum printout or on the Wang Flat-Bed Plotter.

A. COLLECTION AND STORAGE SYSTEM PROGRAM

The Collection and Storage system program collects S-parameter data from the HP 8410S Network Analyzer System and builds a variable length file on cassette tape. The file consists of a file identification record and data records. There are N data records in a file, where N is the number of frequency steps between a user specified start frequency and stop frequency inclusively. Each data record consists of an identification block and up to ten data blocks. Data blocks are comprised of X and Y deflection voltages as measured from the display module of the network analyzer, and the frequency the sweep oscillator was generating when the voltages were measured. Tape formats are presented in Appendix E.

The number of data blocks which can be stored in each data record is from one to ten. This allows for storage of the four scattering parameters S_{21}, S_{12}, S_{11}, S_{22} and for the storage of two sets of calibration data comprising three blocks each. Calibration data is obtained by measuring the reflection coefficients with the network analyzer terminated in a direct short circuit and two offset short circuits for both the forward and reverse channels. This data can be used to compensate for network analyzer errors generated by directivity effects in couplers, tracking and cross coupling in the forward and reflected measuring channels, and the mismatch between the connectors and the sweep oscillator. The theory for implementing calibration data measurement and S-parameter correction is found in Ref. 9.

After loading and initiating execution of the Collection and Storage system program, the program will request four collection parameters from the user. The parameters are the desired start frequency, stop frequency, step size and a Collection Job Code (CJC). The program requests these parameters by interrupting program execution and displaying the numbers 1, 2, 3, 4 in the display register. The user replies by entering in the display register the parameter called for and depressing the GO Key on the calculator keyboard.

After the last collection parameter has been entered by the user, the program stops with a two or six digit number in the display register which tells the user which scattering

parameter or calibration short is to be measured first. The user configures the HP 8410S Network Analyzer for the specified measurement and then depresses the GO key. The program will then collect one block of data for each frequency step specified, including the stop frequency and start frequency. Execution is interrupted after the last block of data is stored. In the display register will be another two or six digit number indicating the next measurement to be taken. The user rewinds the cassette tape, sets up the network analyzer for the measurement, and depresses the calculator GO key. This process repeats until all S-parameters and calibration shorts, specified by the user, have been measured and stored.

A description of the Executive or mainprogram and the twelve subroutines which comprise the Collection and Storage system program is presented in Appendix F. Appendix B gives a step-by-step procedure for using the program and Appendix C contains the Collection Job Code tables.

B. COLLECTION AND DISPLAY SYSTEM PROGRAM

The Collection and Display system program is comprised of system programs and user programs. The system programs perform tasks which are directly related to system operation. These tasks include loading specified user programs, acquiring S-parameter data, retrieving calibration data, and preparing display devices. User programs compute characteristic parameters derived from S-parameter data and display

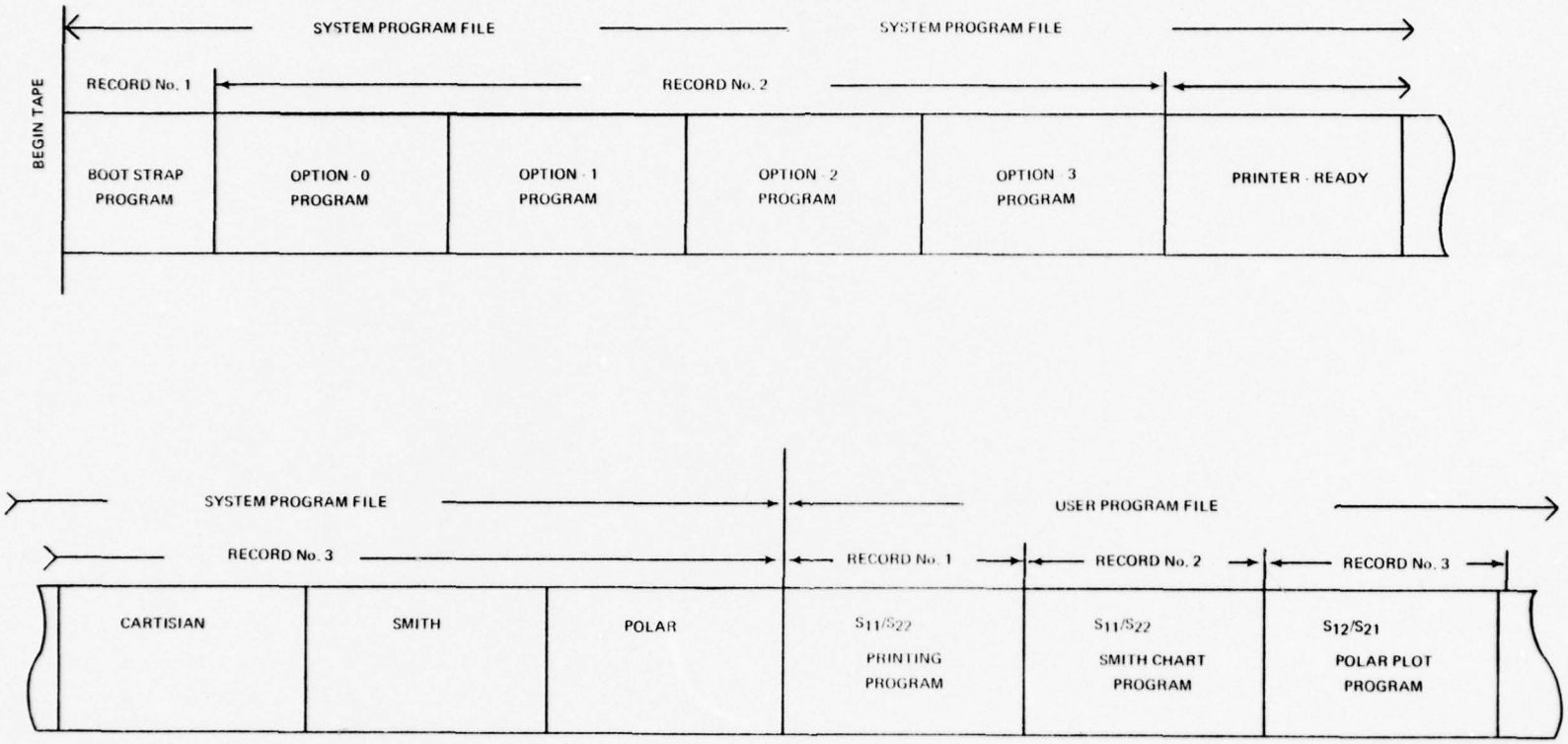


FIGURE 3

COLLECTION AND DISPLAY TAPE ORGANIZATION

the output product either on the 21-column drum printer or as a graphic plot on the flat-bed plotter.

The system programs and user programs are stored on cassette tape in files. The structure of the files, as shown in Figure 3, enable automatic loading and execution of the system.

1. System Programs

The system programs are stored on cassette tape in the System Program File. The file is comprised of three records. The first record contains the system bootstrap program, BOOT. The second record consists of four executive programs called OPTION-0, OPTION-1, OPTION-2 and OPTION-3. The last record in the file contains four display programs called PRINTER READY, CARTISIAN, SMITH, and POLAR.

a. Bootstrap Program

The bootstrap program (BOOT) is the first and only program manually loaded into the calculator memory by the user. BOOT accepts a Display Job Code (DJC) from the user and based upon the parameters specified in the DJC, loads one of the four executive programs over itself. The executive program selected is immediately executed upon the completion of the loading process.

b. Executive Programs

There exist four executive programs, two of which are operational. All four programs perform the same basic functions. They load and execute one of the four display programs; they interact with the user in defining

parameters and configuring equipment to carry out the display task; they load and pass system control to a specified User program; and they all contain a subroutine called GET DATA.

The four executive programs are configured according to the requirements of their GET DATA subroutines. S-parameter data is obtainable from either the HP 8410S Network Analyzer or from a data tape previously built by the Collection and Storage system program. The executive program, OPTION-0, contains a GET DATA subroutine and other required subroutins which enable automatic acquisition of S-parameter data from the HP 8410S Network Analyzer. OPTION-1 has a GET DATA subroutine and other associated subroutines which enable retrieval of S-parameter data from a cassette tape. The two remaining executive programs, OPTION-2 and OPTION-3, will apply calibration data, retrieved from cassette tape, to S-parameter data collected from either the network analyzer or cassette tape. The GET DATA subroutines and associated subroutines needed to obtain the calibration data and S-parameter data are operational in both programs. To make the programs operational, as designed, will require a subroutine which applies the calibration data to the S-parameter data.

The design of the four executive programs relieve User programs of having to interface to the devices which provide input data. They also permit User program flexibility since they can be written and executed independent of data source.

c. Display Programs

One of the four display programs, designated in the Display Job Code, is loaded and executed by the resident executive program to prepare either the Wang 612 Flat-Bed Plotter or the 21-column drum printer for use by a User program. The preparation involves either advancing the paper tape of the drum printer or plotting one of three coordinate systems on the plotter. The coordinate systems available to the User programs are Cartisian, Polar and a modified Smith Chart. This aspect of the system design relieves User programs of having to plot its own display coordinates.

2. User programs

The three user programs presently available were originally written by John Carlton [Ref. 9]. The programs have been modified to make them compatible with the systems programs.

a. S_{11}/S_{22} Printing Program

This program uses the calculator's 21-column drum printer to type out ten characteristics derived from reflection measurements obtained from the HP 8414A Polar Display module or cassette tape. These are frequency, VSWR, REΓ, Im Γ, $|\Gamma|$, $\angle\Gamma$, RE Z, Im Z, $|Z|$, and $\angle Z$. The program requests S-parameter data by calling the system subroutine GET DATA. GET DATA returns an X and Y deflection voltage and the frequency of the sweep oscillator. The output characteristics are computed and printed by the user program.

GET DATA is called again to provide the next data set and the process continues until all data has been collected and printed.

b. S_{11}/S_{22} Smith Chart Program

This program uses the flat-bed plotter as the display device. S-paramter reflection measurements are obtained by calling the system subroutine GET DATA. GET DATA returns the frequency and the real and imaginary parts of the reflection measurement to the program. The program prepares the input data for display and plots the output on the simplified Smith Chart drawn by the system display program The normalized inpedance of each point can be listed on the drum printer if desired.

The program can be used for devices which exhibit both negative and positive resistance. If $|\Gamma| > 1$, then the Smith Chart lines of constant resistance are interpreted as negative.

c. S_{12}/S_{21} Polar Plot Program

This program is designed for transmission measurements using the polar display. Transmission measurements provided by GET DATA are prepared and plotted on the polar coordinates previously drawn by the system display program. Frequency, magnitude and angle of each transmission coefficient can be listed on the drum printer, if desired.

d. Future User Programs

Additional User programs can be stored on tape in the User Program File without modification to the system

programs. To make them compatible with the Collection and Display System they must be written and stored in the User Program File as shown in Figure 4.

User programs may use registers 00 through 21. When requesting data from the system subroutine GET DATA, the X and Y displacement voltages are returned in registers 00 and 01. The measured frequency is returned in register 02. Data stored in registers 00 through 03 by the User program must be relocated prior to calling GET DATA if they are to be used upon return from GET DATA.

Subroutine address codes 1001 through 1015 are available for use by User programs. Address codes 1100 through 1115 are used by the System programs. All mark address codes except 0801 through 0915 are available for use by the user programs.

The calculator core memory available for a User program is dependent upon the executive program under which it is run. Under OPTION-0, a user program of up to 1000 program instructions can be stored and executed. OPTION-1 will allow programs with up to 1100 program instructions. The size of a user program, which can be run under OPTION-2 or OPTION-3, will depend upon the core requirement of the subroutine which applies the correction data to the S-parameter data.

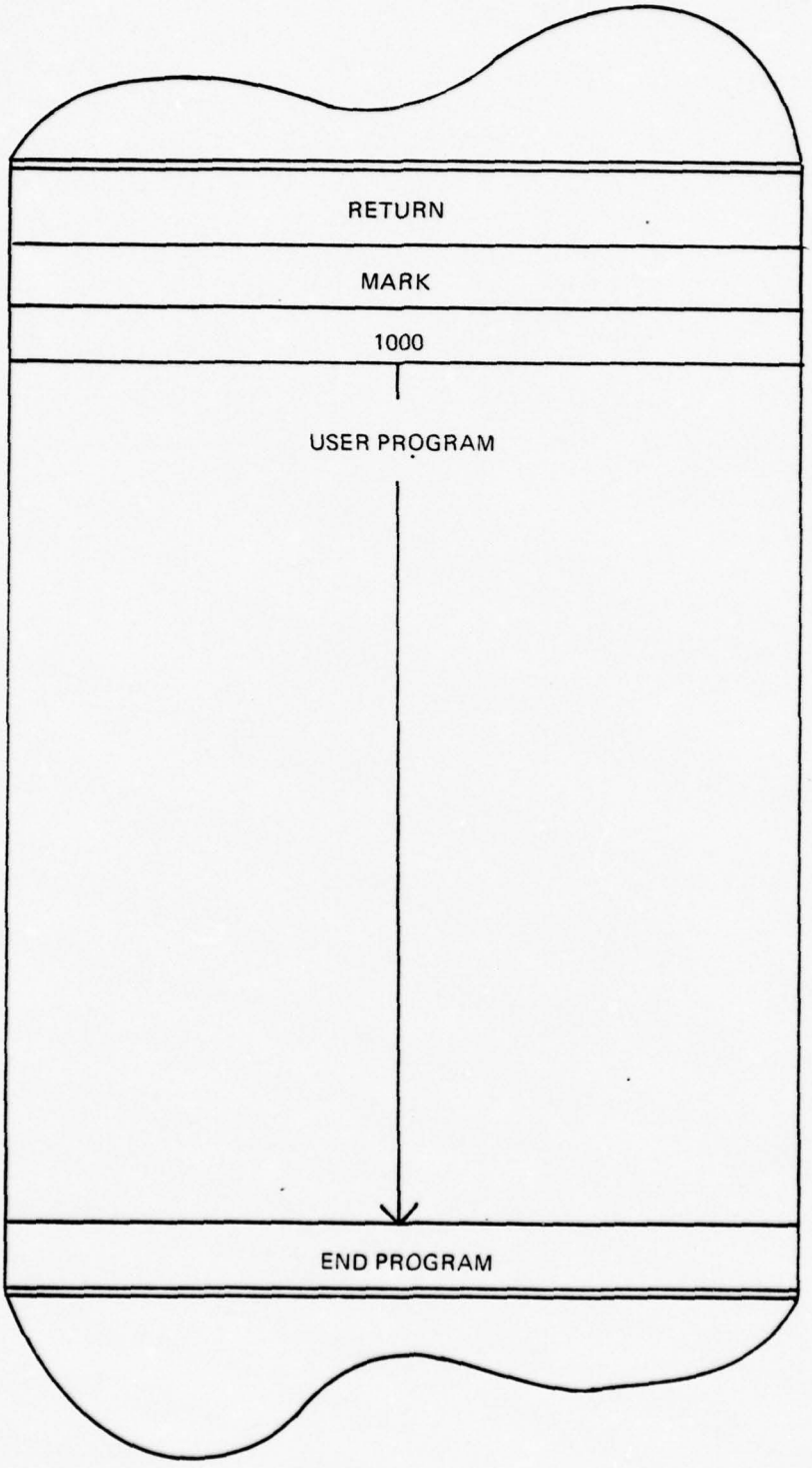


FIGURE 4

USER PROGRAM FORMAT

IV. CONCLUSIONS

The Wang 614 Programmable Calculator has proven capable of performing many of the functions normally associated with a micro-processor or mini-computer. While its processing and input/output speeds are slower than that expected of one of these units, it is capable of user/system interface and automatic, multichannel input/output functions.

The design and implementation of the software programs and the digital to analog interface have changed the calculator-aided microwave network analyzer system described by John C. Carlton [Ref. 1], to a calculator controlled microwave network analyzer system.

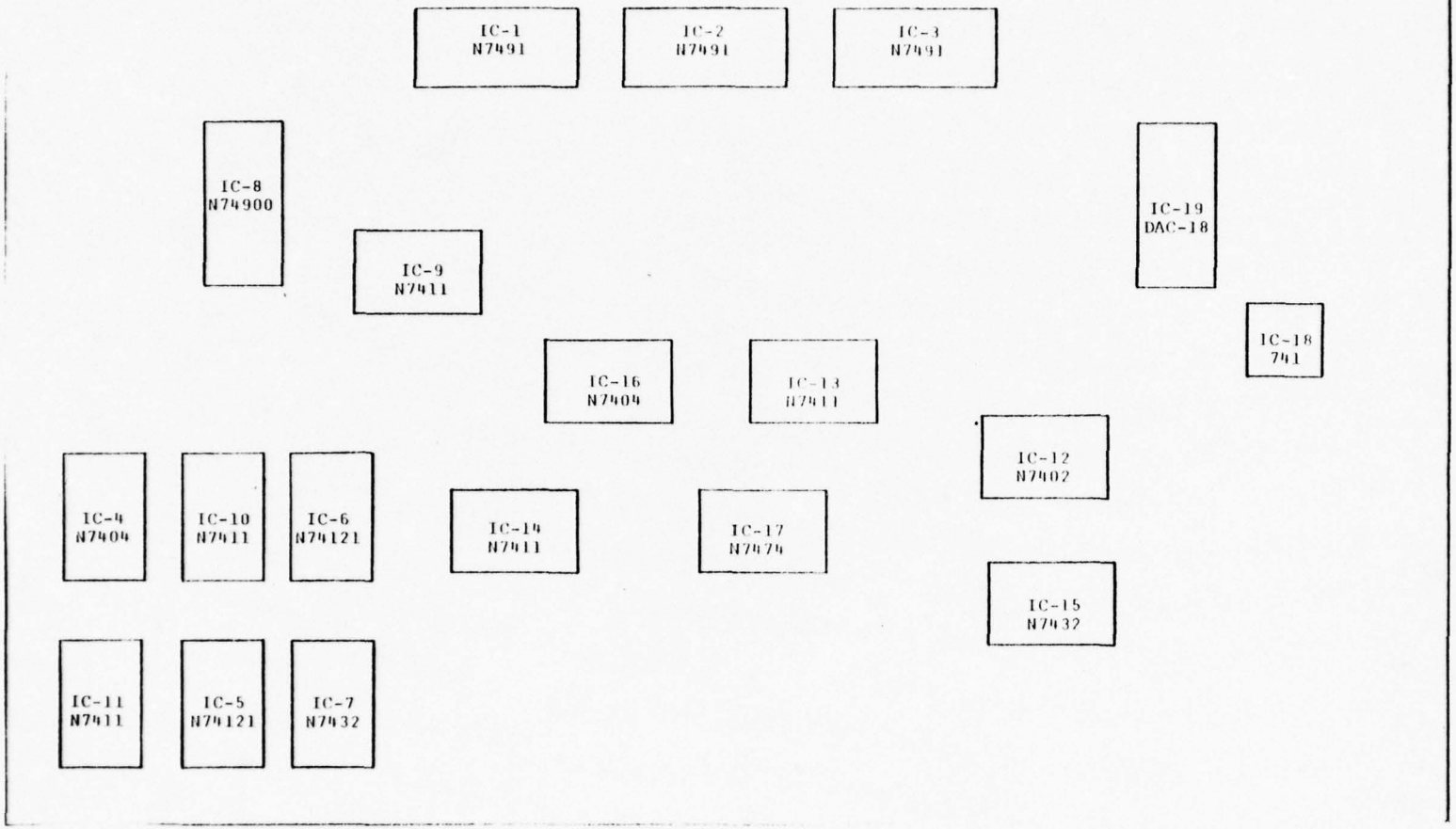
V. RECOMMENDATIONS

An investigation into the feasibility of implementing S-parameter correction by the use of calibration data as described in the paper by Silva and McPhuw [Ref. 9] is recommended.

A user program which computes and plots the phase and magnitude transfer function of microwave devices is recommended. Also, additional user programs may prove desirable.

Appendix A

Digital to Analog Interface Wiring Tables



Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1	NC																		
2																			11
3																			12
4		4	4												11				
5		5	5					5	2				5			13			
6																			10
7																			9
8	GND																		
9	NC																		
10	NC																		
11	NC																		
12													4	2					
13		14																	
14							8												
15	NC																		
16	VCC																		

IC-1

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1																			
2												3							7
3												2							8
4	4		4												11				
5	5		5					5	2				5			13			
6												5							6
7												6							5
8		GND																	
9		NC																	
10		NC																	
11		NC																	
12														13					
13			14																
14	13																		
15		NC																	
16		NC																	

IC-2

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1			NC																
2												11							3
3												12							4
4	4	4													11				
5	5	5						5	2				5			13			
6												9							2
7												8							1
8			GND																
9			NC																
10			NC																
11			NC																
12														4					
13			NC																
14		13																	
15			NC																
16			NC																

IC-3

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1								8		2&10									
2										4	2								
3								9		13	13								
4										3&9									
5				*															
6									11		9								
7	GND																		
8									9										
9				*															
10											11								
11				*															
12						5			5										
13								19											
14	Vcc																		

IC-4

NOTE * See Input Port Table

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1					*														
2					NC														
3											8								
4					Vcc														
5					Vcc														
6					NC														
7					GND														
8					NC														
9					NC														
10					+														
11					+°														
12					NC														
13					NC														
14					Vcc														

IC-5

NOTE * See Input Port Table
+ Pin 10 Connected to Pin 11 by a .01 Mfd Capacitor
° Pin 11 Connected to Vcc by a OHM Resister

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1						NC													
2						NC													
3								23&12	8										
4						Vcc													
5				13				19											
6							9												
7						GND													
8						NC													
9						NC													
10						+													
11						+°													
12						NC													
13						NC													
14						Vcc													

IC-6

NOTE + Pin 10 is Connected to Pin 11 by a 1.0 µfc Capacitor
° Pin 11 is Connected to Vcc by a OHM Resistor

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1										6									
2										12									
3							4												
4							3												
5							11												
6									3										
7							GND												
8	14																		
9						6													
10									6										
11							5												
12										8									
13											12								
14							Vcc												

IC-7

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1								NC											
2								*											
3								*											
4									1										
5	5	5	5						2				5			13			
6								NC											
7								GND											
8				1						2&10									
9				3						13	13								
10								*											
11								*											
12								23											
13								NC											
14								NC											
15								*											
16								*											
17								NC											
18								NC											
19				13		5													
20								NC											
21								*											
22								*											
23						3		12	8										
24								Vcc											

IC-8

NOTE *See Input Port Table

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1								4											
2	5	5	5					5					5			13			
3							6												
4									Vcc										
5				12															
6							10												
7									GND										
8						3		23&12											
9				8															
10									Vcc										
11				6							9								
12															13				
13									Vcc										
14									Vcc										

IC-9

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1								8		*									
2				1						10									
3				4						9									
4				2							2								
5										*									
6							1												
7										GND									
8							12												
9										3									
10										2									
11										*									
12							2												
13				3				9			13								
14										Vcc									

IC-10

NOTE * See Input Port Table

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1											*								
2				2						4									
3											NC								
4											NC								
5											NC								
6											NC								
7											GND								
8					3														
9				6					11										
10											Vcc								
11				10															
12							13												
13				3				9		13									
14											Vcc								

IC-11

NOTE * See Input Port Table

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1													2						
2		3																	8
3		2																	7
4													1						
5		6																	6
6		7																	5
7												GND							
8			7																1
9			6																2
10													13						
11			2																3
12			3																4
13													3						
14												Vcc							

IC-12

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1												4							
2												1							
3												13							
4	12													2					
5	5	5	5					5	2							13			
6													10						
7													GND						
8																	2		
9													Vcc						
10													6						
11													12						
12													11						
13												10							
14													Vcc						

IC-13

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1																			
2	12												4						
3														12					
4			12																
5														Vcc					
6																	12		
7														GND					
8														NC					
9														NC					
10														NC					
11														NC					
12														3					
13		12																	
14														Vcc					

IC-14

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1															NC				
2															NC				
3															NC				
4															NC				
5															NC				
6															NC				
7															GND				
8															12				
9																	5		
10																	9		
11	4	4	4																
12																			
13									12						8				
14																			
															Vcc				

IC-15

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1										1						*			
2																	3&11		
3																NC			
4																NC			
5																NC			
6																NC			
7																GND			
8																NC			
9																NC			
10																NC			
11																NC			
12																			
13	5	5	5					5	2				5	1					
14																Vcc			

IC-16

NOTE *See Input Port Table

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1																	Vcc		
2													8						
3																	11		
4																	Vcc		
5															9				
6																	NC		
7																	GND		
8																	NC		
9															10				
10																	Vcc		
11																	3		
12														6					
13																	Vcc		
14																	Vcc		

IC-17

Pin / To																	IC-18	IC-19
1	Connected to One End of 20K OHM Potentiometer R-3																	
2	Connected to GND by a 1.5 MEGOHM Resistor																6+	
3																		15 & 18
4																	-15V	
5	Connected to One End of 20K OHM Potentiometer R-3																	
6	Output to HP 8690B Sweep Oscillator																2	
7																	+15V	
8																	NC	

IC-18

NOTE ° Pin 6 is Connected to Pin 2 by
a 562 OHM Resistor
R-3 Wiper Connected to -15 Volts,
Ends Connected to Pins 1 and 5

Pin / To	IC-1	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1			7									8							
2			6									9							
3			2									11							
4			3									12							
5		7										6							
6		6										5							
7		2										3							
8		3										2							
9	7																		
10	6																		
11	2																		
12	3																		
13																			+5V
14																		4	-16V
15																			18
16																			
17																			GND
18																		3	15
19																			NC
20																			
21																			GND
22																			+16V
23																			
24																			

IC-19

Pin / To	PORT	IC-2	IC-3	IC-4	IC-5	IC-6	IC-7	IC-8	IC-9	IC-10	IC-11	IC-12	IC-13	IC-14	IC-15	IC-16	IC-17	IC-18	IC-19
1	Vcc																		
2	Vcc																		
3	Vcc																		
4					1														
5					1														
6					1														
7	Vcc																		
8	Vcc																		
9					1														
12																			
13																			
14																			
15																			
20										1						1			
21										5									
22										11									
23											1								
24																			
25																			
26																			
27				5															
28																			
31				9															
32				11															

INPUT PORT

APPENDIX B

PROCEDURES FOR USING THE COLLECTION AND STORAGE SYSTEM PROGRAM

1. Energize all components of the HP 8410S Network Analyzer System and the Wang Calculator. Calibrate the display module. Ensure the HP 8690B Sweep Oscillator is in the CW mode and the External FM pushbutton is depressed.

2. Load the Collection and Storage system program.

3. Remove the tape containing the system program and insert a blank tape, rewind, and depress TAPE READY.

4. Depress the GO key on the calculator keyboard.

5. The calculator will occasionally interrupt execution with a number showing in the display register. Respond as specified below according to the number in the display register.

Display Register Contents	Response
1	Clear display, Enter Start Frequency in HZ Depress GO key
2	Clear Display Enter Stop Frequency in HZ Depress GO key
3	Clear Display Enter Step Size in HZ Depress GO key
4	Clear Display Enter Collection Job Code Obtained From Appendix C Depress GO key
.21	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure S_{21} Clear Display Enter Difference Between dB Calibration Setting and dB Measurement Setting [dB(c) - dB(m)] Depress GO key
.12	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure S_{12} Clear Display Enter Difference Between dB Calibration Setting and dB Measurement Setting [dB(c) - dB(m)] Depress GO key
.11	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure S_{11} Clear Display Enter Difference Between dB Calibration Setting and dB Measurement Setting [dB(c) - dB(m)] Depress GO key

Display Register Contents	Response
.22	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure S_{22} Clear Display Enter Difference Between dB Calibration Setting and dB Measurement Setting [dB(c) - dB(m)] Depress GO key
10.2112	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure Transmission Coefficients with Channel Terminated in a Direct Short [L(0)] Clear Display Enter Line Length Depress GO key
11.2112	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure Transmission Coefficients with Channel Terminated in an Offset Short [L(1)] Clear Display Enter Line Length Depress GO key
12.2112	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure Transmission Coefficients with Channel Terminated in a Second Offset Short [L(2)] Clear Display Enter Line Length Depress GO key
10.1122	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure Reflection Coefficients with Channel Terminated in a Direct Short [L(0)] Clear Display Enter Line Length Depress GO key

Display Register Contents	Response
11.1122	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure Reflection Coefficients with Channel Terminated in an Offset Short [L(1)] Clear Display Enter Line Length Depress GO key
12.1122	Rewind Tape Depress TAPE READY Configure Network Analyzer to Measure Reflection Coefficients with Channel Terminated in a Second Offset Short [L(2)] Clear Display Enter Line Length Depress GO key
5	Rewind Tape Depress TAPE READY Depress GO key
9.9999	Rewind Tape Remove Tape Proper Termination

APPENDIX C

COLLECTION JOB CODE TABLES

1. Choose the appropriate table:

   a. If calibration data is <u>not</u> to be collected use Table 1.

   b. If calibration data is to be collected use Table 2.

2. Choose the appropriate Collection Job Code:

   a. Determine which S-parameters are to be collected and stored.

   b. Find the row in the table which has a 1 in each S-parameter column decided upon.

   c. Use the Collection Job Code specified for the appropriate row.

TABLE 1

NO CALIBRATION DATA

Display Job Code	S_{21}	S_{12}	S_{11}	S_{22}
0.0101	0	0	0	1
0.0102	0	0	1	0
0.0203	0	0	1	1
0.0104	0	1	0	0
0.0205	0	1	0	1
0.0206	0	1	1	0
0.0307	0	1	1	1
0.0108	1	0	0	0
0.0209	1	0	0	1
0.0210	1	0	1	0
0.0311	1	0	1	1
0.0212	1	1	0	0
0.0313	1	1	0	1
0.0314	1	1	1	0
0.0415	1	1	1	1

TABLE 2

CALIBRATION DATA

Collection Job Code	S_{21}	S_{12}	S_{11}	S_{22}
2.0600	0	0	0	0
1.0401	0	0	0	1
1.0402	0	0	1	0
1.0503	0	0	1	1
1.0404	0	1	0	0
2.0805	0	1	0	1
2.0806	0	1	1	0
2.0907	0	1	1	1
1.0408	1	0	0	0
2.0809	1	0	0	1
2.0810	1	0	1	0
2.0911	1	0	1	1
1.0512	1	1	0	0
2.0913	1	1	0	1
2.0914	1	1	1	0
2.1015	1	1	1	1

Appendix D

Collection and Storage System Program Memory Map

Register Number:

16	17	18	19	20	21	22	23	24	25
# OF RECORDS	ID BLOCK FLAG	# OF CALIBRATION SETS	# BLOCK/ RECORD	S-PARAMETERS TO BE COLLECTED	COLLECTION JOB CODE	ΔF VS 0701/2	ΔF VS 0405/6	ΔF VS 0305/6	ΔF VS 0205/6

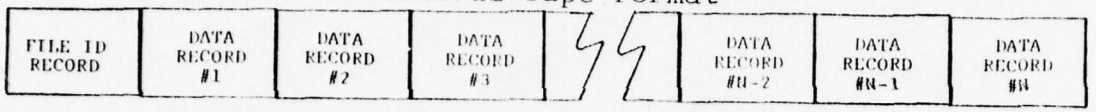
26	27	28	29	30	...	49	50	51	52
ΔF VS 0105/6	START FREQ	STOP FREQ	STEP SIZE			JOB CODE	START FREQ	STOP FREQ	STEP SIZE

53	54	55	56	57	58	59	60	61	62
TRANS. L(0)	TRANS. L(1)	TRANS. (2)	REFL. L(0)	REFL. L(1)	REFL. L(2)	S_{21} dB DIFF.	S_{12} dB DIFF.	S_{11} dB DIFF.	S_{22} dB DIFF.

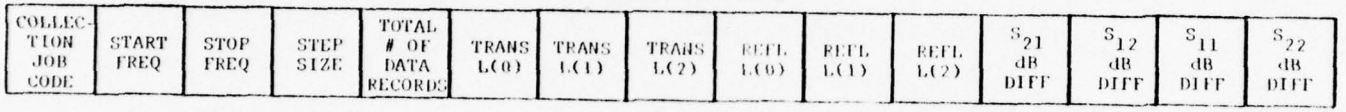
Appendix E

Data Tape Formats

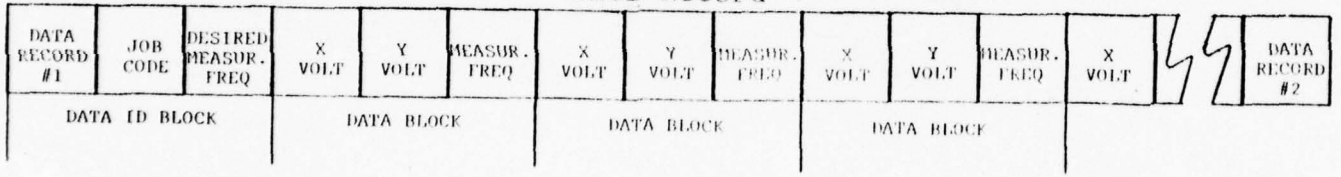
General Tape Format



File ID Record



Data Record



Data Record Format For
Collection Job Codes

0.0101
0.0102
0.0104
0.0108

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT	Y VOLT	MEASUR. FREQ

Data Record Format For
Collection Job Codes

0.0203
0.0205
0.0206
0.0209
0.0210
0.0212

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT	Y VOLT	MEASUR. FREQ	X VOLT	Y VOLT	MEASUR. FREQ

Data Record Format For
Collection Job Codes

0.0307
0.0311
0.0313
0.0314

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT	Y VOLT	MEASUR. FREQ	X VOLT	Y VOLT	MEASUR. FREQ

X VOLT	Y VOLT	MEASUR. FREQ

Data Record Format For
Collection Job Codes

0.0415
1.0401
1.0402
1.0404
1.0408

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT CALIB L(0) OR S_{21}	Y VOLT CALIB L(0) OR S_{21}	MEASUR. FREQ	X VOLT CALIB L(1) OR S_{12}	Y VOLT CALIB L(1) OR S_{12}	MEASUR. FREQ

X VOLT CALIB L(2) OR S_{11}	Y VOLT CALIB L(2) OR S_{11}	MEASUR. FREQ	X VOLT Sxy OR S_{22}	Y VOLT Sxy OR S_{22}	MEASUR. FREQ

Data Record Format For Collection Job Codes

1.0503
1.0512

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT CALIB L(0)	Y VOLT CALIB L(0)	MEASUR. FREQ	X VOLT CALIB L(1)	Y VOLT CALIB L(1)	MEASUR. FREQ

X VOLT CALIB L(2)	Y VOLT CALIB L(2)	MEASUR. FREQ	X VOLT Sxx OR Sxy	Y VOLT Sxx OR Sxy	MEASUR. FREQ	X VOLT Syy OR Syx	Y VOLT Syy OR Syx	MEASUR. FREQ

Data Record Format For
Collection Job Code

2.0600

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT TRANS. CALIB L(0)	Y VOLT TRANS. CALIB L(0)	MEASUR. FREQ	X VOLT TRANS. CALIB L(1)	Y VOLT TRANS. CALIB L(1)	MEASUR. FREQ
X VOLT TRANS. CALIB L(2)	Y VOLT TRANS. CALIB L(2)	MEASUR. FREQ	X VOLT REFL. CALIB L(0)	Y VOLT REFL. CALIB L(0)	MEASUR. FREQ	X VOLT REFL. CALIB L(1)	Y VOLT REFL. CALIB L(1)	MEASUR. FREQ
X VOLT REFL. CALIB L(2)	Y VOLT REFL. CALIB L(2)	MEASUR. FREQ						

Data Record Format For
Collection Job Codes

2.0805
2.0806
2.0809
2.0810

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT TRANS. CALIB L(0)	Y VOLT TRANS. CALIB L(0)	MEASUR. FREQ	X VOLT TRANS. CALIB L(1)	Y VOLT TRANS. CALIB L(1)	MEASUR. FREQ
X VOLT TRANS. CALIB L(2)	Y VOLT TRANS. CALIB L(2)	MEASUR. FREQ	X VOLT REFL. CALIB L(0)	Y VOLT REFL. CALIB L(0)	MEASUR. FREQ	X VOLT REFL. CALIB L(1)	Y VOLT REFL. CALIB L(1)	MEASUR. FREQ
X VOLT REFL. CALIB L(2)	Y VOLT REFL. CALIB L(2)	MEASUR. FREQ	X VOLT Sxy	Y VOLT Sxy	MEASUR. FREQ	X VOLT Sxx	Y VOLT Sxx	MEASUR. FREQ

Data Record Format For Collection Job Codes

2.0907
2.0911
2.0913
2.0914

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT TRANS. CALIB L(0)	Y VOLT TRANS. CALIB L(0)	MEASUR. FREQ	X VOLT TRANS. CALIB L(1)	Y VOLT TRANS. CALIB L(1)	MEASUR. FREQ
X VOLT TRANS. CALIB L(2)	Y VOLT TRANS. CALIB L(2)	MEASUR. FREQ	X VOLT REFL. CALIB L(0)	Y VOLT REFL. CALIB L(0)	MEASUR. FREQ	X VOLT REFL. CALIB L(1)	Y VOLT REFL. CALIB L(1)	MEASUR. FREQ
X VOLT REFL. CALIB L(2)	Y VOLT REFL. CALIB L(2)	MEASUR. FREQ	X VOLT Sxy	Y VOLT Sxy	MEASUR. FREQ	X VOLT Syx OR Sxx	Y VOLT Syx OR Sxx	MEASUR. FREQ
X VOLT Syy	Y VOLT Syy	MEASUR. FREQ						

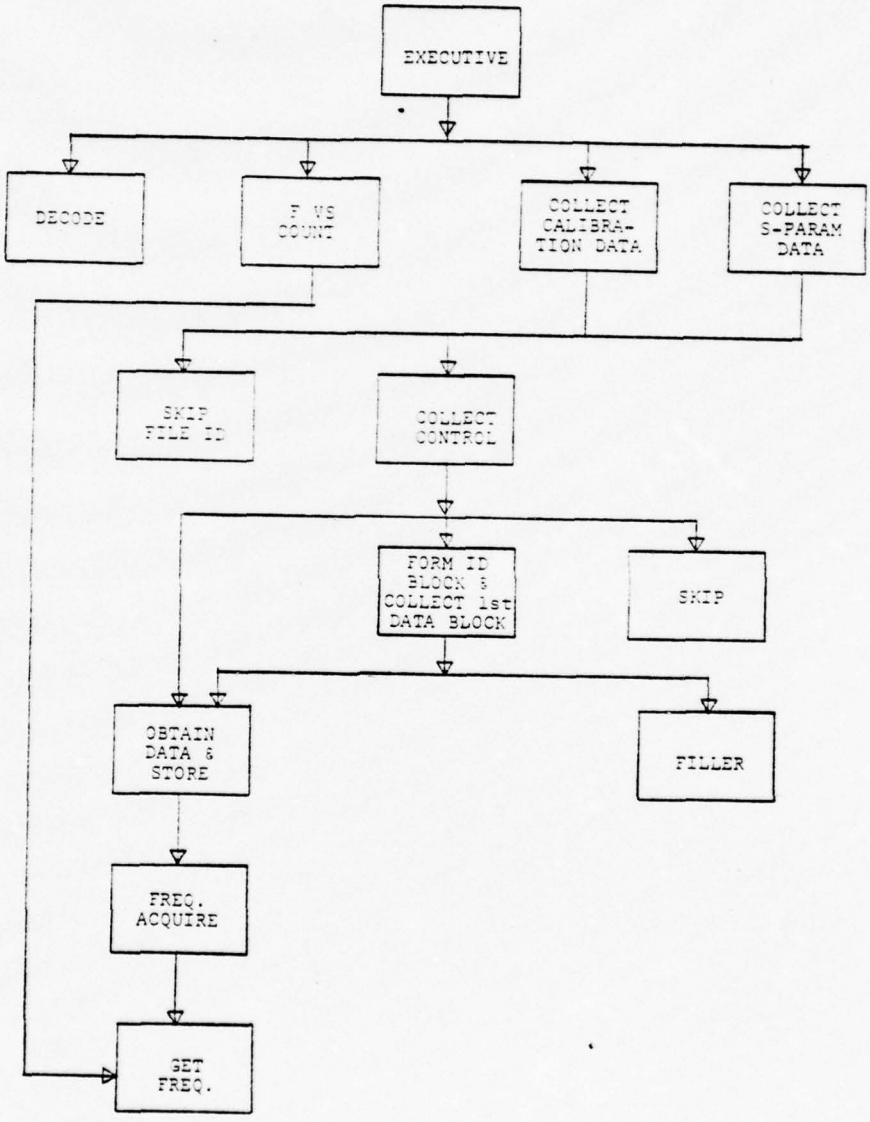
Data Record Format For Collection Job Code

2.1015

DATA RECORD #	COLLEC-TION JOB CODE	DESIRED MEASUR. FREQ	X VOLT TRANS. CALIB L(0)	Y VOLT TRANS. CALIB L(0)	MEASUR. FREQ	X VOLT TRANS. CALIB L(1)	Y VOLT TRANS. CALIB L(1)	MEASUR. FREQ
X VOLT TRANS. CALIB L(2)	Y VOLT TRANS. CALIB L(1)	MEASUR. FREQ	X VOLT REFL. CALIB L(0)	Y VOLT REFL. CALIB L(0)	MEASUR. FREQ	X VOLT REFL. CALIB L(1)	Y VOLT REFL. CALIB L(1)	MEASUR. FREQ
X VOLT REFL. CALIB L(2)	Y VOLT REFL. CALIB L(2)	MEASUR. FREQ	X VOLT S_{21}	Y VOLT S_{21}	MEASUR. FREQ	X VOLT S_{12}	Y VOLT S_{12}	MEASUR. FREQ
X VOLT S_{11}	Y VOLT S_{11}	MEASUR. FREQ	X VOLT S_{22}	Y VOLT S_{22}	MEASUR. FREQ			

Appendix F

Collection and Storage System Program Flow Charts and Descriptions



SUBROUTINE NAME:	ADDRESS CODE:
EXECUTIVE	1000

DESCRIPTION:

The EXECUTIVE program is the primary interface between the user and the system program. It calls upon the user to supply the collection parameters: start frequency, stop frequency, step size and a Collection Job Code (CJC). The program then calls the appropriate subroutines which carry out the tasks specified by the CJC. When collection and storage is complete, the program writes the file identification record on the data tape.

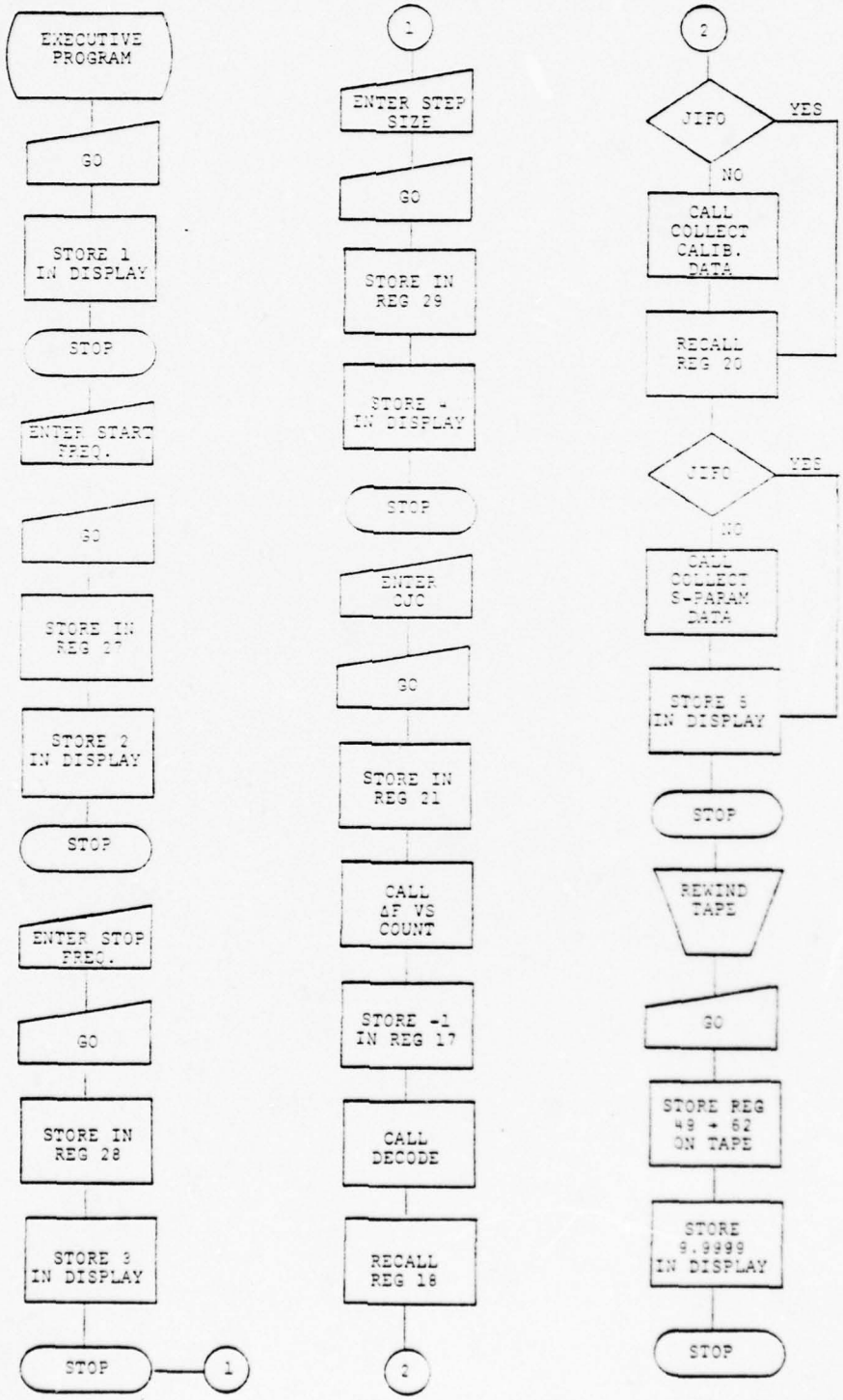
CALLED FROM:

CALLS SUBROUTINES:

- ΔF VS COUNT
- DECODE
- COLLECT CALIBRATION DATA
- COLLECT S-PARAMETER DATA

REGISTERS USED:

NUMBER	CODE	PURPOSE
17	T↓01	Flag - First measurement
18	T↓02	Number of calibration data sets to be collected
20	T↓04	S-parameters to be collected
21	T↓05	Collection Job Code
27	T↓11	start frequency
28	T↓12	stop frequency
29	T↓13	step size


EXECUTIVE PROGRAM
GO
STORE 1 IN DISPLAY
STOP
ENTER START FREQ.
GO
STORE IN REG 27
STORE 2 IN DISPLAY
STOP
ENTER STOP FREQ.
GO
STORE IN REG 28
STORE 3 IN DISPLAY
STOP
1
1
ENTER STEP SIZE
GO
STORE IN REG 29
STORE + IN DISPLAY
STOP
ENTER NOP
GO
STORE IN REG 31
CALL ΔF VS COUNT
STORE -1 IN REG 17
CALL DECODE
RECALL REG 18
2
2
JIFO
YES
NO
CALL COLLECT CALIB. DATA
RECALL REG 30
JIFO
YES
NO
CALL COLLECT S-PARAM DATA
STORE 5 IN DISPLAY
STOP
REWIND TAPE
GO
STORE REG 49 → 62 ON TAPE
STORE 9.9999 IN DISPLAY
STOP

SUBROUTINE NAME:	ADDRESS CODE:
ΔF VERSES COUNT	1001

DESCRIPTION:

This subroutine is used to determine the frequency change caused by the execution of each of the five Group II function codes. When the subroutine FREQUENCY ACQUIRE drives the sweep oscillator to a desired frequency, it does so by executing a Group II function code immediately followed by a stop code. This causes the 12 bit counter of the interface to increase or decrease its count by a specific amount for each of the five function codes. The change in frequency which each code causes is dependent upon the frequency range of the RF plug-in unit being used. This subroutine determines the change in frequency caused by each function code and stores this information.

CALLED FROM:

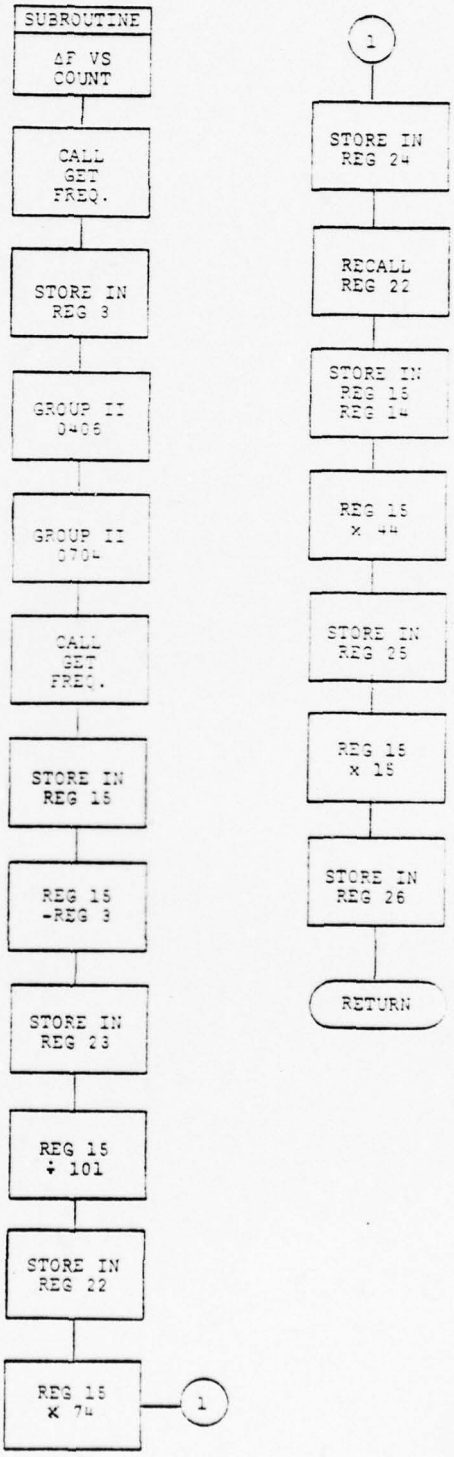
EXECUTIVE

CALLS SUBROUTINES:

GET FREQUENCY

REGISTERS USED:

NUMBER	CODE	PURPOSE
22	T↓06	ΔF for 0701/0702 codes
23	T↓07	ΔF for 0405/0406 codes
24	T↓08	ΔF for 0305/0306 codes
25	T↓09	ΔF for 0205/0206 codes
26	T↓10	ΔF for 0105/0106 codes


SUBROUTINE
ΔF VS COUNT
CALL GET FREQ.
STORE IN REG 3
GROUP II 0406
GROUP II 0704
CALL GET FREQ.
STORE IN REG 15
REG 15 -REG 3
STORE IN REG 23
REG 15 ÷ 101
STORE IN REG 22
REG 15 × 74
1
1
STORE IN REG 24
RECALL REG 22
STORE IN REG 15 REG 14
REG 15 × 44
STORE IN REG 25
REG 15 × 15
STORE IN REG 26
RETURN

SUBROUTINE NAME: DECODE	ADDRESS CODE: 1002

DESCRIPTION:

This subroutine takes the Collection Job Code (CJC) and decodes the number. The CJC is in the following format, X.YYZZ. The X is the number of calibration data sets that are to be collected, either 0, 1, or 2. The YY in the CJC is the number of data blocks/record which will be stored on tape. The ZZ is a coded representation of the S-parameters to be measured.

CALLED FROM:

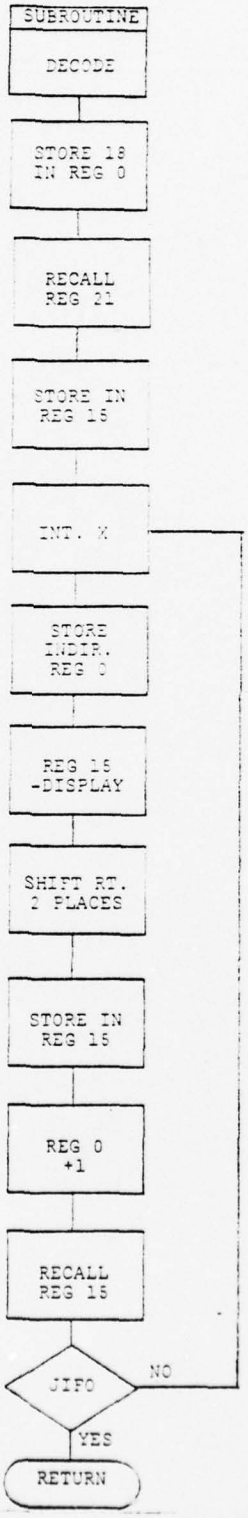
EXECUTIVE

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
0	00	Indirect address pointer
18	T↓02	Number of calibration sets
19	T↓03	Number of data blocks/record
20	T↓04	S-parameters
21	T↓05	Collection Job Code


SUBROUTINE
DECODE
STORE 18 IN REG 0
RECALL REG 21
STORE IN REG 15
INT. X
STORE INDIR. REG 0
REG 15 -DISPLAY
SHIFT RT. 1 PLACES
STORE IN REG 15
REG 0 +1
RECALL REG 15
JIFO
NO
YES
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
COLLECT CALIBRATION DATA	1003

DESCRIPTION:

This subroutine controls the collection of calibration data. If calibration data is to be collected, the user indicates this by putting a 1 or 2 as the first digit in the Collection Job Code. Whether the number is a 1 or 2 depends upon which scattering parameters are to be collected. If only transmission S-parameters or only reflection S-parameters are to be collected, then one set of data is required. If both a transmission and a reflection S-parameter are to be collected, then two sets of calibration data will be collected.

The subroutine is called by the EXECUTIVE program when calibration data is to be collected. The subroutine determines which calibration data set is to be collected, and tells the user which channel of the test unit to activate and which of the three short circuits to set up. The user responds by: configuring the network analyzer as specified, entering in the display register the offset length of the short, and depressing the GO Key on the calculator. The offset length of the short is saved and is put in the file

CALLED FROM:

EXECUTIVE

CALLS SUBROUTINES:

COLLECTION CONTROL
SKIP FILE ID

REGISTERS USED:

NUMBER	CODE	PURPOSE
9	09	Number of blocks to be skipped to first available block
10	10	Number of calibration data blocks/ record to be recorded
18	T↓02	Number of calibration sets to be collected
20	T↓04	S-parameter code
53	-↓05	Transmission channel offset length L(0)
54	-↓06	Transmission channel offset length L(1)

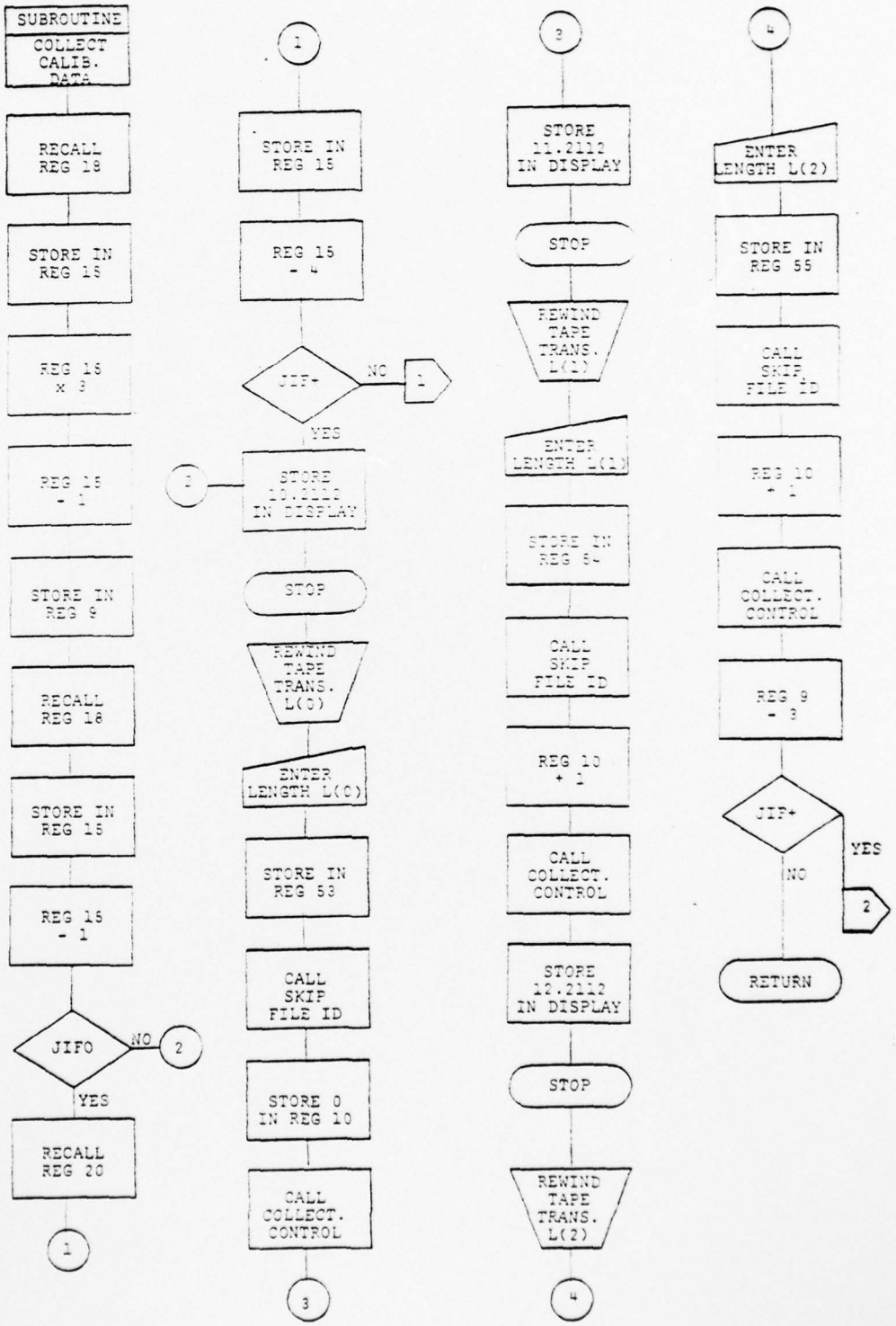
SUBROUTINE NAME:	ADDRESS CODE:
COLLECT CALIBRATION DATA	1003

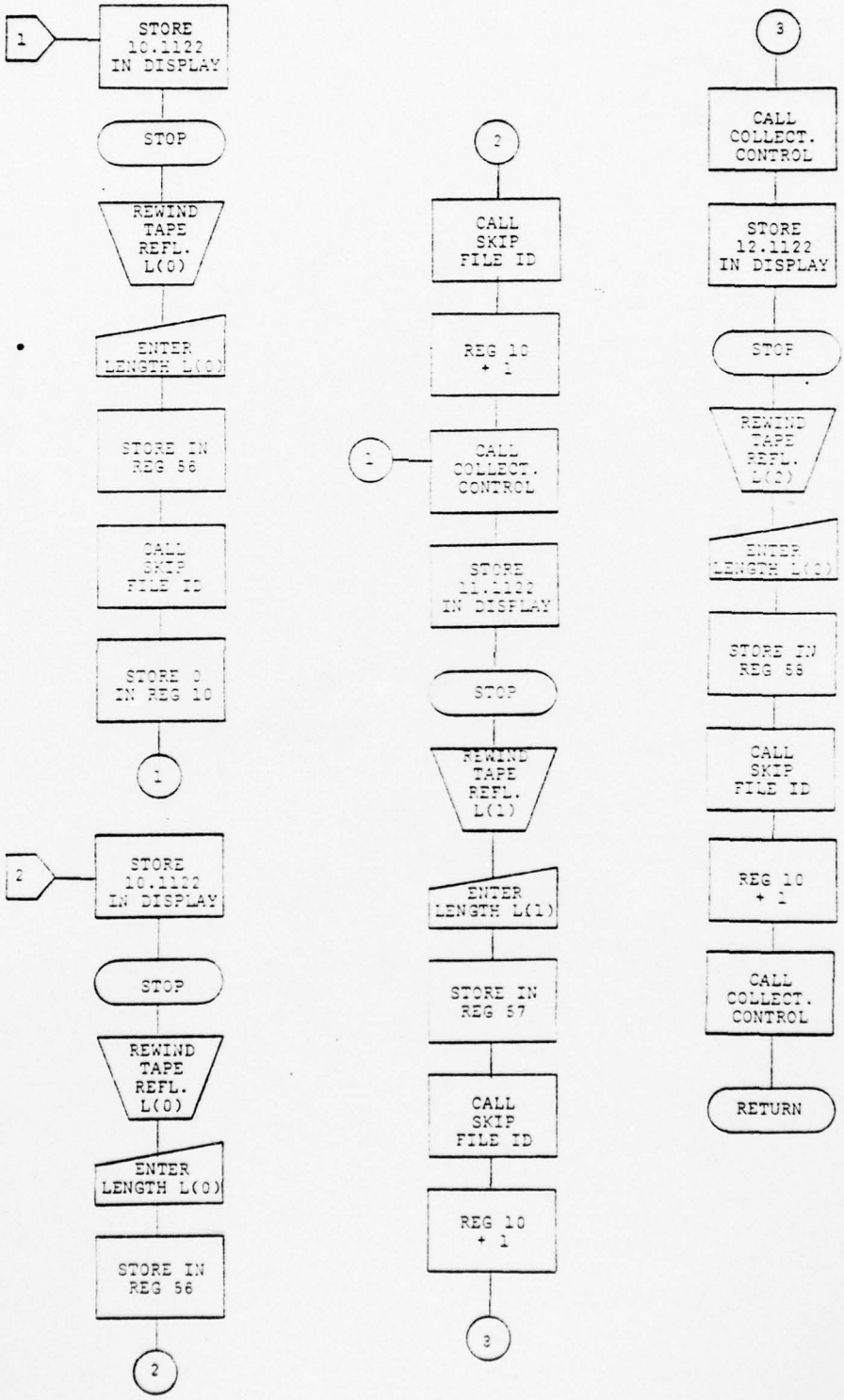
DESCRIPTION CONTINUED:

identification record later. The subroutine passes control to the COLLECTION CONTROL subroutine where the calibration data is collected. When all the calibration data for the configured short circuit is collected and stored, control returns to COLLECT CALIBRATION DATA. Here the program stops with a number in the display which tells the user which measurement to be taken next. The network is set up as indicated; the tape rewound, offset length entered, and the GO Key depressed. This routine is continued until all calibration data is collected. When this occurs, program control returns to the EXECUTIVE

REGISTERS USED CONTINUED:

55	-↓07	Transmission channel offset length L(2)
56	-↓08	Reflection channel offset length L(0)
57	-↓09	Reflection channel offset length L(1)
58	-↓10	Reflection channel offset length L(2)


SUBROUTINE
COLLECT CALIB. DATA
RECALL REG 18
STORE IN REG 15
REG 15 x 3
REG 15 - 1
STORE IN REG 9
RECALL REG 18
STORE IN REG 15
REG 15 - 1
JIFO
NO
2
YES
RECALL REG 20
1
1
STORE IN REG 15
REG 15 - 4
JIF+
NO
1
YES
2
STORE 11.2112 IN DISPLAY
STOP
REWIND TAPE TRANS. L(0)
ENTER LENGTH L(0)
STORE IN REG 53
CALL SKIP FILE ID
STORE 0 IN REG 10
CALL COLLECT. CONTROL
3
3
STORE 11.2112 IN DISPLAY
STOP
REWIND TAPE TRANS. L(2)
ENTER LENGTH L(2)
STORE IN REG 54
CALL SKIP FILE ID
REG 10 + 1
CALL COLLECT. CONTROL
STORE 12.2112 IN DISPLAY
STOP
REWIND TAPE TRANS. L(2)
4
4
ENTER LENGTH L(2)
STORE IN REG 55
CALL SKIP FILE ID
REG 10 + 1
CALL COLLECT. CONTROL
REG 9 - 3
JIF+
YES
2
NO
RETURN


1
STORE 10.1122 IN DISPLAY
STOP
REWIND TAPE REFL. L(0)
ENTER LENGTH L(0)
STORE IN REG 58
CALL SKIP FILE ID
STORE 0 IN REG 10
1
2
STORE 10.1122 IN DISPLAY
STOP
REWIND TAPE REFL. L(0)
ENTER LENGTH L(0)
STORE IN REG 56
2
2
CALL SKIP FILE ID
REG 10 + 1
1
CALL COLLECT. CONTROL
STORE 11.1122 IN DISPLAY
STOP
REWIND TAPE REFL. L(1)
ENTER LENGTH L(1)
STORE IN REG 57
CALL SKIP FILE ID
REG 10 + 1
3
3
CALL COLLECT. CONTROL
STORE 12.1122 IN DISPLAY
STOP
REWIND TAPE REFL. L(2)
ENTER LENGTH L(2)
STORE IN REG 58
CALL SKIP FILE ID
REG 10 + 1
CALL COLLECT. CONTROL
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
COLLECT S-PARAMETER DATA	1004

DESCRIPTION:

This subroutine controls the collection of S-parameter data. It determines which S-parameters are to be collected by use of the two digit code provided in the Collection Job Code. It informs the user which parameter is to be collected by stopping execution and displaying a two-digit number in the display register. The user replies by: configuring the network analyzer for the measurement specified; entering in the display register the difference between the dB setting necessary to calibrate the network analyzer and the dB setting used for measurement; rewinding the tape; and depressing the GO key. The subroutine passes control to COLLECTION CONTROL where the data is collected and stored. When the last block of data for the S-parameter being measured is stored, control is returned to COLLECT S-PARAMETER DATA. The program is interrupted again with another two-digit number appearing in the display register. The user configures the network analyzer for the measurement specified, etc. until all the S-parameters, as specified by the Collection Job Code, have been collected and stored.

CALLED FROM:

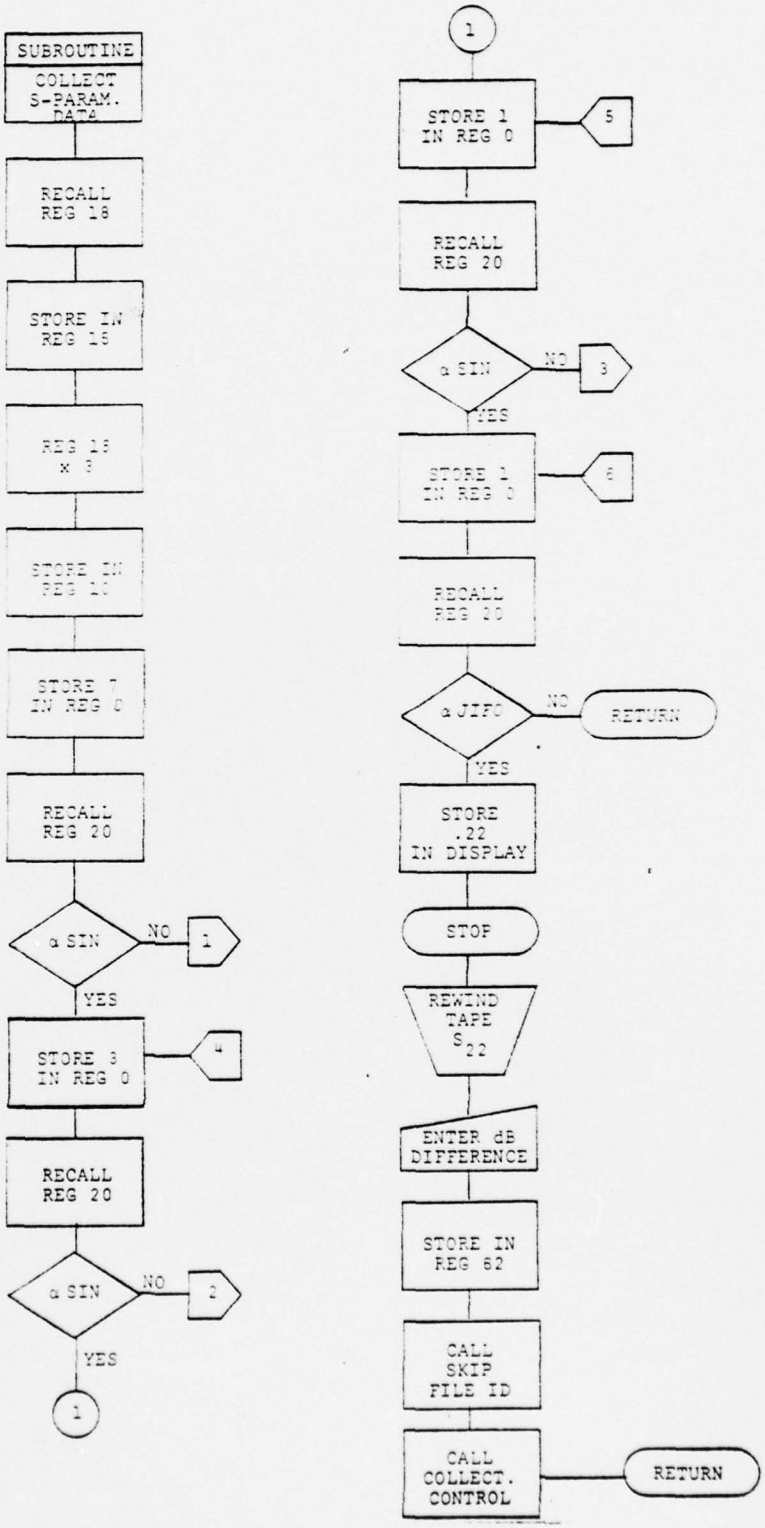
EXECUTIVE

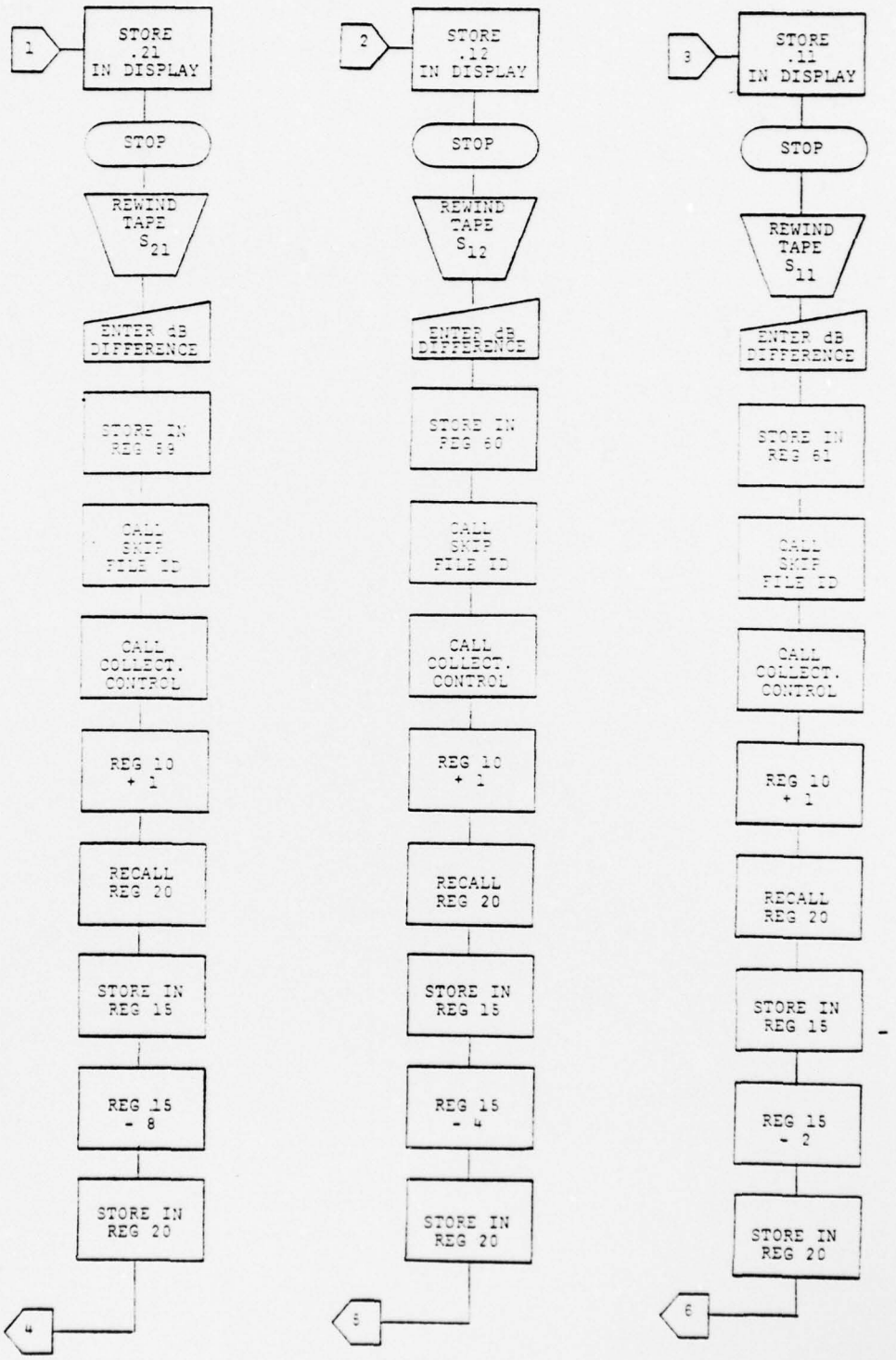
CALLS SUBROUTINES:

COLLECTION CONTROL
SKIP FILE ID

REGISTERS USED:

NUMBER	CODE	PURPOSE
9	09	Number of S-parameters/record to be stored
10	10	Number of blocks to skip to first available
18	T↓02	Number of calibration sets collected
20	T↓04	S-parameters to be measured
59	-↓11	dB difference for S_{21}
60	-↓12	dB difference for S_{12}
61	-↓13	dB difference for S_{11}
62	-↓14	dB difference for S_{22}


SUBROUTINE
COLLECT S-PARAM. DATA
RECALL REG 18
STORE IN REG 19
REG 18 x 8
STORE IN REG 20
STORE 7 IN REG 0
RECALL REG 20
α SIN
NO
1
YES
STORE 8 IN REG 0
4
RECALL REG 20
α SIN
NO
2
YES
1
1
STORE 1 IN REG 0
5
RECALL REG 20
α SIN
NO
3
YES
STORE 1 IN REG 0
6
RECALL REG 20
α JIFO
NO
RETURN
YES
STORE .22 IN DISPLAY
STOP
REWIND TAPE S22
ENTER dB DIFFERENCE
STORE IN REG 62
CALL SKIP FILE ID
CALL COLLECT. CONTROL
RETURN


1
STORE .21 IN DISPLAY
STOP
REWIND TAPE S_{21}
ENTER dB DIFFERENCE
STORE IN REG 60
CALL SKIP FILE ID
CALL COLLECT. CONTROL
REG 10 + 1
RECALL REG 20
STORE IN REG 15
REG 15 - 8
STORE IN REG 20
4
2
STORE .12 IN DISPLAY
STOP
REWIND TAPE S_{12}
ENTER dB DIFFERENCE
STORE IN REG 60
CALL SKIP FILE ID
CALL COLLECT. CONTROL
REG 10 + 1
RECALL REG 20
STORE IN REG 15
REG 15 - 4
STORE IN REG 20
5
3
STORE .11 IN DISPLAY
STOP
REWIND TAPE S_{11}
ENTER dB DIFFERENCE
STORE IN REG 61
CALL SKIP FILE ID
CALL COLLECT. CONTROL
REG 10 + 1
RECALL REG 20
STORE IN REG 15
REG 15 - 2
STORE IN REG 20
6

SUBROUTINE NAME:	ADDRESS CODE:
GET FREQUENCY	1005

DESCRIPTION:

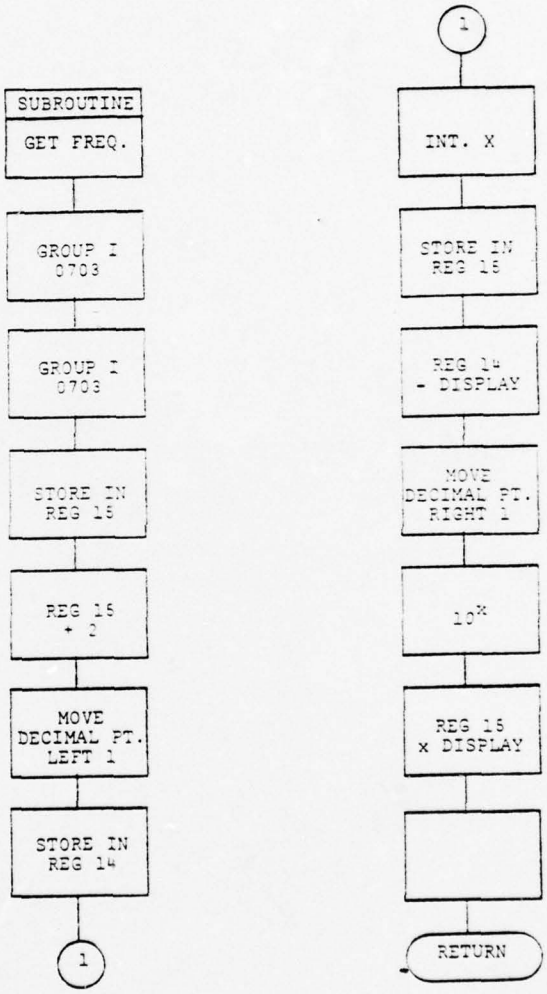
This subroutine accesses the frequency counter with a Group I 0703 code and converts the number received in the display register to the correct frequency reading. The first Group I 0703 code sent to the counter triggers the counter to sample the sweep oscillator output RF signal. The second Group I 0703 code recovers the RF signal frequency in the following format: XXXXXY, where XXXXX are the five most significant digits of the frequency and the Y is the frequency exponent minus two. For example, a frequency of 8.1436×10^9 Hz would be received as 814363.000. The rest of the subroutine is used to convert this number (814363.000) to 8.1436×10^9.

CALLED FROM: ΔF VS COUNT COLLECTION CONTROL

CALLS SUBROUTINES: None

REGISTERS USED:

NUMBER	CODE	PURPOSE
display	-	Present frequency


SUBROUTINE
GET FREQ.
GROUP I 0703
GROUP I 0703
STORE IN REG 15
REG 15 + 2
MOVE DECIMAL PT. LEFT 1
STORE IN REG 14
1
1
INT. X
STORE IN REG 15
REG 14 - DISPLAY
MOVE DECIMAL PT. RIGHT 1
10^x
REG 15 x DISPLAY
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
SKIP	1006

DESCRIPTION:

This subroutine advances the cassette tape the number of blocks indicated by the number found in the display register. The tape is advanced by reading blocks from tape into a scratch I/O Buffer.

CALLED FROM:

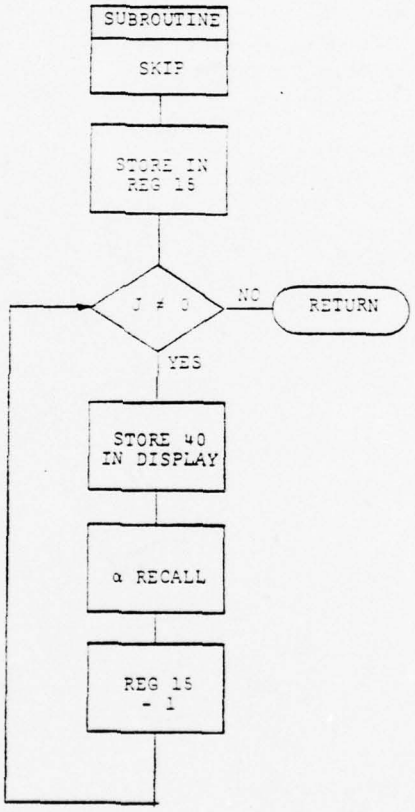
COLLECTION CONTROL

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
38	+↓06	scratch I/O buffer
39	+↓07	scratch I/O buffer
40	+↓08	scratch I/O buffer
display	-	# blocks to be skipped


SUBROUTINE
SKIP
STORE IN REG 15
I ≠ 0
NO
RETURN
YES
STORE 40 IN DISPLAY
α RECALL
REG 15 - 1

SUBROUTINE NAME:	ADDRESS CODE:
COLLECTION CONTROL	1007

DESCRIPTION:

The subroutine controls the cassette tape for the collection of both S-parameter data and calibration data. It first determines if the ID block for each record has been written on tape by checking for a minus one in register 17. If register 17 equals minus 1, then the FORM ID BLOCK AND COLLECT FIRST DATA BLOCK subroutine is called. When the first two blocks of each record have been written on tape, control returns to COLLECTION.CONTROL, where registers are adjusted for the next measurement. Program control then returns to the calling subroutine, either COLLECT S-PARAMTER DATA or COLLECT CALIBRATION DATA, where the program is interrupted so that the network analyzer can be configured for the next measurement.

CALLED FROM:

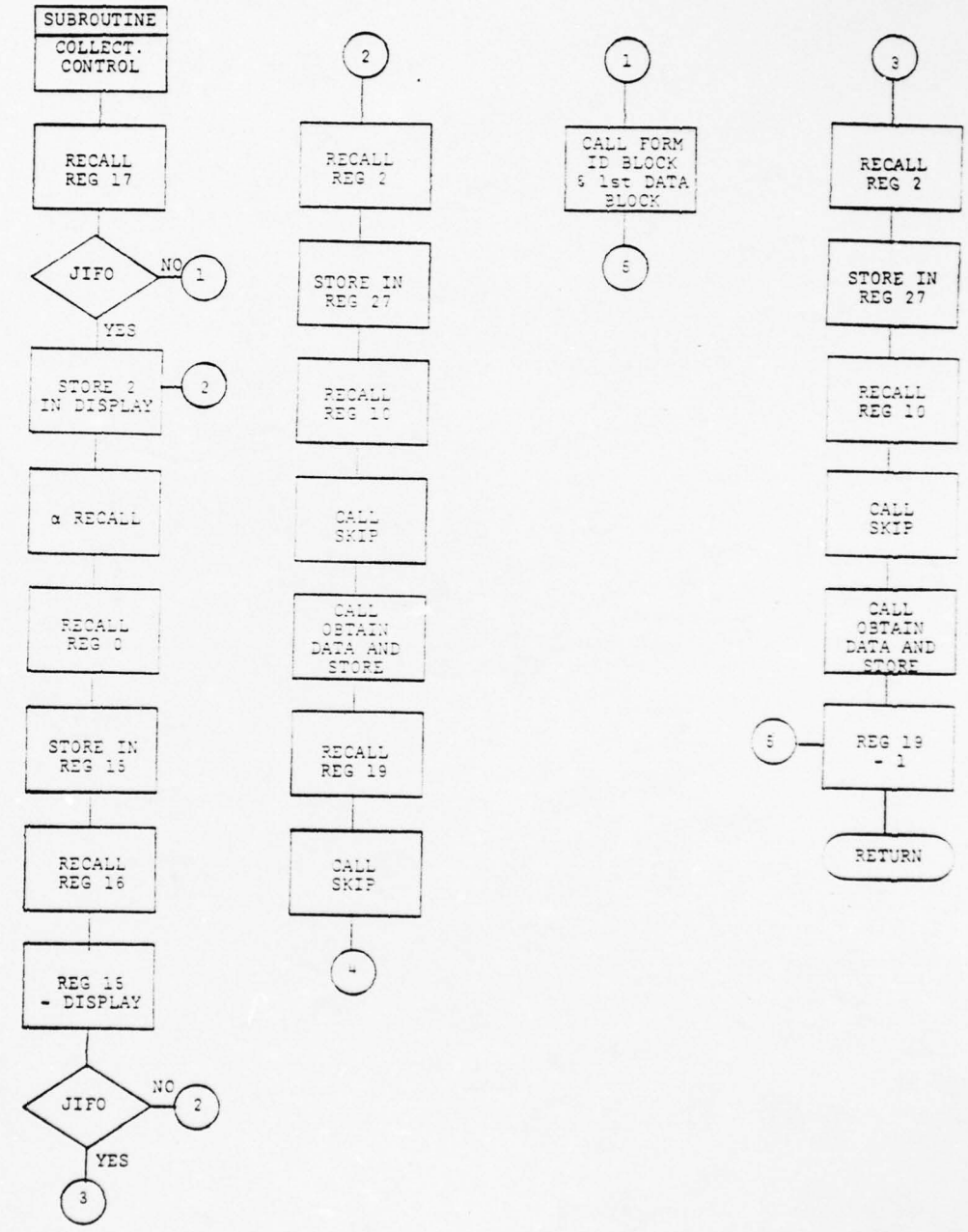
COLLECT CALIBRATION DATA
COLLECT S-PARAMETER DATA

CALLS SUBROUTINES:

FORM ID BLOCK AND COLLECT FIRST DATA BLOCK
SKIP
OBTAIN DATA AND STORE

REGISTERS USED:

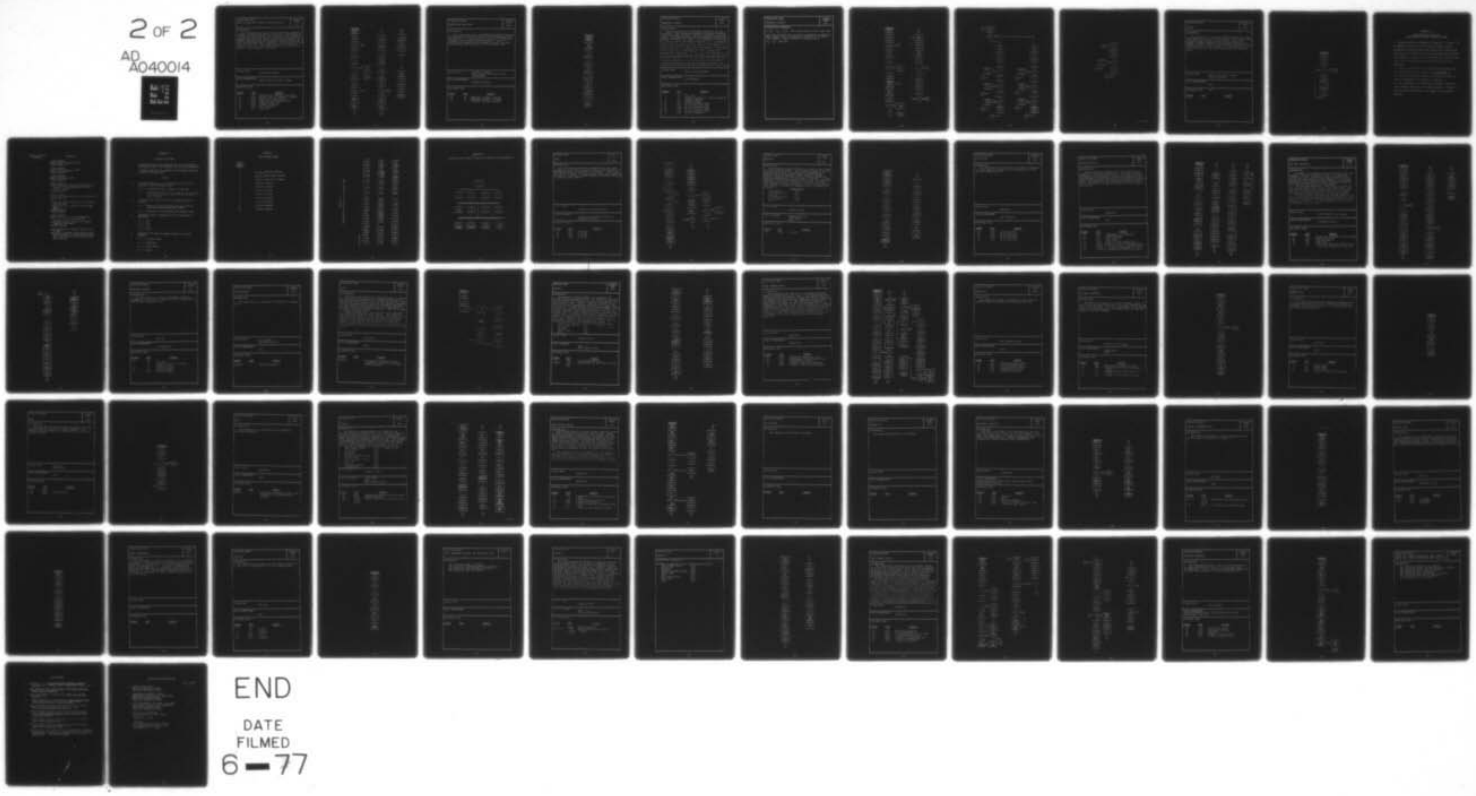
NUMBER	CODE	PURPOSE
10	10	Number of blocks to skip to next available block
16	T↓01	Total number of records in file
17	T↓02	Flag to indicate if ID blocks recorded
19	T↓04	Number of blocks left to be recorded
27	T↓11	Desired frequency


SUBROUTINE
COLLECT. CONTROL
RECALL REG 17
JIFO
NO
1
YES
STORE 2 IN DISPLAY
2
α RECALL
RECALL REG 0
STORE IN REG 18
RECALL REG 16
REG 16 - DISPLAY
JIFO
NO
2
YES
3
2
RECALL REG 2
STORE IN REG 27
RECALL REG 10
CALL SKIP
CALL OBTAIN DATA AND STORE
RECALL REG 19
CALL SKIP
4
1
CALL FORM ID BLOCK & 1st DATA BLOCK
5
3
RECALL REG 2
STORE IN REG 27
RECALL REG 10
CALL SKIP
CALL OBTAIN DATA AND STORE
6
REG 19 - 1
RETURN

AD-A040 014 NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF F/G 17/2.1
A CALCULATOR CONTROLLED MICROWAVE NETWORK ANALYZER SYSTEM.(U)
MAR 77 D K YOUNG

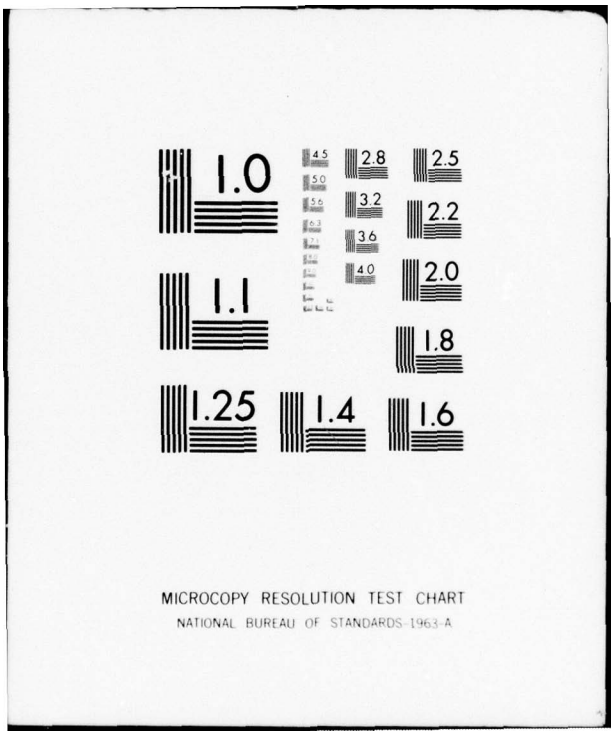
UNCLASSIFIED NL

2 OF 2
AD A040014



END

DATE FILMED
6-77


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SUBROUTINE NAME: FORM ID BLOCK AND COLLECT FIRST DATA BLOCK	ADDRESS CODE: 1008

DESCRIPTION:

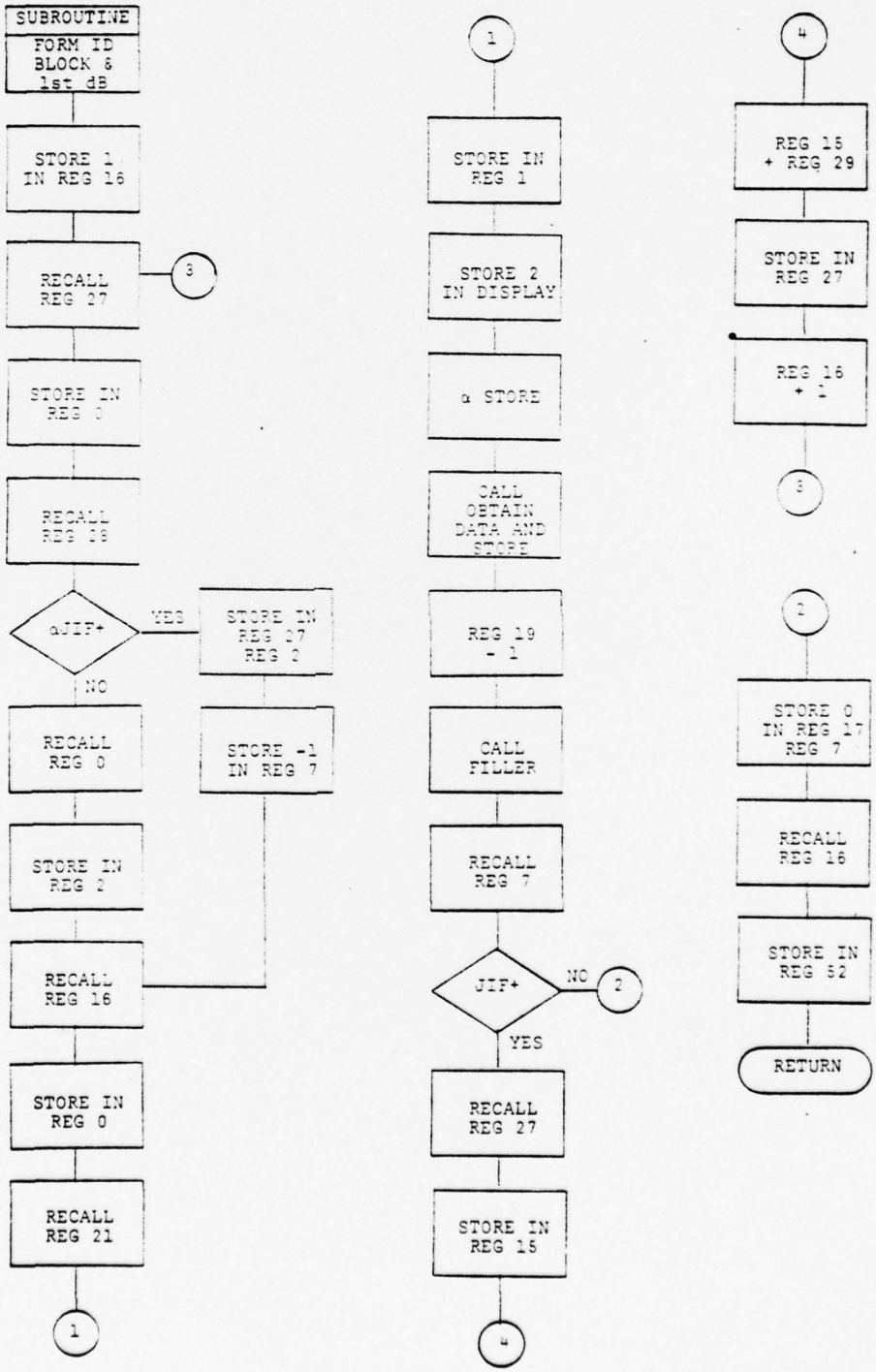
This subroutine is called by the subroutine COLLECTION CONTROL the first time data is collected. Its purpose is to form the identification block and to collect the first block of data for each record. The ID block consists of an integer indicating the record number, the Collection Job Code, and the frequency at which all the data in the record is to be measured. Upon completion of the subroutine, register 17 is set to zero and register 16 is set to the number of data records in the file.

CALLED FROM: COLLECTION CONTROL

CALLS SUBROUTINES: OBTAIN DATA AND STORE, FILLER

REGISTERS USED:

NUMBER	CODE	PURPOSE
7	07	Flag used to indicate last record
16	T↓01	Running total of number of records
17	T↓02	Flag - first measurement
19	T↓04	Number of data blocks/record
21	T↓06	Collection Job Code
27	T↓11	desired frequency
28	T↓12	stop frequency
29	T↓13	step size


SUBROUTINE
FORM ID BLOCK & 1st dB
STORE 1 IN REG 16
RECALL REG 27
3
STORE IN REG 0
RECALL REG 28
αJIF+
YES
STORE IN REG 27 REG 2
NO
RECALL REG 0
STORE -1 IN REG 7
STORE IN REG 2
RECALL REG 16
STORE IN REG 0
RECALL REG 21
1
1
STORE IN REG 1
STORE 2 IN DISPLAY
α STORE
CALL OBTAIN DATA AND STORE
REG 19 - 1
CALL FILLER
RECALL REG 7
JIF+
NO
2
YES
RECALL REG 27
STORE IN REG 15
4
4
REG 15 + REG 29
STORE IN REG 27
REG 16 + 1
3
2
STORE 0 IN REG 17 REG 7
RECALL REG 16
STORE IN REG 52
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
OBTAIN DATA AND STORE	1009

DESCRIPTION:

This subroutine calls the FREQUENCY ACQUIRE subroutine which drives the sweep oscillator to the frequency found in register 27. It then collects the X and Y deflection voltages from the Wang 605-1A Interfaces. The X, Y deflection voltages and the frequency at which voltages were measured are then stored on the cassette tape.

CALLED FROM: COLLECTION CONTROL
FORM ID BLOCK AND COLLECT FIRST MEASUREMENT

CALLS SUBROUTINES:

FREQUENCY ACQUIRE

REGISTERS USED:

NUMBER	CODE	PURPOSE
00	00	Temporary storage X voltage
01	01	Temporary storage Y voltage
02	02	Temporary storage frequency

SUBROUTINE
OBTAIN DATA AND STORE
CALL FREQ. ACQUIRE
STORE IN REG 2
GROUP I 0701
STORE IN REG 0
GROUP I 0702
STORE IN REG 1
STORE 2 IN DISPLAY
α STORE
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
FREQUENCY ACQUIRE	1010

DESCRIPTION:

This subroutine is the software control of the D/A interface. The subroutine compares the desired frequency with the present frequency the sweep oscillator is generating. It compares them by first determining whether the present frequence (f_p) needs to be increased or decreased in order to match the desired frequency (f_d). A direction flag is set to minus one of f_p needs to be increased or set to plus one if f_p needs to be decreased. It next computes $|f_p - f_d|$ to determine how much f_p needs to be increased or decreased. If $|f_p - f_d| \leq 900$ KHZ, then f_p is put in the display register and control is returned to the calling subroutine. If $|f_p - f_d| > 900$ KHZ then the subroutine compares $|f_p - f_d|$ with the five ΔF/CODE values computed and stored by the ΔF VS COUNT subroutine. It chooses the function code which produces the s allest value

CALLED FROM: OBTAIN DATA AND STORE

CALLS SUBROUTINES: GET FREQUENCY

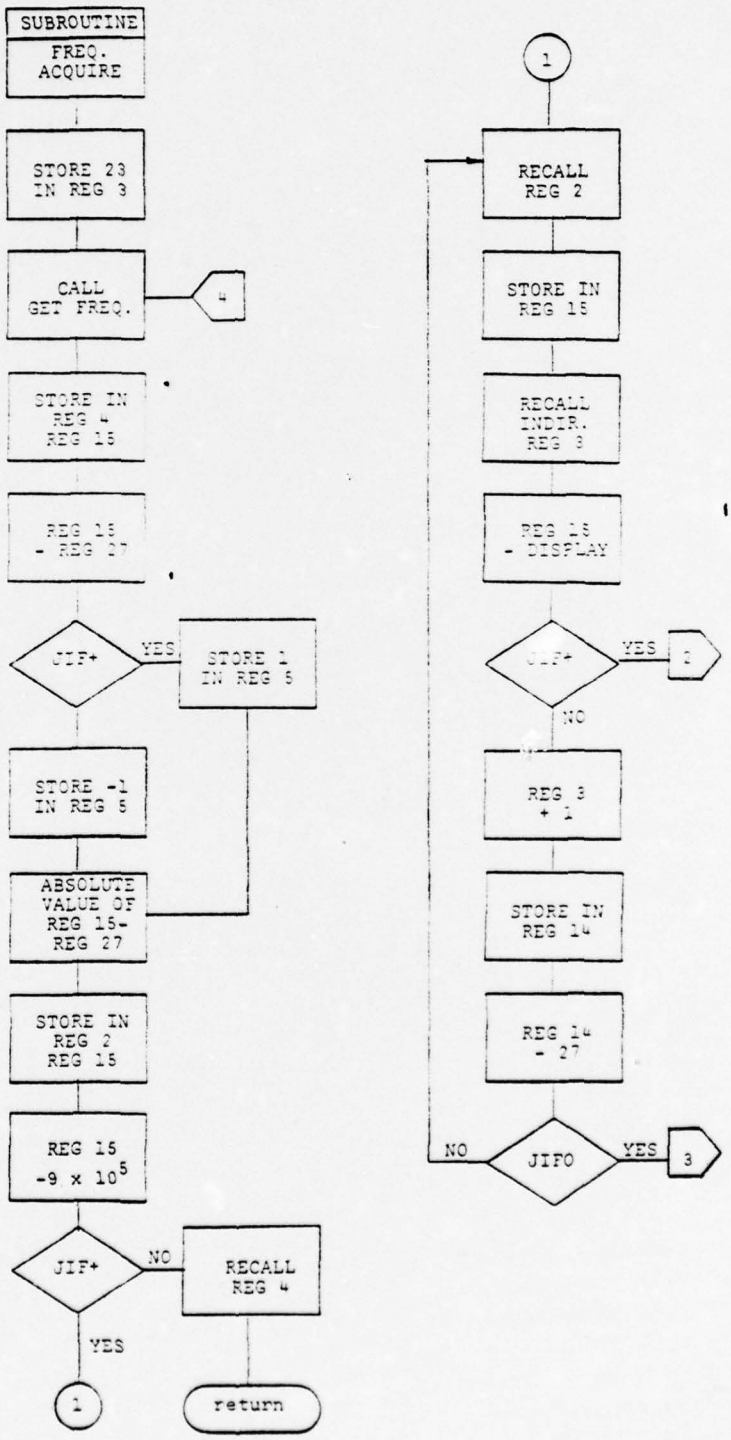
REGISTERS USED:

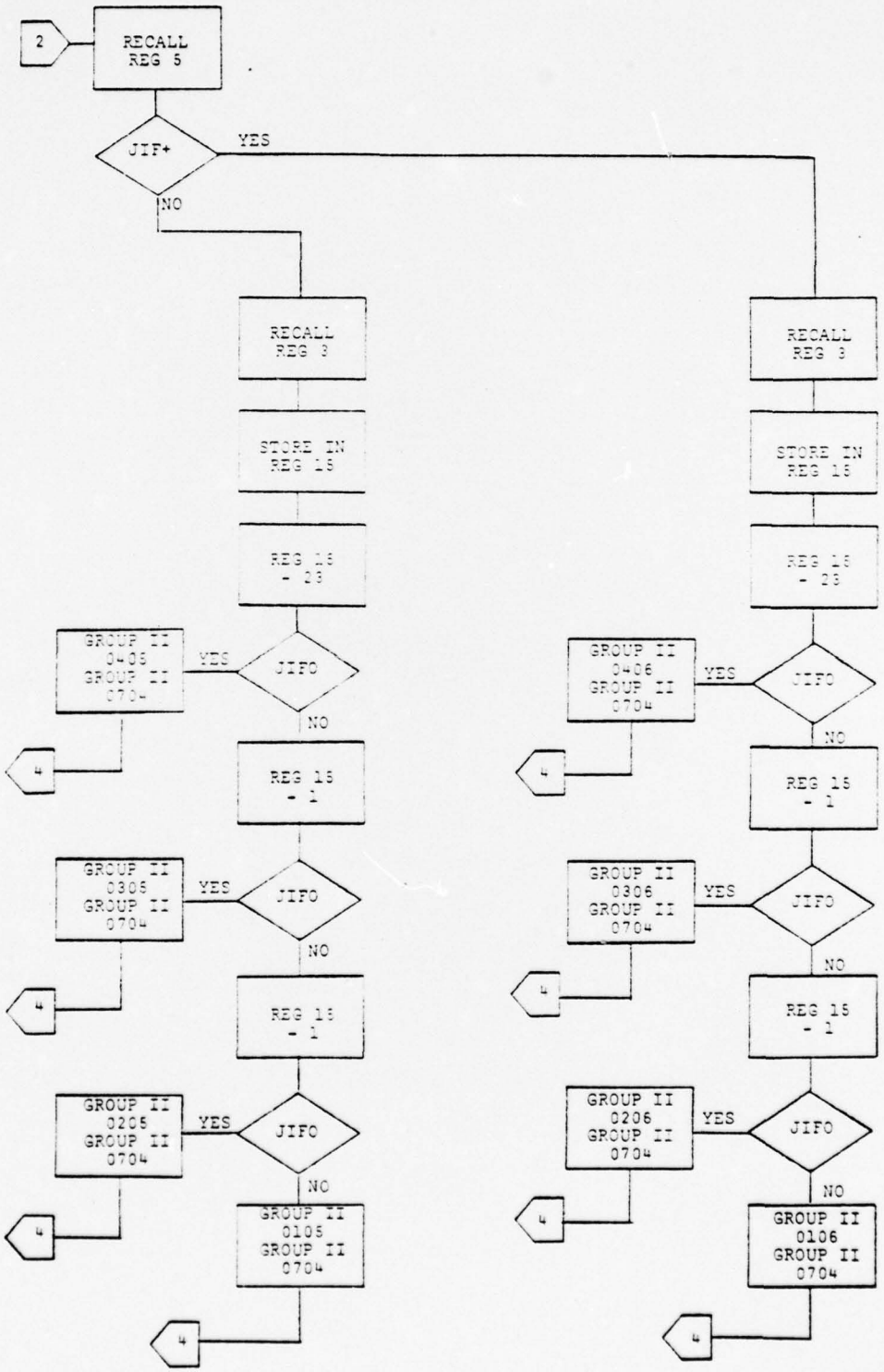
NUMBER	CODE	PURPOSE
2	02	$\|f_p - f_d\|$
3	03	Indirect pointer to F/Code registers
4	04	Present frequency
5	05	direction Flag
22	+↓06	ΔF for 0701/0702 codes
23	_↓07	ΔF for 0405/0406 codes
24	−↓08	ΔF for 0305/0306 codes
25	∓↓09	ΔF for 0205/0206 codes
26	+↓10	ΔF for 0105/0106 codes
27	+↓11	desired frequency

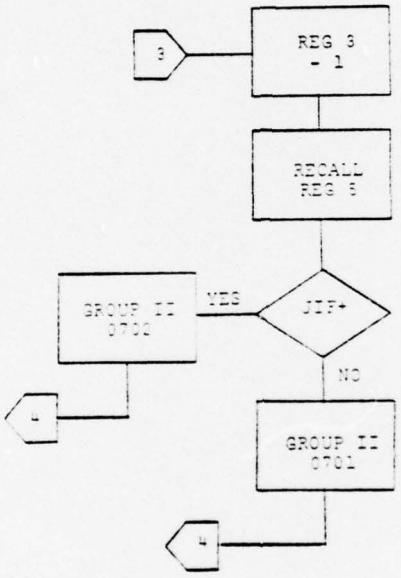
SUBROUTINE NAME:	ADDRESS CODE:
FREQUENCY ACQUIRE	1010

DESCRIPTION CONTINUED:

of $\left|\Delta F - |f_p - f_d|\right|$. The chosen function code along with with the direction flag are used to generate the GROUP II, XXXX command sequence immediately followed by a GROUP II 0704 command. This procedure is repeated until $|f_p - f_d| \leq 900$ KHZ.


SUBROUTINE
FREQ. ACQUIRE
STORE 23 IN REG 3
CALL GET FREQ.
4
STORE IN REG 4 REG 15
REG 15 - REG 27
JIF+
YES
STORE 1 IN REG 5
STORE -1 IN REG 5
ABSOLUTE VALUE OF REG 15- REG 27
STORE IN REG 2 REG 15
REG 15 -9 x 10^5
JIF+
NO
RECALL REG 4
YES
1
return
1
RECALL REG 2
STORE IN REG 15
RECALL INDIR. REG 3
REG 15 - DISPLAY
JIF+
YES
2
NO
REG 3 + 1
STORE IN REG 14
REG 14 - 27
NO
JIFO
YES
3


2
RECALL REG 5
JIF+
YES
NO
RECALL REG 8
STORE IN REG 16
REG 16 - 23
GROUP II 0408 GROUP II 0704
YES
JIFO
NO
4
REG 16 - 1
GROUP II 0308 GROUP II 0704
YES
JIFO
NO
4
REG 16 - 1
GROUP II 0208 GROUP II 0704
YES
JIFO
NO
4
GROUP II 0108 GROUP II 0704
4
RECALL REG 8
STORE IN REG 16
REG 16 - 23
GROUP II 0406 GROUP II 0704
YES
JIFO
NO
4
REG 16 - 1
GROUP II 0306 GROUP II 0704
YES
JIFO
NO
4
REG 16 - 1
GROUP II 0206 GROUP II 0704
YES
JIFO
NO
4
GROUP II 0106 GROUP II 0704
4


3
REG 3
- 1
RECALL
REG 3
JIF+
YES
GROUP II
0702
4
NO
GROUP II
0701
4

SUBROUTINE NAME:	ADDRESS CODE:
FILLER	1011

DESCRIPTION:

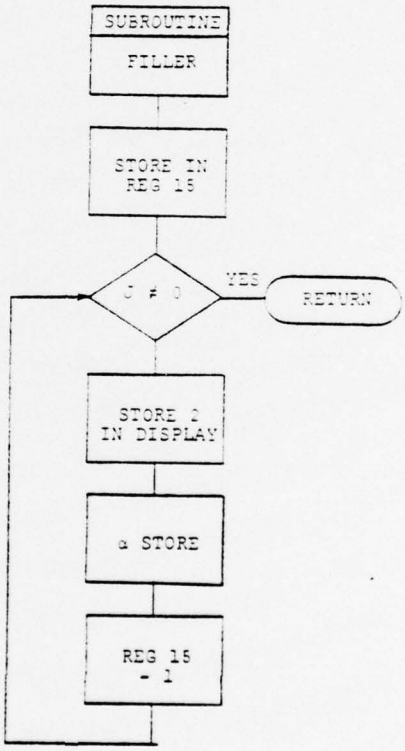
This subroutine is called by FORM ID BLOCK AND COLLECT FIRST DATA BLOCK. It is used to advance the cassette tape by storing the contents of registers 0, 1 and 2 the number of times indicated by the number received in the display register. This is done to advance the tape to the location where the next ID block is to be recorded and to allow room for the data blocks which are to be recorded later.

CALLED FROM: FORM ID BLOCK AND COLLECT FIRST DATA BLOCK

CALLS SUBROUTINES: None

REGISTERS USED: None

NUMBER	CODE	PURPOSE


SUBROUTINE
FILLER
STORE IN
REG 15
C ≠ 0
YES
RETURN
STORE 1
IN DISPLAY
α STORE
REG 15
- 1

APPENDIX G

PROCEDURES FOR USING THE COLLECTION AND DISPLAY SYSTEM PROGRAMS

1. Energize hardware components as required. If data is to be obtained from the HP 8410S Network Analyzer System, calibrate the display module and ensure the HP 8690B Sweep Oscillator is in the CW mode and the External FM pushbutton is depressed. If data is to be obtained from cassette tape only, the HP 8410S Network Analyzer System need not be energized.

2. Insert the Collection and Display system program tape into the tape drive and depress the LOAD PROGRAM Key.

3. Enter in the display register the desired Display Job Code (see Appendix H) and depress the GO Key.

4. The calculator will occasionally interrupt execution with a number showing in the display register. Respond as indicated below according to the number in the display register.

Display Register Contents	Response
1	Clear Display Enter Start Frequency in HZ Depress GO Key
2	Clear Display Enter Stop Frequency in HZ Depress GO Key
3	Clear Display Enter Step Size in HZ Depress GO Key
4	Clear Display Enter Difference Between Calibration dB Setting and dB Measurement Setting [dB(c) - dB(m)] Depress GO Key
5	Clear Display Enter User Program Number (see Appendix I) Depress GO Key
6	Rewind and Remove Collection and Display Program Tape Insert Data Tape, Rewind, Depress TAPE READY Clear Display Depress GO Key
7	Clear Display Enter a 1, 2, 3 or 4 to indicate S_{21}, S_{12}, S_{11} or S_{22}, respectively. Configure Network Analyzer to Measure Parameter Specified Depress GO Key
8	Data Specified as Being on Tape is Not on Tape Reinitiate Software System Using a Different Display Job Code Which Obtains Data From the HP 8410S Microwave Network Analyzer

APPENDIX H

DISPLAY JOB CODES

Display Job Codes are formed by the user to specify the display job to be performed by the system programs.

A Display Job Code is entered in the display register in the following format

W.XYZ

W specifies whether or not calibration data is to be applied to the S-parameter data

W = 0 → calibration data is Not to be applied.

W = 1 → calibration data is to be applied and the data has been previously collected and is available on tape.

X designates the location of the S-parameter data to be used

X = 0 → data is to be collected from the HP 8410S Microwave Network Analyzer System

X = 1 → data is to be retrieved from cassette tape

Y designates which S-parameter is to be measured or retrieved

Y = 1 → S_{21}
Y = 2 → S_{12}
Y = 3 → S_{11}
Y = 4 → S_{22}

Z specifies the display program needed by the user program

Z = 0 → Printer Ready

Z = 1 → Cartisian

Z = 2 → Smith Chart

Z = 3 → Polar

APPENDIX I

USER PROGRAM TABLE

User Program Number	
1	S_{11}/S_{22} Printing Program
2	S_{11}/S_{22} Smith Chart Program
3	S_{12}/S_{21} Polar Plot Program
4	(Future Program)
5	(Future Program)
6	(Future Program)
7	(Future Program)
8	(Future Program)
9	(Future Program)
10	(Future Program)
11	(Future Program)

Appendix J

Collection and Display System Memory Map

REGISTER NUMBER:

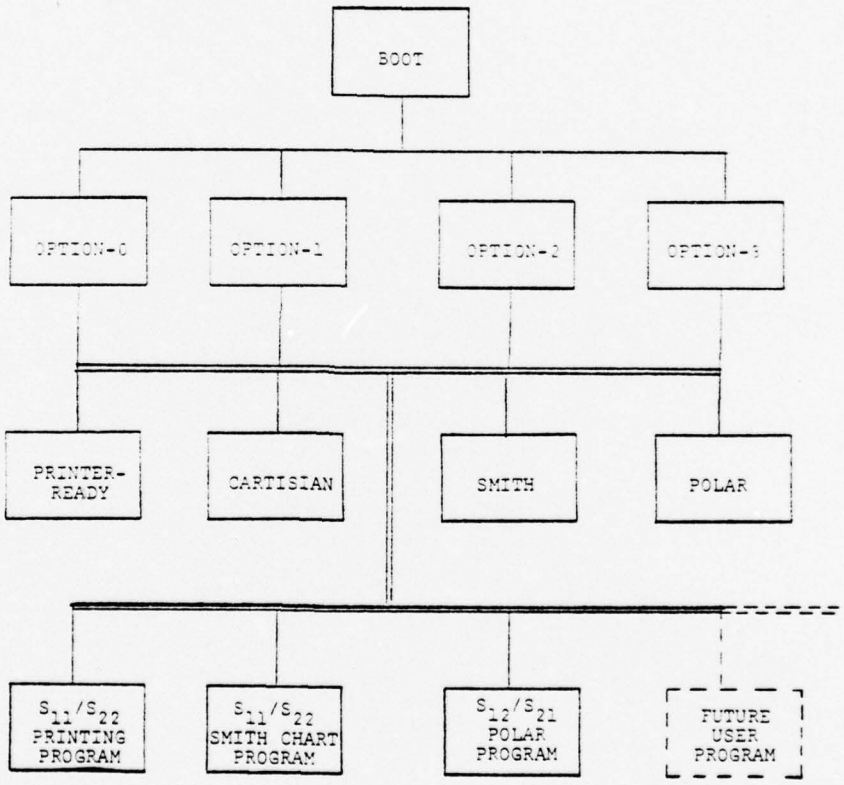
25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
X VOLT L(0)	Y VOLT L(0)	MEAS FREQ	X VOLT L(1)	Y VOLT L(1)	MEAS FREQ	X VOLT L(2)	Y VOLT L(2)	MEAS FREQ	W OF DJC	X OF DJC	Y OF DJC	Z OF DJC	ΔF VS STEP	ΔF VS 040X

40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
ΔF VS 030X	ΔF VS 020X	ΔF VS 010X		# OF CALIB. SETS	# OF DATA BLOCK/ REC	S-PARA ON TAB	DATA RECORD #	CJC	DESIR FREQ	STOP FREQ	STEP SIZE	N TOTAL # OF DATA REC	TRANS L(0)	TRANS L(1)

55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
TRANS L(2)	REFL L(0)	REFL L(1)	REFL L(2)	S_{21} dB DIFF.	S_{12} dB DIFF.	S_{11} dB DIFF.	S_{22} dB DIFF.		# SKIPS TO DES. CALIB. SET	# SKIPS TO DES. S-PARA.	# SKIPS TO NEXT ID BLK.	SKIP BUFFER	SKIP BUFFER	SKIP BUFFER

Appendix K

Collection and Display System Flow Charts and Descriptions



PROGRAM NAME:	ADDRESS CODE:
BOOT	None

DESCRIPTION:

The bootstrap program BOOT decomposes the four digit Display Job Code (DJC) provided by the user and stores the individual digits in registers 34 through 37. Based upon the first two digits of the DJC, Boot loads, from tape, one of the four executive programs OPTION-0, OPTION-1, OPTION-2 or OPTION-3 over itself.

CALLED FROM:

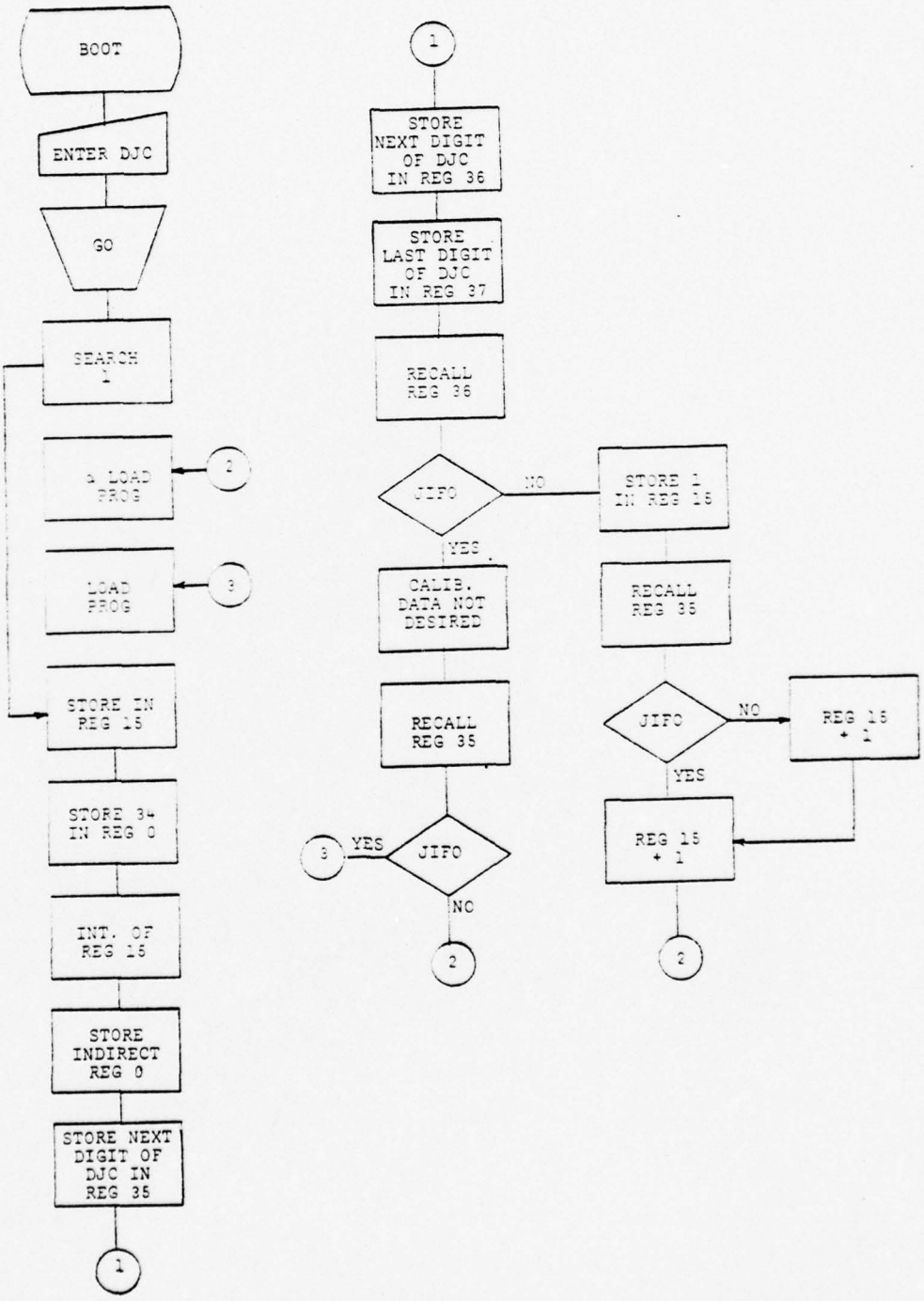
Loaded by the system user

CALLS PROGRAMS:

Loads one of the four executive programs from tape

REGISTERS USED:

NUMBER	CODE	PURPOSE
34	+↓02	W of DJC
35	+↓03	X of DJC
36	+↓04	Y of DJC
37	+↓05	Z of DJC


BOOT
ENTER DJC
GO
SEARCH 1
a LOAD PROG
LOAD PROG
STORE IN REG 15
STORE 34 IN REG 0
INT. OF REG 15
STORE INDIRECT REG 0
STORE NEXT DIGIT OF DJC IN REG 35
1
3
1
STORE NEXT DIGIT OF DJC IN REG 36
STORE LAST DIGIT OF DJC IN REG 37
RECALL REG 36
JIFO
NO
STORE 1 IN REG 15
YES
CALIB. DATA NOT DESIRED
RECALL REG 35
JIFO
NO
REG 15 + 1
YES
REG 15 + 1
RECALL REG 35
3
YES
JIFO
NO
2
2

PROGRAM NAME:	ADDRESS CODE:
OPTION-0	None

DESCRIPTION:

The executive program OPTION-0 is loaded by the system bootstrap program (BOOT). The program is composed of subroutines which permit acquisition of S-parameter data from the HP 8410S Microwave Network Analyzer System. OPTION-0 loads and executes one of the four display programs as designated by the last digit of the DJC. It then requests a User Program Number from the user by interrupting execution with a 5 showing in the display register. The program then loads and passes control to the specified user program. OPTION-0 is composed of the following subroutines:

	Address Code
ΔF VS COUNT	1113
DEVELOPE FILE ID	1114
GET DATA	1112
FREQUENCY ACQUIRE	1111
GET FREQUENCY	1110
LOAD	1115

CALLED FROM:

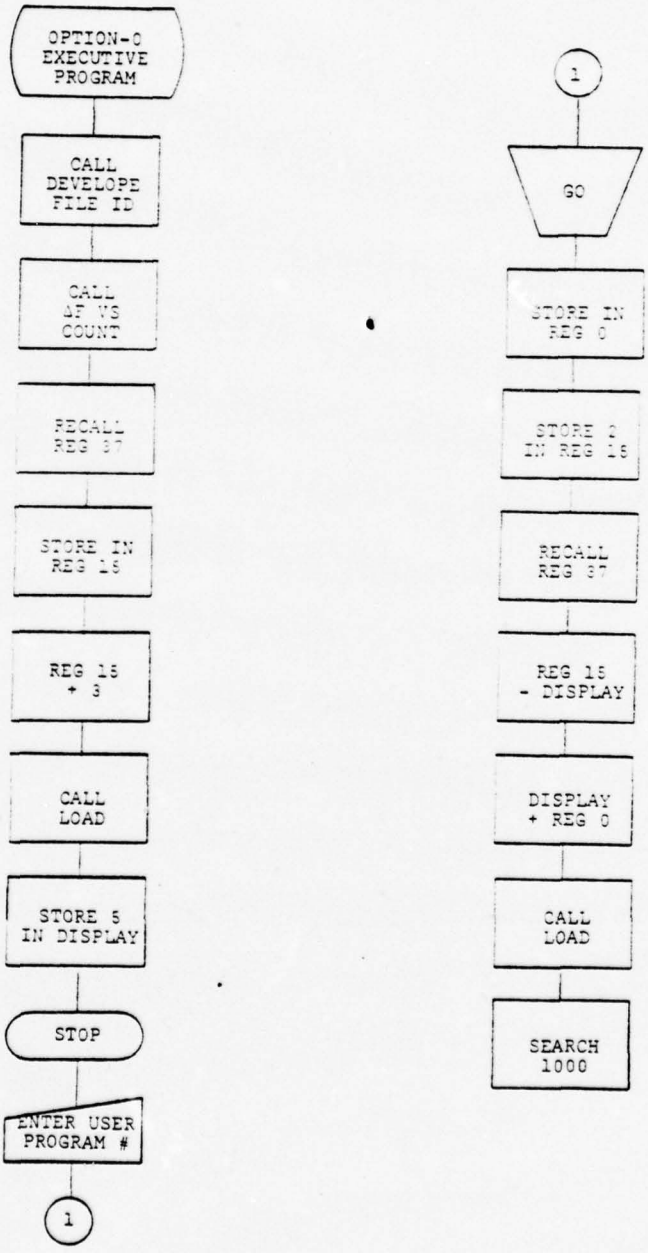
Loaded by Boot

CALLS PROGRAMS:

DEVELOPE FILE ID
ΔF VS COUNT
LOAD

REGISTERS USED:

NUMBER	CODE	PURPOSE
37	+↓05	Z of DJC


OPTION-0
EXECUTIVE
PROGRAM
CALL
DEVELOPE
FILE ID
CALL
AP WS
COUNT
RECALL
REG 07
STORE IN
REG 16
REG 16
+ 3
CALL
LOAD
STORE 5
IN DISPLAY
STOP
ENTER USER
PROGRAM #
1
1
GO
STORE IN
REG 0
STORE 0
IN REG 16
RECALL
REG 07
REG 16
- DISPLAY
DISPLAY
+ REG 0
CALL
LOAD
SEARCH
1000

SUBROUTINE NAME:	ADDRESS CODE:
ΔF VS COUNT	1113

DESCRIPTION:

See description of subroutine ΔF VS COUNT in Appendix F. Flow chart is identical with the exception of the different registers used.

CALLED FROM:

EXECUTIVE

CALLS SUBROUTINES:

GET FREQUENCY

REGISTERS USED:

NUMBER	CODE	PURPOSE
38	+↓06	ΔF VS 0701/0702
39	+↓07	ΔF VS 0405/0406
40	+↓08	ΔF VS 0305/0306
41	+↓09	ΔF VS 0205/0206
42	+↓10	ΔF VS 0105/0106

SUBROUTINE NAME:	ADDRESS CODE:
DEVELOPE FILE ID	1114

DESCRIPTION:

This subroutine interfaces with the system user by requesting collection information. It requests a start frequency, a stop frequency, a step size, and the difference between the dB setting used for calibration of the network display module and the dB setting used for measurement. The subroutine then computes the number of data points (N) between the start frequency and stop frequency inclusively.

CALLED FROM:

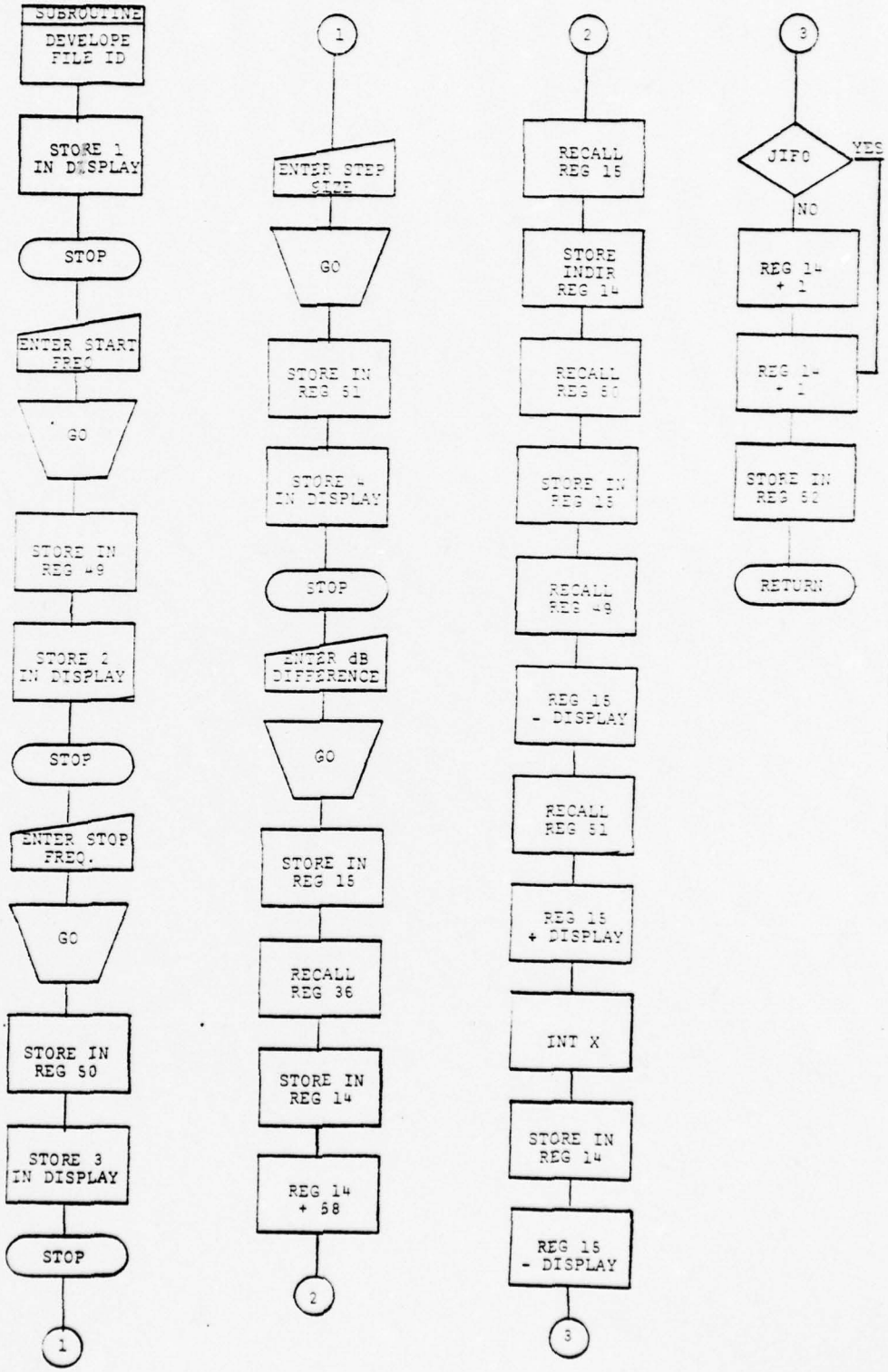
EXECUTIVE

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
36	+↓04	S-paramter to be measured
49	-↓01	Start Frequency
50	-↓02	Stop Frequency
51	-↓03	Step Size
52	-↓04	Total # of data points (N)
59	-↓11	Used to store dB difference provided by user. Location depends on which S-parameter is to be measured as indicated by Reg 36
60	-↓12	
61	-↓13	
62	-↓14	


SUBROUTINE
DEVELOPE FILE ID
STORE 1 IN DISPLAY
STOP
ENTER START FREQ
GO
STORE IN REG 49
STORE 2 IN DISPLAY
STOP
ENTER STOP FREQ.
GO
STORE IN REG 50
STORE 3 IN DISPLAY
STOP
1
1
ENTER STEP SIZE
GO
STORE IN REG 51
STORE 4 IN DISPLAY
STOP
ENTER dB DIFFERENCE
GO
STORE IN REG 15
RECALL REG 36
STORE IN REG 14
REG 14 + 58
2
2
RECALL REG 15
STORE INDIR REG 14
RECALL REG 50
STORE IN REG 13
RECALL REG 49
REG 15 - DISPLAY
RECALL REG 51
REG 15 + DISPLAY
INT X
STORE IN REG 14
REG 15 - DISPLAY
3
3
JIFO
YES
NO
REG 14 + 1
REG 14 + 1
STORE IN REG 50
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
GET DATA (OPTION-0)	1112

DESCRIPTION:

GET DATA is the system subroutine called by the user program to provide S-parameter data. The subroutine returns an X and Y deflection voltage obtained from the network analyzer and the output frequency of the sweep oscillator. The subroutine keeps track of how many data sets have been called for and will terminate the system when the (N + 1)st data set is requested.

The GET DATA subroutine in the OPTION-0 program has one feature which is not found in the other three. When the (N + 1)st data set is called for by a user program the system interrupts execution with the total number of data sets returned showing in the display register.

By entering the start frequency and depressing the GO Key on the calculator keyboard a recovery process in initiated. This allows for the measurement of more than one S-parameter under the same user program without having to reinitiate the whole system.

CALLED FROM:

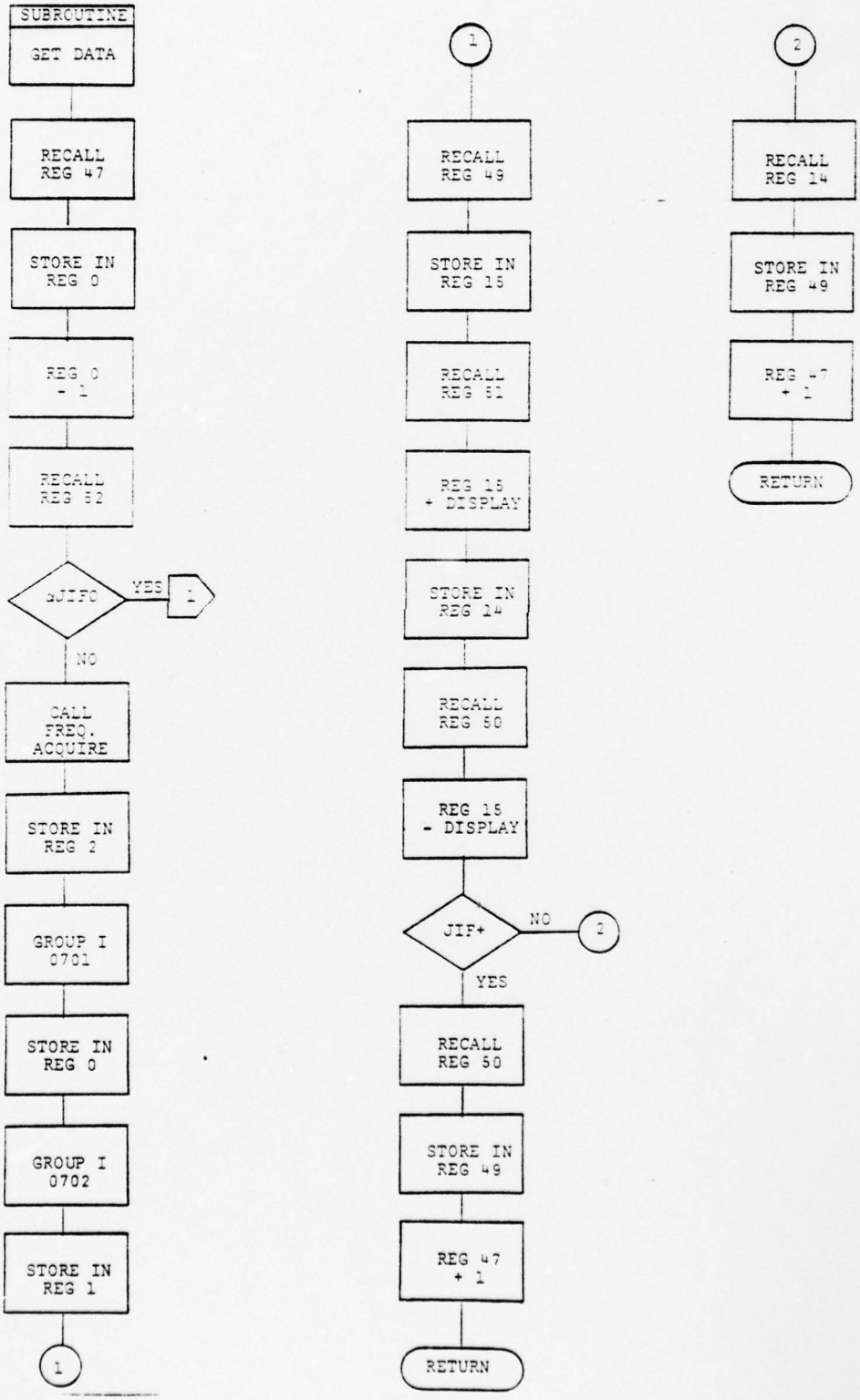
CORE RESIDENT User Program

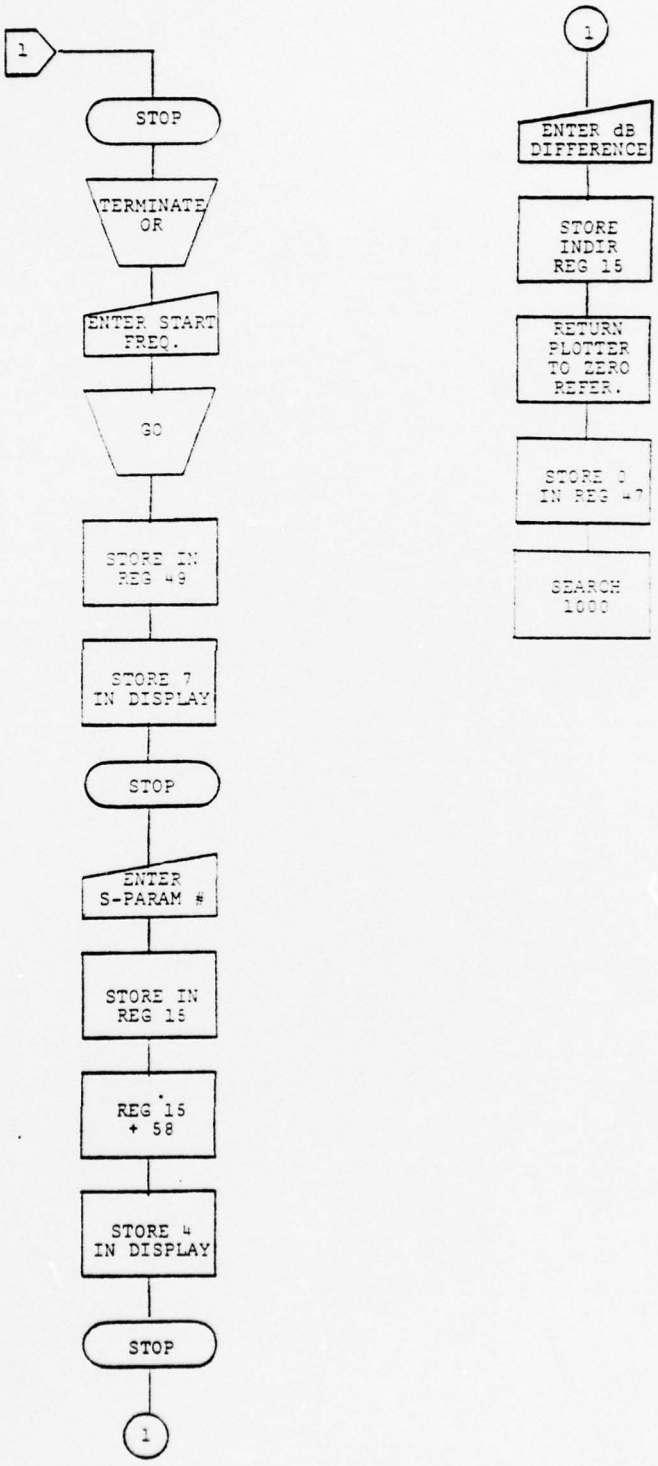
CALLS SUBROUTINES:

FREQUENCY ACQUIRE

REGISTERS USED:

NUMBER	CODE	PURPOSE
47	+↓15	# data sets returned to user program
49	-↓01	Desired frequency
50	-↓02	Stop frequency
51	-↓03	Step size
52	-↓04	Total # of Data sets between start and stop frequencies inclusively


SUBROUTINE
GET DATA
RECALL REG 47
STORE IN REG 0
REG 0 - 1
RECALL REG 52
JUFO
YES
1
NO
CALL FREQ. ACQUIRE
STORE IN REG 2
GROUP I 0701
STORE IN REG 0
GROUP I 0702
STORE IN REG 1
1
1
RECALL REG 49
STORE IN REG 15
RECALL REG 51
REG 15 + DISPLAY
STORE IN REG 14
RECALL REG 50
REG 15 - DISPLAY
JIF+
NO
2
YES
RECALL REG 50
STORE IN REG 49
REG 47 + 1
RETURN
2
RECALL REG 14
STORE IN REG 49
REG 47 + 1
RETURN


1
STOP
TERMINATE OR
ENTER START FREQ.
GO
STORE IN REG 49
STORE 7 IN DISPLAY
STOP
ENTER S-PARAM #
STORE IN REG 15
REG 15 + 58
STORE 4 IN DISPLAY
STOP
1
1
ENTER dB DIFFERENCE
STORE INDIR REG 15
RETURN PLOTTER TO ZERO REFER.
STORE 0 IN REG 47
SEARCH 1000

SUBROUTINE NAME:	ADDRESS CODE:
FREQUENCY ACQUIRE	1111

DESCRIPTION:

See Description of subroutine FREQUENCY ACQUIRE in Appendix F. Flow chart is identical with the exception of the different registers used.

CALLED FROM:

GET DATA

CALLS SUBROUTINES:

GET FREQUENCY

REGISTERS USED:

NUMBER	CODE	PURPOSE
0	00	$\lvert f_p - f_d \rvert$
1	01	Indirect pointer to ΔF/codes Regs 39 - 42.
2	02	Present frequency
3	03	Direction Flag
49	-↓01	Desired Frequency

SUBROUTINE NAME:	ADDRESS CODE:
GET FREQUENCY	1110

DESCRIPTION:

See Description of subroutine GET FREQUENCY in Appendix F.

CALLED FROM: ΔF VS COUNT
FREQUENCY ACQUIRE

CALLS SUBROUTINES: None

REGISTERS USED:

NUMBER	CODE	PURPOSE
Display	-	Present frequency

SUBROUTINE NAME:	ADDRESS CODE:
LOAD	1115

DESCRIPTION:

LOAD is a three instruction subroutine which is called by the executive program to load programs found on tape. The instructions are MARK 1115, α LOAD, END PROGRAM. When called the α LOAD instruction skips the number of programs on tape indicated by the number in the display register. It then loads the next program into core beginning at the location of the END PROGRAM instruction. Once the program is loaded execution begins.

Display programs which are loaded by this subroutine are immediately executed after loading. User programs which are also loaded by this subroutine are written with a RETURN instruction as its first executable instruction. When the return instruction is executed the calculator returns to the address which is on top of subroutine RETURN address stack; in this case it will be the location in the executive program from where the LOAD subroutine was called.

CALLED FROM:

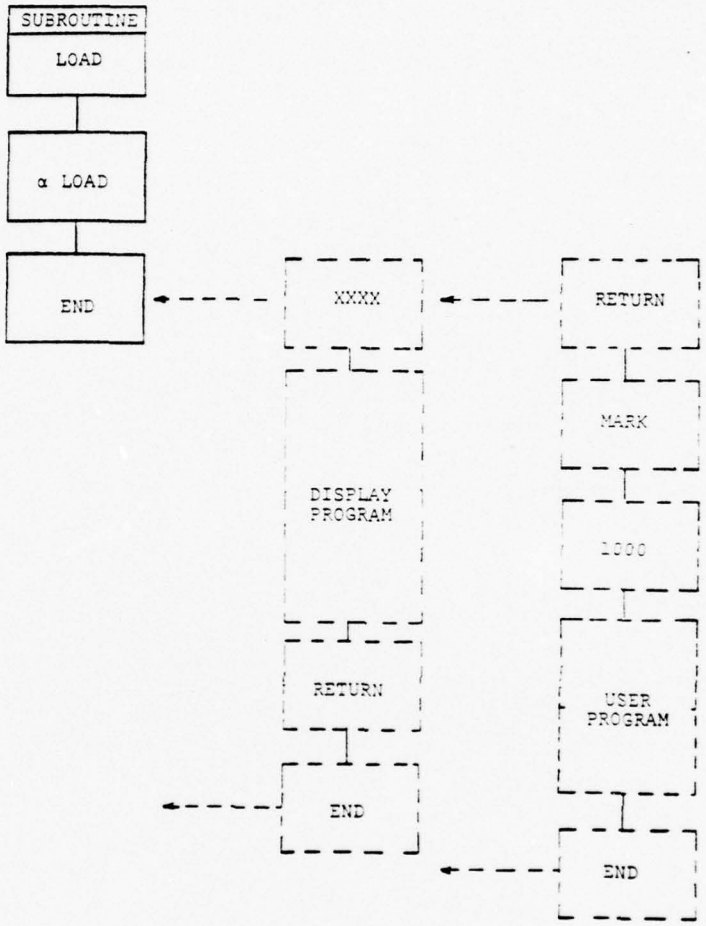
EXECUTIVE

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
Display	-	# in display indicates how many programs on tape will be skipped before loading.


SUBROUTINE
LOAD
α LOAD
END
XXXX
RETURN
DISPLAY PROGRAM
MARK
1000
RETURN
USER PROGRAM
END
END

PROGRAM NAME:	ADDRESS CODE:
OPTION-1	None

DESCRIPTION:

The executive program OPTION-1 is loaded by the system bootstrap program (BOOT). The program is composed of subroutines which permit retrieval of S-parameter data from cassette tape. OPTION-0 loads and executes one of the four display programs as specified by the last digit of the DJC. It then requests a User Program Number from the user by interrupting execution with a 5 showing in the display register. The executive program loads the user program over the display program and then interrupts execution with a 6 showing in the display register. The user removes the program tape and inserts the data tape from which the S-parameter data is to be retrieved. Other preliminary functions are performed by OPTION-1 and then control is passed to the resident user program

OPTION-1 is composed of the following subroutines:

TAPE CONTROL SET-UP	1114	LOAD	1115
DECODE CJC	1109		
GET DATA	1112		
OBTAIN DATA	1107		
SKIP	1106		

CALLED FROM:

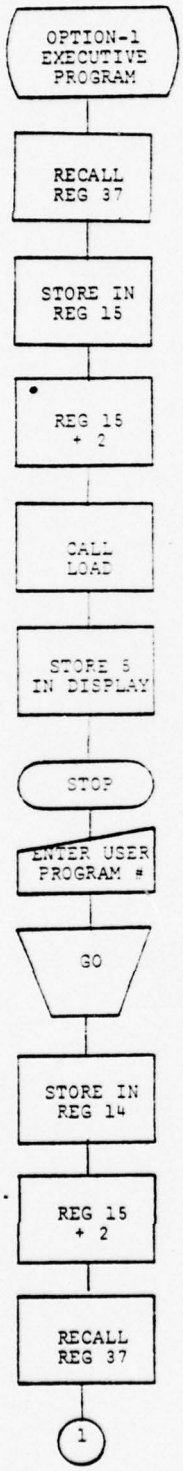
LOADED BY BOOT

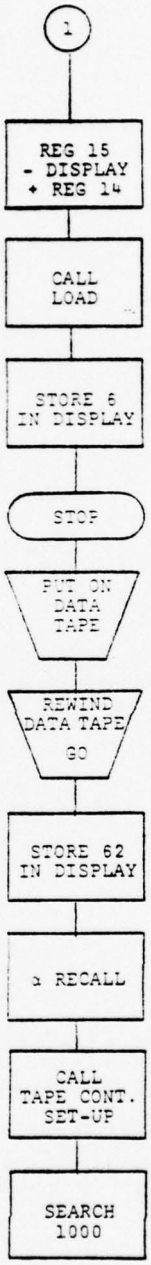
CALLS PROGRAMS:

LOAD
TAPE CONTROL SET-UP

REGISTERS USED:

NUMBER	CODE	PURPOSE
37	+↓05	Z of Display Job Code
48 thru 62	-↓00 thru -↓14	Input buffer for the file ID record


OPTION-1
EXECUTIVE
PROGRAM
RECALL
REG 37
STORE IN
REG 15
REG 15
+ 2
CALL
LOAD
STORE 5
IN DISPLAY
STOP
ENTER USER
PROGRAM #
GO
STORE IN
REG 14
REG 15
+ 2
RECALL
REG 37
1


1
REG 15
- DISPLAY
+ REG 14
CALL
LOAD
STORE 6
IN DISPLAY
STOP
PUT ON
DATA
TAPE
REWIND
DATA TAPE
GO
STORE 62
IN DISPLAY
a RECALL
CALL
TAPE CONT.
SET-UP
SEARCH
1000

SUBROUTINE NAME:	ADDRESS CODE:
TAPE CONTROL SET-UP	1114

DESCRIPTION:

This subroutine is used to set up control registers needed to extract data from tape. It determines how many data blocks must be skipped to drive the cassette tape to the data block containing the S-parameter data specified in the Display Job Code. It then computes how many data blocks must be skipped to drive the cassette tape to the beginning of the next record. This information is obtained through the use of the third digit of the Display Job Code (DJC) and the last two digits of the Collection Job Code (CJC). If a S-parameter specified in the DJC is not recorded on tape the subroutine will terminate the system by putting an 8 in the display register and stopping execution.

CALLED FROM:

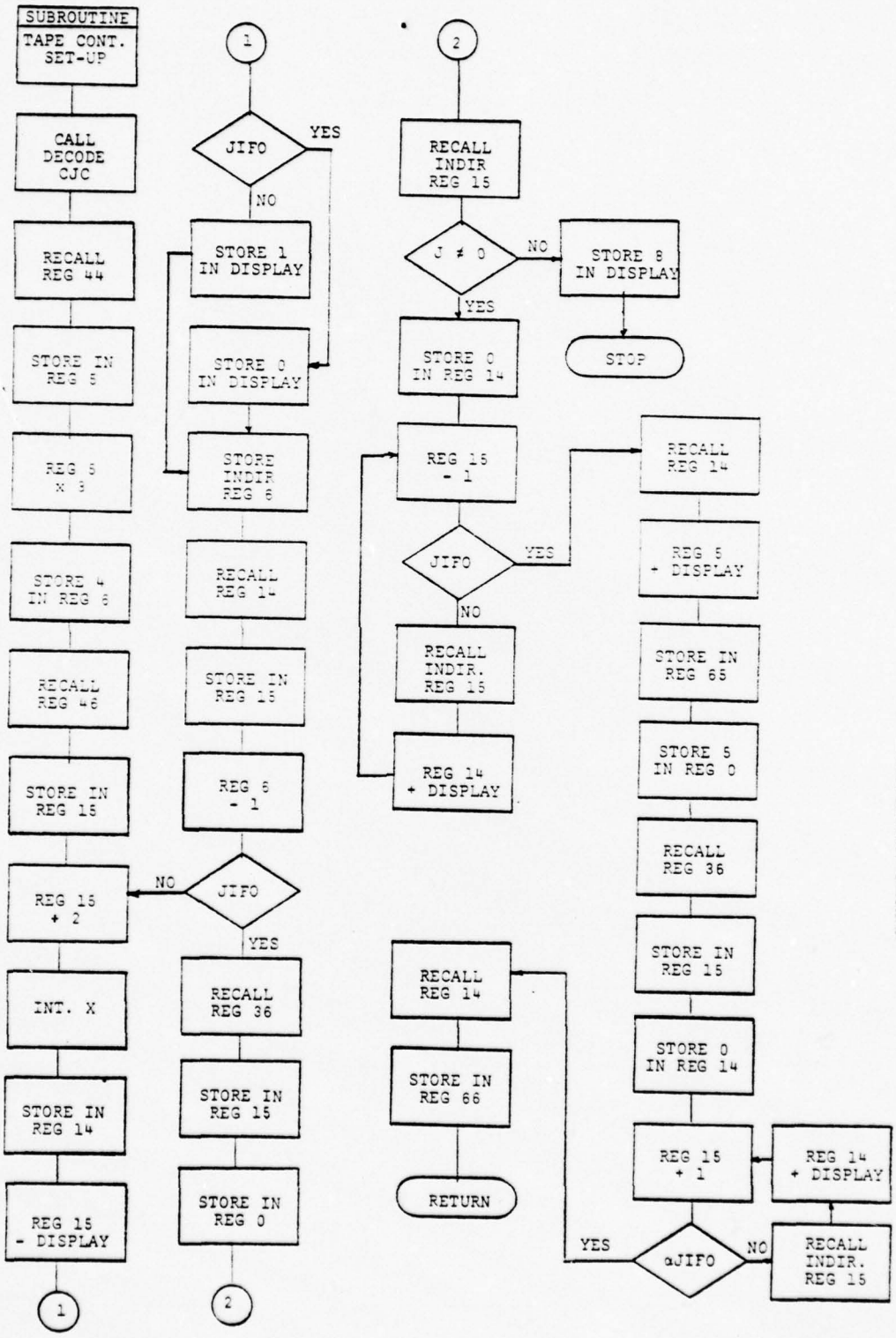
EXECUTIVE

CALLS SUBROUTINES:

DECODE CJC

REGISTERS USED:

NUMBER	CODE	PURPOSE
36	+↓04	S-parameter specified in DJC
44	+↓12	# calibration sets/record on tape
46	+↓14	S-parameters on tape
65	X↓01	# skips to desired S-parameter
66	X↓02	# skips to next record ID block


SUBROUTINE
TAPE CONT. SET-UP
CALL DECODE CJC
RECALL REG 44
STORE IN REG 5
REG 5 X 3
STORE 4 IN REG 6
RECALL REG 46
STORE IN REG 15
REG 15 + 2
INT. X
STORE IN REG 14
REG 15 - DISPLAY
1
1
JIFO
YES
NO
STORE 1 IN DISPLAY
STORE 0 IN DISPLAY
STORE INDIR REG 6
RECALL REG 14
STORE IN REG 15
REG 6 - 1
JIFO
NO
YES
RECALL REG 36
STORE IN REG 15
STORE IN REG 0
2
2
RECALL INDIR REG 15
J ≠ 0
NO
YES
STORE 8 IN DISPLAY
STOP
STORE 0 IN REG 14
REG 15 - 1
JIFO
YES
NO
RECALL INDIR. REG 15
REG 14 + DISPLAY
RECALL REG 14
REG 5 + DISPLAY
STORE IN REG 65
STORE 5 IN REG 0
RECALL REG 36
STORE IN REG 15
STORE 0 IN REG 14
REG 15 + 1
REG 14 + DISPLAY
aJIFO
YES
NO
RECALL INDIR. REG 15
RECALL REG 14
STORE IN REG 66
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
DECODE CJC	1109

DESCRIPTION:

See subroutine DECODE in Appendix F. Flow chart is identical with the exception of the registers used.

CALLED FROM:

TAPE CONTROL SET-UP

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
0	00	Indirect address pointer
44	+↓12	# of calibration sets
45	+↓13	# of data blocks/record
46	+↓14	S-parameters on tape
48	-↓00	Collection Job Code

SUBROUTINE NAME:	ADDRESS CODE:
GET DATA (OPTION-1)	1112

DESCRIPTION:

GET DATA, upon request of the user program, checks to see if the last data block sent to the user program was the last block available. If it was, the system is terminated if not, the next data block is obtained from the tape and passed to the user program.

CALLED FROM:

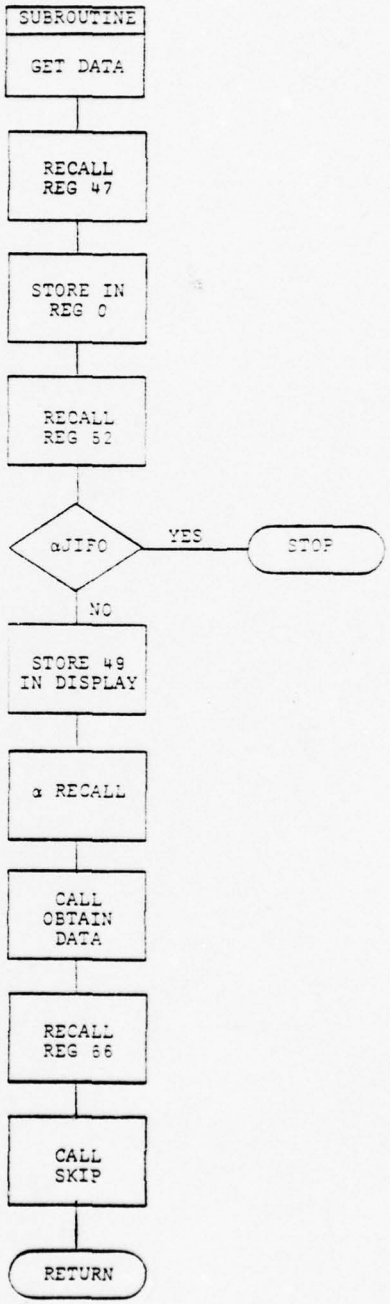
Resident User Program

CALLS SUBROUTINES:

OBTAIN DATA
SKIP

REGISTERS USED:

NUMBER	CODE	PURPOSE
47	+↓15	Record # from record ID block
48	-↓00	Collection Job Code from record ID block
49	-↓01	Desired frequency from record ID block
66	X↓02	# skips to next record ID block


SUBROUTINE
GET DATA
RECALL REG 47
STORE IN REG 0
RECALL REG 52
αJIFO
YES
STOP
NO
STORE 49 IN DISPLAY
α RECALL
CALL OBTAIN DATA
RECALL REG 88
CALL SKIP
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
OBTAIN DATA	1107

DESCRIPTION:

This subroutine obtains the required S-parameter data from tape and loads the X and Y deflection voltages in registers 00 and 01 respectively. The measured frequency is loaded into register 03

CALLED FROM:

GET DATA

CALLS SUBROUTINES:

SKIP

REGISTERS USED:

NUMBER	CODE	PURPOSE
0	00	Input buffer
1	01	Input buffer
2	02	Input buffer
65	X↓01	# skips to desired S-parameter

SUBROUTINE
OBTAIN DATA
RECALL REG 65
CALL SKIP
STORE 2 IN DISPLAY
α RECALL
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
SKIP	1106

DESCRIPTION:

SKIP advances the cassette tape the number of blocks specified by the contents of display register. The cassette tape is advanced by reading blocks of data into a scratch buffer.

CALLED FROM:

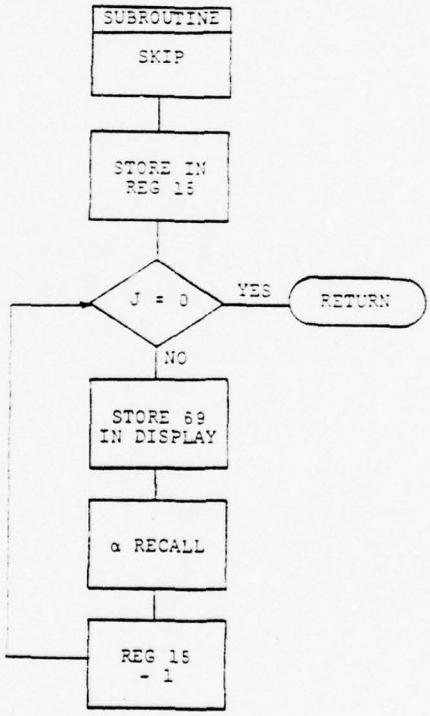
GET DATA
OBTAIN DATA

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
67	X↓03	
68	X↓04	Scratch Buffer
69	X↓05	


SUBROUTINE
SKIP
STORE IN
REG 15
J = 0
YES
RETURN
NO
STORE 69
IN DISPLAY
α RECALL
REG 15
- 1

SUBROUTINE NAME:	ADDRESS CODE:
LOAD	1115

DESCRIPTION:

See description of subroutine LOAD in OPTION-0. Flow chart identical.

CALLED FROM:

EXECUTIVE

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
Display	-	# in display indicates how many programs will be skipped before loading.

PROGRAM NAME:	ADDRESS CODE:
OPTION-2	None

DESCRIPTION:

The executive program OPTION-2 is loaded by the system bootstrap program (BOOT). The program is composed of subroutines which permits retrieval of calibration data from cassette tape and collection of S-parameter data from the HP 8410S Microwave Network Analyzer. The program is operational with the exception of a subroutine called APPLY CALIBRATION DATA which is to apply the calibration data to the S-parameter data as described in Ref. 9.

OPTION-2 is composed of the following subroutines:

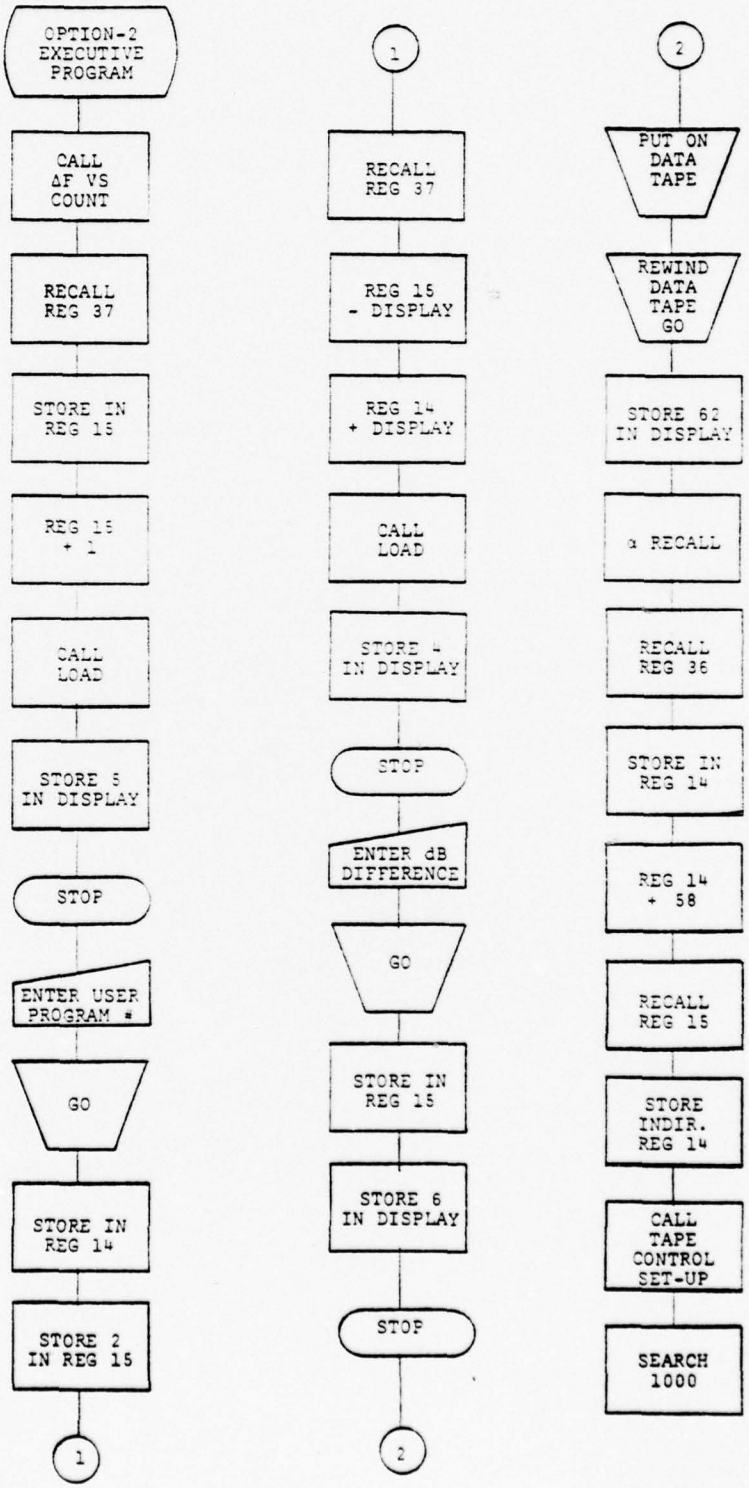
TAPE CONTROL SET-UP	1114	LOAD	1115
F VS COUNT	1113		
DECODE CJC	1109		
GET DATA	1112		
OBTAIN CALIBRATION DATA	1108		
COLLECT DATA	1105		
APPLY CALIBRATION DATA	1104		
XFER DATA	1103		
SKIP	1106		
FREQUENCY ACQUIRE	1111		
GET FREQUENCY	1110		

CALLED FROM: LOADED by BOOT

CALLS PROGRAMS: ΔF VS COUNT
LOAD
TAPE CONTROL SET-UP

REGISTERS USED:

NUMBER	CODE	PURPOSE
36	+↓04	S-parameter desired by user program
37	+↓05	Display program #
48 to 62	-↓00 to 0↓14	Input buffer for the file ID record


OPTION-2 EXECUTIVE PROGRAM
CALL ΔF VS COUNT
RECALL REG 37
STORE IN REG 15
REG 15 + 1
CALL LOAD
STORE 5 IN DISPLAY
STOP
ENTER USER PROGRAM #
GO
STORE IN REG 14
STORE 2 IN REG 15
1
1
RECALL REG 37
REG 15 - DISPLAY
REG 14 + DISPLAY
CALL LOAD
STORE 4 IN DISPLAY
STOP
ENTER dB DIFFERENCE
GO
STORE IN REG 15
STORE 6 IN DISPLAY
STOP
2
2
PUT ON DATA TAPE
REWIND DATA TAPE GO
STORE 62 IN DISPLAY
α RECALL
RECALL REG 36
STORE IN REG 14
REG 14 + 58
RECALL REG 15
STORE INDIR. REG 14
CALL TAPE CONTROL SET-UP
SEARCH 1000

SUBROUTINE NAME:	ADDRESS CODE:
TAPE CONTROL SET-UP	1114

DESCRIPTION:

TAPE CONTROL SET-UP initiates control registers needed to extract calibration data from cassette tape. Based upon the S-parameter designated by the Display Job Code, either three blocks of transmission calibration data or three blocks of reflection calibration data will be retrived from each record. By using the Collection Job Code, the subroutine determines whether calibration data is on tape. If data is available, it determines which data sets are available and how many blocks within a record must be skipped in order to retrieve the desired set.

This number is stored in register 64. The number of data blocks which must be skipped to drive the tape to the next data record is stored in register 65. If the desired set of calibration data is not available on tape the program terminates with a "8" in the display register.

CALLED FROM:

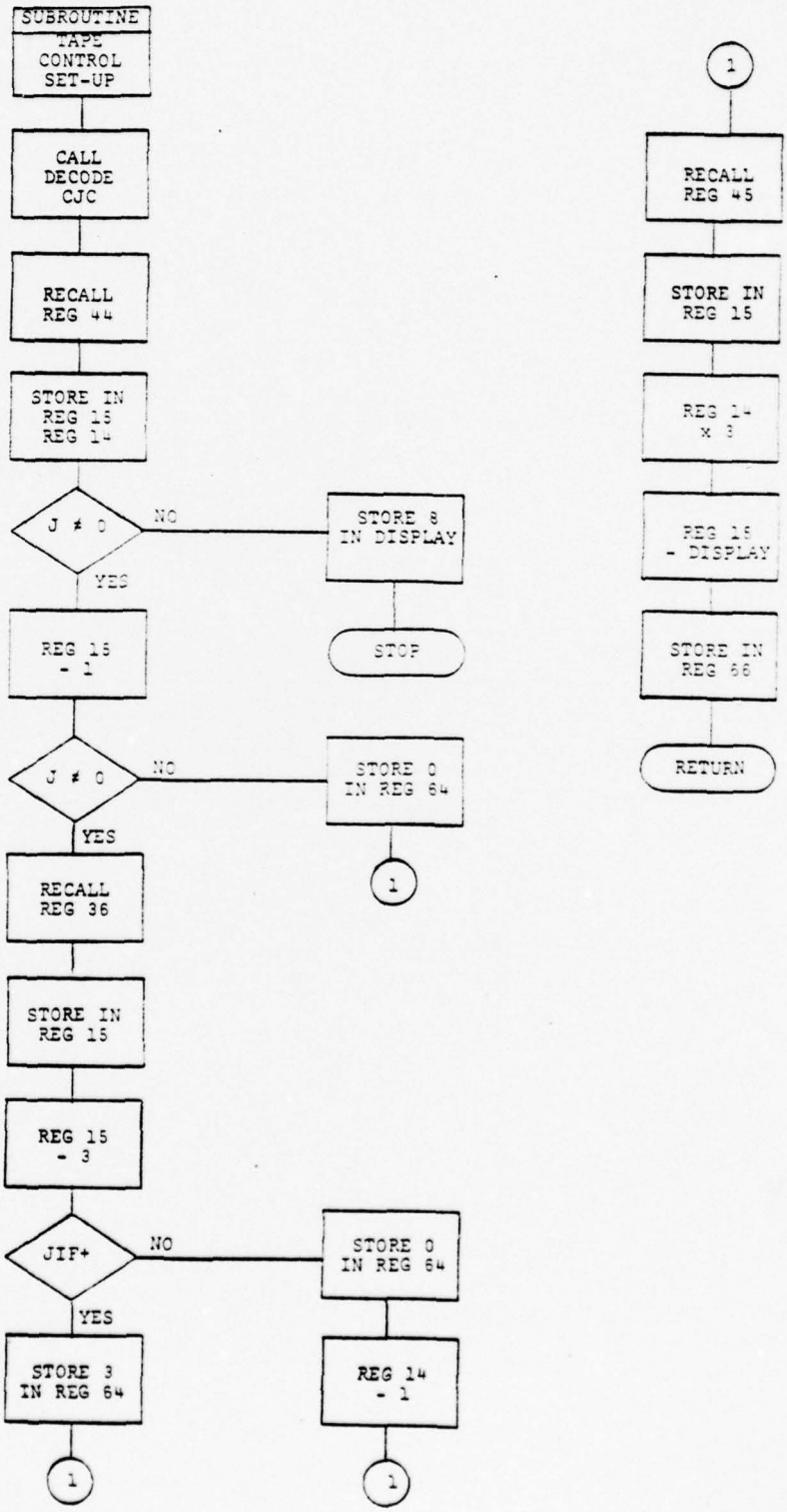
EXECUTIVE

CALLS SUBROUTINES:

DECODE CJC

REGISTERS USED:

NUMBER	CODE	PURPOSE
36	+↓04	S-parameter to be used by user program
44	+↓12	# calibration sets/record
45	+↓13	# data blocks/record
64	+↓00	# skips to desired calibration data set
66	X↓02	# skips to next record ID block


SUBROUTINE TAPE CONTROL SET-UP
CALL DECODE CJC
RECALL REG 44
STORE IN REG 15 REG 14
J ≠ 0
NO
STORE 8 IN DISPLAY
STOP
YES
REG 15 - 1
J ≠ 0
NO
STORE 0 IN REG 64
1
YES
RECALL REG 36
STORE IN REG 15
REG 15 - 3
JIF+
NO
STORE 0 IN REG 64
REG 14 - 1
1
YES
STORE 3 IN REG 64
1
1
RECALL REG 45
STORE IN REG 15
REG 14 x 8
REG 15 - DISPLAY
STORE IN REG 66
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
ΔF VS COUNT	1113

DESCRIPTION:

See subroutine ΔF VS COUNT in OPTION-0

CALLED FROM:

CALLS SUBROUTINES:

REGISTERS USED:

NUMBER	CODE	PURPOSE

SUBROUTINE NAME:	ADDRESS CODE:
DECODE CJC	1109

DESCRIPTION:

See subroutine DECODE CJC in OPTION-1

CALLED FROM:

CALLS SUBROUTINES:

REGISTERS USED:

NUMBER	CODE	PURPOSE

SUBROUTINE NAME:	ADDRESS CODE:
GET DATA (OPTION-2)	1112

DESCRIPTION:

GET DATA, in OPTION-2, first determines if the last data block has been returned to the user program. If it has, the system stops. If there is still more data available, the subroutine calls OBTAIN CALIBRATION DATA, followed by COLLECT DATA and APPLY CORRECTIONS.

CALLED FROM:

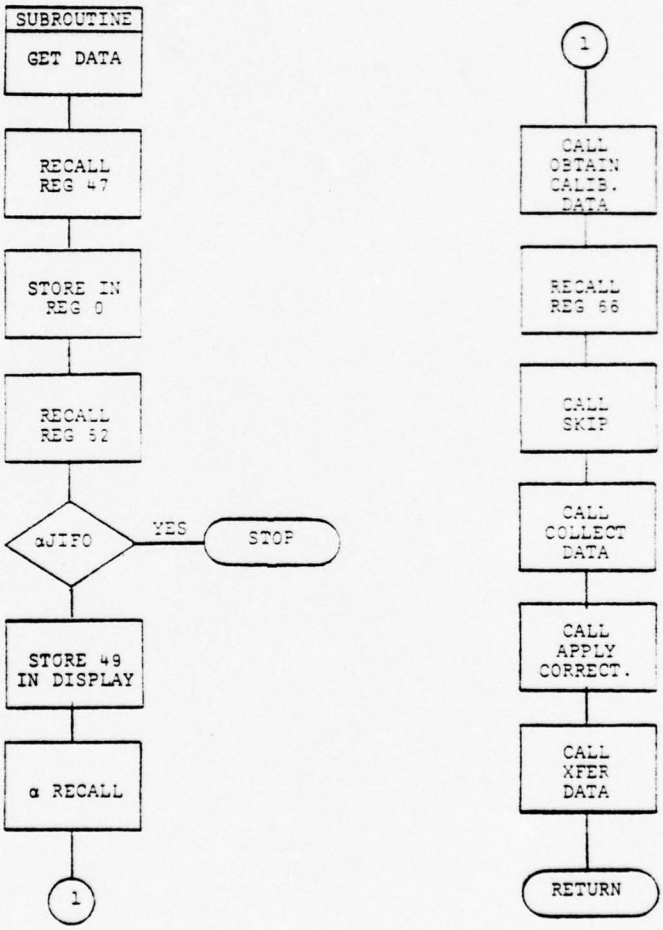
EXECUTIVE

CALLS SUBROUTINES:

OBTAIN CALIBRATION DATA, SKIP, COLLECT DATA, APPLY CORRECTIONS, XFER DATA

REGISTERS USED:

NUMBER	CODE	PURPOSE
47	+↓15	Record #
48	-↓00	CJC
49	-↓01	Desired frequency
52	-↓04	Total # of data records on tape
66	X↓02	# skips to next record


SUBROUTINE
GET DATA
RECALL REG 47
STORE IN REG 0
RECALL REG 52
αJIFO
YES
STOP
STORE 49 IN DISPLAY
α RECALL
1
1
CALL OBTAIN CALIB. DATA
RECALL REG 66
CALL SKIP
CALL COLLECT DATA
CALL APPLY CORRECT.
CALL XFER DATA
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
OBTAIN CALIBRATION DATA	1108

DESCRIPTION:

This subroutine loads the correct calibration data set from tape to registers 25 through 33.

CALLED FROM:

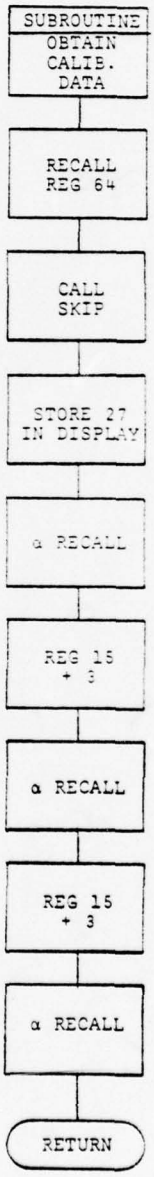
GET DATA

CALLS SUBROUTINES:

SKIP

REGISTERS USED:

NUMBER	CODE	PURPOSE
25 - 33	T↓09 to +↓01	Input buffer for calibration data
64	X↓00	# of skips to calibration data


SUBROUTINE
OBTAIN CALIB. DATA
RECALL REG 64
CALL SKIP
STORE 27 IN DISPLAY
α RECALL
REG 15 + 9
α RECALL
REG 15 + 3
α RECALL
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
COLLECT DATA	1105

DESCRIPTION:

This subroutine calls FREQUENCY ACQUIRE to drive the sweep oscillator to the desired frequency and then access the two micro-interface devices. The frequency returned from FREQUENCY ACQUIRE is stored in register 24 and the X and Y deflection voltages are stored in registers 22 and 23.

CALLED FROM:

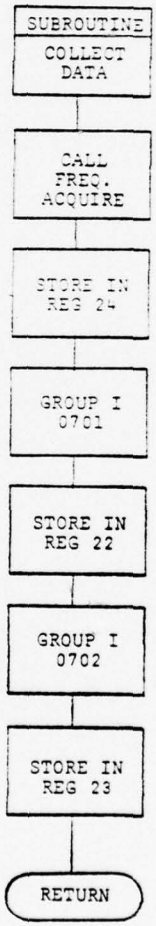
GET DATA

CALLS SUBROUTINES:

FREQUENCY ACQUIRE

REGISTERS USED:

NUMBER	CODE	PURPOSE
22	T↓06	X voltage
23	T↓07	Y voltage
24	T↓08	Frequency


SUBROUTINE
COLLECT DATA
CALL FREQ. ACQUIRE
STORE IN REG 24
GROUP I 0701
STORE IN REG 22
GROUP I 0702
STORE IN REG 23
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
APPLY CORRECTIONS	1104

DESCRIPTION:

The subroutine, at present, consists of just a RETURN instruction. This subroutine should apply the calibration data found in registers 25 - 33 to the S-parameter data found in registers 22 - 24. The offset lengths which were used in measuring the calibration data are found in registers 53 - 58. The corrected S-parameter data must be returned to registers 22 and 23 before returning from this subroutine.

CALLED FROM:

CALLS SUBROUTINES:

REGISTERS USED:

NUMBER	CODE	PURPOSE

SUBROUTINE NAME:	ADDRESS CODE:
XFER DATA	1103

DESCRIPTION:

This subroutine transfers the data found in registers 22, 23, and 24 to registers 00, 01, 02, respectively.

CALLED FROM:

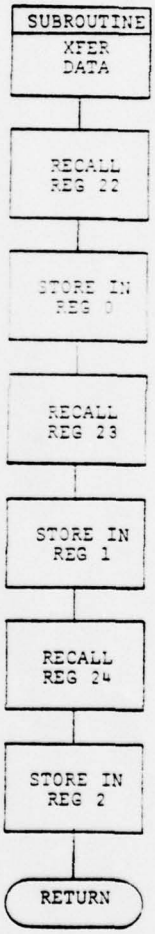
GET DATA

CALLS SUBROUTINES:

None

REGISTERS USED:

NUMBER	CODE	PURPOSE
0	00	X volt
1	01	Y volt
2	02	Frequency
22	T↓06	X volt
23	T↓07	Y volt
24	T↓08	Frequency


SUBROUTINE
XFER DATA
RECALL REG 22
STORE IN REG 0
RECALL REG 23
STORE IN REG 1
RECALL REG 24
STORE IN REG 2
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
SKIP, FREQUENCY ACQUIRE, GET FREQUENCY, LOAD	-

DESCRIPTION:

See subroutine SKIP in OPTION-1
See subroutine FREQUENCY ACQUIRE in OPTION-0
See subroutine GET FREQUENCY in OPTION-0
See subroutine LOAD in OPTION-0

CALLED FROM:

CALLS SUBROUTINES:

REGISTERS USED:

NUMBER	CODE	PURPOSE

PROGRAM NAME:	ADDRESS CODE:
OPTION-3	-

DESCRIPTION:

The executive program OPTION-3 is loaded by the bootstrap program (BOOT). The program is composed of subroutines which enable retrieval of calibration data and S-parameter data from cassette tape. OPTION-3 loads and executes one of the four display programs as specified by the last digit of the Display Job Code (DJC). It then requests a User Program Number from the user by interrupting execution with a 5 showing in the display register. The executive program loads the user program over the display program and then interrupts execution with a 6 showing in the display register. The user removes the program tape and inserts the data tape from which the calibration data and S-parameter data is to be retrieved. Other preliminary functions are performed by OPTION-3 and then control is passed to the resident user program.

CALLED FROM:

LOADED by BOOT

CALLS PROGRAMS:

LOAD
TAPE CONTROL SET-UP

REGISTERS USED:

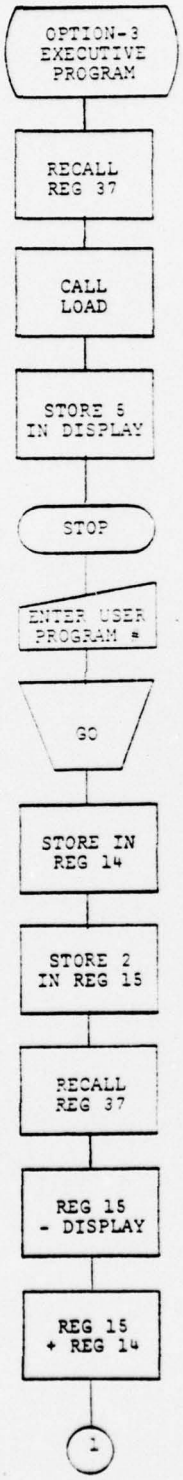
NUMBER	CODE	PURPOSE
37	+↓05	Display program #
48 to 62	-↓00 to -↓14	Input buffer for the file ID record

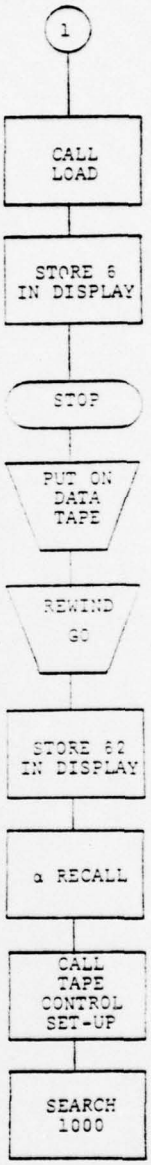
PROGRAM NAME:	ADDRESS CODE:
OPTION-3	-

DESCRIPTION CONTINUED:

OPTION-3 is composed of the following subroutines:

TAPE CONTROL SET-UP	1114
DECODE CJC	1109
GET DATA	1112
OBTAIN CALIBRATION DATA	1108
OBTAIN DATA	1107
SKIP	1106
APPLY CORRECTIONS	1104
XFER DATA	1103
LOAD	1105


OPTION-3
EXECUTIVE
PROGRAM
RECALL
REG 37
CALL
LOAD
STORE 5
IN DISPLAY
STOP
ENTER USER
PROGRAM =
GO
STORE IN
REG 14
STORE 2
IN REG 15
RECALL
REG 37
REG 15
- DISPLAY
REG 15
+ REG 14
1


1
CALL
LOAD
STORE 6
IN DISPLAY
STOP
PUT ON
DATA
TAPE
REWIND
GO
STORE 62
IN DISPLAY
a RECALL
CALL
TAPE
CONTROL
SET-UP
SEARCH
1000

SUBROUTINE NAME:	ADDRESS CODE:
TAPE CONTROL SET-UP	1114

DESCRIPTION:

This subroutine initiates control registers needed to extract the required calibration data and S-parameter data from the cassette tape. Based upon the S-parameter designated by the Display Job Code, either three blocks of transmission calibration data or three blocks of reflection calibration data along with the designated S-parameter data will be retrieved from each record.

By using the Collection Job Code, the subroutine determines whether the required calibration and S-parameter data is on tape. If they are not available, the program terminates with an 8 showing in the display register. If the data is available, the subroutine computes the number of data blocks between the record ID block and the first block of required calibration data. This number is stored in register 64. It then computes the number of blocks from the last block of calibration data to the required S-parameter data. This number is stored in register 65. Finally, the subroutine computes the number of blocks between the required S-parameter data and the next record ID block. This number is stored in register 66.

CALLED FROM:

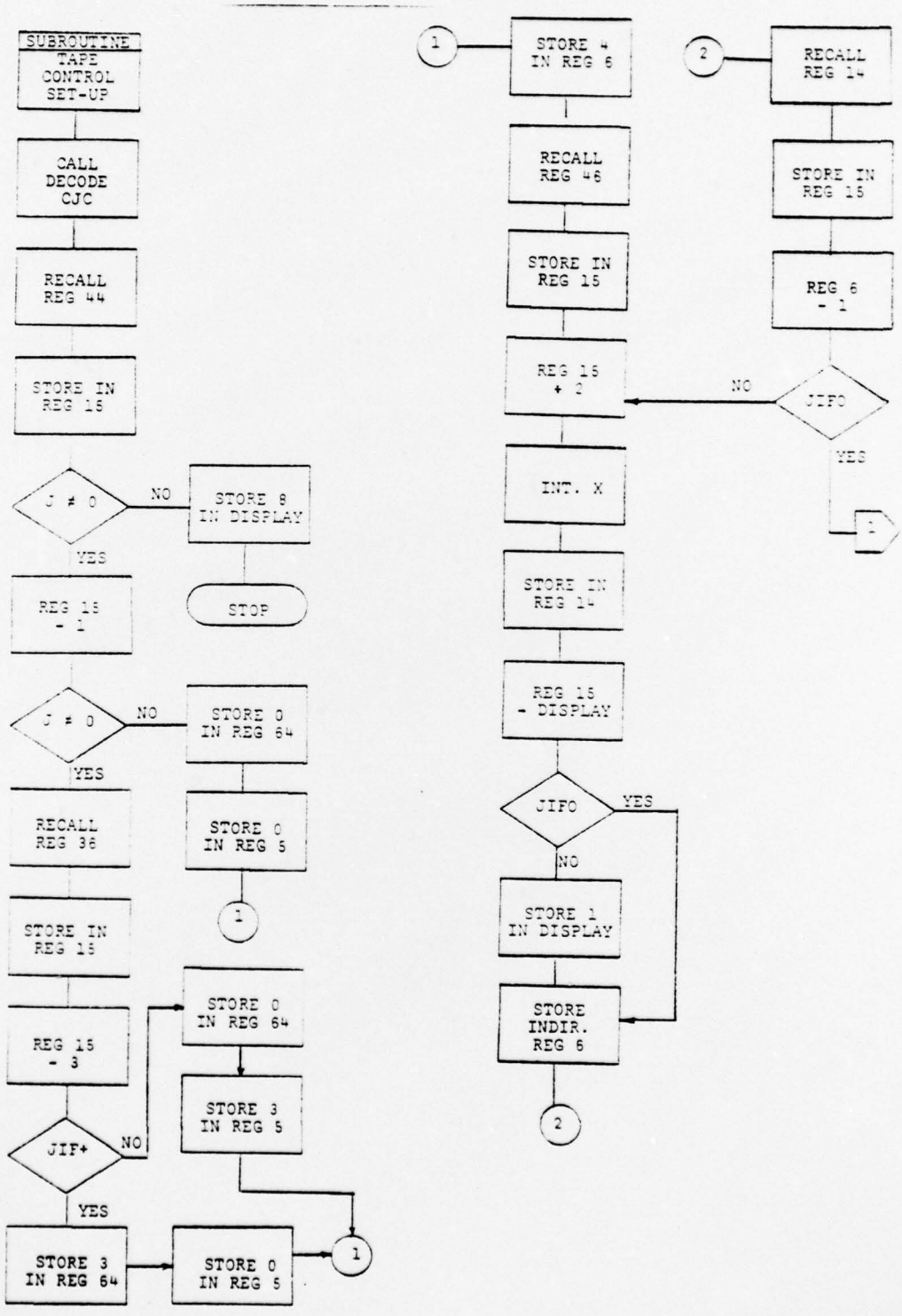
EXECUTIVE

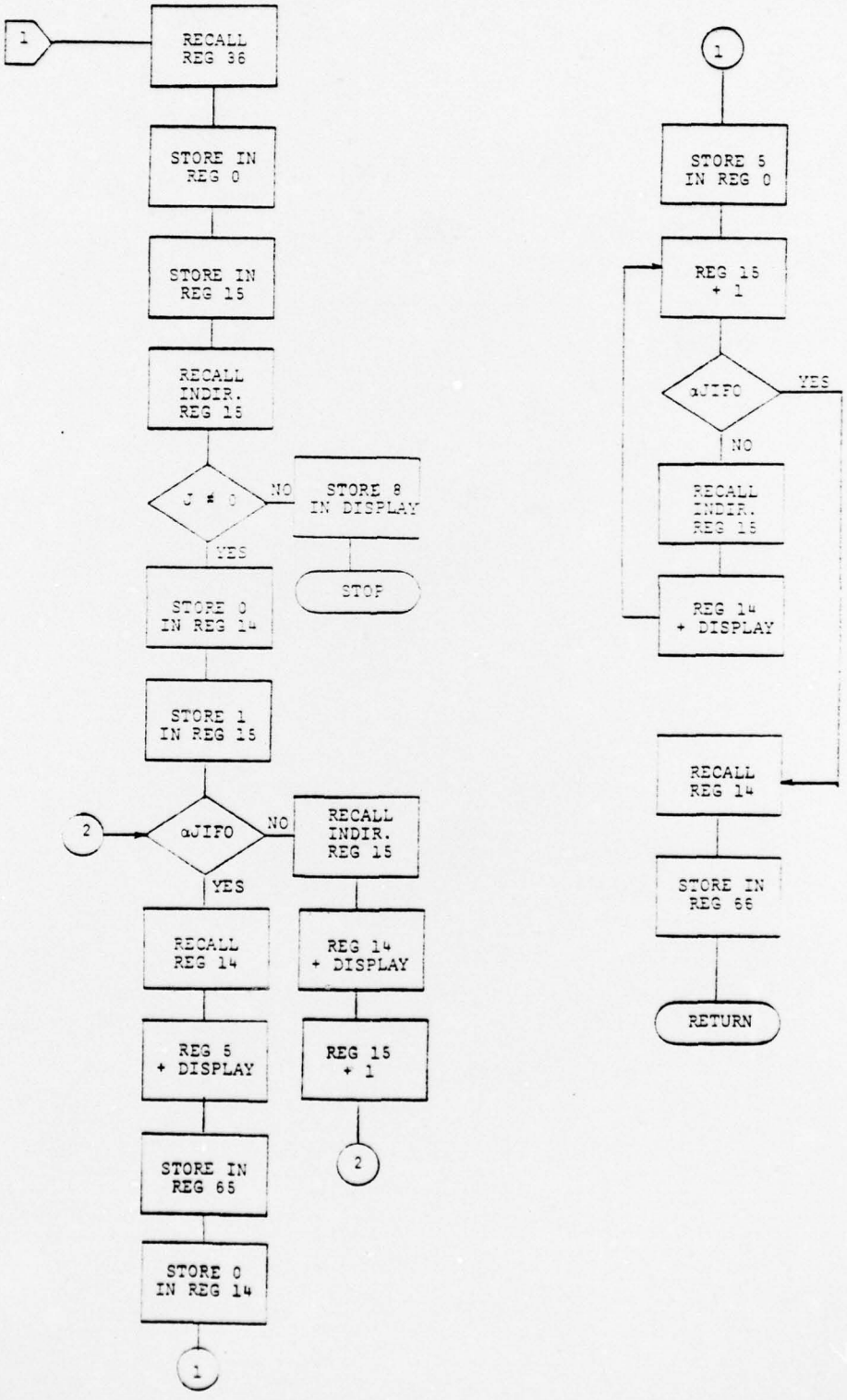
CALLS SUBROUTINES:

DECODE CJC

REGISTERS USED:

NUMBER	CODE	PURPOSE
36	+↓04	Desired S-parameter
44	+↓12	# of calibration sets on tape
46	+↓14	# S-parameters on tape
64	X↓00	# skips to calibration data
65	X↓01	# skips to S-parameter
66	X↓02	# skips to ID block


SUBROUTINE TAPE CONTROL SET-UP
CALL DECODE CJC
RECALL REG 44
STORE IN REG 16
J ≠ 0
NO
STORE 8 IN DISPLAY
STOP
YES
REG 16 - 1
J ≠ 0
NO
STORE 0 IN REG 64
YES
RECALL REG 36
STORE 0 IN REG 5
1
STORE IN REG 16
REG 16 - 3
STORE 0 IN REG 64
STORE 3 IN REG 5
JIF+
NO
YES
STORE 3 IN REG 64
STORE 0 IN REG 5
1
1
STORE 4 IN REG 6
RECALL REG 46
STORE IN REG 15
REG 16 + 2
INT. X
STORE IN REG 14
REG 16 - DISPLAY
JIFO
YES
NO
STORE 1 IN DISPLAY
STORE INDIR. REG 6
2
2
RECALL REG 14
STORE IN REG 15
REG 6 - 1
JIFO
NO
YES
1


1
RECALL REG 36
STORE IN REG 0
STORE IN REG 15
RECALL INDIR. REG 15
C ≠ 0
NO
STORE 8 IN DISPLAY
STOP
YES
STORE 0 IN REG 14
STORE 1 IN REG 15
2
αJIFO
NO
RECALL INDIR. REG 15
YES
RECALL REG 14
REG 14 + DISPLAY
REG 5 + DISPLAY
REG 15 + 1
STORE IN REG 65
STORE 0 IN REG 14
2
1
STORE 5 IN REG 0
REG 15 + 1
αJIFO
YES
NO
RECALL INDIR. REG 15
REG 14 + DISPLAY
RECALL REG 14
STORE IN REG 66
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
GET DATA (OPTION-3)	1112

DESCRIPTION:

This subroutine checks to see if the last data block has been retrieved from tape. If it has, the system is terminated. If not, it calls the necessary subroutines to obtain the calibration data and S-parameter data.

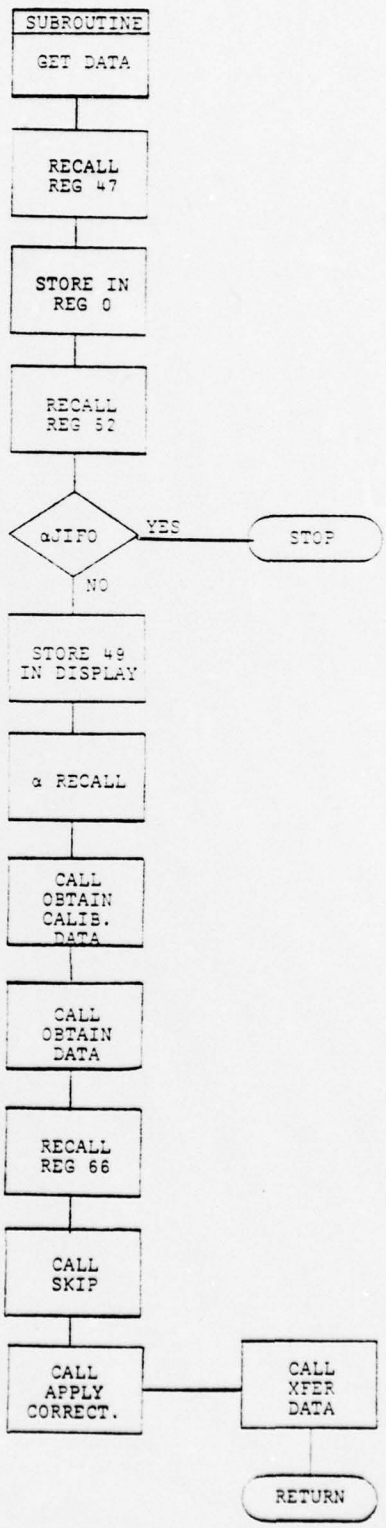
CALLED FROM:

User Program

CALLS SUBROUTINES:
OBTAIN CALIBRATION DATA, OBTAIN DATA, SKIP, APPLY CORRECTIONS, XFER DATA

REGISTERS USED:

NUMBER	CODE	PURPOSE
47	+↓15	Data Record number
48	-↓00	Collection Job Code
49	-↓01	Frequency
52	-↓04	Total # of data records
66	X↓02	# skips to next ID block


SUBROUTINE
GET DATA
RECALL REG 47
STORE IN REG 0
RECALL REG 52
αJIFO
YES
STOP
NO
STORE 49 IN DISPLAY
α RECALL
CALL OBTAIN CALIB. DATA
CALL OBTAIN DATA
RECALL REG 66
CALL SKIP
CALL APPLY CORRECT.
CALL XFER DATA
RETURN

SUBROUTINE NAME:	ADDRESS CODE:
DECODE CJC, OBTAIN CALIBRATION DATA, OBTAIN DATA, SKIP, APPLY CORRECTIONS, XFER DATA, LOAD	

DESCRIPTION:

See subroutine DECODE CJC in OPTION-1
See subroutine OBTAIN CALIBRATION DATA in OPTION-2
See subroutine OBTAIN DATA in OPTION-1
See subroutine SKIP in OPTION-1
See subroutine APPLY CORRECTIONS in OPTION-2
See subroutine XFER DATA in OPTION-2
See subroutine LOAD in OPTION-1

CALLED FROM:

CALLS SUBROUTINES:

REGISTERS USED:

NUMBER	CODE	PURPOSE

BIBLIOGRAPHY

1. Carlton, J. C., Calculator-Aided Microwave Network Analysis, M.S. Thesis, Naval Postgraduate School, 1974.

2. Wang Laboratories, Incorporated, 600 Series Reference Manual With Programming, 1972.

3. Wang Laboratories, Incorporated, Model 612 Flat-Bed Plotter, 1972.

4. Wang Laboratories, Incorporated, Input/Output Interfacing Specifications Wang 600 Series, 1973.

5. Hewlett Packard Company Operating and Service Manual, Model 8412A Phase-Magnitude Display, 1972.

6. Hewlett Packard Company Operating and Service Manual, Model 8410A Network Analyzer, Model 8411A Harmonic Frequency Converter, 1971.

7. Hewlett Packard Company Operating and Service Manual, Model 8414A Polar Display, 1970.

8. Hewlett Packard Company Operating and Service Manual, Model 8690B Sweep Oscillator, 1968.

9. DaSilva, E. F. and McPhun, M. K., "Calibration of Microwave Network Analyzer For Computer-Conected S-Parameter Measurements," Electronics Letters, v. 9, p. na, March 1973.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
2.	Department Chairman, Code 62 Department of Electrical Engineering Naval Postgraduate School Monterey, California 93940	1
3.	Asst. Professor J. B. Knorr, Code 62Ko Department of Electrical Engineering Naval Postgraduate School Monterey, California 93940	1
4.	LT David K. Young, USN Surface Warfare Officers School Bldg 446 Newport, RI 02840	1
5.	Commander Naval Telecommunications Command 4401 Massachusetts Avenue, N. W. Washington, D. C. 20390	1