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2.0 GHZ TO 4.0 GHZ AUTOMATED RADIOMETER OPERATION AND SERVICE MANUAL

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director

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IMPORTANT NOTICE

The specific components selected for the system were chosen on the basis of suitability, availability, and cost at the time of procurement. They do not necessarily represent the only possible choice or even the best choice. The National Bureau of Standards states only that they were used in the equipment described here. Substitution of nominally equivalent components meeting the same specification should cause no difficulty; however NBS has not tested all such possible choices.

2.0 GHZ TO 4.0 GHZ AUTOMATED RADIOMETER

OPERATION AND SERVICE MANUAL

BY

GEORGE J. COUNAS

The equipment described by this manual is the 2.0 to 4.0 GHz subsystem of the automated radiometer. This section of the multiband automated radiometer is a coaxial total power radiometer which implements a six-port reflectometer for impedance characterization and correction and utilizes a newly developed broadband cryogenic noise standard. NBS Noise measurement capability in this frequency band has been expanded by the addition of this system which adds continuous frequency coverage to existing services along with the capability to measure cryogenic noise sources. This manual describes the 2.0 to 4.0 GHz frequency band of the NBS automated radiometer and provides operation and service information.

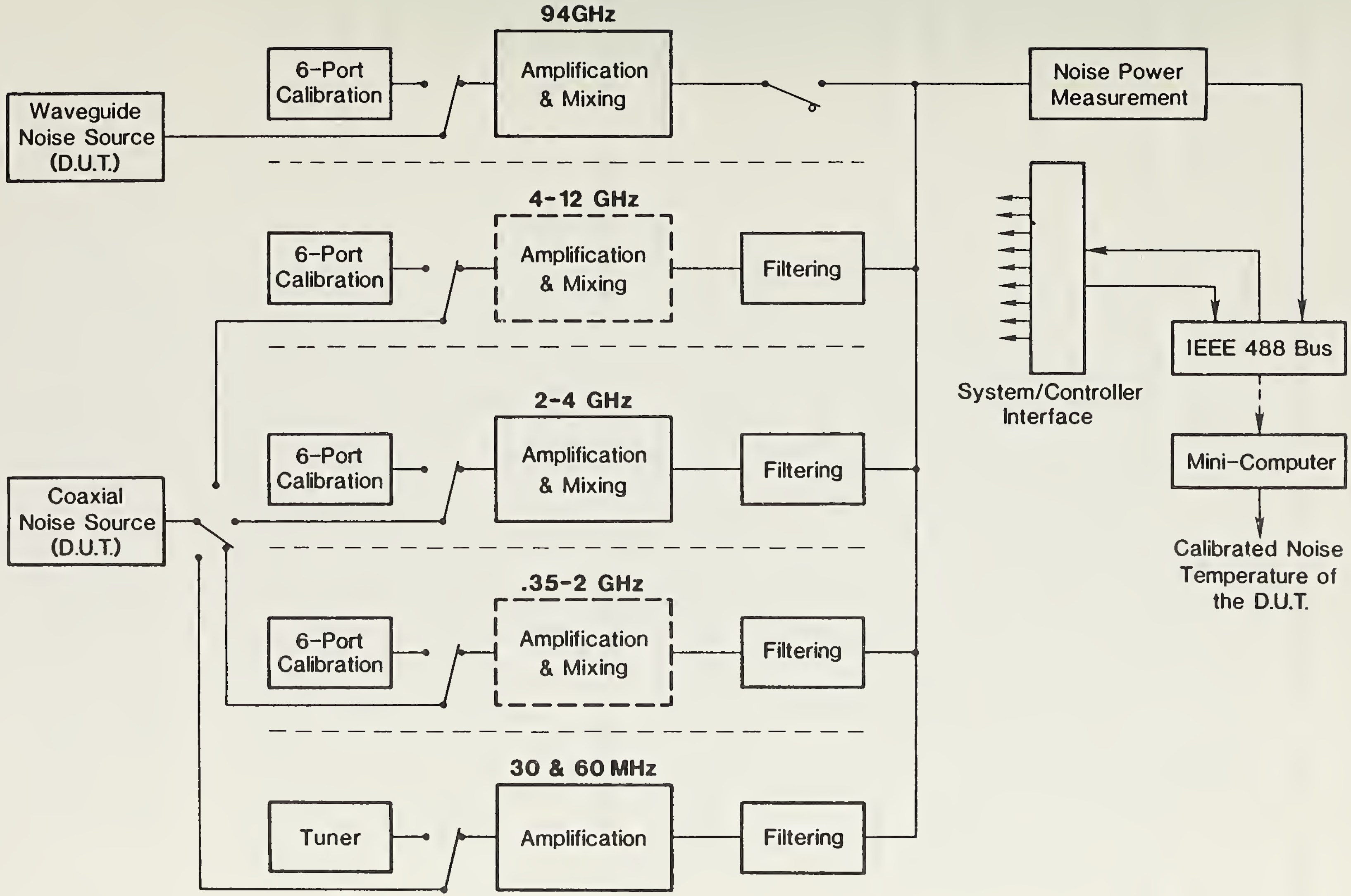
Key words: automated; broadband cryogenic noise standard; six-port reflectometer; total power radiometer.

1. INTRODUCTION

An intensive effort has been made to update the NBS noise measurement services to capitalize on the technological advances made in computer aided measurements in recent years. A noise measurement system has been designed to provide noise measurement services in the following frequency ranges: (1) 30 and 60 MHz, (2) 0.35 to 0.50 GHz, (3) 0.5 to 1.0 GHz, (4) 1.0 GHz to 2.0 GHz, (5) 2.0 to 4.0 GHz, (6) 4.0 to 8.0 GHz, (7) 8.0 to 12.0 GHz, and (8) 94.0 GHz. The system described here is coaxial except for the last section listed which is constructed in the WR-10 waveguide size. Refer to figure 1 which is a simplified block diagram of the system as it will exist when all bands are completed. The 30 and 60 MHz automated radiometer shown at the bottom of the figure was completed in 1981 [1] and the 2.0 to 4.0 GHz section of the NBS automated radiometer has now been constructed. Development of all other bands shown is in progress.

Although the text of this manual will deal principally with the 2.0 GHz to 4.0 GHz frequency band of the automated radiometer, some documentation of the instrumentation used with the other frequency bands shown in Figure 1 will be included. This will provide continuity and ready access when all bands are completed.

Prior to the installation of the 2 to 4 GHz automated radiometer described in this manual, noise calibration services in this frequency band have relied on the manually tuned,



AUTOMATED RADIOMETER SIMPLIFIED DIAGRAM

FIGURE 1

modified, switching radiometer. This modified switching radiometer is a precision noise measurement system which provides an accurate determination of the noise temperature of the device (noise source) under test [2,3]. However, in its present form, this type of noise measurement system has some limitations. Some of these are summarized as follows:

(1) It has been necessary to use a transfer standard to compare the device being calibrated with the primary noise standard. This has limited the frequency coverage to those selected frequencies at which the transfer standard was calibrated.

(2) The present switching radiometer system is not able to measure cryogenic noise standards.

(3) Since the switching radiometers are constructed in a waveguide configuration, coaxial measurements can be made only at reduced accuracy because of adaptor uncertainties or not at all if the adaptor uncertainty cannot be determined.

(4) Because the switching radiometers are manually tuned and operated, measurements made with these systems take approximately four times longer than those made with the automated radiometers.

With the addition of the 2.0 to 4.0 GHz automated radiometer, henceforth referred to as the automated radiometer, the above mentioned limitations have been eliminated. The automated radiometer provides for direct comparison of the noise source being measured with broadband cryogenic and ambient standards, thus eliminating the need for transfer standards with their calibration uncertainties and frequency limitations.

Physically incorporated into this radiometer is a 6-port reflectometer which is used to measure the complex impedances associated with the device under test and the measurement system itself. Using this impedance information, computer correction of mismatch errors is accomplished and this eliminates the need for tuning. Since the noise standards used to make measurements are broadband and mismatch error can now be corrected without tuning, measurement of noise sources at any desired frequency in the band is now possible. The standards and the system measurement ports are coaxial; this permits the calibration of coaxial noise sources without the adaptor uncertainties described for the waveguide system. This system could be used to calibrate waveguide noise sources without using an adaptor if a waveguide cryogenic standard were implemented. In addition, the automated radiometer, as its name implies, is an automatic system and, once certain required calibrations are performed, can make consistent measurements without operator intervention. This speeds up the measurement process without sacrificing accuracy, allows data acquisition not possible with a manual system, and makes possible a more in-depth statistical analysis.

2. GENERAL THEORY OF OPERATION

A. MEASUREMENT PHILOSOPHY

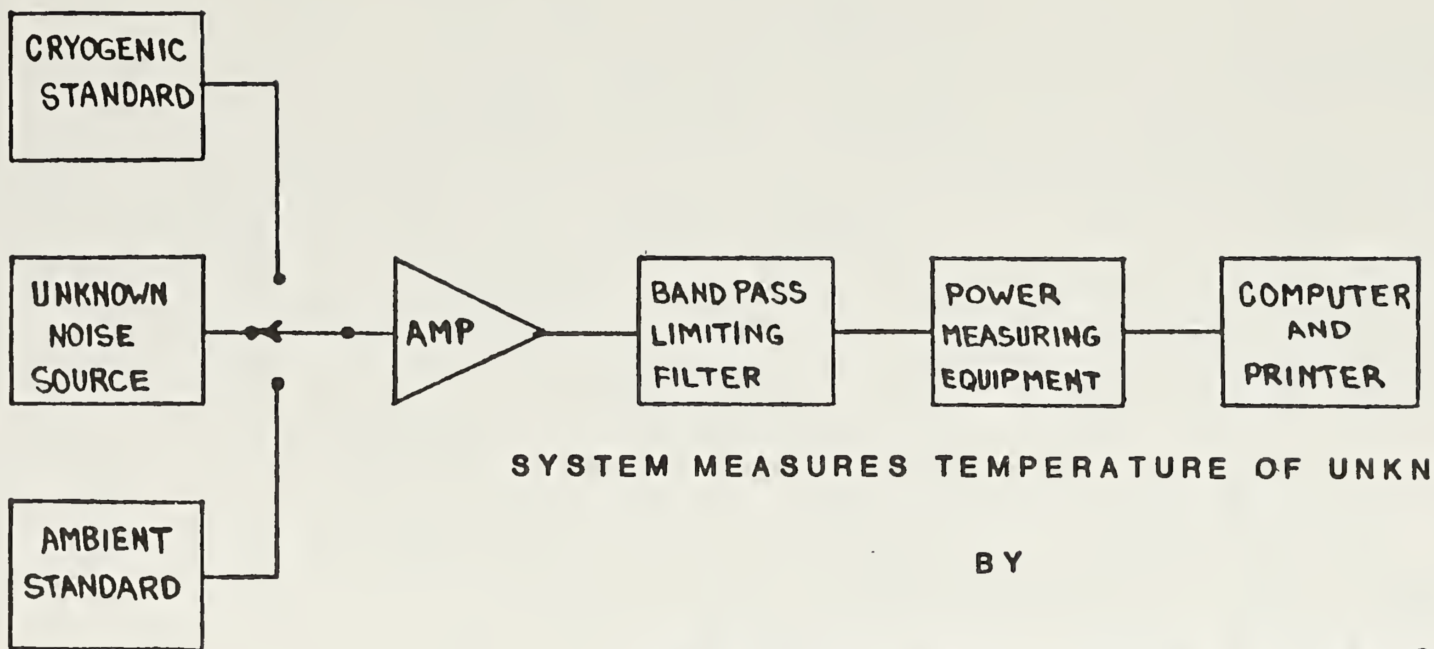
Since the automated radiometer has the capability to measure and store impedance information, software and measurement sequences have been designed to take full advantage of this fact. The emphasis is on the automatic correction of all possible errors and the automatic evaluation of system performance during the normal course of measuring a noise source. Correction of mismatch error, port asymmetry (efficiency) error, check standard evaluation, and a check of system linearity are accomplished automatically in a normal measurement sequence.

B. DESCRIPTION OF THE MEASUREMENT SYSTEM

Figure 1 shows that the 2.0 to 4.0 GHz automated radiometer is but one segment of a multiband measurement system. The 30 and 60 MHz coaxial system and the WR-10 waveguide system share hardware with the other bands but have completely different measurement ports and use measurement procedures which are outside the scope of this manual. The 30 and 60 MHz system manual is already published and the WR-10 waveguide system will be covered in a separate manual when it is completed.

Figure 1 is a simplified block diagram of the entire measurement system. The only band to be covered in detail at this time is the 2.0-4.0 GHz band but the operation of the other bands is similar and hardware and software are shared whenever possible.

Figure 2 is a functional block diagram of the noise measurement system reduced to its simplest form. To calibrate



SYSTEM MEASURES TEMPERATURE OF UNKNOWN

BY

COMPARISON WITH 2 KNOWN SOURCES

SIMPLIFIED BLOCK DIAGRAM OF NOISE MEASUREMENT SYSTEM

FIGURE 2

or find the output noise temperature of the device under test (D.U.T.), the output noise powers of this device, the ambient standard, and the cryogenic standard are amplified, filtered, and measured in sequence. Because the noise temperatures of the two standards are accurately known, the noise equations detailed on pages 50-53 of this manual can be used to compare the output noise powers and noise temperatures of the two standards with the output noise power of the D.U.T. resulting in the determination of the output noise power of this device. These noise power comparisons are made by using the automated radiometer as described in the following paragraphs. In the ensuing discussion all switches are under computer control unless otherwise noted. As can be seen in Figure 1, the frequency band of interest is selected by actuation of the input switches. At this time, the block labeled 6-Port Calibration is accessed by the switch shown. The six port reflectometer is calibrated and then used to measure the complex impedance of the system input ports, the D.U.T., and the standards. This information is stored by the computer and then the input source is switched to the noise measurement position as shown in the figure. In the proper sequence then, the noise power from the D.U.T. and the standards is amplified at the microwave frequency, mixed with power from the local oscillator to obtain the intermediate frequency (I.F.), filtered, amplified again, and measured. To simplify the diagram, both the standards and the D.U.T. are represented by the single block at the left (labeled D.U.T.). The noise temperature of the D.U,T. is then calculatea by the computer. This calculated noise temperature is corrected for mismatch by using the complex

FUNCTIONAL DIAGRAM OF THE AUTOMATED RADIOMETER

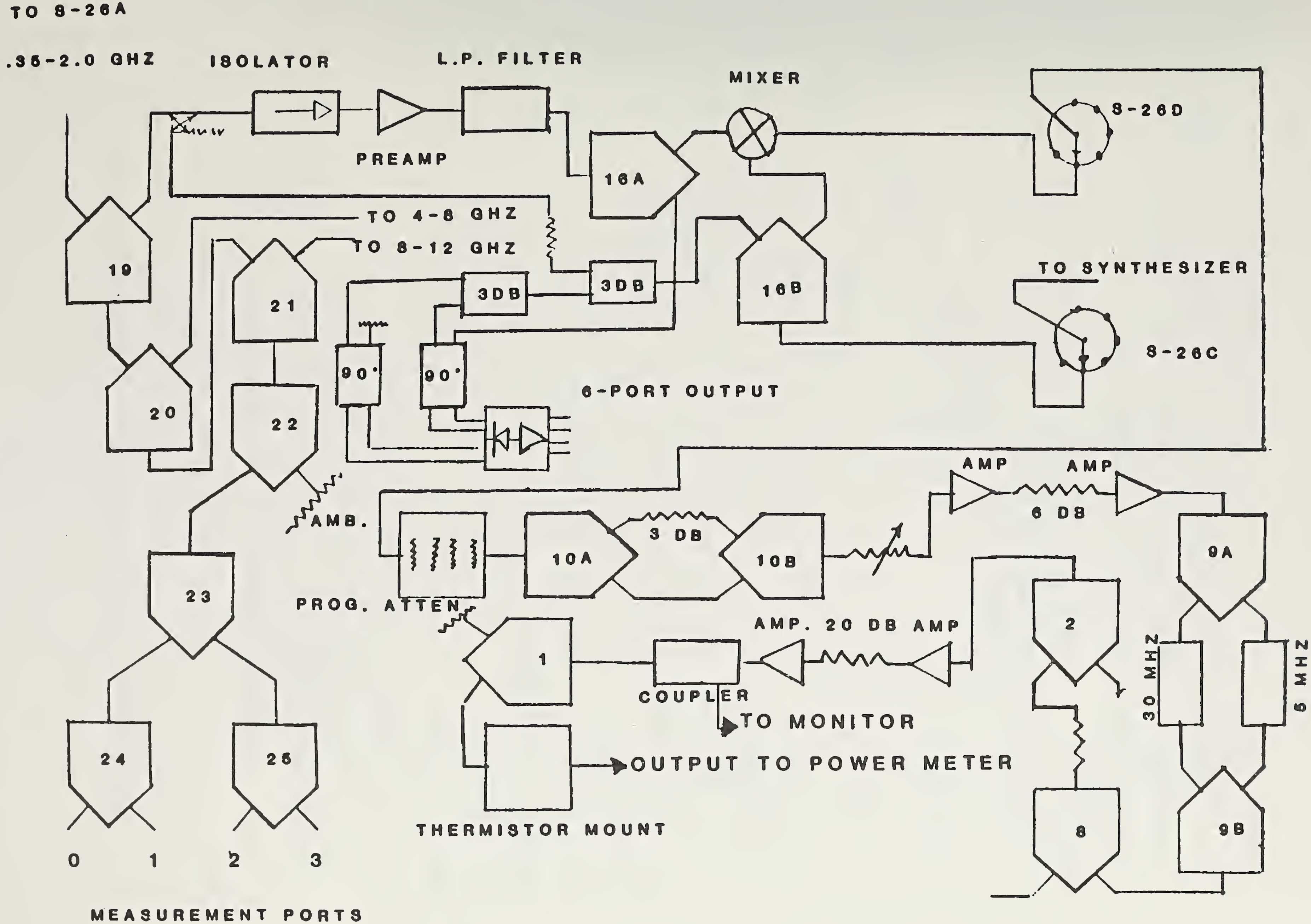
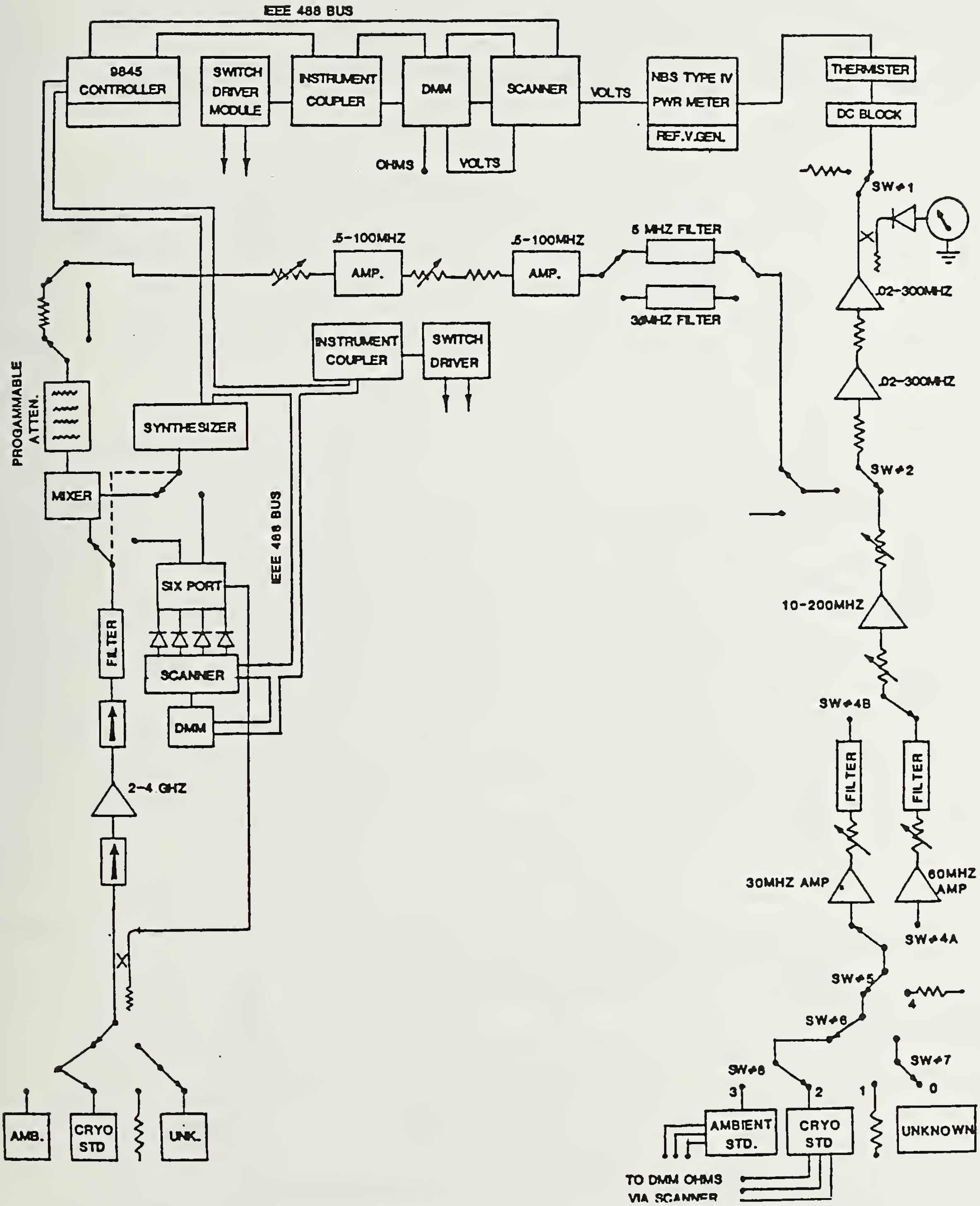


FIGURE 3

impedance information stored earlier, and the final noise temperature of the D.U.T. is tabulated by the computer along with a tabulation of known system errors and measurement statistics. Figure 3 is a functional diagram showing the automated radiometer in more detail. The 2.0 to 4.0 GHz 6-port reflectometer, the band switches, the switching between the standards and the D.U.T., and more detail of the amplifying, mixing, and power measurement is shown. In this system, the local oscillator is a synthesizer which is tuned to the calibration frequency by the computer. Only the noise power that is within the bandpass of the I.F. amplifier and filter is measured and so the local oscillator frequency determines the measurement frequency. Refer to Figure 4. This is a complete block diagram of the automated radiometer and shows the peripheral equipment utilized. As this figure shows, this is a complex system even with the band switching eliminated and only the 2 to 4 GHz, and the 30 and 60 MHz systems represented. For explanation purposes, the system can be divided into 4 main parts which are: (1) the switching and noise source section, (2) the 6-port reflectometer section, (3) the amplifying, mixing, and power measurement section, and (4) the instrument and control section.

(1) The Switching and Noise Source Section

The switching section provides for computer control of band selection switches and the other measurement system switches shown in the figure including those which provide for configuration of the system for either impedance measurement or noise measurement. This section also provides for control of the system output level via a programmable attenuator and 3 dB



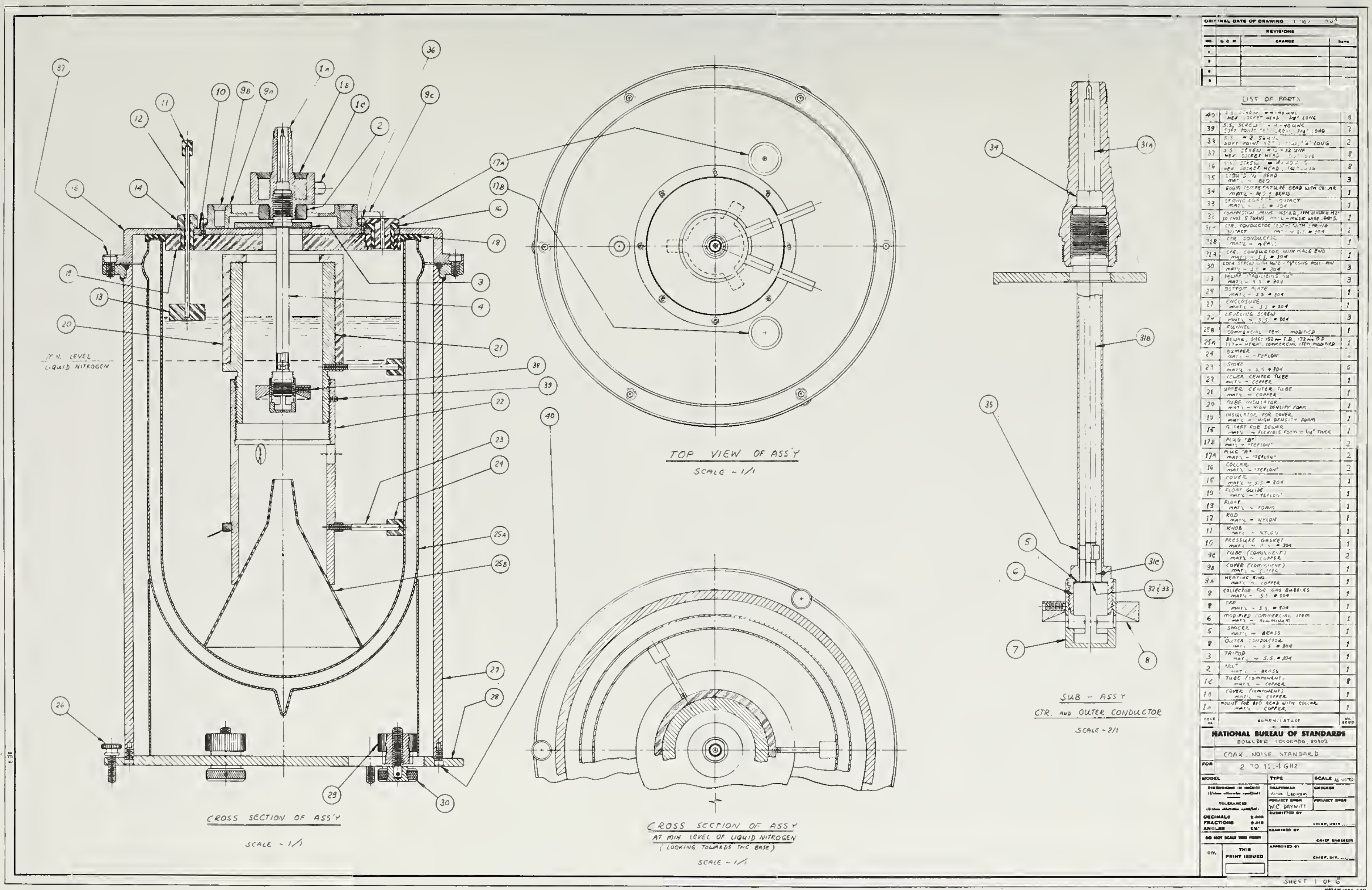
DETAILED BLOCK DIAGRAM 2-4 RADIOMETER

reference attenuator step. Selection of either a 5 MHz or 30 MHz I.F. frequency for the measurement of noise temperature is also provided. These I. F. frequencies will be discussed later.

As described earlier, the measurement of the noise temperature of a device is accomplished by comparing the noise power output of the D.U.T. with the noise power output of two standard noise sources. The D.U.T. is usually either a noise diode network with an effective noise temperature of about 10,000 K, or a load which is actually heated to about 377 K or cooled with liquid nitrogen to about 77 K. These temperatures are within the normal range of the automated radiometer. During a measurement sequence, this device under test is compared to the two noise standards described in the following paragraphs.

The ambient standard is a commercial coaxial load. Long term temperature stability of this load is achieved by encasing it in a water jacket through which is pumped water from a small reservoir. Water from this same source is applied to jackets in contact with the measurement ports and other temperature sensitive system components. This locks them to the same ambient temperature. The entire measurement system is mounted on a massive aluminum table and thermal equilibrium is achieved by piping the water through jackets which are thermally bonded to the table and the measurement system components. The temperature of the ambient load which is used in making noise calculations is found by monitoring the temperature of this device with a calibrated thermometer.

The cryogenic standard [4], shown in Figure 5, is a coaxial load located in a thermally isolated nitrogen bath. This load is



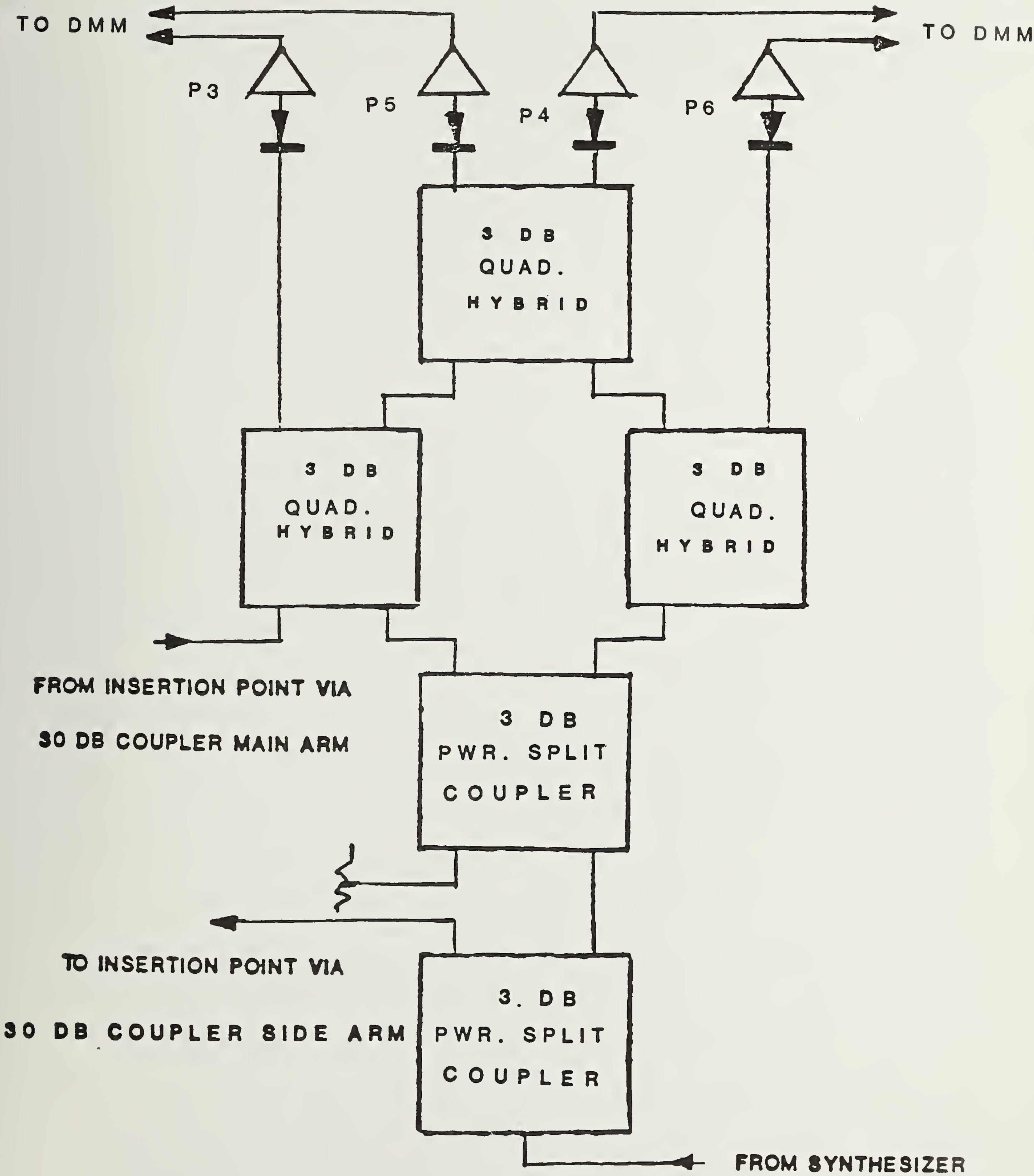
COAXIAL CRYOGENIC NOISE STANDARD

FIGURE 5

continually bathed in liquid nitrogen which keeps its effective noise temperature locked to that of liquid nitrogen (nominally 77 K). The level of the nitrogen in the standard must be kept above the load so that the load is always completely immersed. This level is checked by watching the float shown in the drawing (at the upper left of the side view) and when it reaches a predetermined position, more nitrogen is added. The time interval between fillings is in excess of 4 hours. The temperature of the load can be checked periodically with a thermocouple which can be attached for test purposes; however, the device must be removed during measurements. Both standards are broadband which allows them to be used for noise comparison without tuning; this, along with the 6-port reflectometer, is responsible for the flexible frequency coverage offered by the automated radiometer.

(2) The 6-Port Reflectometer Section

The 6-port reflectometer section replaces most of the measurement system when it is selected and is totally disconnected from the system when it is not selected. Again, the purpose of the 6-port reflectometer section is to provide the capability of measuring the complex reflection coefficient (gamma) of the device under test, the measurement system itself, and the standards when necessary; this mismatch information is stored until needed for making corrections. Figure 6 is a block diagram of the modified 6-port reflectometer. The reflectometer is installed in such a way that the noise system preamplifier becomes a part of the reflectometer when it is used. This relationship is shown in Figure 4. The detailed theory of



6-PORT REFLECTOMETER

FIGURE 6

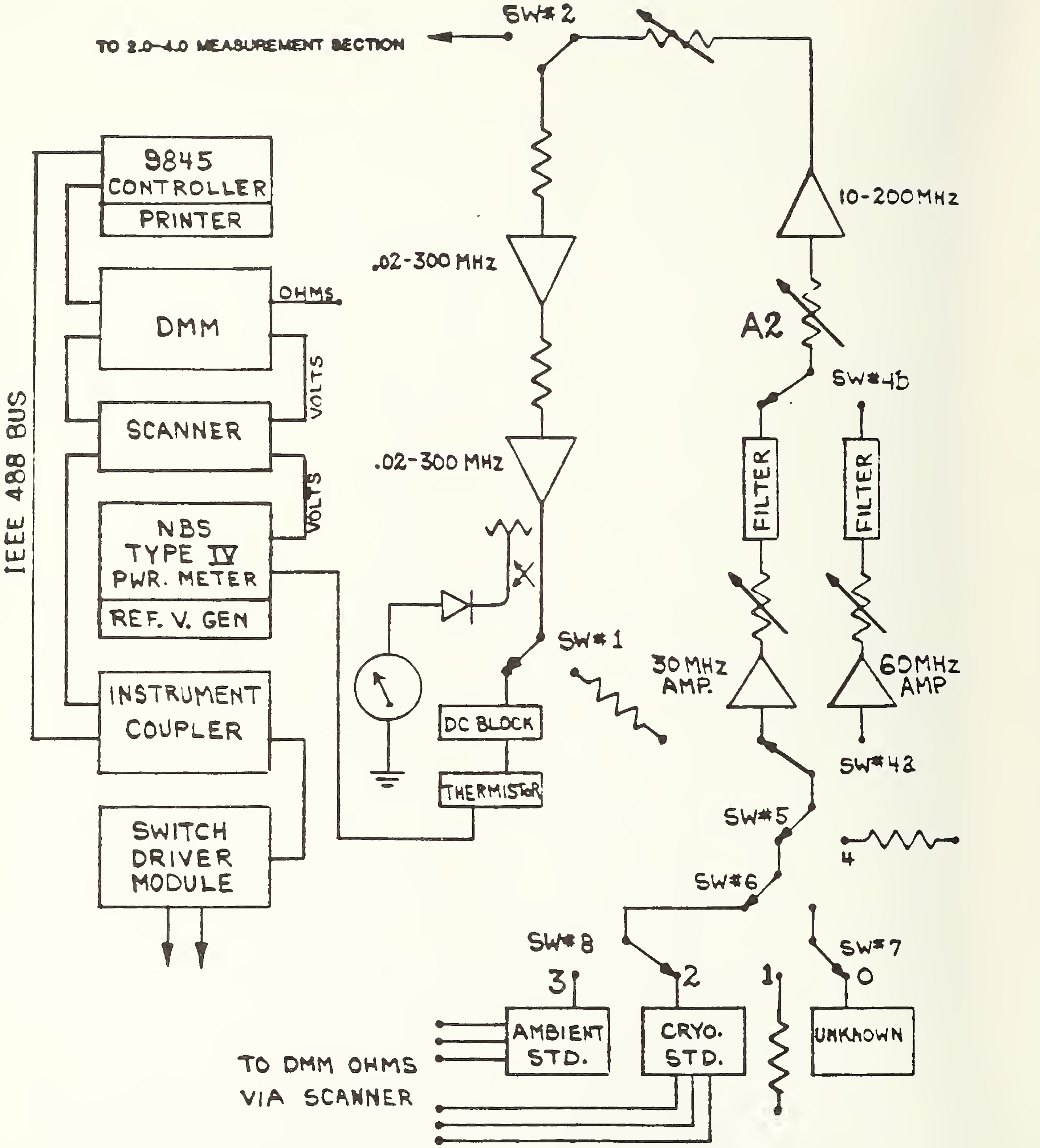
operation of the 6-port is beyond the scope of this manual and is covered rigorously in other publications [5,6].

In the following brief summary, it will be helpful to refer to the system block diagram in Figure 4 and the the 6-port block diagram in Figure 6. Power at the frequency of interest is coupled to the 6-port from the synthesizer. The first two couplers at the bottom of the 6-port diagram are simply 3 dB power splitting couplers; the three couplers at the top of the diagram are 3 dB quadrature couplers which shift cross coupled signals 90 degrees. There are two distinct signal paths through the 6-port. The one on the right shall be designated the reference signal path. The reference signal represents the phase and magnitude of the incident power applied to the 6-port and the device under test. The path on the left shall be designated the measurement or test signal path. This test signal represents the phase and magnitude of the power applied to and reflected from the device under test. The reference and test signals are combined in the three quadrature couplers at the top of Figure 6. The combination takes place in such a way that the coupler outputs have a distinct relationship which can be solved mathematically to yield the magnitude and phase of the reflection coefficient of the item attached to the measurement port and also that of the measurement port itself.

The coupler outputs are detected by the diodes and the resulting D.C. level is amplified by a factor of 100 in the amplifiers shown. This boosts the signals to a high enough level to be easily measured by the DMM. There are four outputs labeled P3, P4, P5, and P6. Measurement of these outputs by a DMM and processing the resulting voltage information with a special computer subprogram yields the impedance information desired.

(3) The Amplifying, Mixing, and Power Measurement Section

Returning to the measurement section of the radiometer, noise powers from the standards and device under test are amplified over the entire 2.0 to 4.0 GHz frequency range by the preamplifier as shown in Figures 3 and 4. Noise feedback from the preamplifier is prevented by the isolators shown and the output is filtered by the 4.0 GHz low pass filter to eliminate harmonic frequencies. The output of the low pass filter is applied directly to the low noise ortho star mixer. Also applied to the mixer is the local oscillator input supplied from the synthesizer which is under computer control. The frequency of the synthesizer is programmed to be the same as the calibration frequency for the device under test. The I.F. output (double sideband) power from the mixer is sent through a programmable attenuator and reference attenuator which set the I.F. amplifier inputs to a level which insures linear operation. Bandswitching will take place at this point and the attenuators and I. F. amplifiers will be shared by all bands from 0.35 to 12.0 GHz. The I. F. amplification takes place first at 0.5 to 100 MHz bandwidth (2 stages) and then the noise calibration I.F. filter is selected by the measurement program. This filter sets the noise power I.F. frequency to either 30 MHz with a 1 MHz bandpass or 5 MHz with a 5 MHz bandpass. Since noise power is a function of bandwidth, the 5 MHz filter provides a higher power level to measure. Experiments show the measurement results obtained with



AUTOMATED RADIOMETER OUTPUT AND 30/60 MEASUREMENT SECTION

FIGURE 7

either I.F. frequency are the same at 2.0 to 4.0 GHz. However, the 5 MHz I.F. might prove superior at lower frequencies.

The filter output is applied to the two power amplifiers through the switches shown. The power amplifier and measurement section is designed to be shared by all frequency bands. Shown at the right in Figure 4, the 30 and 60 MHz automated radiometer is connected or disconnected from this section by the switch SW#2. The power amplifiers in this section have a bandpass of 0.02 to 300 MHz. Both have a gain of 30 decibels. The attenuators in this section are used to isolate components and to provide for linear operation. The output of this section is sampled through the side arm of a directional coupler to give the operator a visual indication of system power levels.

Power output is measured by using a thermistor mount connected to the output port through a DC (direct current) block. This thermistor mount in combination with an NBS Type IV Power Meter [7] and a precision reference voltage generator is used to measure noise power for all of the automated radiometer frequency bands.

(4) The Instrument and Control Section

The instrument and control section encompasses all of the peripheral electronic equipment used to make the noise measurements including the controller, which in this case is the Hewlett Packard 9845 desktop calculator.

The peripheral equipment used to make a measurement is shown in Figures 4 and 7. Figure 7 depicts the equipment used to make a measurement with either the 2.0 to 4.0 GHz automated radiometer or the 30 and 60 MHz automated radiometer as the case may be. Switch SW#2 connects either system as desired to the common output components. Note that all peripherals shown in Figure 7 are shared by both systems. The same equipment is shown in Figure 4 and, in addition, the equipment associated with the 6-port reflectometer is shown. The peripheral instruments are all interconnected on the IEEE 488 Bus. Two switch driver modules are required to provide for control of all the switches. These switch driver modules are connected to the computer by using the two instrument couplers shown in Figure 4. The switch driver assemblies are the only instruments not compatible with the IEEE 488 bus and so two instrument couplers, sophisticated decoders, are used to interface the two switch driver modules to the controller--making both modules bus compatible. These switch driver modules are used to control the various system switches and programmable and reference attenuator assemblies when they are used. An LED (light emitting diode) display on the front panel of each switch driver module gives a visual indication of the digital code from the controller. This display shows the band selected, status of the system switches, and whether a measurement or impedance determination is taking place. The status of the switches shown in Figure 7 is shown on the front panel of one switch driver module while the status of the other system switches is displayed on the front panel of the second switch driver module.

Two scanners (analog multiplexers) and two DMMs (digital multimeters) are used. One of the scanners with its associated DMM is shown in Figure 7. These instruments are shared by the

2.0 to 4.0 GHz band and the 30 and 60 MHz band of the automated radiometer at this time. Use in connection with the 30 and 60 MHz system is covered in the manual for that system. In the 2.0 to 4.0 GHz automated radiometer, the voltage output of the power meter is connected to this DMM through the scanner to collect output voltages which are then converted to the powers and noise temperatures of the measured devices by the software.

The second scanner and DMM are used for measurement of 6-port voltages needed to characterize impedance and also to check voltage output of the 15 V, +25 V and -25 V switch driver power supplies and the 15 V, 20 V, and 28 V amplifier power supplies.

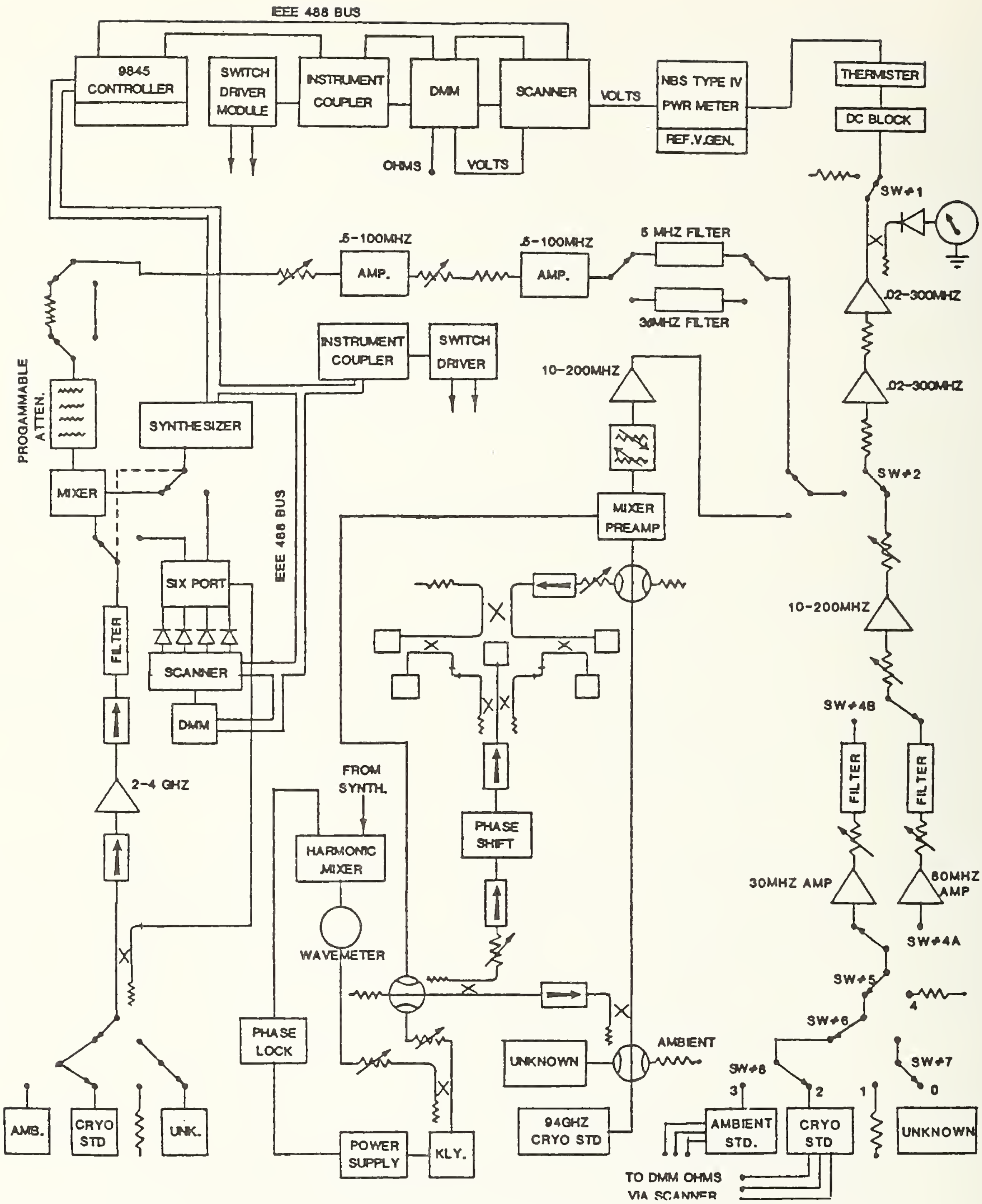
The synthesizer shown in figure 4 is used as a signal source for the six port reflectometer when it is selected and used to measure system, D.U.T., and standard impedances. It is also used as a local oscillator when the noise measurement mode is selected.

Figure 8, a block diagram of the entire measurement system as it exists at this time (August, 1983) is included in this section for ready reference. The 0.35 to 2.0 GHz and 4.0 to 12.0 GHz sections are not implemented at this time. The 94.0 GHz radiometer does exist and is shown in the center of this figure.

C. A MEASUREMENT SEQUENCE

As the measurement program is executed by the computer, all switching is automatic; instructions are printed on the controller video screen detailing any actions required of the operator.

A normal measurement sequence commences with the determination of the port asymmetry error correction factor.



AUTOMATED RADIOMETER (MARCH 1983)

FIGURE 8

This determination proceeds as follows:

1. The 6-port reflectometer portion of the measurement system is selected.
2. The system port to which the device under under test will be attached (normally port #3) is activated.
3. The operator is instructed to (a) place a sliding short on port #3 and slide it as directed, (b) place a sliding load on the port and slide it as directed, (c) place an offset short or open on the port, and (4) place auxiliary noise standard #1 (this is a noise check standard) on the port. The computer uses the information obtained from this sequence to determine the complex impedance of the system at port #3 and the complex impedance of auxiliary noise standard #1. This impedance information is stored for later use. Auxiliary standard #1 is left connected to port #3 at this time.
4. The system port to which the cryogenic standard will be attached is now selected. This is normally port 0.
5. Again the operator is directed to perform the operations involving the sliding short, sliding load, and offset short or open. This time however, the operator is directed to place auxiliary standard #2 on port #0. Now, the computer determines and stores the complex impedance parameters for the system at port #0 and the auxiliary noise standard #2. The auxiliary standard #2 is left connected to port #0 at this time.
6. Now the radiometer is switched in, the 6-port

reflectometer is switched out, and a measurement sequence is started in which the noise power from the auxiliary standard #1 at port #3, the noise power from the ambient load at port #4, and the noise power from the auxiliary standard #2 at port #0 is measured and stored. These powers are measured 9 times and averaged. These averages and associated standard deviations are stored and the operator is directed to interchange the positions of the two auxiliary standards. The sequence is again repeated resulting in the determiniation of the average noise powers from the two standards and the ambient load in the new positions.

The ratio of the noise power from each of the two standards and the noise power from the ambient load is then determined for each position of each device. These ratios and the impedance information stored earlier are used to determine the port asymmetry correction factor to be used when the device under test is measured. The power ratios calculated will be stored now and used later to compare the auxiliary standards with the cryogenic standard resulting in them being automatically evaluated as check standards.

The auxiliary standards are now removed from the measurement system and the actual measurement of the device under test is begun. First, the 6-port configuration is selected and the 6-port is calibrated using the sliding short, sliding load, offset short or open as described above. The only difference in the procedure is that the device under test is placed on measurement port #3 instead of auxiliary standard #1 and the cryogenic standard is placed on measurement port #0 instead of auxiliary standard #2. Complex impedances are thus measured for the device under test, the cryogenic standard and the measurement system ports to which they are attached. These complex impedance values are used to correct the measured noise temperature of the device under test for mismatch. A correction factor, for this purpose, is stored and retrieved when needed. Now the radiometer configuration is selected by the action of the system switches and the measurement of the device under test is begun. The noise powers from the device under test, cryogenic standard, and ambient standard at port #4 are measured in sequence. The ratios of these powers are converted to noise temperature and corrected for mismatch and port asymmetry using the equations detailed on pages 50-53 of this manual. These powers are measured 50 times. After the first 50 measurements are made, the results are averaged and stored. Then 3 dB is inserted in the measurement path by the step attenuator between the mixer and final amplifiers. The 50 measurements are now repeated. This procedure checks amplifier linearity. The final result (reported value) will be the average of the two sets of measurements. This final value will be output at the completion of the measurements along with an error summary and statistical data.

Complete instructions for operating the measurement system to achieve the above results are detailed in the following section of this manual.

3. OPERATING INSTRUCTIONS

A. EQUIPMENT PREPARATION

1. POWER OFF INSPECTION AND SET-UP

a. Thermal stability of the measurement system is achieved by pumping water from a separate reservoir through the system water jackets. The flexible tubing which connects the water jackets to the water reservoir should be inspected for proper connection and serviceable condition and the water level in the reservoir checked. Then the pump should be turned on. Water should be circulating through the water jackets and returning to the reservoir. When this condition is met, the system is ready for further setup.

b. The cryogenic standard should now be filled with liquid nitrogen. The procedure is to remove the plugs in the top of the standard, insert a funnel into one of the openings, and slowly pour liquid nitrogen into the reservoir until the float reaches the proper level. Replace the plugs. This standard should be allowed to stabilize at least an hour before measurements are commenced.

c. Check all cables interconnecting the controller and instruments to assure proper connection and that none are missing.

d. It is suggested that all applicable coaxial connectors on the measurement system, device under test, and tuning apparatus for the six port reflectometer be cleaned at this time with isopropyl alcohol. Also at this time ascertain that the device under test can be physically connected to the measurement system.

2. POWER ON PROCEDURES AND SYSTEM WARM-UP

a. Turn on all D.C. power supplies. (There are four external supplies for the two switch driver modules. These consist of two +15 volt D.C. supplies, one +25 volt D.C. supply, and one -25 volt D.C. supply. In addition, there are two +28 volt D.C. supplies for the output power amplifiers, one +20 volt D.C. supply for the I. F. amplifiers, and one +15 volt D.C. supply for the preamplifier.)

b. Turn on the synthesizer, switch driver modules (2), instrument couplers (2), digital multimeters (2), scanners (2), power meter, reference generator, and controller.

c. Turn on the noise source power supply if applicable. One word of caution. Some coaxial solid state noise sources which use a diode network to generate noise output might be damaged if a sudden loss of voltage or sudden application of voltage is realized. For this reason, always increase or decrease the voltage to these devices GRADUALLY. After the measurement system is turned on, a warmup of at least one hour is desirable for maximum stability. The digital multimeters and synthesizer can be left on overnight to shorten this stabilization time.

B. LOADING AND EXECUTING THE MEASUREMENT PROGRAM

The measurement system is operated under computer control and the current measurement program is "RAD7EF" (see Appendix

II). Load the measurement program and press RUN. Prompts, requesting action by the operator, will be printed on the controller display screen. After the operator has performed the requested action, further instructions will be displayed until the measurement is completed. The following discussion covers major items encountered when executing the measurement program "RAD7EF".

After RUN is pressed, a complete measurement and printout of system voltages is accomplished. If voltages are satisfactory, press CONT. (If not, correct the problem before proceeding)

Next, requests for ambient standard temperature, barometeric pressure, and a description of the device under test (customer name, noise source manufacturer, model, serial number, date, and test number) are requested. Enter the information requested, and press CONT.

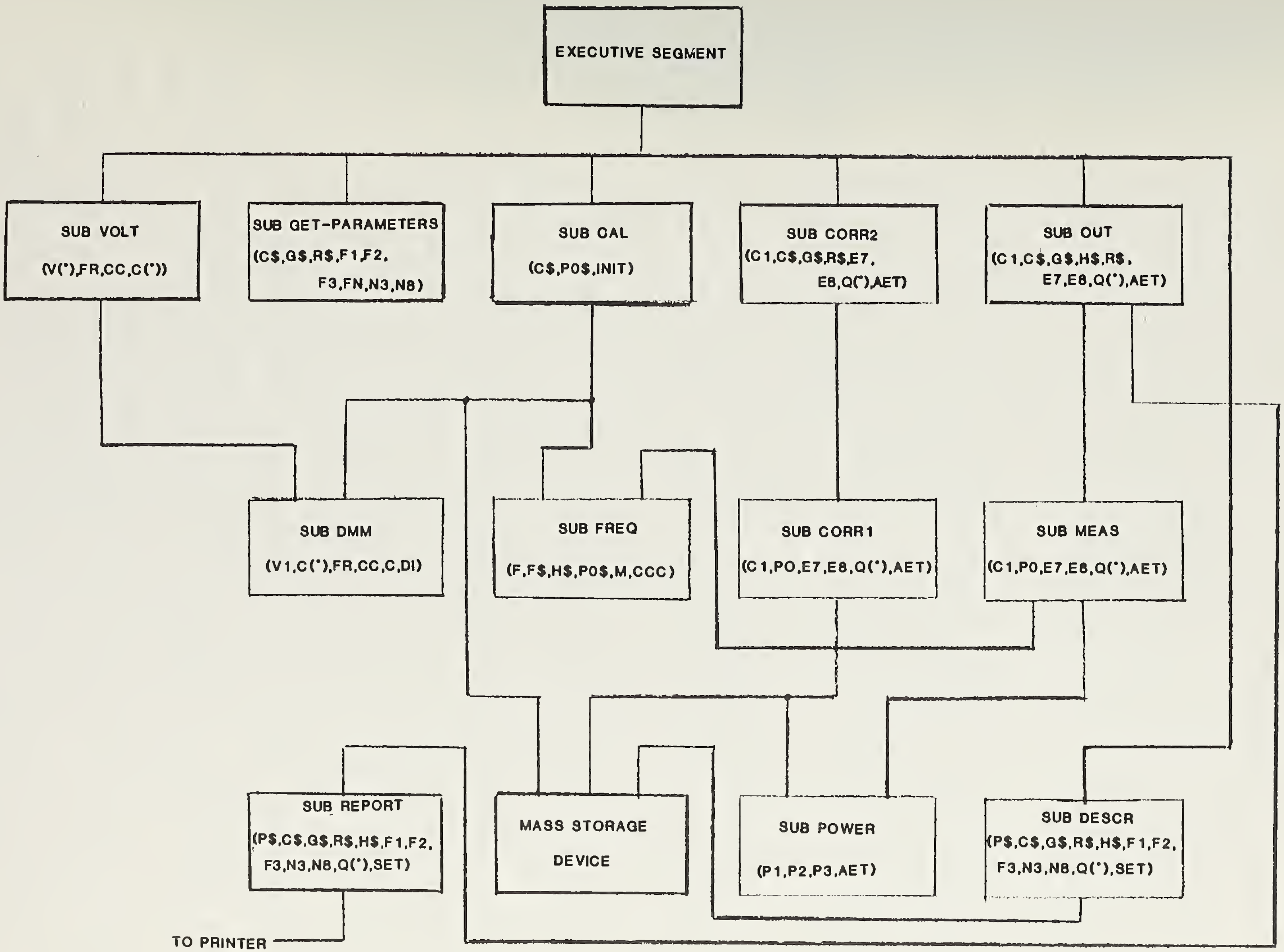
The portion of the measurement program which utilizes the 6-port reflectometer to characterize impedance and port asymmetry is now executed. Place devices on the measurement ports as directed and press CONT after completing the required action. The proper port will be automatically selected by the system switches and all the operator need do is make sure to place the devices (sliding short, sliding load, etc.) on the port requested by the computer. The calibration sequence requires measurement of 7 positions of the sliding short circuit, 5 positions of the sliding load, and a measurement of the coaxial open circuit or coaxial offset short circuit impedance standard being used. The optimum distance to slide the short and load is determined by dividing the wavelength of the calibration frequency by 14 for the sliding short circuit and 10 for the sliding load. At the end of the calibration sequence, the auxiliary standards will be in place on the two ports which were characterized. The system then automatically makes a measurement of the auxiliary standard power and the power from the ambient load. A total of 9 measurements are made and then the operator is requested to interchange the devices on the ports. After the devices are interchanged, press CONT. The 9 power measurements are repeated and port asymmetry is determined and stored by the computer.

The six port reflectometer is now used to determine the complex impedance parameters associated with the measurement system and the device under test. The operator is again directed to place the devices necessary to calibrate the six port reflectometer on the system measurement ports as directed by the computer printout on the screen. This time however, the device under test and cryogenic standard are connected to the system measurement ports when the calibration sequence is completed. At the end of this sequence, the complex impedances of the device under test, cryogenic standard, and the measurement system ports are stored.

Now the actual measurement portion of the program "RAD7EF" is executed. The system will now automatically measure the noise power from the device under test without further operator intervention. One hundred determinations are made at two different power levels and the results, measurement statistics, and error analysis are printed out and stored for future reference. Also printed are the values obtained for the check standards which were automatically measured during the calibration sequence. The stored information is used for control charts and statistical studies while the printed material is used to generate a complete report of calibration for the customer.

C. MEASUREMENT COMPLETION AND SYSTEM SHUTDOWN

After the desired measurements of the devices are completed, system shutdown is accomplished in the reverse order of turn-on.



MAJOR PROGRAM SEGMENTS PROGRAM RAD7EF

FIGURE 9

4. SOFTWARE

A. GENERAL OVERVIEW

Since the 6-port reflectometer was constructed as an integral part of the automated radiometer, the software has been developed to take full advantage of the added measurement capability.

Until now, the normal radiometer system outputs have been the measured noise temperature of the device tested and an error summary detailing error limits for such items as mismatch, port asymmetry, standard uncertainty, and power measurement error. Separate calibrations were required with check standards to verify system performance and linearity. Because the 6-port reflectometer provides accurate complex impedance information, software routines have been incorporated which provide measurements of noise temperature corrected for both mismatch and port asymmetry. The need for tuning has been eliminated and preliminary measurements indicate that reflection coefficient magnitudes as high as 0.8 can be effectively modeled; port asymmetry as high as 6 dB has been effectively handled as well. In addition, information obtained when determining mismatch and port efficiency can be used along with the system output to provide for check standard validation of system performance automatically during the normal course of a measurement. This results in a great savings of time and provides a continuous check of system performance. To summarize then, present hardware and software in combination provide the following information to the calibration customer:

1. Complex impedance of the device tested.
2. Total noise temperature of the device tested.
3. Effective noise temperature of the device tested.
4. Correction of the measured noise temperature of the device under test for mismatch and port asymmetry or path efficiency.
5. Complete error summary of any known errors not corrected for and the estimated measurement uncertainty.

In addition the following items are provided for calibration verification and support:

1. All calibration data including impedances, powers measured, and calculated results are stored for future reference.
2. Measurements are made at two discrete power levels, providing an automatic check of system linearity. Excess error from this source is detected if large variations in results at these two power levels are present.
3. An automatic check of the values of two check standards is made to verify system performance.

The measurement program version currently in use with this system is called "RAD7EF". This program is made up of 13 major segments as shown in Figure 9. The major program segments are shown in block form. The figure is arranged so that the various modules depicted are arranged in the order in which they are used in the program. Time, in this figure, flows from left to right and top to bottom. Lines at the top of a block represent input while lines at the bottom of a block represent output. Each line represents a 2-way transfer of information with a return to the calling subprogram. Variables are passed between subprograms if they are listed in the calling statement or made global by being listed in the common declaration at the beginning of each subprogram. A brief description of each subprogram is presented in the following paragraphs.

The EXECUTIVE SEGMENT provides initialization of variables and switches and calls other subprograms in the proper order.

SUBPROGRAM VOLT is called from the executive segment and provides for the measurement and printout of system power supply voltages prior to making a measurement.

SUBPROGRAM GET-PARAMETERS is called from the executive segment and provides for input of nomenclature for the device under test, frequencies to be calibrated, number of measurements and other housekeeping information.

SUBPROGRAM CAL is called from the executive segment and provides for impedance characterization of the system measurement port, the standards, and the device under test. This subprogram implements the use of the 6-port reflectometer.

SUBPROGRAM CORR2 is called from the executive segment and provides for the characterization of system path efficiency and port asymmetry using impedance parameters generated by subprogram Cal.

SUBPROGRAM OUT is called from the executive segment and provides for measurement of the noise temperature of the device under test and generates an error summary which is printed out along with calibration results.

SUBPROGRAM DESCR is called by the executive segment and provides for storage on cassette or disc of a complete description of the device under test, calibration frequency, all powers measured during the calibration sequence, noise temperatures of the standards, measured noise temperature of the device under test, and statistical information pertaining to the measurement results.

The above described subprograms are called directly from the executive segment but do not necessarily perform their function independently; they call in turn other subprograms which provide necessary interaction between instruments and keep the software efficient and modular. These subprograms and the subprograms which call them are as follows:

SUBPROGRAM DMM is called from subprograms Cal and Volt and provides for voltage measurements made with the DMM. Return is to the calling subprogram.

SUBPROGRAM FREQ is called from subprograms Cal and Meas. This subprogram controls the output of the synthesizer and thus the power and frequency of the local oscillator input to the system mixer. Return is to the calling subprogram.

SUBPROGRAM CORR1 is called from subprogram Corr2 and provides for the measurement of power ratios between the auxiliary standards and ambient standard for use by Corr2 in determining path efficiency and port asymmetry corrections. Return is to Corr2.

SUBPROGRAM MEAS is called by subprogram Out and provides for port switching, measurement of the noise power of the standards and the device under test. This subprogram provides for accumulation of statistical data pertinent to the measurement results and the calculation of the noise temperature of the device under test. Return is to Corr2.

SUBPROGRAM POWER is called from Corr1 and Meas and provides for determination of noise power at the desired system measurement port. This subprogram has the routines necessary to utilize the NBS Type IV power meter to make these power measurements. Return is to the calling subprogram.

SUBPROGRAM REPORT is called from subprogram Out. This subprogram provides a printout of measurement results, an error summary, and statistical information. This printout is a complete report of the calibration of the device under test.

MASS STORAGE DEVICE is not a subprogram but is a physical device (either a cassette transport or disc unit) which provides for storage of information used by the various routines. This enables a recap of a measurement at any time for analysis of results and eliminates the need for large permanent matrices for storage of intermediate and final results.

The above descriptions are intended to give a very brief summary of the software modules contained in the measurement program and show the interaction between the various segments. A listing of this program is included in Appendix II of this manual along with a printout of the variables used and their location.

B. MATRICES

Four major matrices are used in the measurement program to store information while the program is being executed and and also on the mass storage device to permit analysis of system measurement results at some later time. These are:

1. The Q matrix which is a 3 by 100 array used to store the powers measured during a measurement sequence. This enables statistical analysis of the measurement process at any convenient time. The Q matrix elements Q(1,1) through Q(1,100) are used to store powers measured from the device under test, Q(2,1) through Q(2,100) is used to store the measured power from the ambient load, and Q(3,1) through Q(3,100) is used to store the measured powers from the cryogenic standard.
2. The C matrix which is a 16 by 4 by 2 array which is used to store 6-port data during measurement sequences for determining impedances. The contents of the C matrix are shown in Table 1.
3. The Z matrix which is a 1 by 80 array which provides storage for all system constants, measurement results, and other pertinent data. The contents of the Z Matrix are shown in table 2.
4. The F matrix which is a 4 by 15 array which provides storage space for the complex impedances for the system measurement ports, device under test, and the two auxiliary standards used. Table 3 shows the contents of the F matrix.

TABLE 1
C MATRIX

ELEMENT	DEVICE CONNECTED TO SYSTEM PORT DURING CALIBRATION SEQUENCE	6-PORT OUTPUT DESCRIPTION AND SCANNER CHANNEL
C(1,1,1)	Device under test	P5 (Channel 10)
C(1,2,1)	Device under test	P4 (Channel 11)
C(1,3,1)	Device under test	P6 (Channel 12)
C(1,4,1)	Device under test	P3 (Channel 13)
C(2,1,1)	Quarter wave short circuit	P5 (Channel 10)
C(2,2,1)	Quarter wave short circuit	P4 (Channel 11)
C(2,3,1)	Quarter wave short circuit	P6 (Channel 12)
C(2,4,1)	Quarter wave short circuit	P3 (Channel 13)
C(3,1,1)	Sliding short--position 1	P5 (Channel 10)
C(3,2,1)	Sliding short--position 1	P4 (Channel 11)
C(3,3,1)	Sliding short--position 1	P6 (Channel 12)
C(3,4,1)	Sliding short--position 1	P3 (Channel 13)
C(4,1,1)	Sliding short--position 2	P5 (Channel 10)
C(4,2,1)	Sliding short--position 2	P4 (Channel 11)
C(4,3,1)	Sliding short--position 2	P6 (Channel 12)
C(4,4,1)	Sliding short--position 2	P3 (Channel 13)
C(5,1,1)	Sliding short--position 3	P5 (Channel 10)
C(5,2,1)	Sliding short--position 3	P4 (Channel 11)
C(5,3,1)	Sliding short--position 3	P6 (Channel 12)
C(5,4,1)	Sliding short--position 3	P3 (Channel 13)

TABLE 1
C MATRIX continued

ELEMENT	DEVICE CONNECTED TO SYSTEM PORT DURING CALIBRATION SEQUENCE	6-PORT OUTPUT DESCRIPTION AND SCANNER CHANNEL
C(6,1,1)	Sliding short--position 4	P5 (Channel 10)
C(6,2,1)	Sliding short--position 4	P4 (Channel 11)
C(6,3,1)	Sliding short--position 4	P6 (Channel 12)
C(6,4,1)	Sliding short--position 4	P3 (Channel 13)
C(7,1,1)	Sliding short--position 5	P5 (Channel 10)
C(7,2,1)	Sliding short--position 5	P4 (Channel 11)
C(7,3,1)	Sliding short--position 5	P6 (Channel 12)
C(7,4,1)	Sliding short--position 5	P3 (Channel 13)
C(8,1,1)	Sliding short--position 6	P5 (Channel 10)
C(8,2,1)	Sliding short--position 6	P4 (Channel 11)
C(8,3,1)	Sliding short--position 6	P6 (Channel 12)
C(8,4,1)	Sliding short--position 6	P3 (Channel 13)
C(9,1,1)	Sliding short--position 7	P5 (Channel 10)
C(9,2,1)	Sliding short--position 7	P4 (Channel 11)
C(9,3,1)	Sliding short--position 7	P6 (Channel 12)
C(9,4,1)	Sliding short--position 7	P3 (Channel 13)
C(10,1,1)	Sliding Load--position 1	P5 (Channel 10)
C(10,2,1)	Sliding Load--position 1	P4 (Channel 11)
C(10,3,1)	Sliding Load--position 1	P6 (Channel 10)
C(10,4,1)	Sliding Load--position 1	P3 (Channel 10)

TABLE 1
C MATRIX continued

ELEMENT	DEVICE CONNECTED TO SYSTEM PORT DURING CALIBRATION SEQUENCE	6-PORT OUTPUT DESCRIPTION AND SCANNER CHANNEL
C(11,1,1)	Sliding Load--position 2	P5 (Channel 10)
C(11,2,1)	Sliding Load--position 2	P4 (Channel 11)
C(11,3,1)	Sliding Load--position 2	P6 (Channel 10)
C(11,4,1)	Sliding Load--position 2	P3 (Channel 10)
C(12,1,1)	Sliding Load--position 3	P5 (Channel 10)
C(12,2,1)	Sliding Load--position 3	P4 (Channel 11)
C(12,3,1)	Sliding Load--position 3	P6 (Channel 10)
C(12,4,1)	Sliding Load--position 3	P3 (Channel 10)
C(13,1,1)	Sliding Load--position 4	P5 (Channel 10)
C(13,2,1)	Sliding Load--position 4	P4 (Channel 11)
C(13,3,1)	Sliding Load--position 4	P6 (Channel 10)
C(13,4,1)	Sliding Load--position 4	P3 (Channel 10)
C(14,1,1)	Sliding Load--position 5	P5 (Channel 10)
C(14,2,1)	Sliding Load--position 5	P4 (Channel 11)
C(14,3,1)	Sliding Load--position 5	P6 (Channel 10)
C(14,4,1)	Sliding Load--position 5	P3 (Channel 10)
C(15,1,1)	Auxiliary Noise Source	P5 (Channel 10)
C(15,2,1)	Auxiliary Noise Source	P4 (Channel 11)
C(15,3,1)	Auxiliary Noise Source	P6 (Channel 10)
C(15,4,1)	Auxiliary Noise Source	P3 (Channel 10)

TABLE 1
C MATRIX continued

ELEMENT	DEVICE CONNECTED TO SYSTEM PORT DURING CALIBRATION SEQUENCE	6-PORT OUTPUT DESCRIPTION AND SCANNER CHANNEL
C(16,1,1)	Impedance Check Std.	P5 (Channel 10)
C(16,2,1)	Impedance Check Std.	P4 (Channel 11)
C(16,3,1)	Impedance Check Std.	P6 (Channel 10)
C(16,4,1)	Impedance Check Std.	P3 (Channel 10)

The 64 listed elements of the C array are filled when port 3 is characterized during a calibration sequence; the other 64 elements of this array are filled when port 0 is characterized. The devices connected when the second half of the array is filled are identical with the exceptions of locations C(1,1,2), C(1,2,2), C(1,3,2), and C(1,4,2). When these four locations are filled, the cryogenic standard is connected to port 0 instead of the D.U.T..

TABLE 2
Z MATRIX

ELEMENT	DESCRIPTION	PROG LOCATION
Z(1,1)	T2 PO=1	22880
Z(1,2)	T3 PO=1	22890
Z(1,3)	T1 PO=1	22900
Z(1,4)	S1 PO=1	22910
Z(1,5)	T4 PO=1	22920
Z(1,6)	P2 PO=1	22930
Z(1,7)	T2 PO=2	22770
Z(1,8)	T3 PO=2	22780
Z(1,9)	T1 PO=2	22790
Z(1,10)	S1 PO=2	22800
Z(1,11)	T4 PO=2	22810
Z(1,12)	P2 PO=2	22820
Z(1,13)	Std error of mean (Tx)	24320
Z(1,14)	Excess noise ratio in dB (Tx)	24330
Z(1,15)	Bias plus 3 times std. error	24670
Z(1,16)	Te, radiometer sys. temp K	24340
Z(1,17)	System noise figure	24450
Z(1,18)	System gain in dB	24480
Z(1,19)	Source. error cryo. std.	24110
Z(1,20)	% error--cryo. std.	24130

TABLE 2
Z MATRIX continued

ELEMENT	DESCRIPTION	PROG LOCATION
Z(1,21)	Ambient std. source error	24140
Z(1,22)	% error- ambient std.	24170
Z(1,23)	Power ratio source error	24400
Z(1,24)	% error- power ratio	24410
Z(1,25)	N3--number of meas. per set	20480
Z(1,26)	% total mismatch error	24570
Z(1,27)	Non-linearity constant E1	20530
Z(1,28)	% error for non-linearity	24500
Z(1,29)	% error for switch asymmetry	24550
Z(1,30)	Linear sum of bias errors	24610
Z(1,31)	Total # of measurements, N	20500
Z(1,32)	% Error- 3 times SEM	24510
Z(1,33)	Linear sum of errors	24620
Z(1,34)	Frequency F	18400
Z(1,35)	Calibrated Tx (average)	24070
Z(1,36)	Bias error %	24630
Z(1,37)	F1 (start frequency)	20450
Z(1,38)	F2 (stop frequency)	20460
Z(1,39)	F3 (step frequency)	20470
Z(1,40)	N8 NO. of sets per meas.	20490

TABLE 2
Z MATRIX continued

ELEMENT	DESCRIPTION	PROG LOCATION
Z(1,41)	Sum of sqrs T1, 2nd 50, B6	22840
Z(1,42)	Sum of T1, 2nd 50, B8	22860
Z(1,43)	Sum of sqrs T1, 1st 50, B5	22960
Z(1,44)	Sum of T1, 1st 50, B7	22970
Z(1,45)	Sum of P1 (divide by N for ave)	23310
Z(1,46)	Sum of P2 (divide by N for ave)	23320
Z(1,47)	Sum of P3 (divide by N for ave)	23330
Z(1,48)	Sum of sqrs P1	23350
Z(1,49)	Sum of sqrs P2	23360
Z(1,50)	Sum of sqrs P3	23370
Z(1,51)		
Z(1,52)	T1	24070
Z(1,53)	T2	24090
Z(1,54)	T3	24100
Z(1,55)	Bandwidth 5 MHz IF 3.6 MHz	24510
Z(1,56)	Bandwidth 30 MHz IF .95 MHz	24520
Z(1,57)	Aeta, result, port symmetry	16290
Z(1,58)	Frequency of measurement	16420
Z(1,59)	Isolator Error percent	24590
Z(1,60)	Mismatch % error + power ratio	24600

TABLE 2
Z MATRIX continued

ELEMENT	DESCRIPTION	PROG LOCATION
Z(1,61)	Refl. coef. magnitude D.U.T.	6100
F(1,62)	Refl. coef. Angle D.U.T.	6110
Z(1,63)	Refl. coef. real D.U.T.	6120
Z(1,64)	Refl. coef. imag. D.U.T.	6130
Z(1,65)	Mismatch correction factor	6300
Z(1,66)	Result Check standard 1	23590
Z(1,67)	Result Check standard 2	23600
Z(1,68)	Result Check standard 1	23630
Z(1,69)	Result Check standard 2	23640
Z(1,70)		
Z(1,71)	Ratio P1/P2 set 1	23340
Z(1,72)		
Z(1,73)	P7 sum of P1 set 2	23420
Z(1,74)	P8 sum of P2 set 2	23430
Z(1,75)	P9 sum of P3 set 2	23440
Z(1,76)	W4 sum of sqrs P1 set 2	23450
Z(1,77)	W5 sum of sqrs P2 set 2	23460
Z(1,78)	W6 sum of sqrs P3 set 2	23470
Z(1,79)	Ratio P1/P2 set 2	23480
Z(1,80)		

TABLE 3
F MATRIX

ELEMENT	DESCRIPTION	PROG LOCATION
F(1,1)	Measurement frequency	4310
F(1,2)	Space for # short pos analyzed	
F(1,3)	Real part system gamma (1)	11530
F(1,4)	Space for std. dev. F(1,3)	
F(1,5)	Imag. part system gamma (1)	11540
F(1,6)	Space for std. dev. F(1,4)	
F(1,7)	System refl. coef. angle (1)	11510
F(1,8)	Space for std. dev. F(1,7)	
F(1,9)	System refl. coef. magnitude(1)	11500
F(1,10)	Space for std. dev. F(1,9)	
F(1,11)	Refl. coef. magnitude D.U.T.	5760
F(1,12)	Refl. coef. angle D.U.T.	5770
F(1,13)	Real part F(1,11)	5780
F(1,14)	Imag part F(1,11)	5790
F(1,15)	Mismatch factor Mx	5930

TABLE 3
F MATRIX continued

ELEMENT	DESCRIPTION	PROG LOCATION
F(2,1)	Measurement frequency	4310
F(2,2)	Space for # short pos analyzed	
F(2,3)	Real part system gamma (2)	11590
F(2,4)	Space for std. dev. F(2,3)	
F(2,5)	Imag. part system gamma (2)	11600
2(2,6)	Space for std. dev. F(2,4)	
F(2,7)	System refl. coef. angle (2)	11570
F(2,8)	Space for std. dev. F(2,7)	
F(2,9)	System refl. coef. magnitude(2)	11560
F(2,10)	Space for std. dev. F(2,9)	
F(2,11)	Refl. coef. magnitude Cryo std.	5670
F(2,12)	Refl. coef. angle Cryo std.	5680
F(2,13)	Real part F(2,11)	5690
F(2,14)	Imag part F(2,11)	5700
F(2,15)	Mismatch factor Mx	5930

TABLE 3
F MATRIX continued

ELEMENT	DESCRIPTION	PROG LOCATION
F(3,1)	Measurement frequency	4310
F(3,2)	Space for # short pos analyzed	
F(3,3)	Real part system gamma (3)	5730
F(3,4)	Space for std. dev. F(3,3)	
F(3,5)	Imag. part system gamma (3)	5740
F(3,6)	Space for std. dev. F(3,4)	
F(3,7)	System refl. coef. angle (3)	5710
F(3,8)	Space for std. dev. F(3,7)	
F(3,9)	System refl. coef. magnitude(3)	5720
F(3,10)	Space for std. dev. F(3,9)	
F(3,11)	Refl. coef. magnitude Aux. 1	5670
F(3,12)	Refl. coef. angle Aux. 1	5680
F(3,13)	Real part F(3,11)	5690
F(3,14)	Imag part F(3,11)	5700
F(3,15)	Mismatch factor Mx	5930

TABLE 3
F MATRIX continued

ELEMENT	DESCRIPTION	PROG LOCATION
F(4,1)	Measurement frequency	4310
F(4,2)	Space for # short pos analyzed	
F(4,3)	Real part system gamma (4)	5730
F(4,4)	Space for std. dev. F(4,3)	
F(4,5)	Imag. part system gamma (4)	5740
F(4,6)	Space for std. dev. F(4,4)	
F(4,7)	System refl. coef. angle (4)	5710
F(4,8)	Space for std. dev. F(4,7)	
F(4,9)	System refl. coef. magnitude(4)	5720
F(4,10)	Space for std. dev. F(4,9)	
F(4,11)	Refl. coef. magnitude Aux. 2	5670
F(4,12)	Refl. coef. angle Aux. 2	5680
F(4,13)	Real part F(4,11)	5690
F(4,14)	Imag part F(4,11)	5700
F(4,15)	Mismatch factor Mx	5930

C. NOISE EQUATIONS AND THEIR APPLICATION TO THE AUTOMATED RADIOMETER

The end result of a noise measurement sequence is the calculated noise temperature of the device tested and a summary of known errors and system parameters. Certain equivalent numerical relationships are essential to convert the intermediate results obtained with the system hardware to the final form tabulated at the conclusion of a measurement sequence. A summary of these is presented here to provide a ready reference for the theoretical work underlying the software. Documentation for this summary may be found in the Noise Laboratory Notebook "AR2" [8]. This summary is not intended to be self-explanatory. In the following, T1, T2, and T3 are the noise temperatures of the device under test, ambient standard, and cryogenic standard respectively. Tx is the same as and used interchangeably with T1. Noise temperatures are expressed in Kelvins. Temperature in degrees Celsius is converted to Kelvins by adding 273.15.

The notation used in this section is compatible with the computer used. To avoid confusion, the following are defined: (1) The "*" denotes multiplication, (2) The "^" denotes exponentiation, (3) SQR denotes square root, (4) ABS denotes magnitude, (4) LOG denotes logarithm to the base 10, and (5) Ln denotes natural logarithm.

The noise power measured from the device under test is designated P1, that from the ambient standard as P2, and that from the cryogenic standard as P3. The noise temperature of the unknown, Tx, is then determined by first finding the power ratios

Y1 and Y3 and correlating them with the temperatures of the standards to find Tx:

$$Y1=P1/P2 \quad (1)$$

$$Y3=P3/P2 \quad (2)$$

$$Tx=T2+(T3-T2)*(Y1-1)/(Y3-1) \quad (3)$$

In a normal calibration, the determination of Tx is made 100 times and the average of these 100 determinations is reported as is the standard deviation. Equation (3) is the basis for calculating the noise temperature for the device tested, but further enhancements are necessary for maximum accuracy. These are as follows:

Noise Temperature, Tx, corrected for mismatch is calculated using the following:

First the mismatch factor,Mx, between the device under test and the appropriate system port is found:

$$Mx1=(1-Gxm^2)*(1-Gsm^2) \quad (4)$$

$$Mx2=(1-Gxr*Gsr+Gxi*Gsi)^2+(Gxr*Gsi+Gxi*Gsr)^2 \quad (5)$$

$$Mx=Mx1/Mx2 \quad (6)$$

where

Gxm and Gsm are the magnitudes of the reflection coefficients, Gx and Gs, of the device under test and the system ports respectively.

Gxr and Gsr are the real part of Gx and Gs respectively.

Gxi and Gsi are the imaginary part of Gx and Gs respectively.

Then the mismatch factor, Ms, between the cryogenic standard and appropriate system port is found:

Ms1=(1-Gxm'^2)*(1-Gsm'^2) (7)

Ms2=(1-Gxr'*Gsr'+Gxi'*Gsi')^2+(Gxr'*Gsi'+ Gxi'*Gsr') (8)

Ms=Ms1/Ms2 (9)

where

Gxm' and Gsm' are magnitudes of the reflection coefficients, Gx'and Gs', of the cryogenic standard and system ports respectively.

Gxr' and Gsr' are the real parts of Gx' and Gs' respectively.

Gxi' and Gri' are the imaginary parts of Gx' and Gs' respectively.

The mismatch factor for use in correcting T1 is found by:

MF=Ms/Mx (10)

Tx can now be obtained corrected for mismatch:

Tx=T2+MF*(T3-T2)*(Y1-1)/(Y3-1) (11)

Port Asymmetry is evaluated (see Appendix I) as the ratio of the standard port noise efficiency to the measurement port noise efficiency.

Let this ratio equal A1.

Then applying this term in (11)

Tx=T2+MF*A1*(T3-T2)*(Y1-1)/(Y3-1) (12)

Tx has now been corrected for asymmetry (signal path efficiency) and mismatch.

For more accuracy, one further correction must be made to the calculated noise temperature. This is the quantum correction and is needed especially for the ratios of frequency to temperature. This correction is made as follows:

First the cryogenic standard temperature T3 is corrected:

T3′=Zeta*(T3+Dt) (13)

where Zeta=n/(EXP(n)-1),

Dt=the loss and mismatch corrections to the cryogenic standard.

n=(0.0479932*F)/T3, (14)

F=Frequency in GHz.,

and Tn=T3= the temperature of the termination from equation (24).

D1=2.64E-3*SQR(F)*Gs^2*(T2-Tn) (15)

where now Gs is the reflection coefficient magnitude of the cryogenic standard.

D2=.611-2.55E-3*(Tn-76)+3.82E-3*(Ta-297) (16)

D3=(0.6*sqr(F)+.011*F)/0.611 (17)

Dt=D1+D2*D3 (18)

T3′, the quantum corrected value of T3 should now be substituted for T3 in (12).

In a similar manner, a quantum correction is made to T2 to yield:

T2'=Zeta'*T2 (19)

Where Zeta'=n'/(Exp(n')-1)

And n'=0.0479932*F/T2 (20)

The quantum corrected T2' should now be substituted in (12) for T2. This completes the quantum correction for (12).

Some of the other quantities calculated during the course of a measurement are:

The temperature of liquid nitrogen can be calculated from atmospheric pressure by using the vapor pressure equation for liquid nitrogen:

B0=(B1/T+B2+B3*T+B4*(126.2-T)^1.95+B5*T^3)

B0'=(B6*T^4+B7*T^5+B8*T^6+B9*Ln(T))

P=EXP(B0+B0') (21)

where

B1= 8.394409444E3; B2=-1.890045259E3;

B3=-7.282229165; B4= 1.022850966E-2;

B5= 5.556063825E-4; B6=-5.944544662E-6;

B7= 2.715433932E-8; B8=-4.879535904E-11;

B9=5.095360824E2.

Computation: 30 iterations (T= 55 for the 1st iteration) of (21) are performed to obtain an accurate temperature output.

As part of the iteration process:

P=(760*P)-Patm (22)

where Patm = atmospheric pressure in mm

Then T0=T+(85-T0)*ABS(P)/ABS(P)*1718.05458298) (23)

T=T0 for the next iteration.

After iterating:

T3=INT(100*(T0+0.005))/100 +.04 (24)

where the 0.04 K accounts for the average temperature increase from the liquid nitrogen head above the load.

SYSTEM TEMPERATURE

Te=[T3-(Y3)*(T2)]/(Y3-1) (25)

EXCESS NOISE RATIO dB

ENR=10*Log(Tx-290)/(290) (26)

where 290 is a defined quantity

RADIOMETER SYSTEM NOISE FIGURE dB

RST=10*Log(1+Te/290) (27)

RADIOMETER SYSTEM GAIN

RSG=10*Log[(7.244)*(10^13)*(P2)/Bw/(T2+Te)] (28)

where Bw is the system bandwidth in MHz.

and (7.244)*(10^13) is a noise constant

To Calculate the OUTPUT NOISE TEMPERATURE of a Device when an adaptor has been used in its calibration the following is utilized.:

Tx=Tx'/A+T2*(1/A-1) (29)

where Tx' is the output noise temperature of the device. Tx is the noise temperature with the adaptor attached, T2 is the ambient temperature in K (the nominal value of T2 is 300 K),

and A is the alpha for the attenuation present.

A is calculated by: A=10^(-Loss in dB/10) (30)

STANDARD DEVIATION is calculated by:

S.D.=Square root of ((V-T*T/N)/(N-1)) (31)

where T is the sum of the individual measurements; V is the sum of the squares of the individual measurements, and N is the total number of measurements.

STANDARD ERROR OF THE MEAN is given by:

SEM=S.D./Square root of N (32)

AMBIENT STANDARD UNCERTAINTY (U) is 0.5K

R8=(T2/Tx)*ABS(1-(Tx-T2)/(T3-T2) (33)

DT2/T2=(0.5/297)*100=0.17% (34)

Let ES2=the error in % due to the ambient standard in measuring the unknown.

ES2%=(0.17*R8) (35)

CRYOGENIC STANDARD UNCERTAINTY (U) is 0.21%

R9=(T3/T1)*ABS((T1-T2)/(T3-T2))

Let ES3=Error in % due to the cryogenic standard uncertainty in measuring the unknown.

ES3%=0.21*R9 (36)

UNCERTAINTY IN MEASURING POWER RATIOS IS 0.01 dB.

Power Factor (U)=0.0023

A=1+Te/T1 (37)

B=1-T2/T1 (38)

C=(T3+Te)/(T3-T2) (39)

Where Te is defined as the radiometer system temperature.

Let EPR=Error due to the uncertainty in measuring power ratio.

EPR%=0.23*ABS(A-B*C) (40)

See the power equation for use with the NBS Type IV power meter later in this section.

SYSTEM NONLINEARITY ERROR

Let the system non-lineariy error in percent=EL4

EL4%=(Tx-T2)*(Tx-T3)*(E1)*100/Tx (41)

where E1=1.2862E-8

(See Measurement and Calculation of System Non-linearity later in this section)

SWITCH ASYMMETRY ERROR AND PATH EFFICIENCY

(See Appendix I)

Let ESA=The error in percent due to switch asymmetry.

Error=1.28*SEM (42)

Where SEM is the Standard error of the mean for the actual measurements of the power ratios measured when determining port asymmetry.

The factor 1.28 assures a 10% confidence interval.

ESA%=(Error*((T3-T2)/Tx)*100) (43)

Let ESI= the error due to less than infinite isolation between the preamplifier and the measurement ports. (The following error equation is predicated on an isolation of 40 dB.)

Let A=the magnitude of (Tx-T2)/Tx

Let B=the magnitude of (Tx-T3)/Tx

Let C=the magnitude of the reflection coefficient of the device under test.

Then:

ESI%=0.0258*ABS(A)+0.0193*ABS(B)+143.6(C)/Tx (44)

Measurement and Calculation of System Linearity

Linearity of the measurement system is checked by determining the noise temperature of a device at discrete power levels selected to cover the linear operating range of the measurement system. These power levels are set by varying the settings of the system I. F. attenuator and, normally, settings cover a 6 dB range in increments of 1 dB. 50 to 100 measurements are taken at each setting of the attenuator. All measurements are repeated until enough samples of the system output over the operating region are taken to provide a reliable result. For analysis, the values obtained for the device under test are paired. These pairs are then analyzed to determine how much non-linearity exists between the system power levels they represent. Results of all pairs analyzed are then combined to determine the nonlinearity error constant, El, which is subsequently used to evaluate system non-linearity in (41).

Let Tx′=nominal noise temperature of the device measured.

Let T2′=the nominal value of the ambient standard.

Let T3′=the nominal value of the cryogenic standard. (Nominally these values are 10,000, 300, and 77.)

Then

C=1/(Tx′-T2′)*(Tx′-T3′) (45)

Let Po1 and Po2 represent the two power levels analyzed.

Let Tx1 and Tx2=the measured noise temperatures obtained at the respective power levels.

Let D1 and D2=the dial settings of the I.F. attenuator used as a ratio to obtained Po1 and Po2.

Then Er=C(Tx2-Tx1)/(D1-D2) (46)

Normally a minimum of 12 pairs are evaluated.

Then E1=ABS(Average of Er)+0.64*SEM (47)

Where SEM=The standard error of the mean calculated for Er. E1 is now used in equation (41) to determine system non-linearity error. E1 was determined to be 1.2862E-8.

Power Equation For Use With The NBS Type IV Power Meter

During a measurement, the desired port is selected and the noise power from the device connected to that port is measured under computer control using the Type IV power meter, reference voltage generator, and digital multimeter. The reference voltage output is adjusted to equal the power meter voltage with no rf power applied to the thermistor mount before the measurements begin. This zeros the instrument. (Refer to figure 7. Rf power is removed from the thermistor mount by switching system switch number 1 to its terminated port.) Power is then determined with the scanner and system switches providing the proper conditions. A normal computer controlled sequence is:

1) The power meter voltage (A) is measured with the rf power off.
2) The power meter voltage minus the reference voltage (B) is measured with the power off.
3) The power meter voltage minus the reference voltage (C) is measured with the rf power on.
4) The power meter voltage (E) is measured with the power off to check drift.
5) The power meter voltage minus the reference voltage (D) is again checked with the power off.
6) Power (P) is then obtained by:

$$P=[(A+E)-C+(B+D)/2][C-(B+D)/2]/R0 \quad (49)$$

where R0 is the resistance of the thermistor mount (normally 200 ohms) [6].

5. MAINTENANCE

A. EQUIPMENT DESCRIPTION

Since the measurement system is largely made up of commercially available equipment, operating, periodic maintenance, and troubleshooting instructions can be found in the appropriate manuals supplied with the instruments. A list of the equipment presently being used, the manufacturer, and the model number follows:

****

IMPORTANT NOTICE

The specific components selected for use with the system were chosen on the basis of suitability, availability, and costat the time of procurement. They do not necessarily represent the only possible choice or even the best choice. The National Bureau of Standards states only that they were used in the system described here. Substitution of nominally equivalent components meeting the same specifications should cause no difficulty; however NBS has not tested all such possible choices.

****

INSTRUMENT NAME	MANUFACTURER	MODEL
1. Controller	Hewlett Packard Co.	9845B
2. Digital Multimeter	John F. Fluke Co.	8502A
3. Digital Multimeter	Hewlett Packard Co.	3456A
4. Scanner (2)	Hewlett Packard Co.	3495A
5. Instrument Coupler (2)	ICS Electronics Corp.	4883
6. Synthesizer	Systron Donner Corp.	1618

INSTRUMENT NAME	MANUFACTURER	MODEL
7. 2-4 GHz Preamplifier	Amplica	6331SN
8. Amplifier	Aertech	AM110
9. Amplifier	Avantek	AV-4
10. Power Supplies	Power Mate Corp	BP34D
11. Noise Standard	NBS	Cryogenic
12. Switch Driver Module (2)	NBS	30-60
13. Power Meter	NBS	Type IV

Technical details, schematic diagrams, and parts lists for the switch driver modules and the associated intercabling are included in this manual.

B. SYSTEM CHECKS

A number of checks are performed automatically in the process of making a measurement with the system and its software. These include: 1) A check of system power measurements which is made by running the system power set portion of the program at the beginning of a measurement sequence. If the power meter, reference generator, and digital multimeter are not performing adequately, this fact will be made apparent by the values displayed during this program segment. Erratic and obviously wrong power values and large variations between consecutive measurements are the usual indication of malfunction of these instruments. Band and measurement port switches are also exercised during this test, and defective switching can cause a either a substantial spread in measurement results, no change in power when a measurement port is changed, or a null to be read at one or more ports. 2) System voltage checks are made automatically before the measurement sequence begins. The values of these voltages are displayed . The operator must approve the displayed values before measurements continue. These checks reaffirm that the voltmeter portion of the digital multimeters are working properly, that intercabling between instruments is intact, and that the system power supplies are adjusted and functioning properly. 3) Large scatter in successive readings of power taken during a calibration are an indication of erratic switch operation or poor peripheral instrument performance. Experience will dictate what this scatter should be for a given item. Three times the standard error is normally below 1 percent of the noise power measured.

In addition, system operation is verified in two other ways during a measurement sequence.

1) Measurements of the device under test at two different power levels are required and will pinpoint excessive system non-linearity.

2) During a measurement sequence, automatic evaluation is made of two check standards. If the results of the evaluation are out of tolerance, applicable reference standards with effective noise temperatures of 10,000 K, 6,000 K, 3,000 K, 377 K, and 77 K can be checked immediately to test system accuracy. These measurements provide an excellent check of overall system performance. Results obtained by measurement of the reference standards are the single most important indicator of system

precision and accuracy. These results will show whether or not a major failure has occurred in such a subtle manner that the failure was not detected by other checks.

If the system fails to perform properly during any of the tests, try to pinpoint the location of the trouble by logically analyzing in which test the trouble occurred, and working backwards to isolate the instrument or component responsible for the failure. For example, if a switch is intermittent, the tests outlined will give an indication of the measurement port involved (possibly a large scatter in power measured at one port). Improper switch operation can then be isolated to the faulty switch and/or driver card by parts substitution and in-circuit testing. Software written specifically to exercise and test the switches is available in a program named "SWITCH". This program exercises all system switches and indicators connected with the switch driver modules. To use this program, simply load "SWITCH" and press run. All switches are exercised in a logical sequence, and the system indicators along with measurements that can be made at the switch terminals aid in finding faults in this section of the measurement system. In the event that a major repair is made on the system preamplifiers or input port switches, a complete analysis of the impedance and noise figure of the radiometer "front-end" should be made and parameters contained in the Z-matrix changed if necessary. System linearity and bandwidth should also be re-evaluated and the constants relating to these parameters changed in the system software if a change in the constants occurred.

Diagnostic tests of commercial units, to which faults have been isolated, can be performed by following the instructions provided in the applicable operation and service manual.

With the exception of the switch test program, no specialized diagnostic software has been written to aid in troubleshooting the equipment because the above described tests will isolate most faults to at least the instrument level.

C. COMPONENT DESCRIPTION AND TECHNICAL INFORMATION

For commercial equipment used in the system, this information is available in manuals supplied by the manufacturer.

1. Switch Driver Modules

Two of these units are utilized. The first one controls the switches contained in the 30/60 MHz radiometer and the noise power measuring section shared by both systems; this unit is comprised of power supplies, remote switches, a decoder card, LED (light emitting diode) display, and switch driver output cards. Two types of switch driver cards are used in this unit; one type is used to control 15 V switches and the other type is used to provide control for the 25 V programmable attenuator. This switch driver module also contains an output display card with its associated analog meter. This output display card is the only card requiring adjustments and these are covered with the description for this card. The second switch driver module contains driver cards to control the measurement port, reflectometer, and radiometer switches for all bands contained in the automated radiometer from 0.35 to 12.0 GHz. Two types of switch driver cards are used in this module also. One type, identical to the second described for the first unit above, controls the 15 V switches. The other type though, is completely different and supplies the -28 V control for the Transco rotary band switches used in the system. The modules are designed so that if a card is of the same type, it can be interchanged between modules. In the following descriptions, cards with a first digit of 1 such as 110, 113, etc. are located in the first module described. Cards with a first digit of 2 such as 210, 213, etc. are located in the second module.

a) Power Supplies and Switches

The switch driver modules contain one 5V power supply which supplies operating voltage for the integrated circuits on the decoder, switch driver, and output display cards. 15 V, 25 V,and -28 V drive voltages for the switches controlled by the switch driver cards are also supplied to this unit from external power supplies after passing through two remotely controlled switches. This permits the drive voltage for the system switches to be turned on and off by the controller. Also present in one unit are the positive and negative 15V supplies for the operational amplifiers on the output display card.

b) Card 110, Decoder Card

This card uses a type 7442 decoder chip which is a BCD to decimal decoder (1 of 10). Four of these elements are used; one spare which is presently not used is supplied. Figure 12 shows the truth table for this type of decoder chip. In Figure 12, the BCD (binary coded decimal) inputs labeled D, C, B, A correspond to device pin numbers 15, 14, 13, and 12 respectively. The decimal outputs listed correspond, in ascending order, to device pin numbers 1 through 10.

Inputs from the controller are sent to the decoder card via the instrument coupler. These inputs are decoded and sent to the proper switch driver card to achieve the desired switch action. Referring to Figures 10 and 7, outputs from pins 33, 35, 38, and 40 on this card control the switching of ports 0, 1, 2, and 3. Outputs from pins 41 and 43 select either the port 0-1 position or the port 2-3 position of switch #6. Outputs from pins 46 and 48 position switch #5 to connect ports 0-3 or port 4 to the remainder of the measurement system. Outputs from pins 49 and 51 select either the 30 MHz or the 60 MHz position of switches 4a and 4b. As can be seen in Figure 10, input pin 24 on the decoder card is the "strobe" input for all of the decoder chips. This signal is used to enable the decoder output. Removing this signal provides for removing switch current without disturbing switch position. This signal is utilized in this manner to prevent heating of the switches. Outputs from pins 7 and 8 on this card are used to control the remote switches for the 15 V and 25 V power supplies for the switch drivers. The output from pin 9 on this card is used as a control bit for the thermistor mount switch and provides for removing current from this switch after it is properly positioned. The output from pin 6 on this card is the return flag signal to the controller from this card.

The LED display on the front panel of the first switch driver module is located on the decoder card. The upper 8 bits of the display represent the digital input bits to the decoder since a LED is connected to pins 10, 21, 12, 13, 14, 15, 16, and 17. The lower portion of the LED display is formed by connecting a LED to each of the following output pins: 33, 34, 38, 40, 41, 43, 46, 48, 49, 51, 54, 56, 7, 8, and 9. By observing the lower portion of the display, the output of the decoder card can be determined at any time. The LED display on the front panel of the second switch control module is arranged in a different manner, but the operation is similar. The control bits from the decoder card are routed to the LEDs on the front panel, and the front panel display is labeled to show which port, strobe, or other function is enabled at the time.

Table 4 lists the instrument coupler control bits to the 110 decoder card and describes the switches controlled as well as the connections to the computer to switch driver cable connector, J104.

c) Card 210, Decoder Card

Physically, this card is identical to the 110 decoder card except that the LED output display for this card is located on the front panel of the switch control module number 2 instead of being located on the front of the card.

Inputs to this card are received from the controller via J204. Refer to Figures 10 and 3. The port control section on this card is identical to that on the 110 card with outputs at pins 33, 34, 38, 40, 41, 43, 46, and 48 providing control for measurement port switches 24, 25, 23, and 22. In addition outputs from pins 7, 8, and 9 provide control for radiometer/reflectometer switches 13a and 13b in the 2.0 to 4.0 GHz radiometer. Corresponding switches in the 0.35 to 0.50, 0.5 to 1.0, 4.0 to 8.0, 8.0 to 12.0 GHz radiometers are also controlled by these outputs as well as the rotary band switches. Table 5 lists the instrument coupler control bits to this card and describes the switches controlled as well as the computer to switch driver connector pins contained in J20

TABLE 4
COMPUTER TO SWITCH DRIVER CONTROL VIA INSTRUMENT COUPLER 1

INSTRUMENT COUPLER 1

GROUP-------	Q4	Q3	Q2	Q1
DIGIT-------	MSD	MSD1	MSD2	MSD3
BCD---------	8421	8421	8421	8421
J204 PIN----	BCDE	FHJK	LNMP	RSTU

GROUP	CPU BIT	J104 PIN	BCD	SWITCH CONTROLLED
	15	B	8	NOT USED
	14	C	4	NOT USED
Q4	13	D	2	PROG ATTEN 8DB
	12	E	1	PROG ATTEN 4DB
	11	K	8	PROG ATTEN 2DB
	10	J	4	PROG ATTEN 1DB
Q3	9	H	2	SWITCH 10A & 10B 3DB STEP
	8	F	1	SWITCH 1 POWER MEASURE
	7	L	8	+15 V 25 V CONTROL
	6	M	4	CONTROL BIT (STROBE)
Q2	5	N	2	SWITCH 4A AND 4B 30 OR 60 MHZ
	4	P	1	SWITCH 5 PORT 4
	3	R	8	SWITCH 8 & 6 PORT 3
	2	S	4	SWITCH 8 & 6 PORT 2
Q1	1	T	2	SWITCH 7 & 6 PORT 1
	0	U	1	SWITCH 7 & 6 PORT 0

TABLE 5
COMPUTER TO SWITCH DRIVER CONTROL VIA INSTRUMENT COUPLER 2

INSTRUMENT COUPLER 2

GROUP	Q6	Q5	Q4	Q3	Q2	Q1
DIGIT	MSD	MSD1	MSD2	MSD3	MSD4	MSD5
BCD	8421	8421	8421	8421	8421	8421
J204 PIN	BCDE	FHJK	LNMP	RSTU	dcba	jhfe

GROUP	CPU BIT	J204 PIN	BCD	SWITCH CONTROLLED
	23	B	8	SW. 16A AND 16B 2.0-4.0 RAD./REFL.
	22	C	4	SW. 15A AND 15B 1.0-2.0 RAD./REFL.
Q6				
	21	D	2	SW. 21 & S26B, S26C, S26D POS. 3; 8.0-12.0 BAND
	20	E	1	SW. 20 & S26B, S26C, S26D POS. 4; 4.0-8.0 BAND
	19	F	8	SW. 19 & S26B, S26C, S26D POS. 2; 2.0-4.0 BAND
	18	H	4	S26A POS. 5; S26B, S26C,
Q5				S26D, POS. 1; 1.0-2.0 BAND
	17	J	2	S26A POS. 4; S26B, S26C, S26D POS. 5; .5-1.0 BAND
	16	K	1	S26A POS. 3; S26B, S26C, S26D POS. 6; .35-.5 BAND
	15	L	8	STROBE 2
	14	N	4	STROBE 1
Q4	13	N	2	SW. 14A AND 14B RAD./REFL. 0.5-1.0 BAND
	12	P	1	STROBE

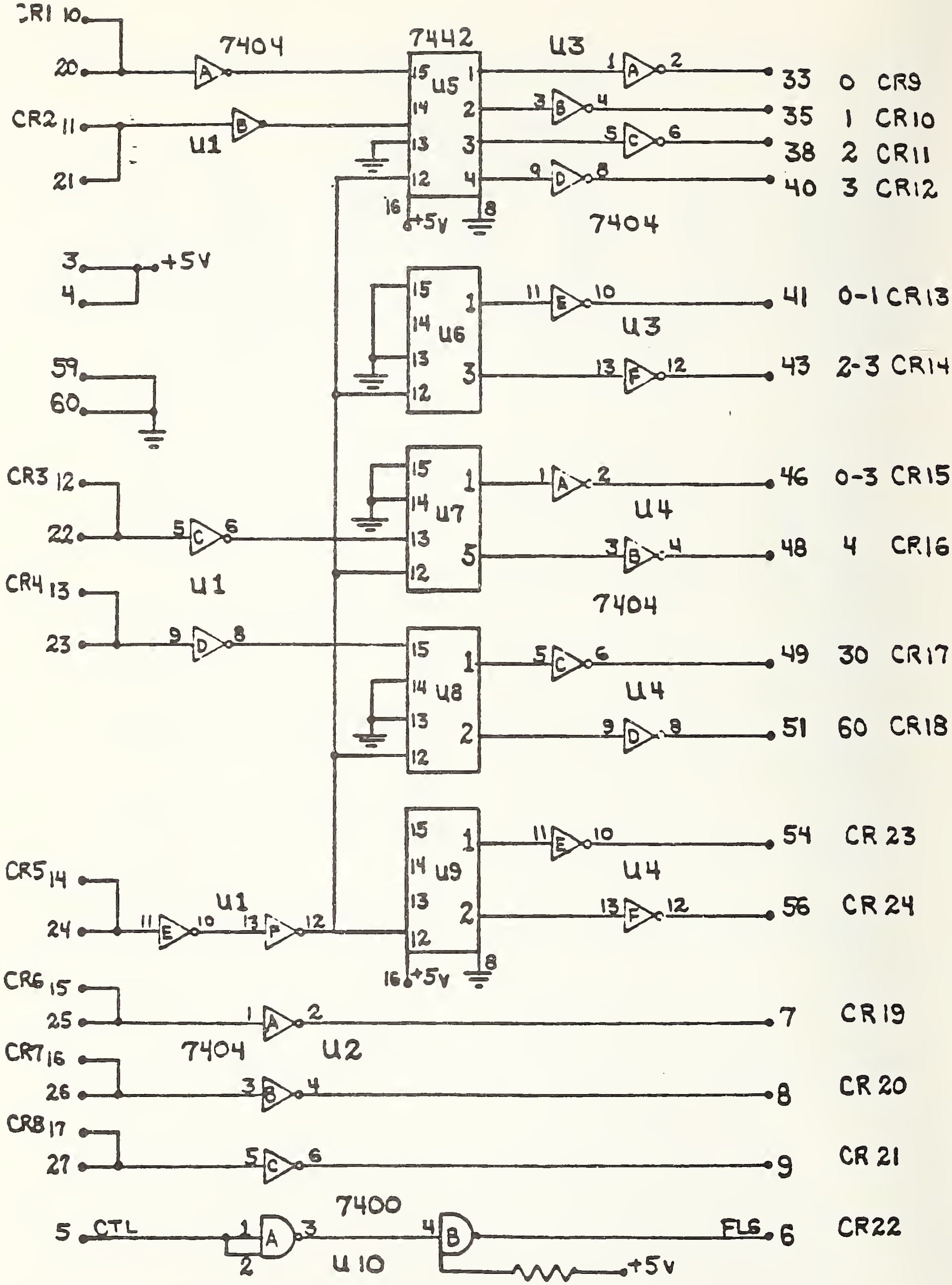
TABLE 5 continued

COMPUTER TO SWITCH DRIVER CONTROL VIA INSTRUMENT COUPLER 2

INSTRUMENT COUPLER 2

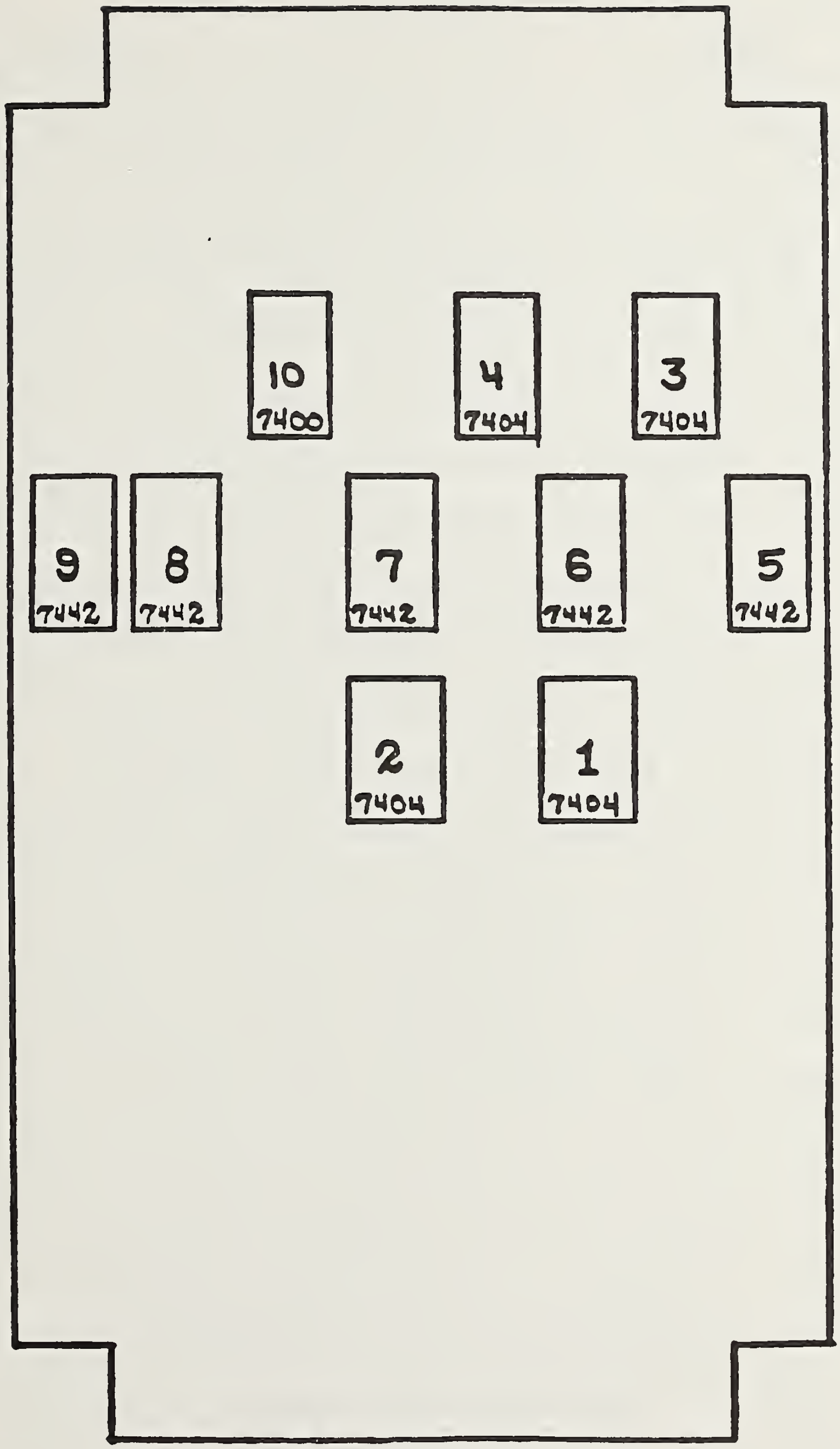
GROUP-------	Q6	Q5	Q4	Q3	Q2	Q1
DIGIT-------	MSD	MSD1	MSD2	MSD3	MSD4	MSD5
BCD---------	8421	8421	8421	8421	8421	8421
J204 PIN----	BCDE	FHJK	LNMP	RSTU	dcba	jhfe

GROUP	CPU BIT	J204 PIN	BCD	SWITCH CONTROLLED
Q3	11	R	8	SW. 13A AND 13B 0.35-0.50 RAD./REFL.
	10	S	4	SW. 22 PORT 4
	9	T	2	SW. 23 AND 24 PORT 2
	8	U	1	SW. 23 AND 25 PORT 1
Q2	7	d	8	SYNTHESIZER L.O TO FREQ LOCK
	6	c	4	SW. 9A AND 9B 5/30 I.F.
	5	b	2	SW. 18A and 18B 8.0-12 RAD./REFL.
	4	a	1	SW. 17A AND 17B 4.0-8.0 RAD./REFL.
Q1	3	j	8	SW. 11A AND 11B 94 GHZ STEP
	2	h	4	SW. 27A AND 27B 94 GHZ RAD.
	1	f	2	SPARE
	0	e	1	SPARE



110-210 DECODER CARD SCHEMATIC DIAGRAM

FIGURE 10



110-210 DECODER CARD PARTS PLACEMENT

FIGURE 11

SN7442

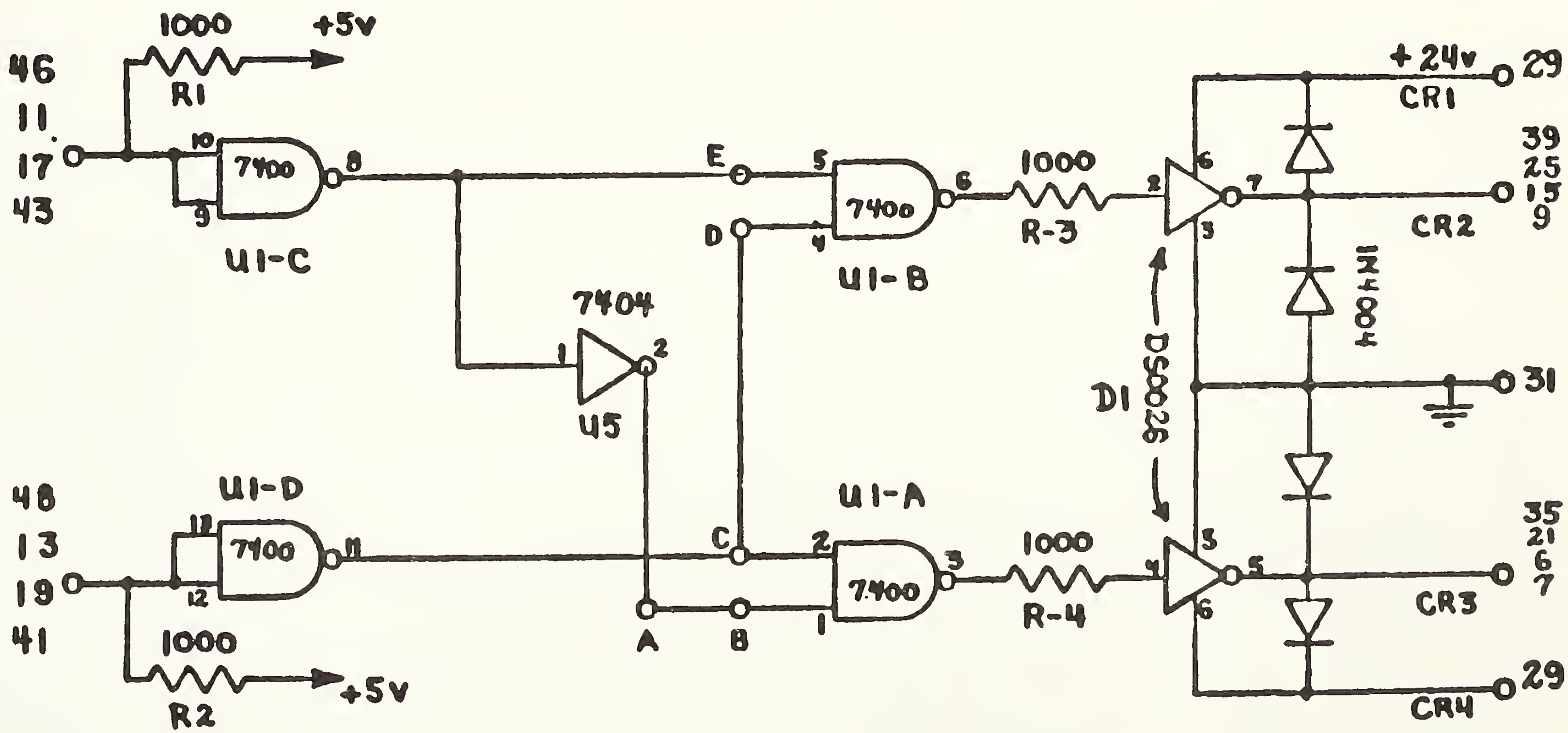
BCD INPUT				DECIMAL OUTPUT									
D	C	B	A	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	1	1	1	1	1	1	1	1	1
0	0	0	1	1	0	1	1	1	1	1	1	1	1
0	0	1	0	1	1	0	1	1	1	1	1	1	1
0	0	1	1	1	1	1	0	1	1	1	1	1	1
0	1	0	0	1	1	1	1	0	1	1	1	1	1
0	1	0	1	1	1	1	1	1	0	1	1	1	1
0	1	1	0	1	1	1	1	1	1	0	1	1	1
0	1	1	1	1	1	1	1	1	1	1	0	1	1
1	0	0	0	1	1	1	1	1	1	1	1	0	1
1	0	0	1	1	1	1	1	1	1	1	1	1	0
1	0	1	0	1	1	1	1	1	1	1	1	1	1
1	0	1	1	1	1	1	1	1	1	1	1	1	1
1	1	0	0	1	1	1	1	1	1	1	1	1	1
1	1	0	1	1	1	1	1	1	1	1	1	1	1
1	1	1	0	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1

DECODER TRUTH TABLE

FIGURE 12

d) Switch Driver Cards

The two switch driver modules use three different switch driver designs. One is intended to use the decoder outputs from cards 110 and 210 to control switching. This configuration is found on cards 111, 112, and 113, and 211. The other model uses a data bit and a control bit from the controller with no decoder in between. This configuration is found on cards 114, 212, 213, and 214. Use of this card represents a hardware update to utilize a design incorporated in the automated radiometer. Referring to Figure 13, the cards are configured for the decoder input model by installing jumper wires between points B and C, and points D and E with no connection between points D and C and points A and B. There are 4 complete switch driver circuits on a card; Figure 13 shows only one of these circuits for illustration purposes with inputs and outputs for all four circuits indicated by multiple pin numbers. Inputs are in pairs and produce outputs in pairs (inputs of the proper polarity at pins 46 and 48 produce outputs of opposite polarity at pins 9 and 7). Connected to opposite sides of a switch, these outputs cause it to toggle with a change in polarity. Inputs which cause the paired outputs to have the same polarity produce a positive voltage which is applied to both sides of a switch. There is no current flow, and as a result, the switch does not toggle. The 30/60 MHz system port switches #7 and #8 shown in Figure 7 are controlled by the outputs of driver card 111. The action of switches #5 and #6 in Figure 7 is controlled by driver card 112. The frequency selection switches #4a and #4b also shown in Figure



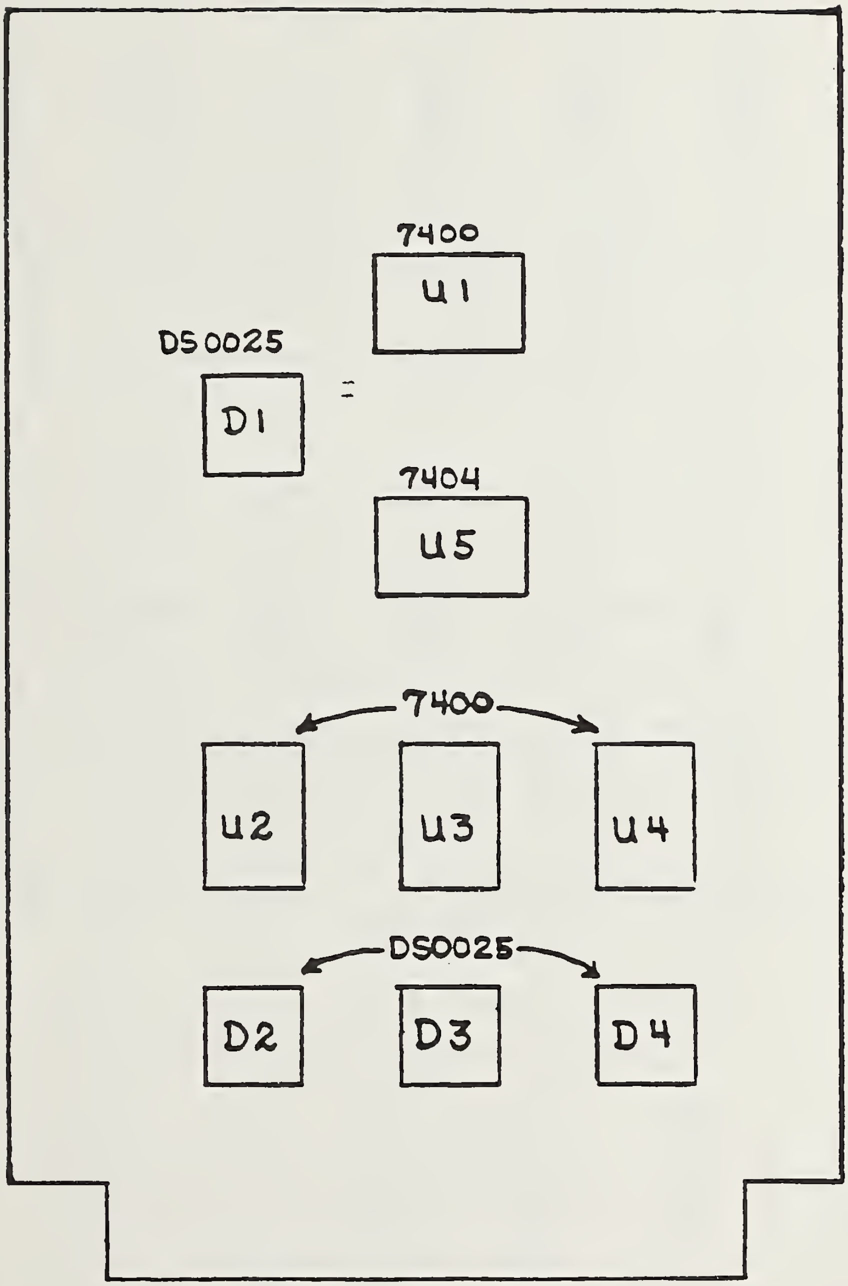
U2, U3, U4 SAME AS U1

D2, D3, D4 SAME AS D1

WHEN DS0025 IS USED
SHORT CIRCUIT R3 AND R4

111-114 SWITCH DRIVER CARD SCHEMATIC DIAGRAM

FIGURE 13



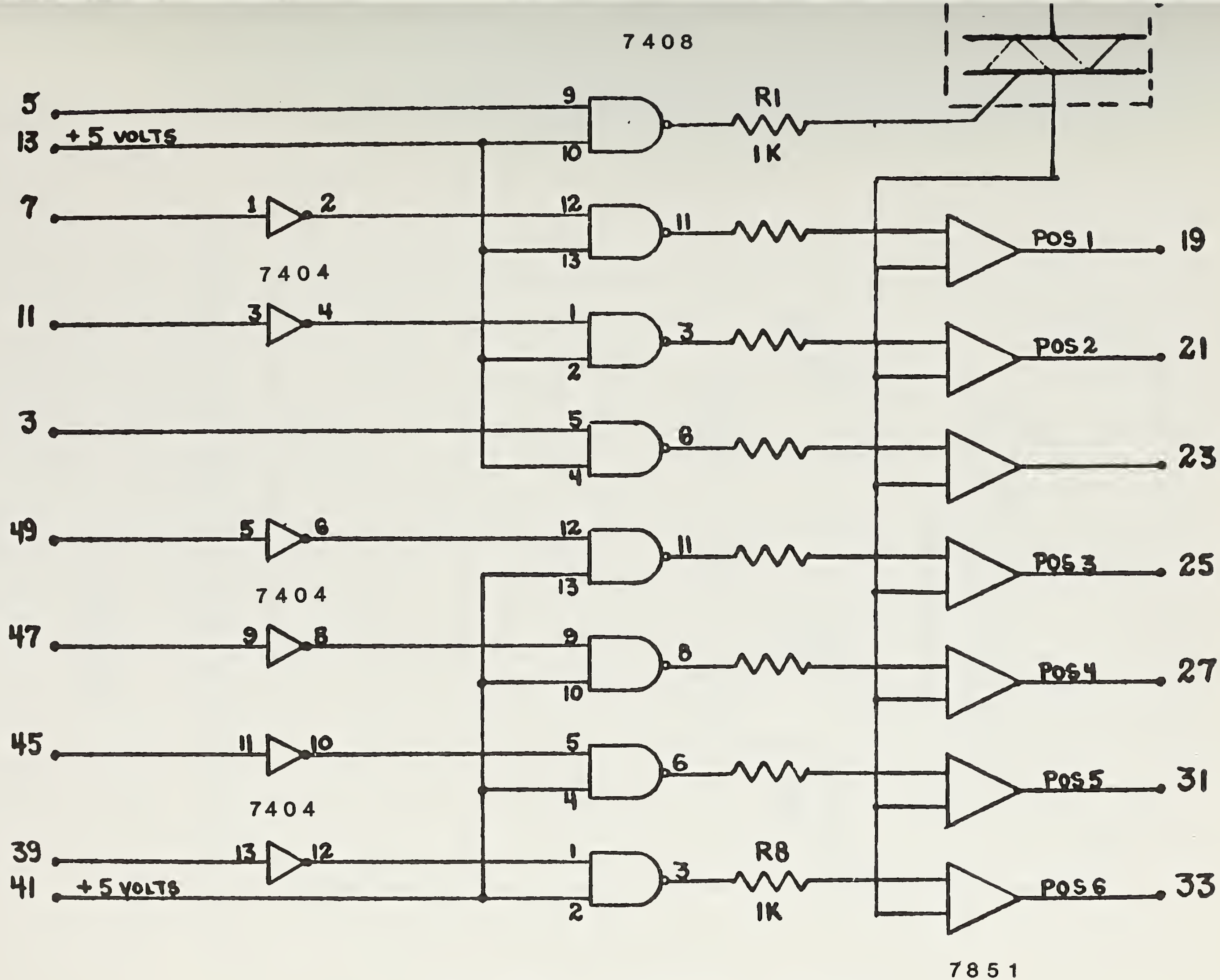
SWITCH DRIVER CARD PARTS PLACEMENT

FIGURE 14

7 are controlled by the output from driver card 113. The .35 to 12.0 GHz radiometer port switches 22, 23, 24, and 25 shown in Figure 3 are controlled by driver card 211. Card 114 is similar to the other switch driver cards but, as previously mentioned, is designed to operate without the decoder. To configure this card, remove the jumpers described previously and install jumpers between points A and B and points D and C. Binary bit 7 or decimal 128 from the decoder card is used as the enabling input for the drivers on this card. It is applied to pin 19 on card 114. The source for this control bit is the controller. This same configuration is used on cards 212, 213, and 214 to control the radiometer/reflectometer switches and some of the band select switches on the .35 to 12.0 GHz automated radiometer system.

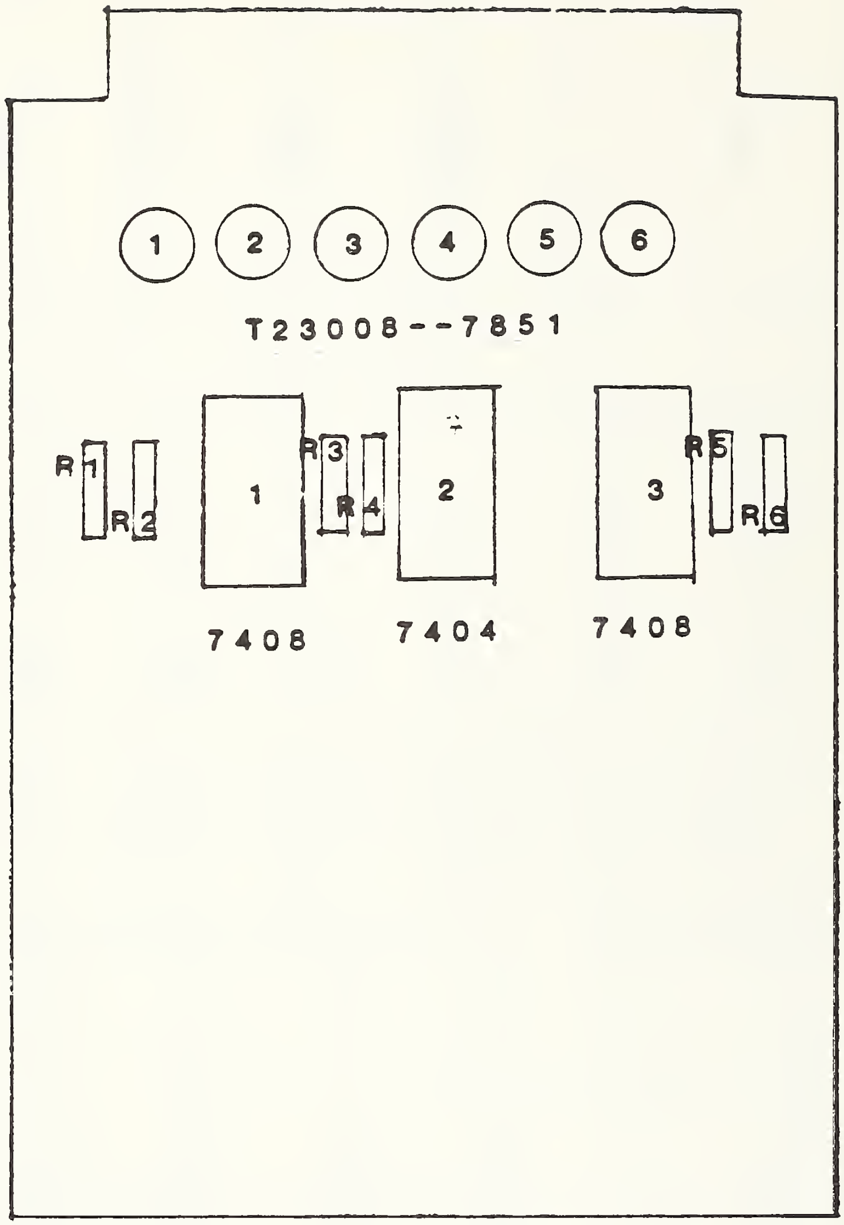
The 25 V switch driver cards 115, and 116 are identical to card 111 except for the 25 V drive voltage output. This voltage makes it necessary to use the DS0025 chip for a driver. In this case the resistors must be shorted. Also, pin 11 of the 7400 chip should be bent up or tied high. This is necessary for the switch driver to properly operate the programmable attenuator switches.

There is one other switch driver configuration used with this system. It is used to control the Transco rotary band switches. This configuration is shown in Figure 15. It is found on cards 217, 218, 219, and 220. This switch driver is a reversed polarity model and the drive voltage controlled is -28V. This requires a completely different design; silicon controlled rectifiers are used as the switch instead of the clock driver



TRANSCO SWITCH DRIVER

FIGURE 15



TRANSCO SWITCH DRIVER PARTS PLACEMENT

FIGURE 16

chips used on the other cards. Control signals from the controller are inverted by the hex inverter chips at the card input and then decoded by the and gate logic which follows. Outputs from the AND gates turn on the desired SCR (silicon controlled rectifier) and this in turn provides a current path for the -28 V drive voltage through the control winding of the Transco switches. Current through this winding is quenched by the opening of internal switch contacts which interrupt the drive current. Care should therefore be exercised in programming these devices since damage to the switch can occur if two inputs occur simultaneously.

e) 117 Output Display Card Operation and Adjustment

Figure 17 is the schematic diagram for this card. Figure 18 is the parts placement diagram, and Figure 19 is the schematic diagram for the front panel connections. The output display printed circuit card monitors the output of the diode detector. The input on pin 13 is amplified by IC-501 and input to the overload level comparator, IC-506, through the overload-adjust potentiometer "H" (R5). If the rf power exceeds 5 milliwatts the overload comparator triggers and latches. This energizes the sonalert alarm and overvoltage LED via Pin 52. The comparator cannot be reset by pressing the reset button until the power level has been reduced to a safe level.

The incoming signal level is also processed through a series of amplifiers to the front panel RF level meter. The output of the log-amplifier, IC501, passes through a sample and hold circuit, IC-502. The output of the sample and hold circuit drives the log-amplifier, IC-504, to convert the meter reading to a dB scale. IC-503 forms a constant current source to set the zero reference of the log amplifier. The output of IC-504 is connected to the input of the meter driver amplifier, IC-505. The gain of this amplifier is switched for gains of 10, 1, and .1 to obtain meter scales of 1.0 decibel, 0.1 decibel, and 0.01 decibel. Potentiometer "D" (R14) adjusts the times 1 scale zero reference.

Adjustment of the Output Display Card

This is the only card in the switch driver module which requires adjustment. Adjustment is necessary only when the circuit has been repaired. The adjustments establish the logarithmic amplifier gain for the decibel scale on the front panel signal level meter and set the overload alarm threshold. Complete alignment requires two, 1 milliampere constant current sources. Refer to Figure 16 when adjustment of the 1700 card is performed. Adjustments should be made in the following order:

1. Mount the 1700 printed circuit card on a PC extension card and remove the signal input cable from the diode detector to the front panel.
2. Connect an external voltmeter between TP 1 and ground. Adjust "A" (R7), DC offset of first amplifier, for zero on the voltmeter.
3. Connect the external voltmeter to TP V and adjust offset control, "C" (R9) for a zero reading on the voltmeter.
4. Remove the jumper from test point V to test point W.

Connect a temporary jumper from test point X to test point Y. Adjust "E" (R19), DC offset of the first log-amplifier, for a zero voltmeter reading.

5. Remove the temporary jumper from test point X to test point Y. Remove the jumper from TP Z to TP Z1. Connect one +1 milliampere constant current source into TP Z1 from ground. Connec the other +1 milliampere constant current source into TP W from ground. Set both current sources to 1 milliampere. (Place two suitable current meters in series with the sources and adjust the output of the current sources to 1 milliampere on these meters.) Connect the external voltmeter between TP 2 and ground. Adjust "F" (R20), the DC offset of the second stage of the log amplifier, for zero volts on the voltmeter.

6. Remove both constant current sources. Replace the jumper from test point V to test point W. Replace the jumper between test point Z and test point Z1.

7. Connect a suitable cable between the DET IN jack on the front panel and the system diode detector output connector at one end of coaxial switch #1.

    (a) Place a diode noise standard on port 0 and apply voltage (normally 28volts) to it.

    (b) After making sure all ports are properly terminated, turn the measurement system on.

    (c) Place the preamplifier voltage switch to the 30 MHz or up position.

(d) Turn on all system power supplies.

(e) Load the measurement program (30M20).

(f) Type the following on the 9845 keyboard:

OUTPUT 702;"0","0","7","0"

PRESS EXECUTE

(g) Remove the termination from the auxiliary port on system switch #1. Place a suitable thermistor mount on this port and connect it to an external power meter.

(e) Set attenuator A2 for 1 milliwatt of system output power at this port.

8. Connect an external voltmeter to TP 1. Adjust "B" (R6), the first amplifier gain, for 1 volt on the voltmeter.

9. Adjust system attenuator A2 to set the external power meter reading to 2 milliwatts. Switch the meter range selector on the front panel to the X1 position. Adjust "D" (R14), log reference zero offset, for a zero reading on the front panel signal level meter.

10. Increase the setting of system attenuator A2 by 5 dB. Adjust "G" (R21), log-amplifier gain, for a front panel meter reading of -5 divisions. Decrease the attenuator A2 setting 10 dB and note the front panel meter reading. Touch up "G" if necessary to obtain approximately a +5 reading on the meter scale. Recheck the -5 reading.

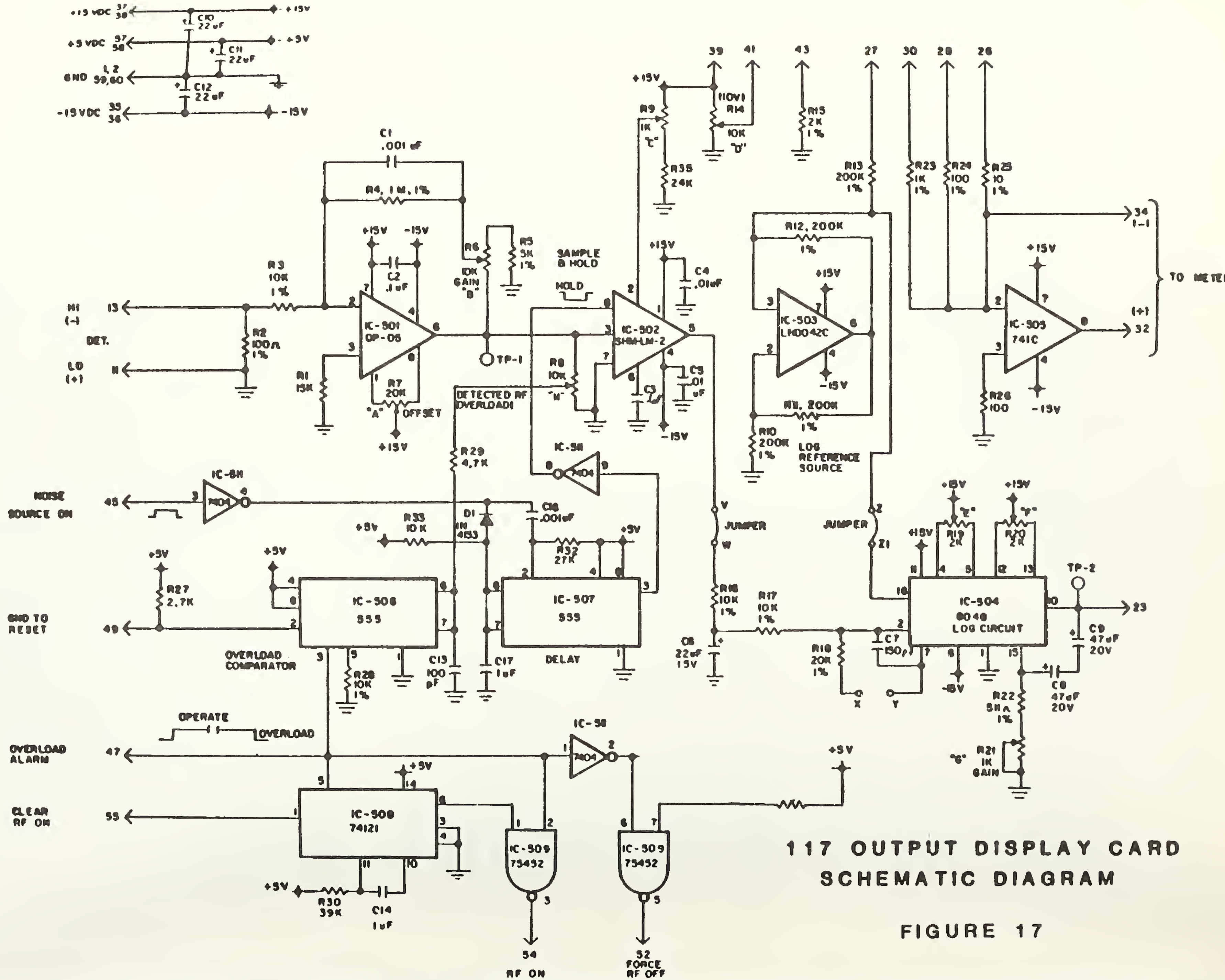
11. Set the input attenuator for a power level of 1

milliwatt on the power meter. Readjust "D" for a +3 reading on the front panel meter.

12. Adjust the front panel attenuators for a 5 milliwatts (+7dBM) power indication on the power meter. Adjust "H" (R5), overload threshold adjust, clockwise until the alarm sounds. Now turn R5 1/2 turn counter-clockwise. Reduce the input power and push the reset button on the front panel. Slowly increase the power to test the alarm threshold. The alarm should be activated at the +5 milliwatt power level.

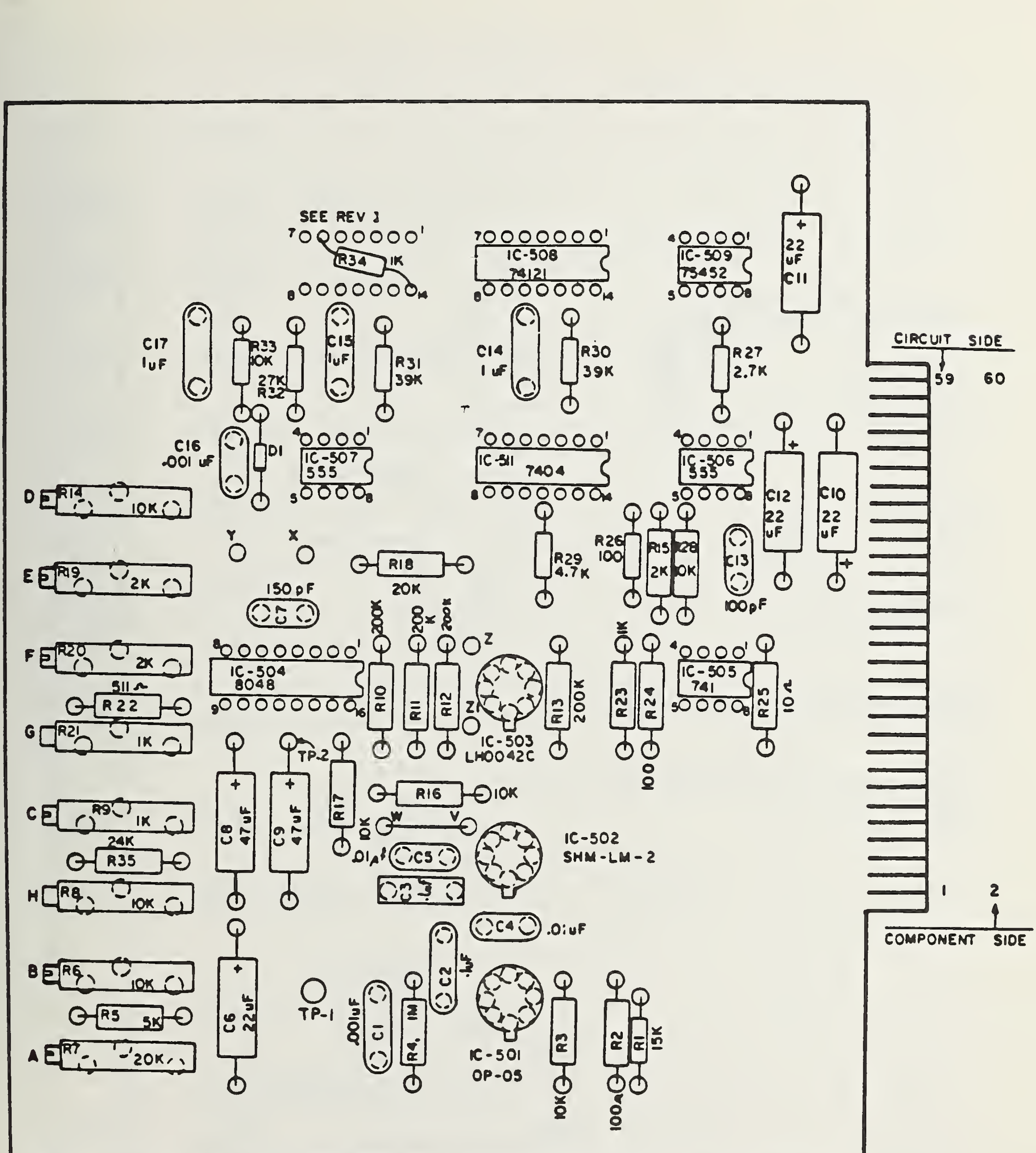
13. Adjust attenuator A2 until the external power meter reads 2 milliwatts. Adjust "D" (R14), log reference zero offset, for a zero reading on the front panel signal level meter.

This completes the alignment of the Output Display Card. These adjustments do not affect system operation or accuracy. They do however, affect the quality of the information conveyed by the display to the operator.



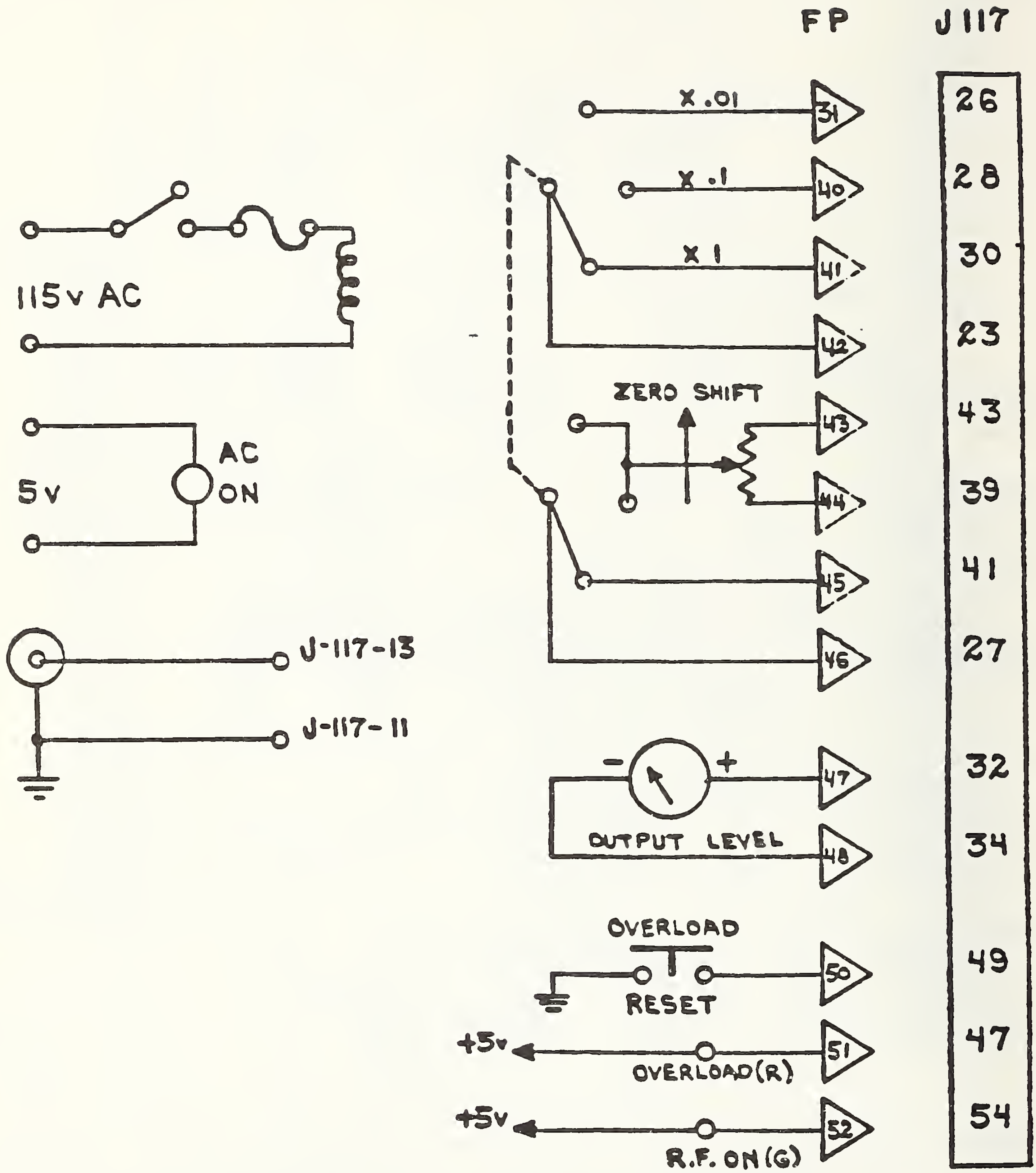
117 OUTPUT DISPLAY CARD
SCHEMATIC DIAGRAM

FIGURE 17



117 OUTPUT DISPLAY CARD PARTS PLACEMENT

FIGURE 18



117 OUTPUT DISPLAY CARD FRONT PANEL CONNECTIONS

FIGURE 19

2. INTERCONNECTION AND WIRING DIAGRAMS

The system interconnection cables include the IEEE 488 bus cables which connect the controller to the scanner, digital multimeter, and instrument coupler. In addition to the instrument bus interconnection cables, the equipment is coupled together by the following:

TABLE 6
SYSTEM CABLES--INSTRUMENTS TO SCANNER

	Cable #	Figure #	Source	Destination
1.	Cable 1	20	DC Power Supplies	Scanner 2
2.	Cable 1a	20	Scanner	DMM 1 Rear Panel Input Connector
3.	Cable 2	20	Type IV Power Meter	Scanner
4.	Cable 2a	20	Scanner	Rear Panel Input Connector
5.	Cable 3	21	Ambient Standard	External Terminal Bd. On Scanner 1
7.	Cable 4	21	Cryogenic Standard	External Terminal Bd. On Scanner 1
8..	Cable 5	21	External Terminal Board on Scanner	DMM Front Input Terminals
9.	Cable 6	22	6-Port Output	Scanner 2 Input
10	Cable 8	22	Scanner 2	DMM 2

The cables listed in Table 6 are those directly concerned with the transfer of measurement information from the various instruments to the digital multimeters which act as central processing points since they measure the cable outputs and send the measured results back to the controller on the IEEE 488 bus.

Commands from the controller are sent to the switch control modules via the instrument couplers. The switch control modules then operate the system switches by accessing them through the module to switch intercabling. Figures 23 through 50 detail the pin connections of the output jacks on the switch driver modules. Components numbered between 100 and 200 are associated with switch driver module 1 while those numbered between 200 and 300 are associated with switch driver number 2. An overview of all connections made to the switch driver module from the controller and within the switch driver module number 1 to the various switch driver cards is shown in Figure 22.

Figure 23 is a diagram of J104 which is the input cable from the instrument coupler to the switch driver module number 1.

Figure 24 is a diagram of J102 which is the output jack from the switch driver module to the system switches.

Figure 25 is a wiring list for J-102 and its associated cable.

Figure 26 is a diagram showing the inputs and outputs to J-110, the decoder edge connector.

Figures 27 through 33 are diagrams of the switch driver card edge connectors J-111, J-112, J-113, J-114, J-115, J-116, and J-117 contained in switch driver module 1.

Figure 34 is a listing of the connections to J-202.

Figure 35 details the switch driver module end of the transco switch driver control cable.

Figure 36 details the connections to the switch driver module from the computer.

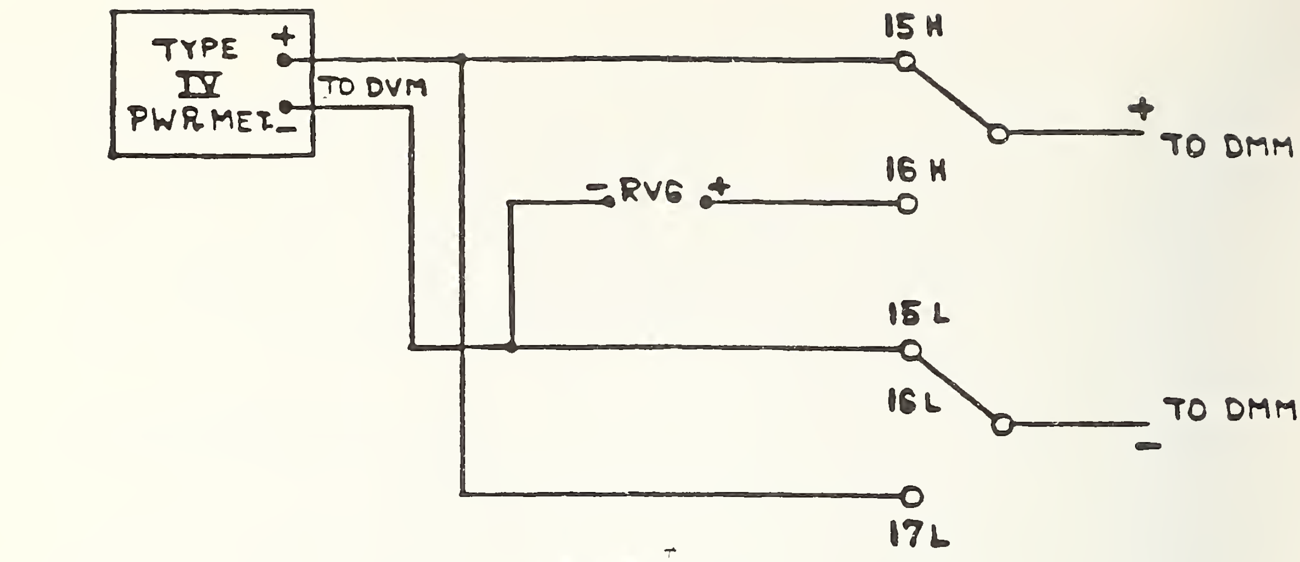
Figure 37 shows the outputs from and inputs to the decoder card in switch driver module 2 at J-210.

Figures 38-45 show the outputs and inputs to the switch driver cards in switch driver module 2 at J-211, J-212, J-213, J-214, J-215, J-216, J-217, J-218, J-219, and J-220. Outputs from these jacks control all radiometer switches associated with all bands from .350 GHz to 12.0 GHz.

Figures 46-48 show the details of the interconnection between the switch driver modules and the switches.

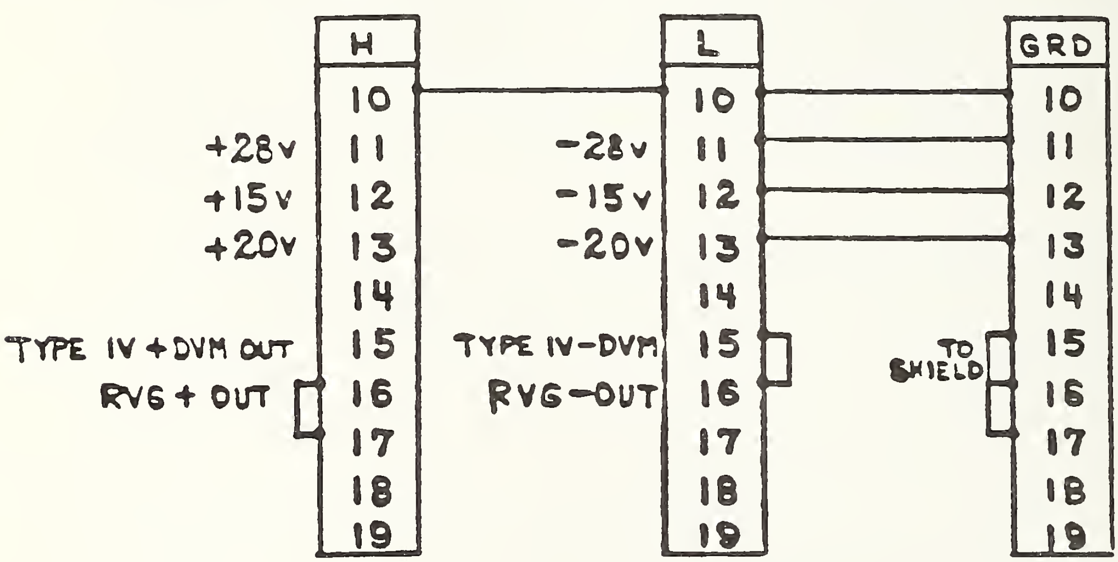
Figures 49 and 50 are diagrams showing the pinout of the outputs from both instrument couplers. One output connector is designated J-3a while the other is designated J-3b. They are the instrument coupler outputs to switch driver module 1 and switch driver module 2 respectively. The block on the right of each of the figures is a listing of control bits applied to the connector at the other end of the cable connected to J-3. This connector (designated P-102 and P-202) plugs into the rear of each switch driver module.

Figure 51 is a diagram showing the connections to the 6-port output amplifiers.



CABLE 2

SCANNER DECADE (LOW THERMAL) CHANNELS 10-19

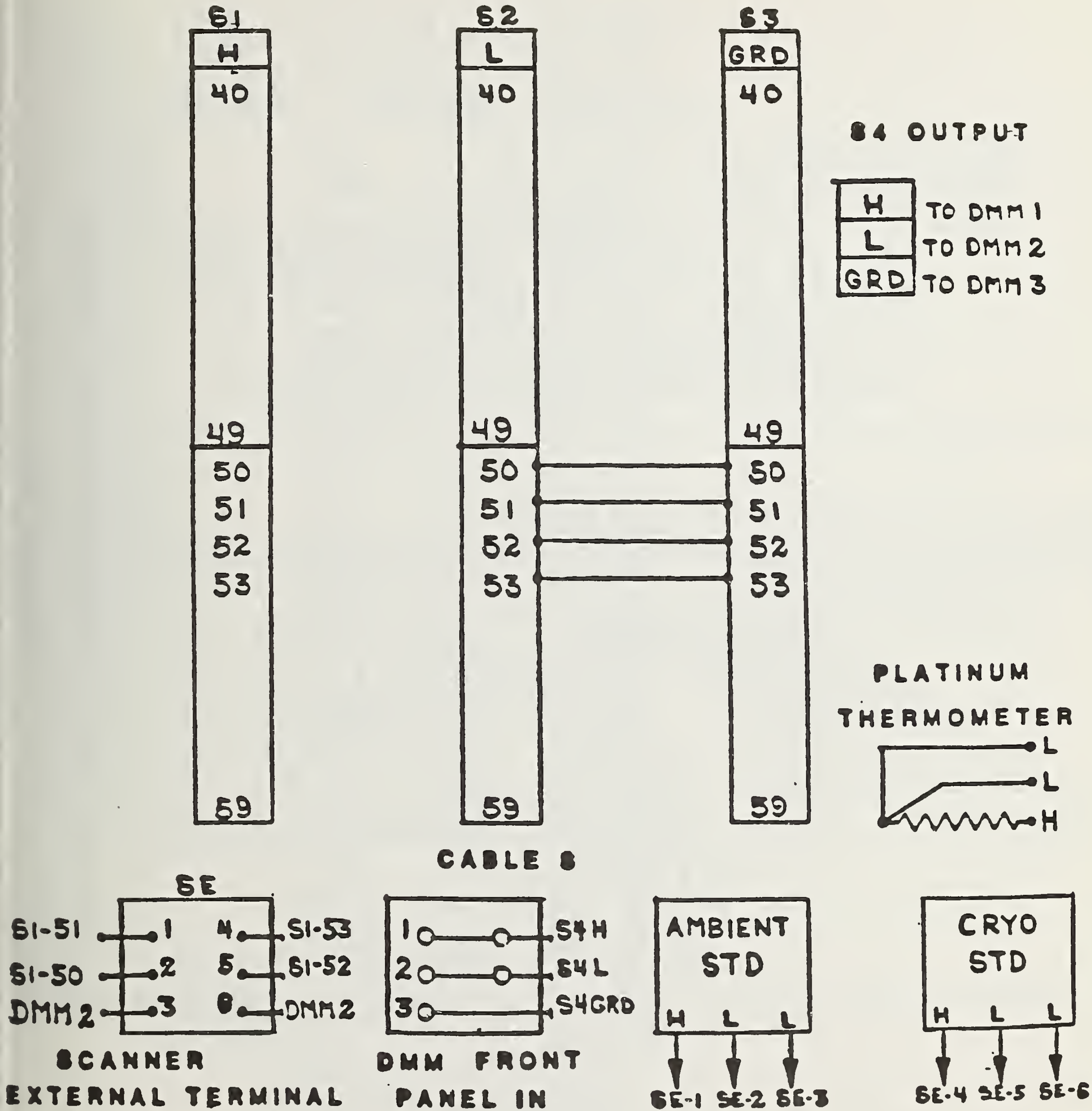


SCANNER CONNECTIONS CABLE 1 (10-13)

SCANNER CONNECTIONS CABLE 2 (15-17)

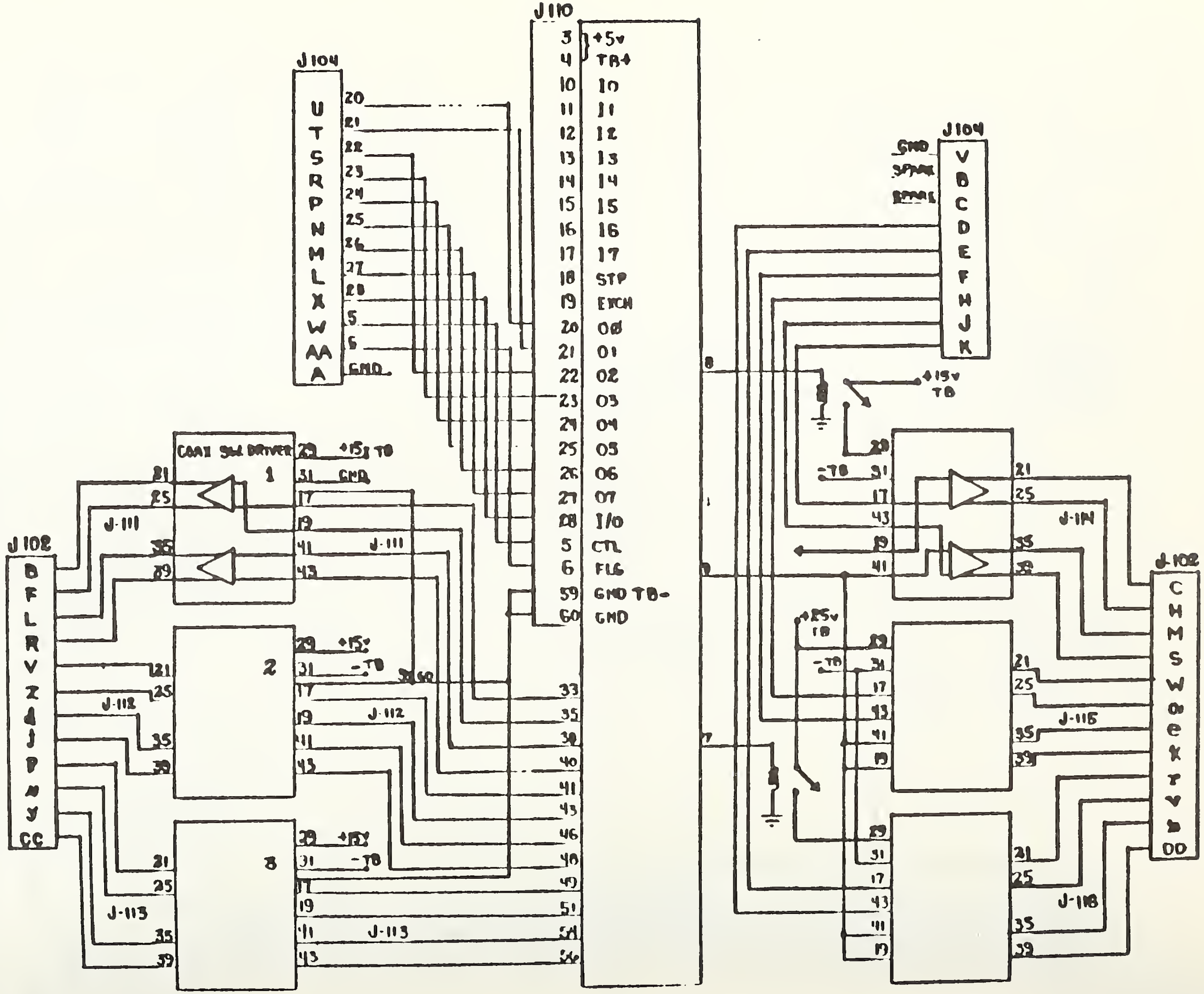
POWER METER WIRING DIAGRAM AND SCANNER CONNECTIONS

FIGURE 20



NOISE STANDARDS WIRING DIAGRAM AND SCANNER CONNECTIONS

FIGURE 21



SYSTEM CABLE INTERCONNECTION DIAGRAM

FIGURE 22

J-104

GND	V	
DO 15	B	SPARE
DO 14	C	SPARE
DO 13	D	J116-43
DO 12	E	J116-17
DO 11	F	J115-43
DO 10	H	J115-17
DO 9	J	J114-43
DO 8	K	J114-17
DO 7	L	J110-27
DO 6	M	J110-26
DO 5	N	J110-25
DO 4	P	J110-24
DO 3	R	J110-23
DO 2	S	J110-22
DO 1	T	J110-21
DO 0	U	J110-20
PCNTL	W	J110-5
I/O	X	J110-28
PFLG	AA	J110-6
GND	A	J110-60

PIN CONNECTIONS FOR J104, SWITCH DRIVER MODULE INPUT

FIGURE 23

J102

	A	d	SW5+ J112-35
J111-21 SW7+	B	e	J115-35
J114-21	C	f	
	D	h	
	E	j	SW5- J112-39
J111-25 SW7-	F	k	J115-39
J114-25	H	m	
	J	n	
	K	p	SW + J113-21
J111-35 SW8+	L	r	J116-21
J114-35	M	s	
	N	t	
	P	u	SW - J113-25
J111-39 SW8-	R	v	J116-25
J114-39	S	w	
	T	x	
	U	y	SPARE J113-35
J112-21 SW8+	V	z	J116-35
J115-21	W	AA	
	X	BB	
	Y	CC	SPARE J113-39
J112-25 SW6-	Z	DD	J116-39
J115-25	a	EE	
	b	FF	
	c	HH	

PIN CONNECTIONS FOR J102, SWITCH DRIVER MODULE OUTPUT

FIGURE 24

	A		
BRN	B	J111-21	PORT-0 SW7
BRN	C	J-114-21	RF ON +
	D		
	E		
RED	F	J-111-25	PORT-1 SW7
RED	H	J-114-25	RF ON -
	J		
	K		
OR	L	J-111-35	PORT-3 SW8
OR	M	J-114-35	REF +
	N		
	P		
YEL	R	J-111-39	PORT-2 SW8
YEL	S	J-114-39	REF -
	T		
	U		
GRN	V	J-112-21	TR-0-1 SW6
GRN	W	J-115-21	1dB +
	X		
	Y		
BLU	Z	J-112-25	TR2-3 SW6
BLU	a	J-115-25	1dB -
	b		
	c		

VIO	d	J-112-35	PORT-4 SW5
VIO	e	J-115-35	2dB +
	f		
	h		
GRY	j	J-112-39	PORT 0-3 SW5
GRY	k	J-115-39	2dB -
-	m		
	n		
WHT	p	J-113-21	60 MHz
WHT	r	J-116-21	4dB +
	s		
	t		
BLK	u	J-113-25	30 MHz
BLK	v	J-116-25	4 dB -
	w		
	x		
	y	J-113-35	
BRN	z	J-116-35	8 dB +
	AA		
	BB		
	CC	J-113-39	
RED	DD	J-116-39	8dB -
	EE		
	FF		
	HH		

COMPLETE WIRING DIAGRAM FOR J102

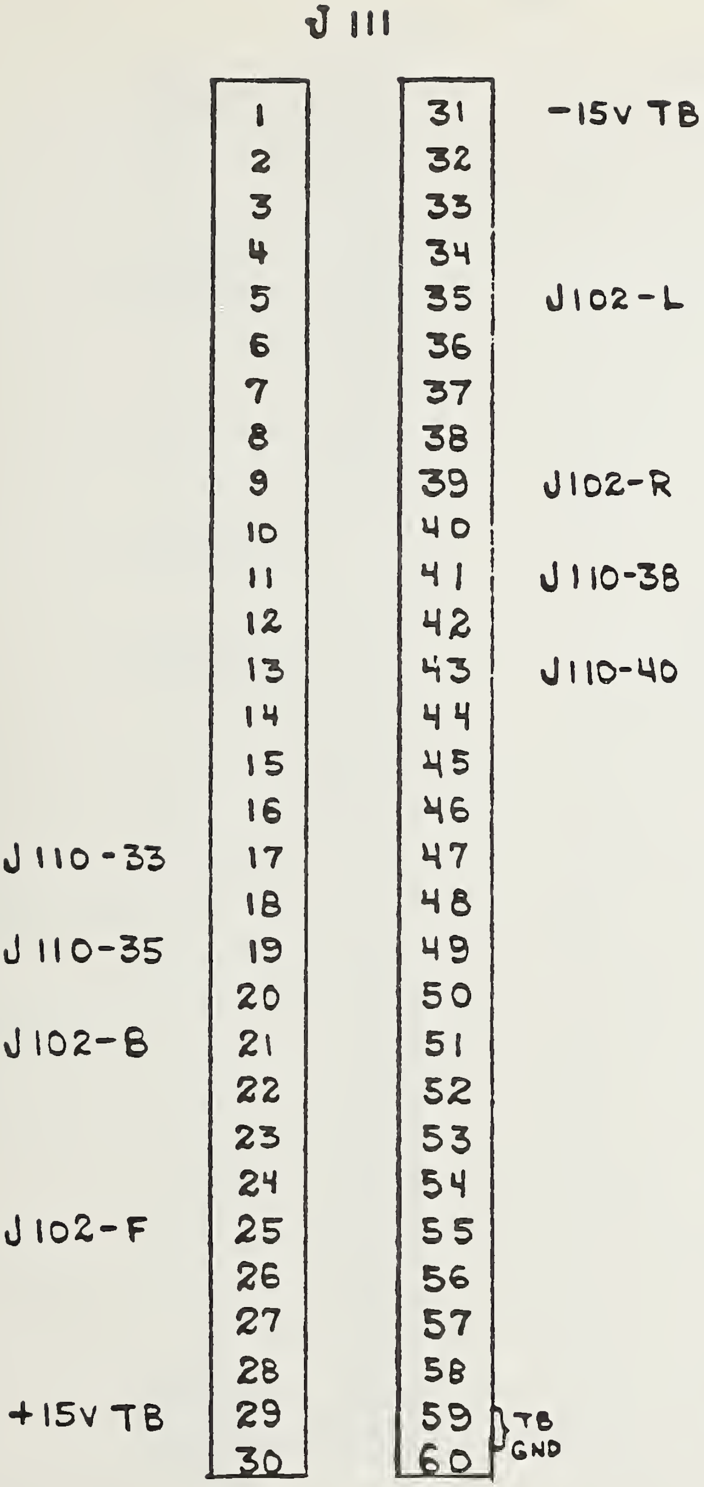
FIGURE 25

J110

	1	31	
	2	32	
+5V	3	33	J111-17
TB+	4	34	
J104 - W	5	35	J111-19
J104 - AA	6	36	
+25v SWITCH	7	37	
+15v SWITCH	8	38	J111-41
J114, 15, 16 - 41+19	9	39	
	10	40	J111-43
	11	41	J112-17
	12	42	
	13	43	J112-19
	14	44	
	15	45	
	16	46	J112-41
	17	47	
	18	48	J112-43
	19	49	J113-17
J104 - U	20	50	
J104 - T	21	51	J113-19
J104 - S	22	52	
J104 - R	23	53	
J104 - P	24	54	J113-41
J104 - N	25	55	
J104 - M	26	56	J113-43
J104 - L	27	57	
J104 - X	28	58	
	29	59	-5V GND
	30	60	TB-

J110 DECODER INPUT AND OUTPUT CONNECTIONS

FIGURE 26



J111, SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

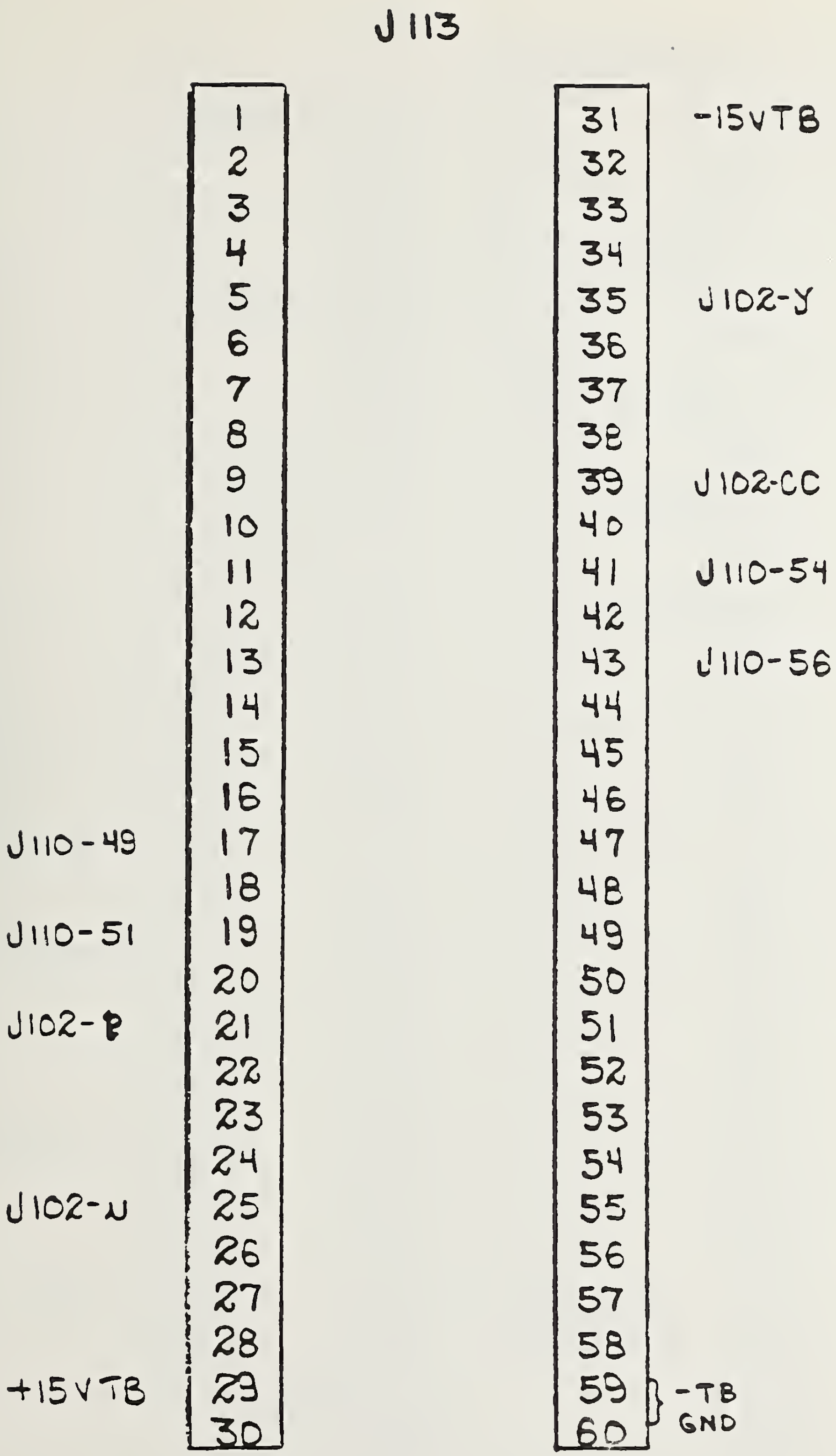
FIGURE 27

J 112

	1	31	-15 TB
	2	32	
	3	33	
	4	34	
	5	35	J 102-d
	6	36	
	7	37	
	8	38	
	9	39	J 102-j
	10	40	
	11	41	J 110-46
	12	42	
	13	43	J 110-48
	14	44	
	15	45	
	16	46	
J 110-41	17	47	
	18	48	
J 110-43	19	49	
	20	50	
J 102-V	21	51	
	22	52	
	23	53	
	24	54	
J 102-Z	25	55	
	26	56	
	27	57	
	28	58	
+15 TB	29	59	GND-TB
	30	60	GND-TB

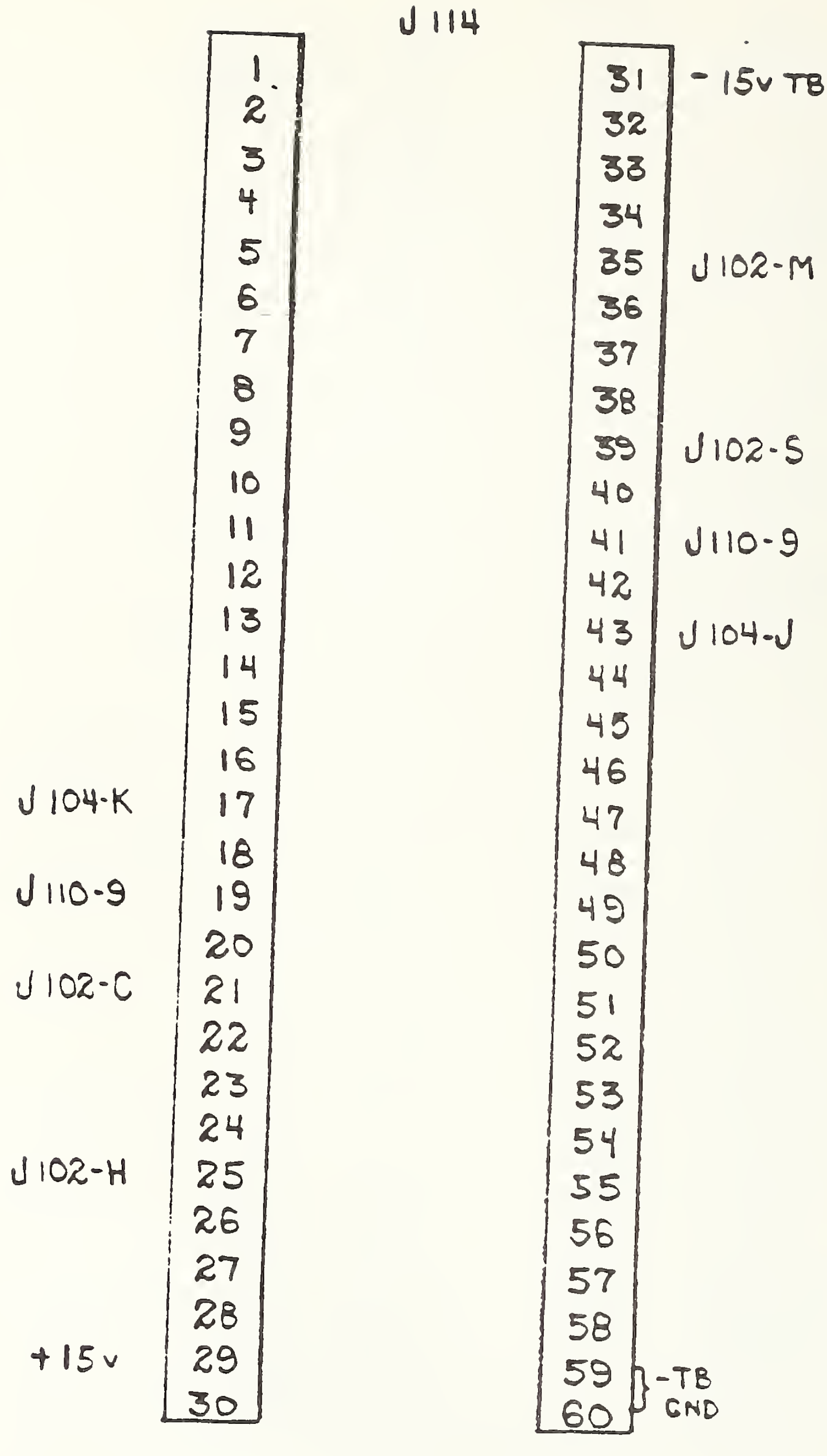
J112, SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 28



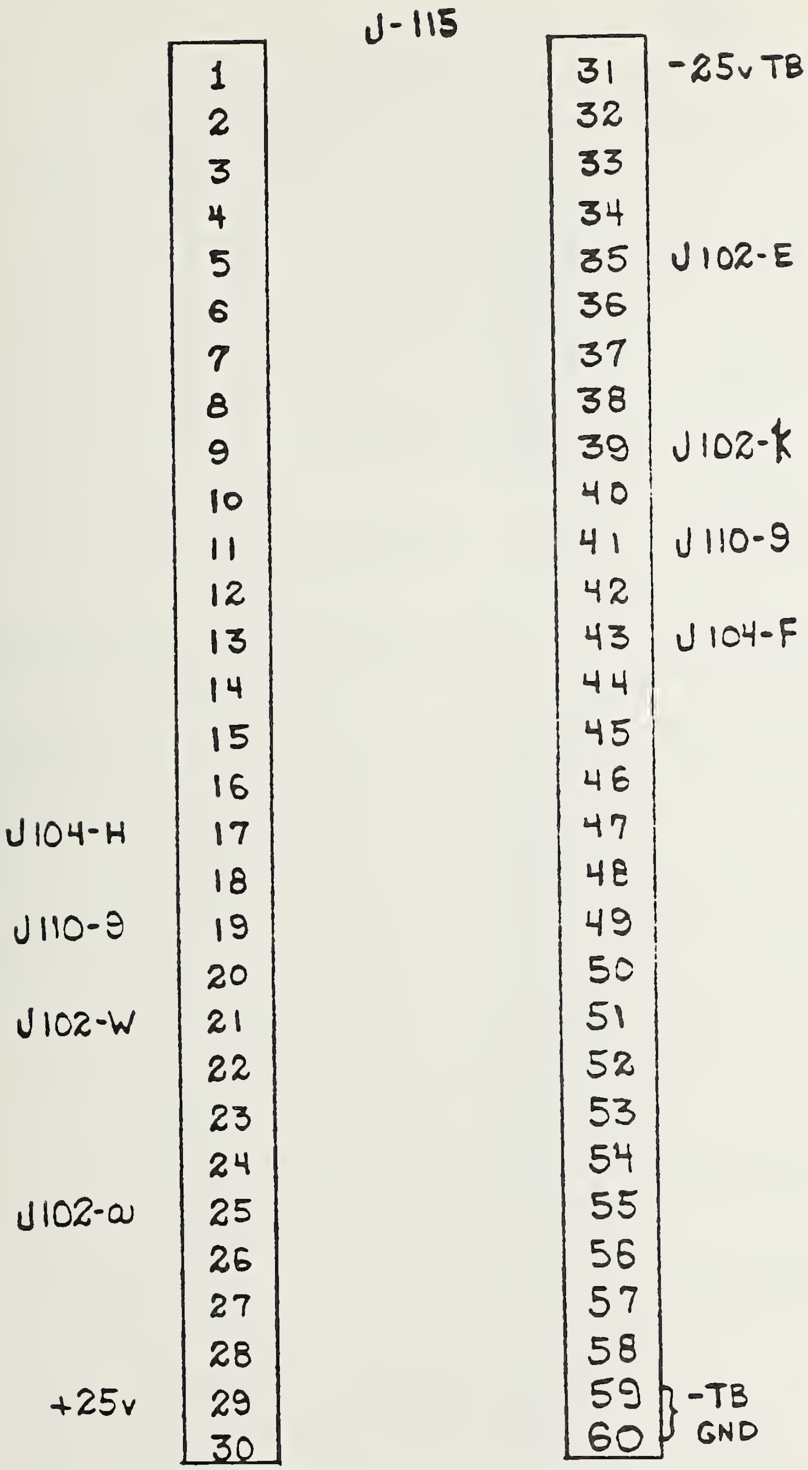
J113. SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 29



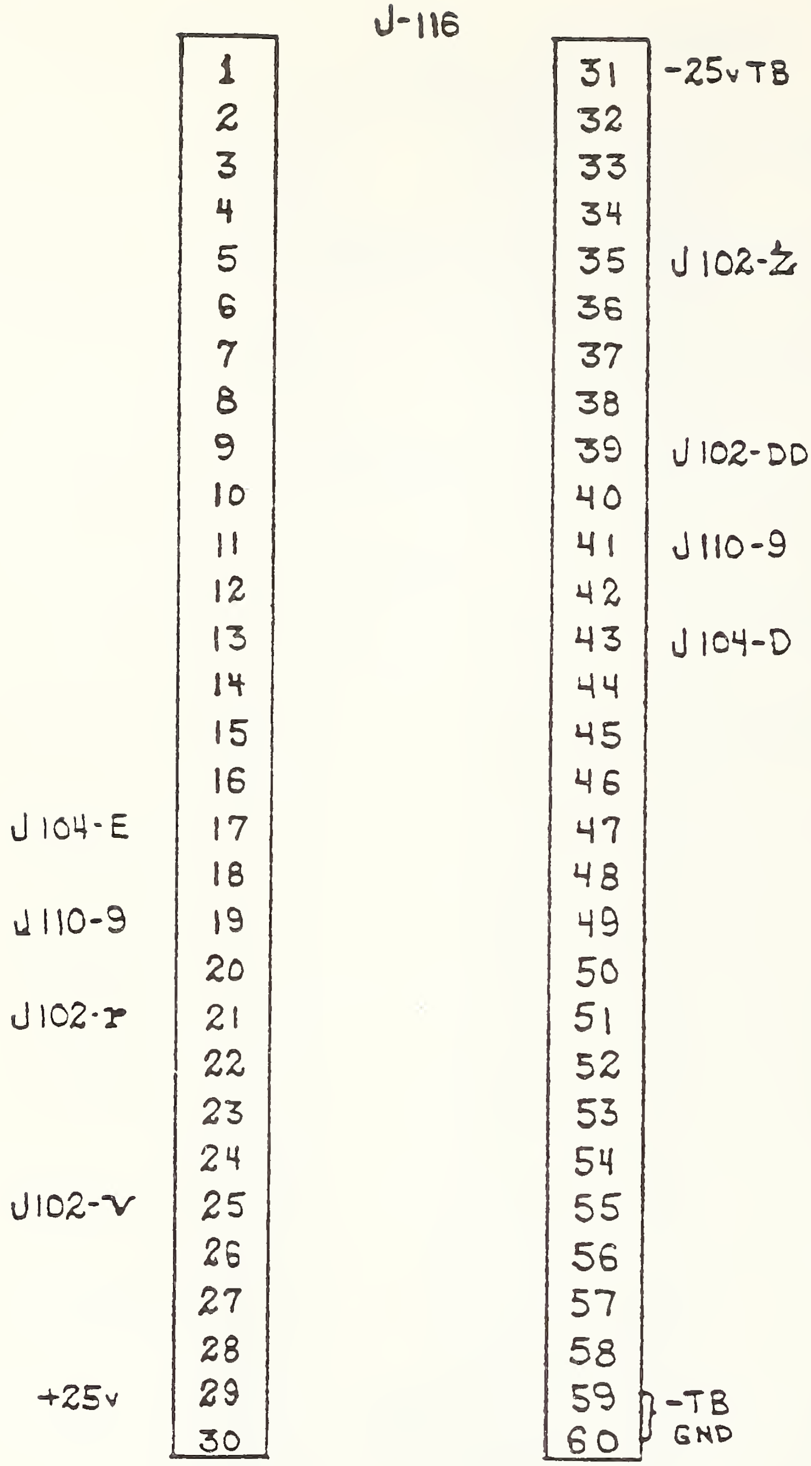
J114 SWITCH DRIVER CARD INPUT AND CONNECTIONS

FIGURE 30



J115 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 31



J116 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 32

J117

ANALOG GND	1	31	
" "	2	32	FP-47
	3	33	
	4	34	FP-48
	5	35	
	6	36	-15v
	7	37	
	8	38	+15v
	9	39	FP-44
	10	40	
SHIELD XTAL DET.	11	41	FP-45
	12	42	
XTAL DET.	13	43	FP-43
	14	44	
	15	45	
	16	46	
	17	47	FP-51 LED R
	18	48	
	19	49	FP-50 RESET
	20	50	
	21	51	
	22	52	J-114-19
FP-42	23	53	
	24	54	LED-GRN FP-52
	25	55	
FP-31	26	56	
FP-46	27	57	+5v
FP-40	28	58	+5v
	29	59	GND
FP-41	30	60	"

J117 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 33

J202

J212-6	A	OR
J211-21	B	BRN
	C	
J214-25	D	
J212-15	E	YEL
J211-25	F	RED
	H	
J214-21	J	
J212-7	K	BLU
J211-35	L	OR
	M	
	N	
J212-9	P	GRN
J211-39	R	YEL
	S	
	T	
J213-21	U	VIO
J211-6	V	GRN
	W	
	X	
J213-25	Y	GRY
J211-15	Z	BLU
	a	
	b	
J213-35	c	BLK

VIO	d	J211-7
	e	
	f	
WH	h	J213-39
GRY	j	J211-9
	k	
	m	
	n	
WH	p	J212-21
	r	
	s	
GRN	t	J213-6
BLK	u	J212-25
	v	
	w	
BLU	x	J213-15
BRN	y	J212-35
	z	
BRN	AA	J214-15
VIO	BB	J213-7
RED	CC	J212-39
	DD	
	EE	
GRY	FF	J213-9
RED	HH	J214-6

J202 SWITCH DRIVER TO SWITCH CABLE CONNECTIONS

FIGURE 34

J203

	J219-33	A	RED		d		
	J217-25	B	BLU	OR	e	JS26D-H	YEL
	J220-33	C	RED	OR	f	JS26B-H	BLU
	J218-33	D	RED	YEL	h	JS26C-J	VIO
	J219-31	E	GRN		j		
	J217-27	F	OR	YEL	k	JS26D-J	GREY
	J220-31	H	GRN	YEL	m	JS26B-J	RED
	J218-31	J	GRN	BLK	n	JS26C-K	BLK
	J219-19	K	WH		p		
	J217-31	L	GRN	BLK	r	JS26D-K	BRN
	J220-19	M	WH	BLK	s	JS26B-K	RED
	J218-19	N	WH	WH	t	JS26C-L	OR
	J219-21	P	GRN		u		
BRN	JS26A-K	R	BLK	WH	v	JS26D-L	YEL
	J220-21	S	GRN	WH	w	JS26B-L	GRN
	J218-21	T	GRN	BRN	x	JS26C-M	BLU
	J219-27	U	OR		y		
WH	JS26A-L	V	WH	BRN	z	JS26D-M	VIO
	J220-27	W	OR	BRN	AA	JS26B-M	GREY
	J218-27	X	OR	RED	BB	JS26C-N	WH
	J219-25	Y	BLU		CC		
OR	JS26A-M	Z	BRN	RED	DD	JS26D-N	BLK
	J220-25	&	BLU	RED	EE	JS26B-N	VIO
	J218-25	b	BLU		FF	+28 VOLTS	
GRN	JS26C-H	c	OR		HH	28V GND	

SWITCH DRIVER TO TRANSCO SWITCHES

S26A S26B S26C S26D

FIGURE 35

J204

	GND	A	BLK
	J212-46	B	RED
	J212-11	C	OR
J218-19-20,-49	J213-46	D	YEL
J218-19-20,-47	J213-11	E	GRN
J218-19-20,-11	J214-11	F	BLU
J218-19-20,-7	J217-45	H	VIO
J218-19-20,-45	J217-47	J	GRY
J218-19-20,-39	J217-49	K	BLK
	J210-27	L	WH
	J210-26	M	RED
	J210-25	N	OR
	J210-24	P	YEL
	J210-23	R	GRN
	J210-22	S	BLU
	J210-21	T	VIO
	J210-20	U	GRY
	GND	V	BLK
	J210-5	W	WH
	J210-28	X	OR
		Y	
		Z	
	J213-17	a	GRN
	J213-43	b	VIO
	J214-17	c	

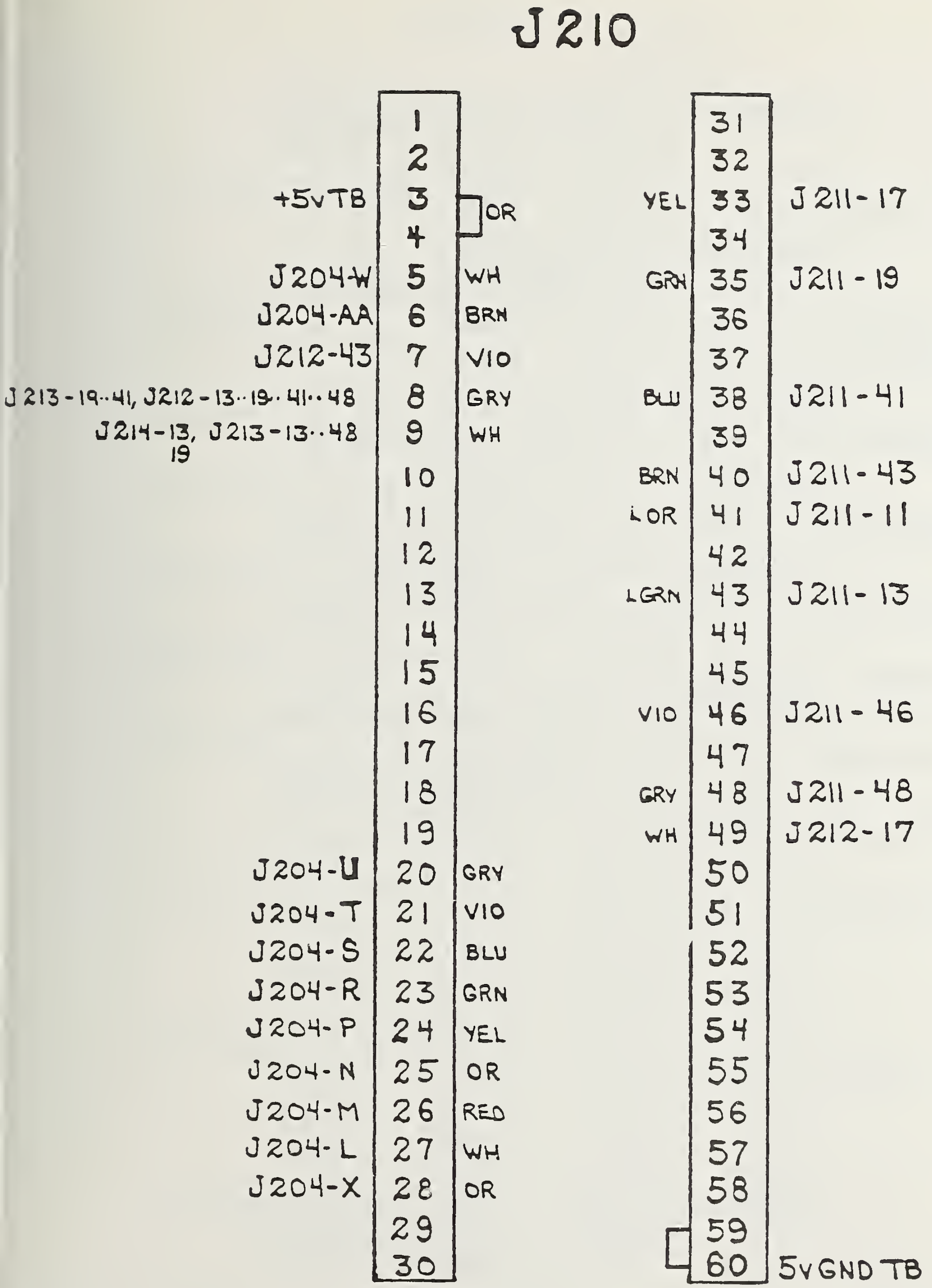
	d	
	e	
	f	
	h	
	j	
	k	
	m	
	n	
	p	
	r	
	s	
	t	
	u	
	v	
	w	
	x	
	y	
	z	
BRN	AA	J210-6
	BB	
	CC	
	DD	
	EE	
	FF	
	HH	

OUTPUT BIT #	PIN
0	U
1	T
2	S
3	R
4	P
5	N
6	M
7	L
8	K
9	J
10	H
11	F
12	E
13	D
14	C
15	B
16	a
17	b
18	c
19	d

PCNTL - W
I/O - X
PFLG - AA

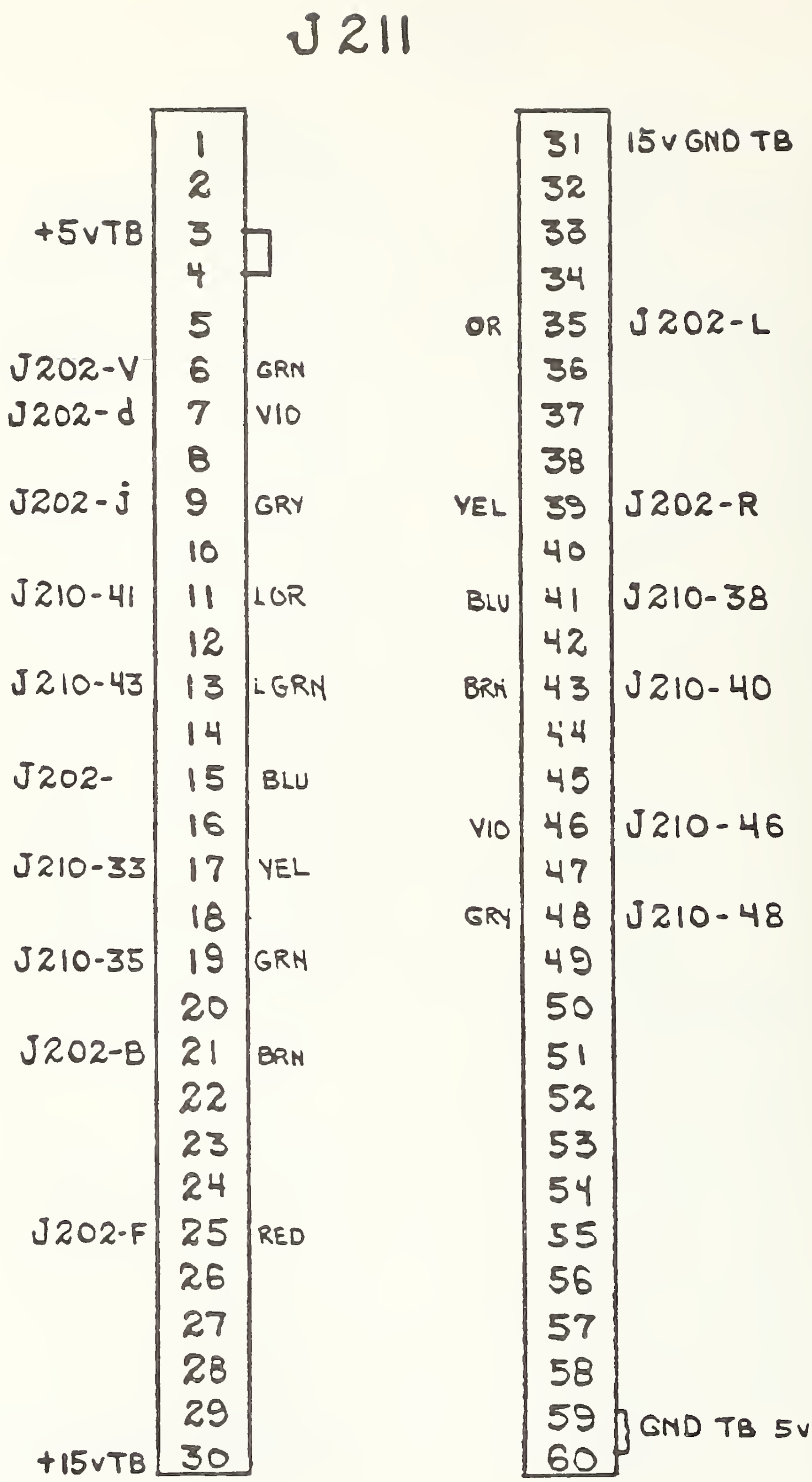
COMPUTER TO SWITCH DRIVER CONNECTIONS

FIGURE 36



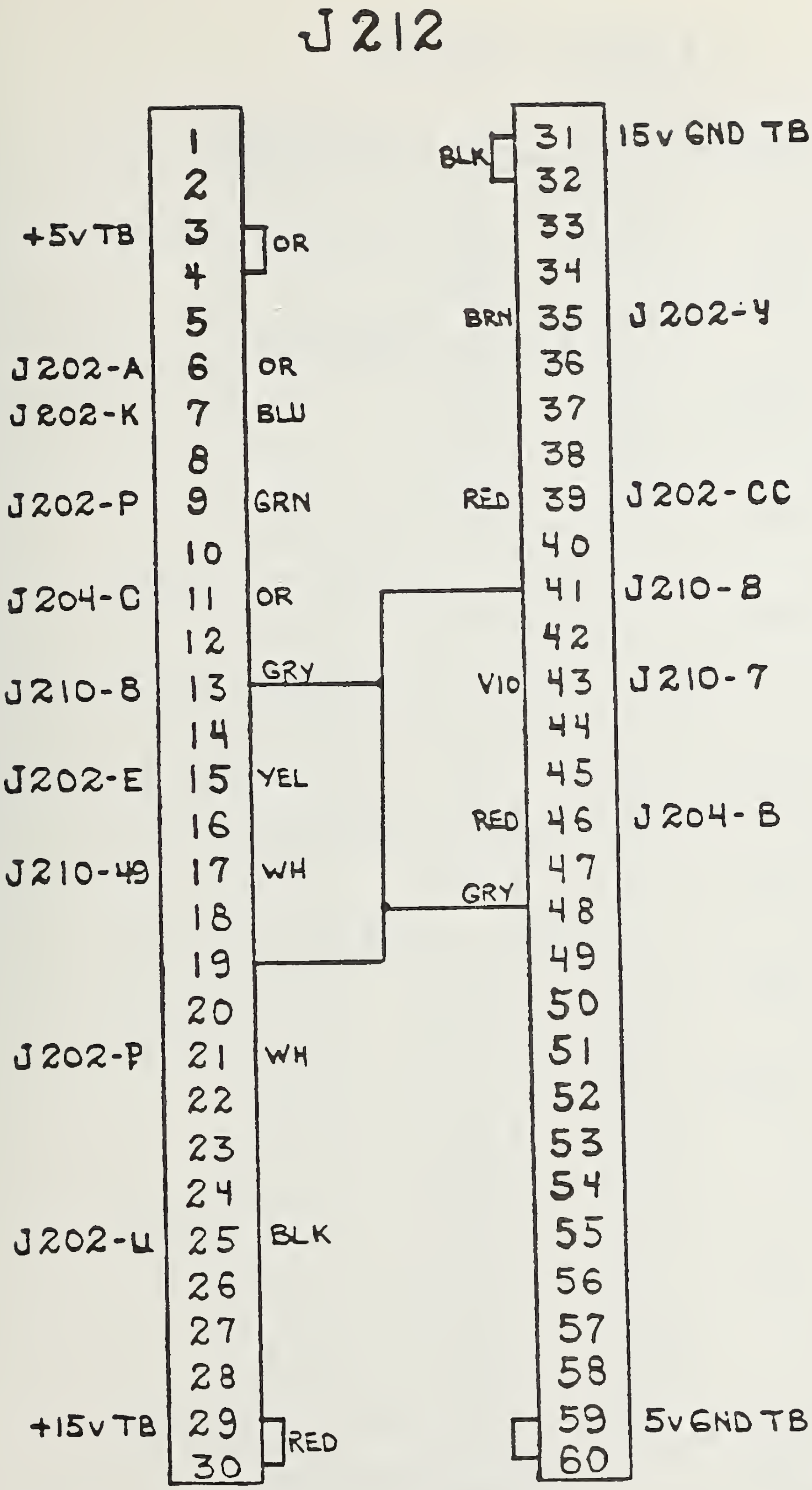
J210 DECODER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 37



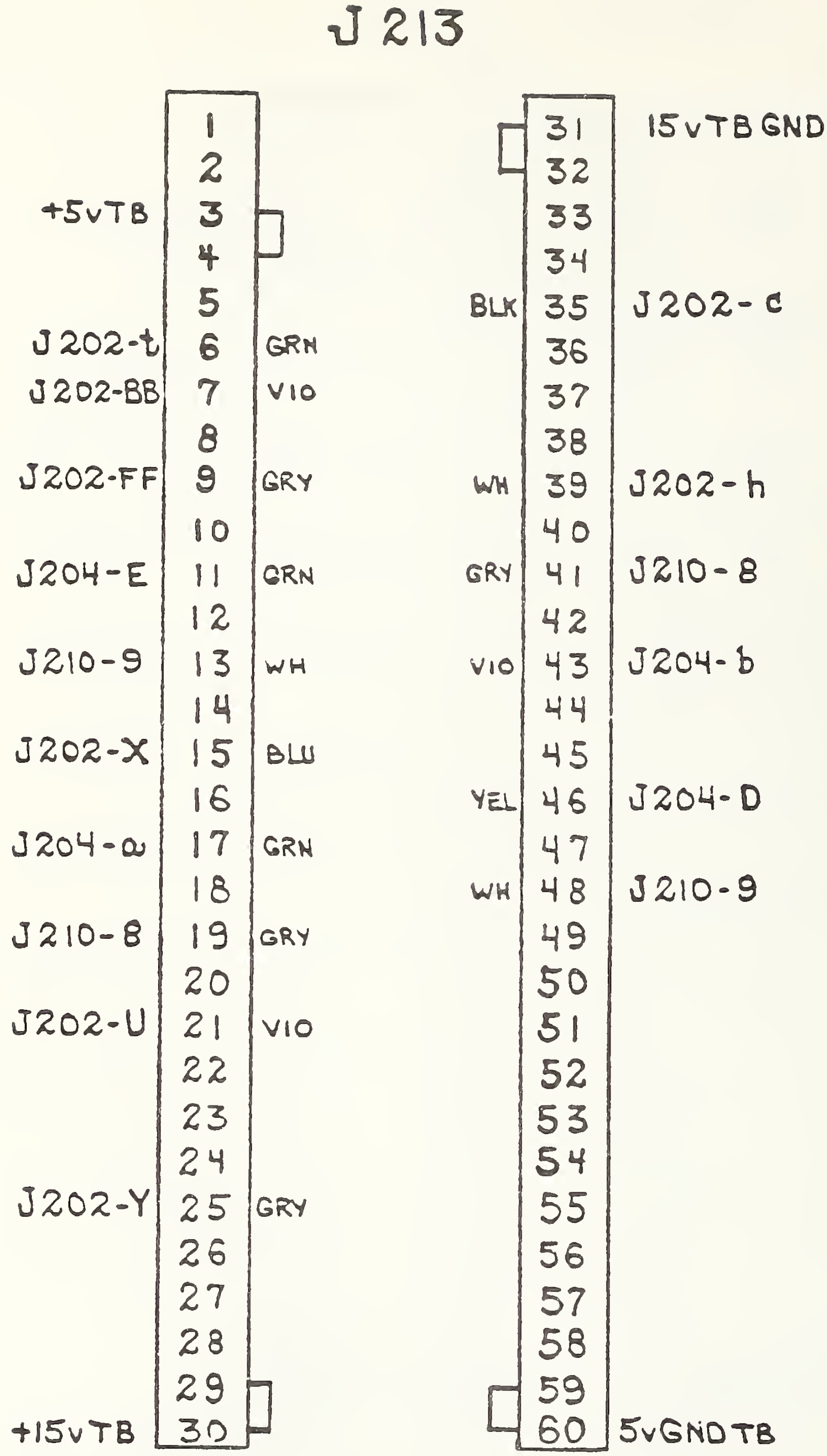
J211 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 38



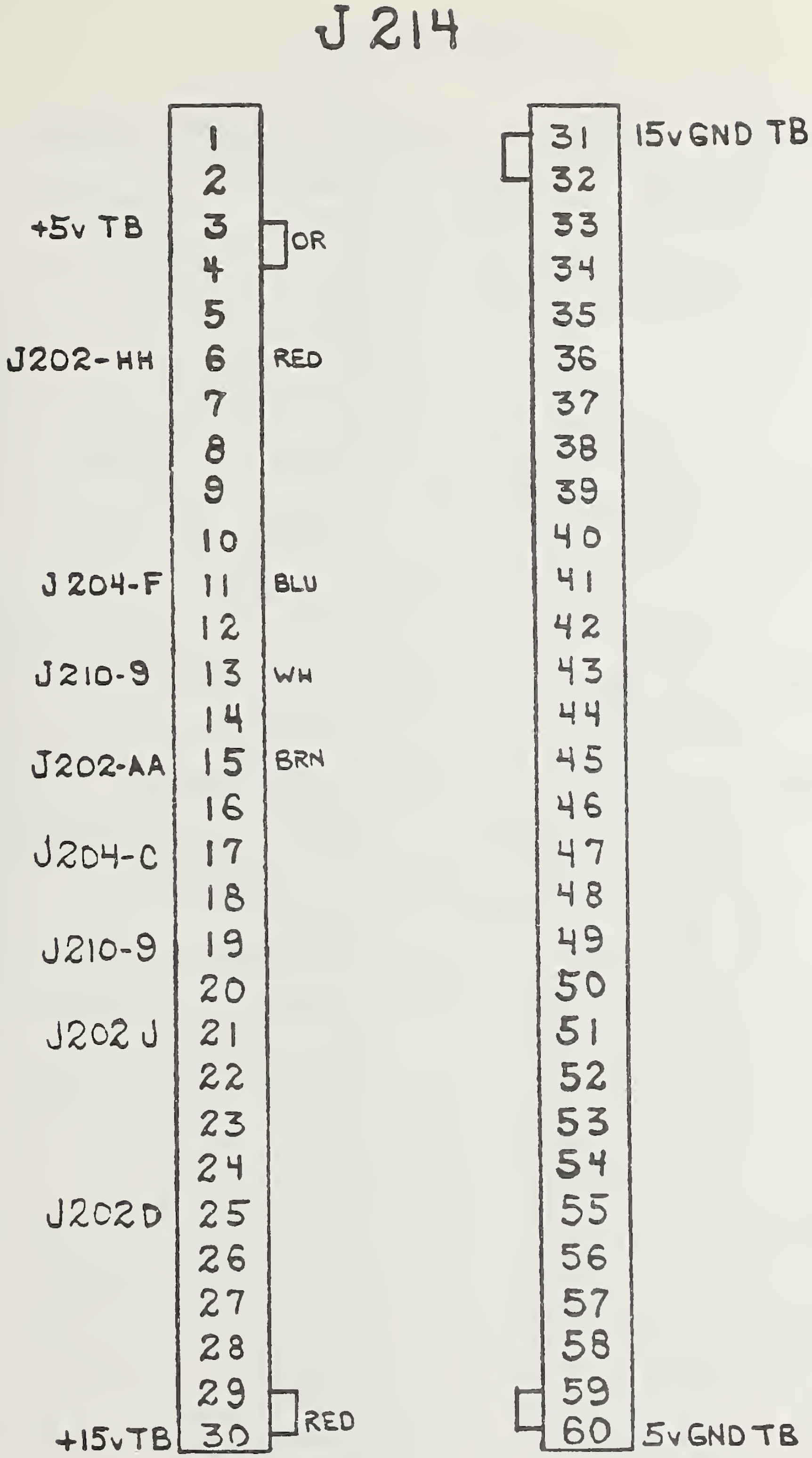
J212 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 39



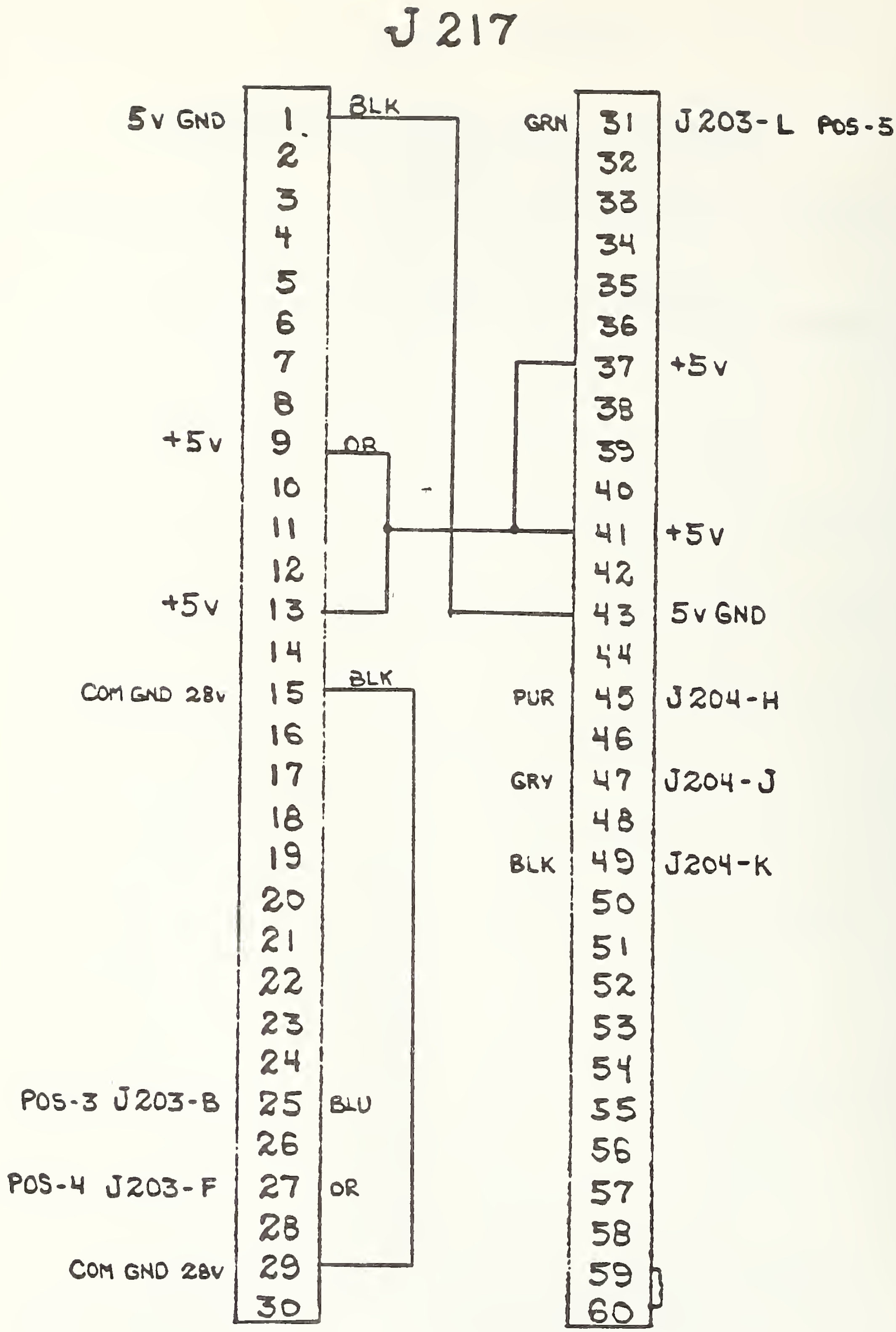
J2 13 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 40



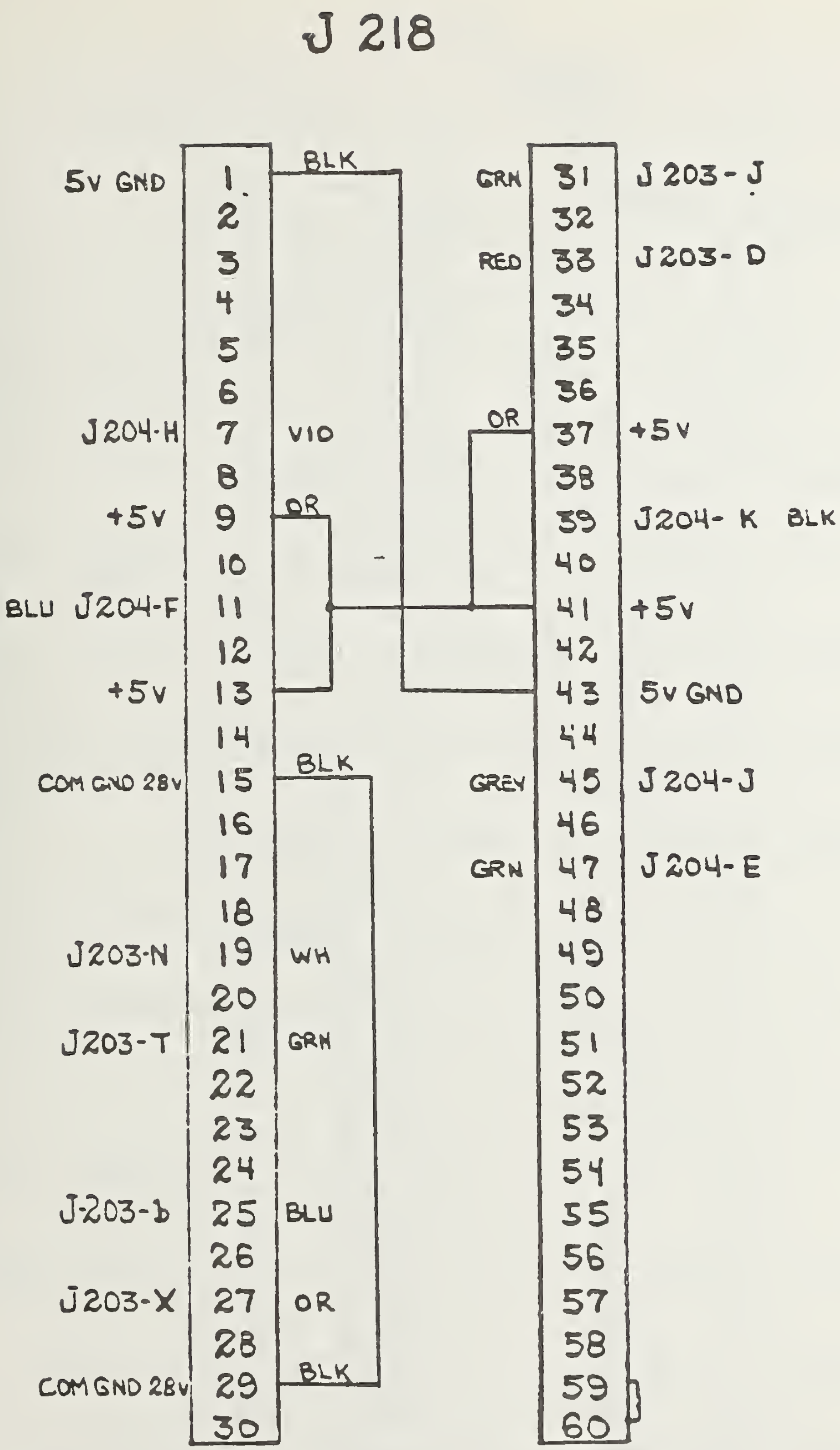
J214 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 41



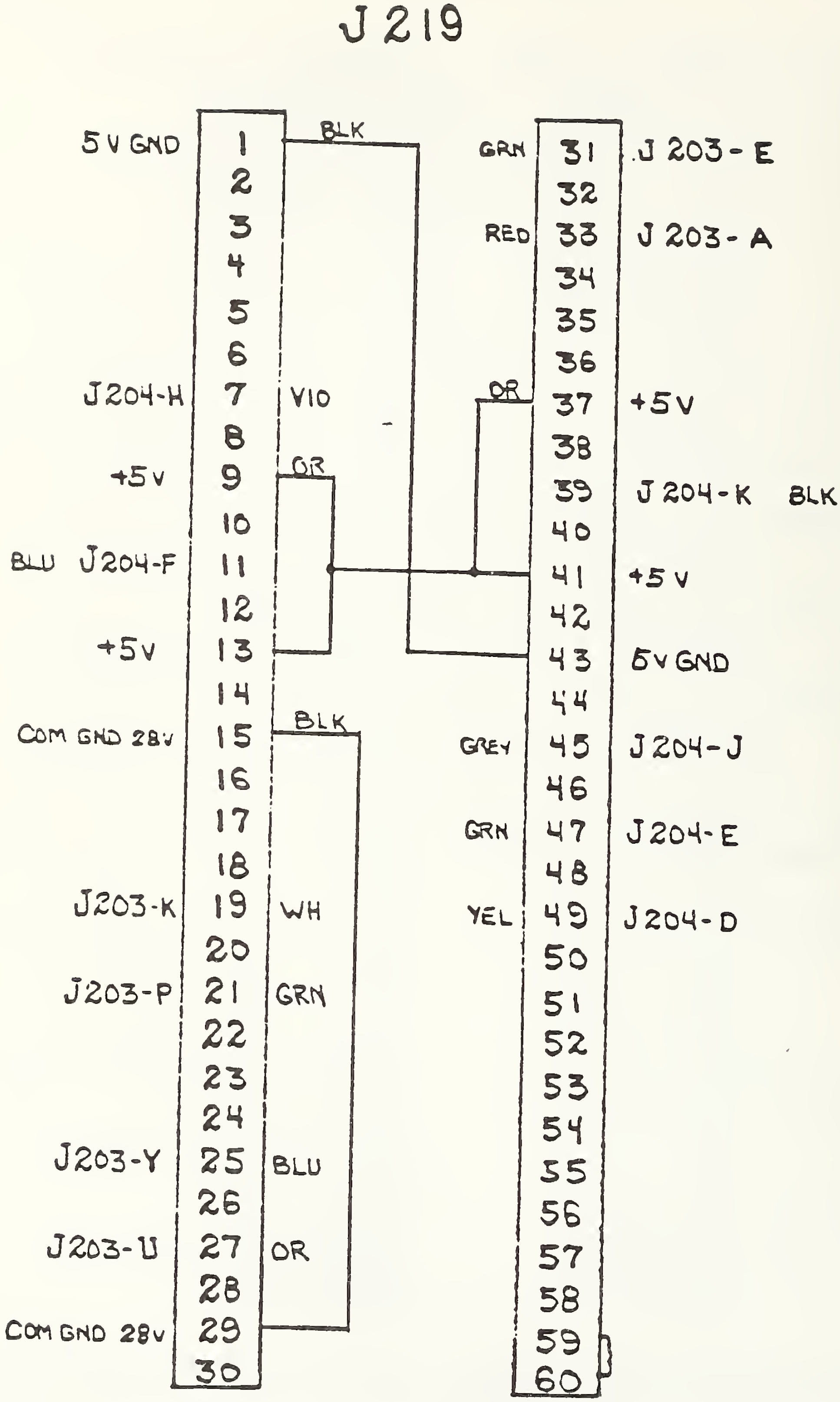
J217 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 42



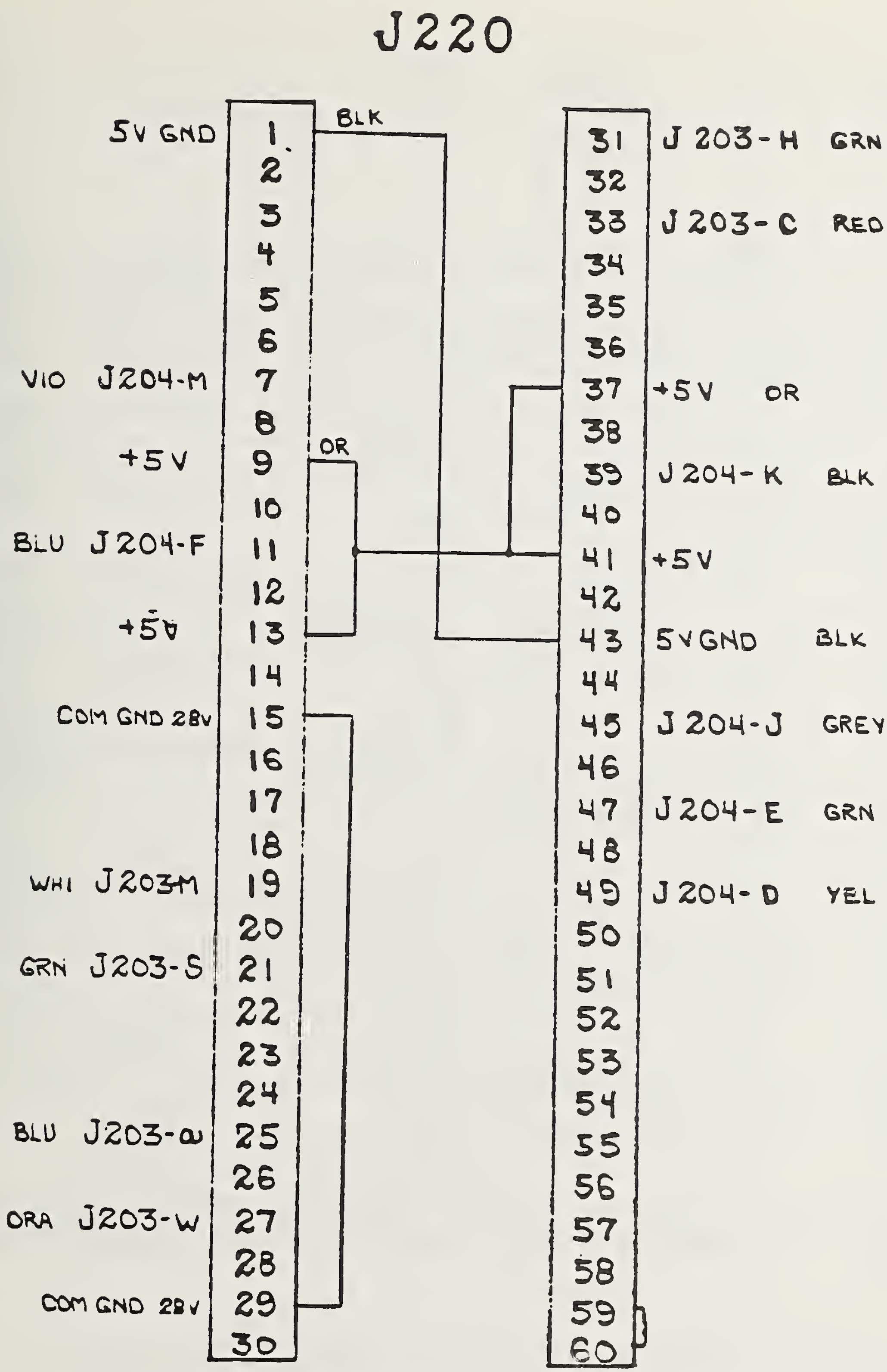
J218 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 43



J219 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 44



J220 SWITCH DRIVER CARD INPUT AND OUTPUT CONNECTIONS

FIGURE 45

ORIGIN		J202	SIG NAME	ORIGIN		J202	SIG NAME
J212-6	OR	A	+SW 15A+15B	J211-7	VIO	d	PORT 4 SW22
J211-21	BRN	B	PORT 0 SW24			e	
		C				f	
J214-25		D	-SW9A+9B	J213-39	WH	h	-SW18A+18B
J212-15	YEL	E	-SW15A+15B	J211-9	GRY	j	PORTS 0-3 SW22
J211-25	RED	F	PORT 1 SW24			k	
		H				m	
J214-21		J	+SW9A+9B			n	
J212-7	BLU	K	+SW16A+16B	J212-21	WH	p	+SW13A+13B
J211-35	OR	L	PORT 3 SW25			r	
		M				s	
		N		J213-6	GRN	t	+SW20
J212-9	GRN	P	-SW16A+16B	J212-25	BLK	u	-SW13A+13B
J211-39	YEL	R	PORT 2 SW25			v	
		S				w	
		T		J213-15	BLU	x	-SW20
J213-21	VIO	U	+SW17A+17B	J212-35	BRN	y	+SW14A+14B
J211-6	GRN	V	TR 0-1 SW23			z	
		W		J214-15	BRN	AA	-SW19
		X		J213-7	VIO	BB	+SW21
J213-25	GRY	Y	-SW17A+17B	J212-39	RED	CC	-SW14A+14B
J211-15	BLU	Z	TR 2-3 SW23			DD	
		a				EE	
		b		J213-9	GRY	FF	-SW21
J213-35	BLK	c	+SW18A+18B	J214-6	RED	HH	+SW19

CONNECTIONS AND CONTROL FUNCTIONS J202

FIGURE 46

CARD	FUNCTION	INPUT	SOURCE	OUTPUT	DESTINATION
211	PORT 0 SW24	17	J210-33	21	J202 B
211	PORT 1 SW24	19	J210-35	25	J202 F
211	PORT 2 SW25	41	J210-38	35	J202 L
211	PORT 3 SW25	43	J210-40	39	J202 R
211	BRANCH 0-1 SW23	11	J210-41	15	J202 Z
211	BRANCH 2-3 SW23	13	J210-43	6	J202 V
211	PORT 0-3 SW22	46	J210-46	9	J202 j
211	PORT 4 SW22	48	J210-48	7	J202 d
212	SW15a + 15b +	11	J204-C	15	J202 E
	−	-13	J210-8	6	J202 A
212	SW16a+16b +	46	J204-B	9	J202 P
	−	48	J210-8	7	J202 K
212	SW13a+13b +	17	J210-49	25	J202 u
	−	19	J210-8	21	J202 P
212	SW14a+14b +	43	J210-7	39	J202 CC
	−	41	J210-8	35	J202 y
213	SW17a+17b +	17	J204-a	25	J202-Y
	−	19	J210-8	21	J202-u
213	SW18a+18b +	41	J210-8	35	J202-c
	−	43	J204-b	39	J202-h
213	SW 20 +	13	J210-9	6	J202-t
	−	11	J204-E	15	J202-x
213	SW 21 +	48	J210-9	7	J202-BB
	−	46	J204-D	9	J202-FF
214	SW 19 +	13	J210-9	6	J202-HH
	−	11	J204-F	15	J202-AA

SWITCH CONTROL FUNCTIONS AND CONNECTIONS

FIGURE 47

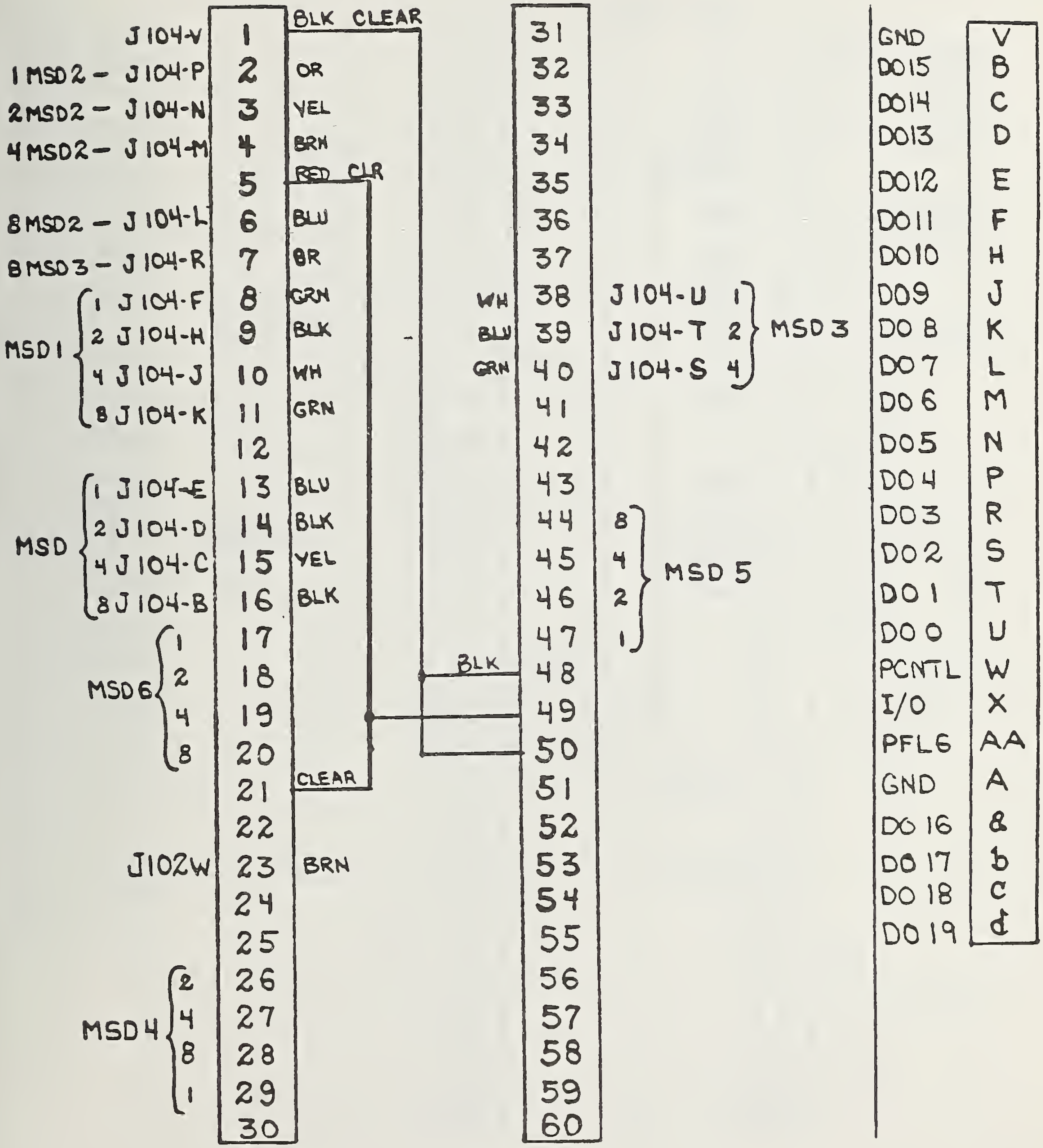
SOURCE		J203	SIG NAME	SOURCE		J203	
J219-33	RED	A	JS26C-F			d	
J217-25	BLU	B	JS26A-C	JS26D-H	OR	e	JS26D-1
J220-33	RED	C	JS26D-F	JS26B-H	OR	f	JS26B-1
J218-33	RED	D	JS26B-F	JS26C-J	YEL	h	JS26C-2
J219-31	GRN	E	JS26C-E			j	
J217-27	OR	F	JS26A-D	JS26D-J	YEL	k	JS26D-2
J220-31	GRN	H	JS26D-E	JS26B-J	YEL	m	JS26B-2
J218-31	GRN	J	JS26B-E	JS26C-K	BLK	n	JS26C-3
J219-19	WH	K	JS26C-A			p	
J217-31	GRN	L	JS26A-E	JS26D-K	BLK	r	JS26D-3
J220-19	WH	M	JS26D-A	JS26B-K	BLK	s	JS26B-3
J218-19	WH	N	JS26B-A	JS26C-L	WH	t	JS26C-4
J219-21	GRN	P	JS26C-B			u	
JS26A-K	BLK	R	JS26A-3	JS26D-L	WH	v	JS26D-4
J220-21	GRN	S	JS26D-B	JS26B-L	WH	w	JS26B-4
J218-21	GRN	T	JS26B-B	JS26C-M	BRN	x	JS26C-5
J219-27	OR	U	JS26C-D			y	
JS26A-L	WH	V	JS26A-4	JS26D-M	BRN	z	JS26D-5
J220-27	OR	W	JS26D-D	JS26B-M	BRN	AA	JS26B-5
J218-27	OR	X	JS26B-D	JS26C-N	RED	BB	JS26C-6
J219-25	BLU	Y	JS26C-C			CC	
JS26A-M	BRN	Z	JS26A-5	JS26D-N	RED	DD	JS26D-6
J220-25	BLU	a	JS26D-C	JS26B-N	RED	EE	JS26B-6
J218-25	BLU	b	JS26B-C	28V		FF	28V
JS26C-H	OR	c	JS26C-1	28V COM GND		HH	GND

SW POS	IND PIN			
1A	1H	350-500	3	6
2B	2J	500-1000	4	5
3C	3K	1000-2000	5	1
4D	4L	2000-4000		2
5E	5M	4000-8000		4
6F	6N	8000-12400		3

ROTARY SWITCH CONTROL FUNCTIONS AND CONNECTIONS

FIGURE 48

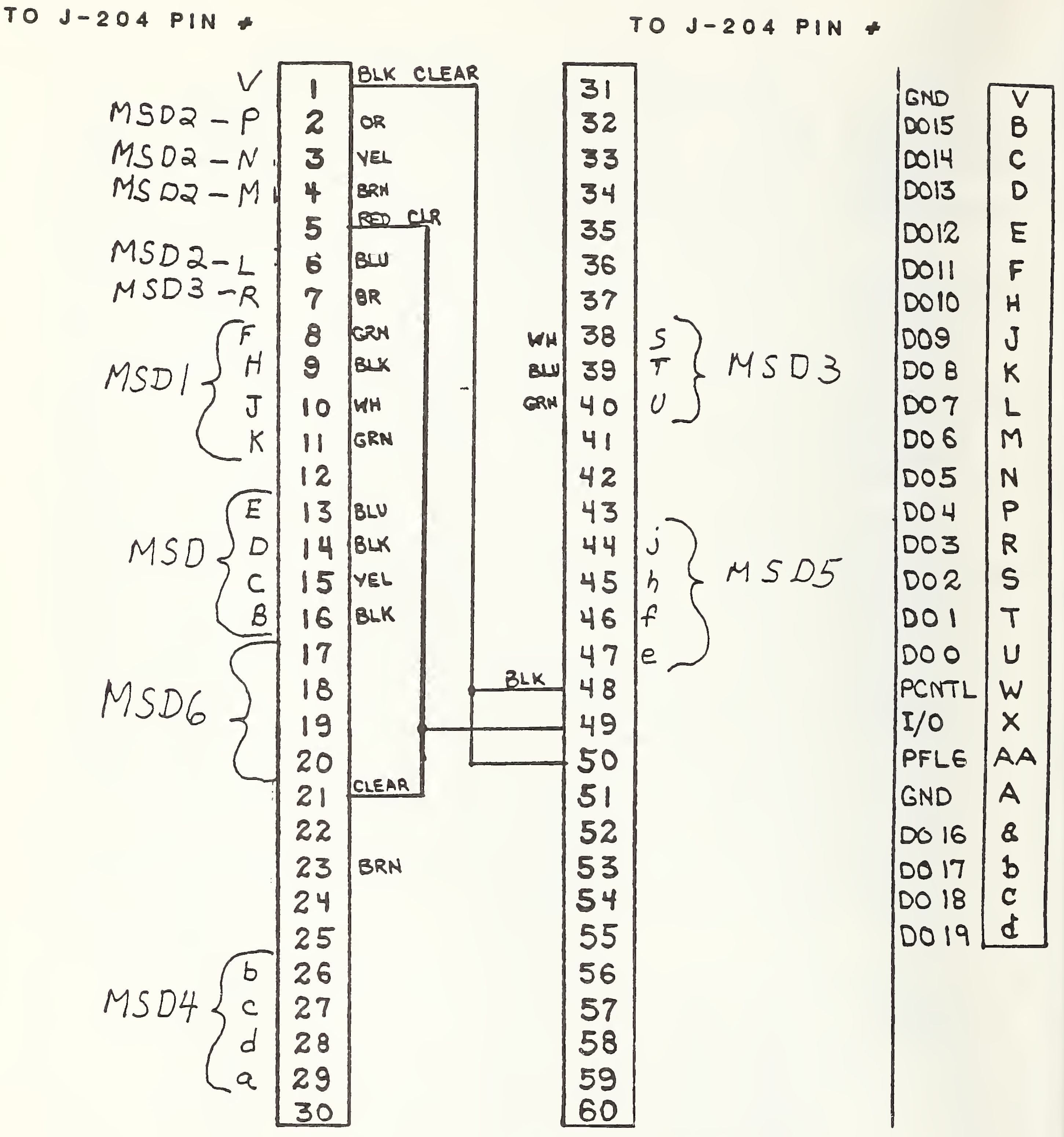
SWITCH DRIVER 1



INSTRUMENT COUPLER OUTPUT J3A

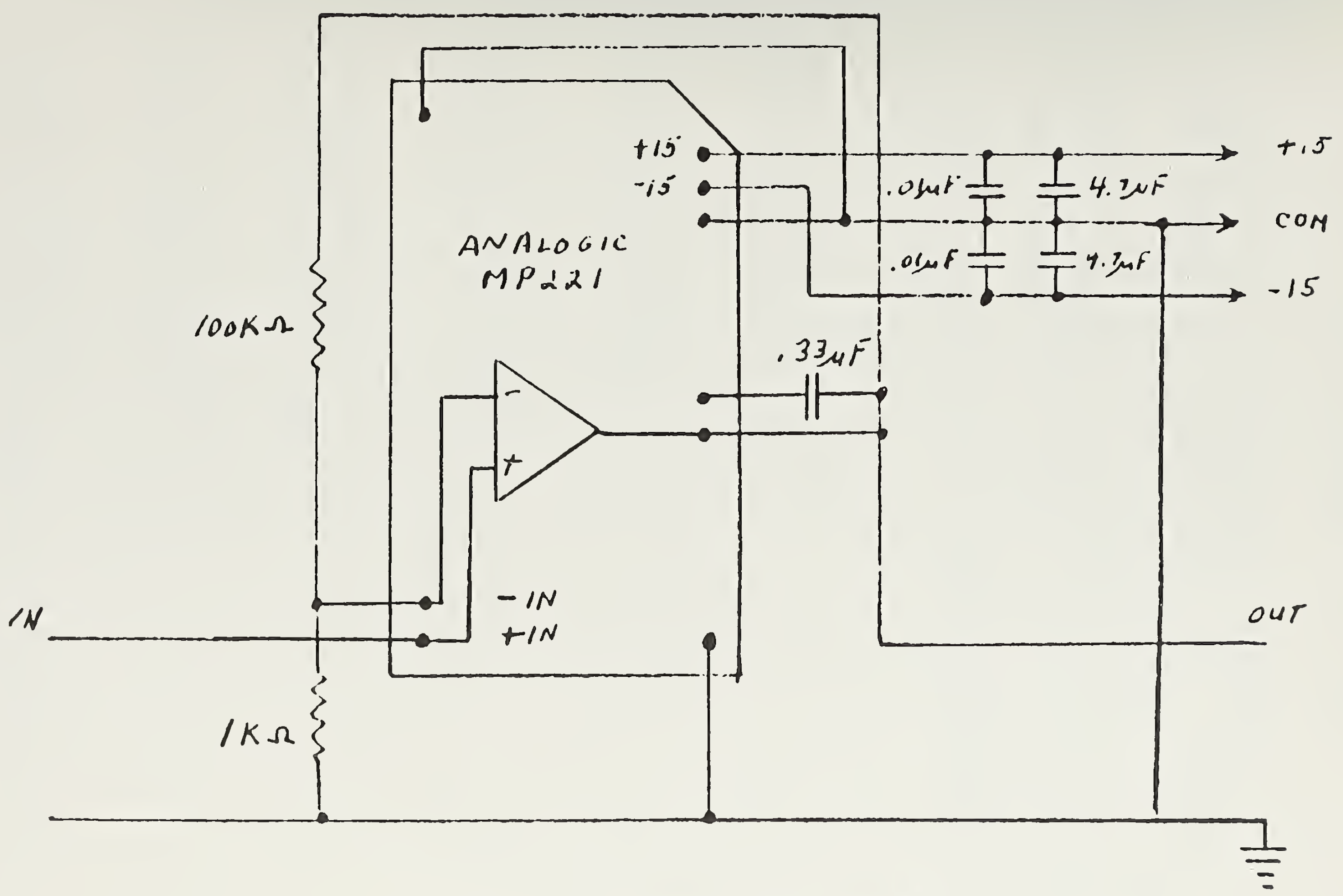
FIGURE 49

SWITCH DRIVER 2



INSTRUMENT COUPLER OUTPUT J3B

FIGURE 50



8-PORT OUTPUT AMPLIFIER

FIGURE 51

4. PARTS LISTS

Information relating to the parts lists for the digital voltmeter, scanner, instrument coupler, thermistor mount, power meter, and power supplies can be obtained from the instrument manual supplied by the manufacturer. The parts lists for NBS manufactured equipment will be found in TABLE 8. Manufacturers Codes used in these parts lists are tabulated in TABLE 7.

TABLE 7
MANUFACTURER'S CODE TABLE

3M
3M Company, Electronics Products Division
3M Center
St. Paul, Minnesota 55101

AB
Allen-Bradley Company
1201 S. Second Street
Milwaukee, Wisconsin 53204

ALCO
Alcoswitch Division of Alco Electronic Products, Inc.
P.O. Box 1348
Lawrence, Massachusetts 01842

AMPH
Amphenol Connector Division
Bunker-Ramo Corporation
Broadview, Illinois 60153

BRNS
Bourns, Incorporated, Trimpot Division
1200 Columbia Avenue
Riverside, California 92507

BUD
Bud Radio Incorporated
4605 East 355th Street
Willoushby, Ohio 44094

CORG
Corning Glass Works
Electronic Products Division
Corning, New York 14830

DATL
Datel Systems, Incorporated
1020 Turnpike Street
Canton, Massachusetts 02021

DIAL
Dialignt Corporation
Division of North American Phillips Corporation
Brooklyn , New York 11237

DUNC
Duncan Electric Company, Inc.
2865 Fairview Road
Lafayette, Indiana 47902

TABLE 7
MANUFACTURER'S CODE TABLE continued

GARY
Garry Manufacturing, Inc.
1010 Jersey Avenue
New Brunswick, New Jersey 08902

ITSL
Intersil, Incorporated
10900 North Tantau Avenue
Cupertino, California 95014

MODT
Modutec, Incorporated
18 Marshall Street
Norwalk, Connecticut 06854

MONO
Precision Monolithics, Inc.
1500 Space Drive
Santa Clara, California 95050

MOT
Motorala Semiconductor Products, Incorporated
2002 West 10th Place
Tempe, Arizona 85281

NATL
National Semiconductor Corp.
2900 Semiconductor Drive
Santa Clara, California 95051

NBS
National Bureau of Standards
325 Broadway
Boulder, Colorado 80302

SAMT
Samtec, Incorporated
2652 Charlestown Road
New Albany, Indiana 47150

SCBE
Scanbe Canosa Industries
3445 Fletcher Avenue
El Monte, California 91731

TABLE 7
MANUFACTURER'S CODE TABLE continued

SEAC

Seacor, Incorporated
598 Broadway
Norwood, New Jersey 07648

SPRG

Sprague Electric Company
418 Marshall Street
North Adams, Massachusetts 012147

THER

Thermalloy Inc.
2021 West Valley View
Dallas, Texas 75234

TABLE 8
PARTS LIST FOR SWITCH DRIVER MODULE COMPONENTS

DECODER CARD

(110,210)

Catagory 1-------------------Resistors--------------------------------

R1	1ea	Resistor, Carbon, 0.25W 5%	AB	FSN 5905-681-6462

Catagory 4-------------------Diodes--

CR1-CR24,	24ea	LED Indicator	DIAL	550-0506

Catagory 5--------------------Integrated Circuits----------------------

U1,	1ea	I. C. Hex Inverter	TI	SN7404N
U2,	1ea	I. C. Hex Inverter	TI	SN7404N
U3	1ea	I. C. Hex Inverter	TI	SN7404N
U4	1ea	I. C. Hex Inverter	TI	SN7404N
U5	1ea	I. C. Decoder	TI	SN7442N
U6	1ea	I. C. Decoder	TI	SN7442N
U7	1ea	I. C. Decoder	TI	SN7442N
U8	1ea	I. C. Decoder	TI	SN7442N
U9	1ea	I. C. Decoder	TI	SN7442N
U10	1ea	I. C. Quad Nand Gate	TI	SN7400N

Catagory 6------------------Connectors--------------------------------

	10ea	DIP Socket 14 Pin	THER	8204-NF-414-1

SWITCH DRIVER CARD

(111,112,113,114,115,116,117,211,212,213,214)

Catagory 1---------------------Resistors---------------------------

R1	4ea	Resistor, Carbon, 0.25W 5%,1K	AB	FSN 5905-681-6462
R2	4ea	Resistor, Carbon, 0.25W 5%,1K	AB	FSN 5905-681-6462
R3	4ea	Resistor, Carbon, 0.25W 5%,1K	AB	FSN 5905-681-6462
R4	4ea	Resistor, Carbon, 0.25W 5%,1K	AB	FSN 5905-681-6462

Catagory 4---------------------Diodes------------------------------------

CR1	4ea	Diode Rectifier	MOTO	1N4004
CR2	4ea	Diode Rectifier	MOTO	1N4004
CR3	4ea	Diode Rectifier	MOTO	1N4004
CR4	4ea	Diode Rectifier	MOTO	1N4004

TABLE 8
PARTS LIST FOR SWITCH DRIVER MODULE COMPONENTS continued

Catagory 5---------------------Integrated Circuits--------------------

U1	4ea	I. C. Quad Nand Gate	TI	SN7400N
U2	1ea	I. C. Hex Inverter	TI	SN7404N
U3	2ea	I. C. Mos Memory Clock Driver	NATL	DS0025C
U4	2ea	I. C. Mos Memory Clock Driver	NATL	DS0025C

Catagory 6-----------Connectors--

	5ea	14 Pin DIP Socket	THER	8204-NF-414-1
	4ea	8 Pin DIP Socket	THER	8204-NF-408-1

OUTPUT DISPLAY CARD

(117)

Catagory 1-------------------Resistors------------------------------

R1	1ea	Resistor, Carbon, 0.25W, 5%, 15K	AB	CB
R2	2ea	Resistor, MF, 0.25W, 1%, .1K	CORG	NC5
R3	4ea	Resistor, MF, 0.25W, 1%, 10K	CORG	NC5
R4	1ea	Resistor, MF, 0.25W, 1%, 1000K	CORG	NC5
R5	1ea	Resistor, MF, 0.25W, 1%, 5.1K	CORG	NC5
R6	3ea	Resistor, Var, Trim, CERMET, 10K	BRNS	3006W-1-103
R7	1ea	Resistor, Var, Trim, CERMET, 20K	BRNS	3006W-1-203
R8		Same as R6		
R9	2ea	Resistor, Var, Trim, CERMET, 1K	BRNS	3006W-1-102
R10	4ea	Resistor, MF, 0.25W, 1%, 200K	CORG	NC5
R11		Same as R10		
R12		Same as R10		
R13		Same as R10		
R14		Same as R6		
R15	1ea	Resistor, MF, 0.25W, 1%, 2K	CORG	NC5
R16		Same as R3		
R17		Same as R3		
R18	1ea	Resistor, MF, 0.25W,1%, 20K	CORG	NC5
R19	2ea	Resistor, Var, Trim,CERMET,2K	BRNS	300-62-1-202
R20		Same as R19		
R21		Same as R9		
R22	1ea	Resistor, MF, 0.25W, 1%, 511K	CORG	NC5
R23	1ea	Resistor, MF, 0.25W, 1%, 1K	CORG	NC5
R24		Same as R2		
R25	1ea	Resistor, MF, 0.25W, 1%, .01K	CORG	NC5
R26	1ea	Resistor, Carbon, 0.25W, 5%, .1K	AB	CB
R27	1ea	Resistor, Carbon, 0.25W, 5%, 2.7K	AB	CB
R28		Same as R3		
R29	1ea	Resistor, Carbon, 0.25W, 5%, 4.7K	AB	CB
R30	2ea	Resistor, Carbon, 0.25W, 5%, 39K	AB	CB

TABLE 8
PARTS LIST FOR SWITCH DRIVER MODULE COMPONENTS continued

OUTPUT DISPLAY CARD

(117)

R31		Same as R30		
R32	lea	Resistor, Carbon, 0.25W, 5%, 27K	AB	CB
R33	lea	Resistor, Carbon, 0.25W, 5%, 10K	AB	CB
R34	lea	Resistor, Carbon, 0.25W, 5%, 1K	AB	CB
R35	lea	Resistor, Carbon, 0.25W, 5%, 24.3K	AB	CB
Catagory 2---------------Capacitors--------------------------				
C1	2ea	Capacitor, Disc, .001UF		
C2	lea	Capacitor, Disc, Ceramic, .1UF		
C3	lea	Capacitor, Polycarbonate, .1UIF	SEAC	CMK
C4	2ea	Capacitor, Disk, .01UF		
C5		Same as C4		
C6	4ea	Capacitor, Tant, 35V, 22UF		
C7	lea	Capacitor, DIP, Mica, 150PF		
C8	2ea	Capacitor, Tant, 20V, 47UF		
C9		Same as C8		
C10		Same as C6		
C11		Same as C6		
C12		Same as C6		
C13	lea	Capacitor, DIP, Mica, 100PF		
C14	3ea	Capacitor,HI-K MONO,50V, 1UF	SPRG	5C023105X025053
C15		Same as C14		
C16		Same as C1		
C17		Same as C14		
Catagory 4--------------------Diodes--------------------------------				
D1	lea	Diode, Silicon,100V	MOT	1N4153
Catagory 5------------------Integrated Circuits--------------------				
IC1	lea	I. C. Op Amp	MONO	OP-05C
IC2	lea	I. C. Sample and Hold	DATL	SHM-LM-2
IC3	lea	I. C. FET, Op Amp	NATL	LH0042C
IC4	lea	I. C. Log Amp	ITSL	ICL 8048ECBE
IC5	lea	I. C. Op Amp	NATL	LM741C

TABLE 8
PARTS LIST FOR SWITCH DRIVER MODULE COMPONENTS continued

OUTPUT DISPLAY CARD

(117)

IC6	2ea	I. C. Timer	NATL	LM 555
IC7		Same as IC6		
IC8	lea	I. C. One Shot	TI	SN74121N
IC9	lea	I. C. Nand Drive	TI	SN7552N
IC11	lea	I. C. Hex Inverter	TI	SN74LS04N

Catagory 7------------------Terminals----------------------------------

K1	2ea	Socket, Round, DIP, 8Pin	SANT	
K2	lea	Socket, Dual, In-line, DIP	SANT	IC-316-SGG
K3		Same as K1		
J1	2ea	Jack, Jumper, IC, 1Pin	GARY	AA-C
J2		Same as J1		
T1	lea	Term, Test Point, 1Pin	GARY	AA-C

Catagory 10------------------Hardware----------------------------------

B1	PC Brd, RF Process Ckt	NBS	PC-500

TRANSCO SWITCH DRIVER CARD
(217,218,219,220)

Catagory 1------------------Resistors---------------------------------

R1	8ea	Resistor, 1/4 watt, carbon, 1K,5%	AB	CB
R2	Same as R1			
R3	Same as R1			
R4	Same as R1			
R5	Same as R1			
R6	Same as R1			
R7	Same as R1			
R8	Same as R1			

Catagory 4--------------------Diodes-----------------------------------

SCR1	8ea	Silicon Controlled Rectifier	RCA	COXO	448 40526
SCR2	Same as SCR1				
SCR3	Same as SCR1				
SCR4	Same as SCR1				
SCR5	Same as SCR1				
SCR6	Same as SCR1				

TABLE 8
PARTS LIST FOR SWITCH DRIVER MODULE COMPONENTS continued

TRANSCO SWITCH DRIVER CARD

(217,218,219,220)

Catagory 4--------------------Diodes--------------------

SCR7	Same as SCR1			
SCR8	Same as SCR1			

Catagory 5--------------------Integrated Circuits--------------------

IC1	1ea	I. C. Hex Inverter	TI	SN 7404
IC2	2ea	I. C. Quad 2 Input And Gate	TI	SN 7408

Catagory 10------------------Hardware--------------------

B1		PC Brd, RF Process Ckt	NBS	PC-8-74

Front Panel and Chassis

Catagory 1--------------------Resistors--------------------

R1	1ea	Resistor, Var, 10 Turn, 10K	DUNC	3253

Catagory 3--------------------Diodes--------------------

D1	1ea	LED, Green	DIAL	9173
D2	1ea	LED, Red	DIAL	550-0506

Catagory 6--------------------Connectors--------------------

J1	1ea	Connector, Panel, BNC	AMPH	U6492/U
J102	1ea	Connector, Amp, 50 Pin	AMPH	AMP200277 2
J104	1ea	Same as J102		
J110	6ea	Edge Connector, PC, 50 Pin	AMPH	261-10030[illegible]
J111		Same as J110		
J112		Same as J110		
J113		Same as J110		
J114		Same as J110		
J117		Same as J110		

Catagory 8--------------------Switches--------------------

S1	1ea	Switch, AC Power, Toggle	ALCO	MST 105D
S2	1ea	Switch, Push Button	ALCO	MSP 105F
S3	1ea	Switch, Rotary, 3Pole	ALCO	MRB-3-3

Catagory 9--------------------Meters--------------------

M1	1ea	Meter,Panel, 0 Center, 1.5Ma	MODT	25DMA1.5U1.5

TABLE 8
PARTS LIST FOR SWITCH DRIVER MODULE COMPONENTS continued

Front Panel and Chassis

Catagory 10---------------------Hardware----------------------------

Plate, Front Panel 7"X9"	BUD	91F363
Card Cage	SCBE	60047A

Catagory 10---------------------Hardware----------------------------

Fuseholder	Littlefuse	342001

Catagory 11-------------------Miscellaneous--------------------------

Power Supply 5V, 1A	Standard	SPS/15

ACKNOWLEDGMENTS

The existence of this measurement system is the result of a joint effort involving cooperation of many people over a long period of time. These include: Gerome Reeve for the original system design; William C. Daywitt for the design of the broadband cryogenic standard, error analysis, and theoretical support; and Neil Larson and John Wakefield for the hardware design refinements and technical support.

REFERENCES

1 Counas, G. J., T. H. Bremer; NBS 30/60 Megahertz Noise Measurement System, Operation and Service Manual, NBSIR 81-1656; December 1981

2 Miller C. K. S., W. C. Daywitt, and M. G. Arthur; Noise Standards, Measurements, and Receiver Noise Definitions; Proc. IEEE. 55, pp. 865-877; June 1967

3 Wells J. S., W. C. Daywitt, and C. K. S. Miller; Measurement of Effective Temperature of Microwave Noise Sources; IEEE Trans. on I&M, IM-13, pp. 17-28; March 1964

4 Daywitt, William C.; A Coaxial Noise Standard For The 1 GHz To 12.4 GHz Frequency Range; NBS Technical Note, 1983

5 Hoer, Cletus A.; Using Six-Port and Eight Port Junctions To Measure Active and Passive Circuit Parameters; NBS Technical Note 673, September, 1975

6 Engen, Glenn F.; Calibrating the Six-Port Reflectometer by Means of Sliding Terminations; IEEE Trans. on MTT, Vol. MTT-26, No. 12; December 1978

7 Larson, N. T.; NBS Type IV Power Meter, Operation and Maintenance Manual; NBSIR 77-866; October 1977

8 Daywitt, William C.; Private Communication

APPENDIX I

PORT ASYMMETRY MEASUREMENTS

NBS AUTOMATED RADIOMETER

2.0 TO 4.0 GHZ

PURPOSE OF TESTS:

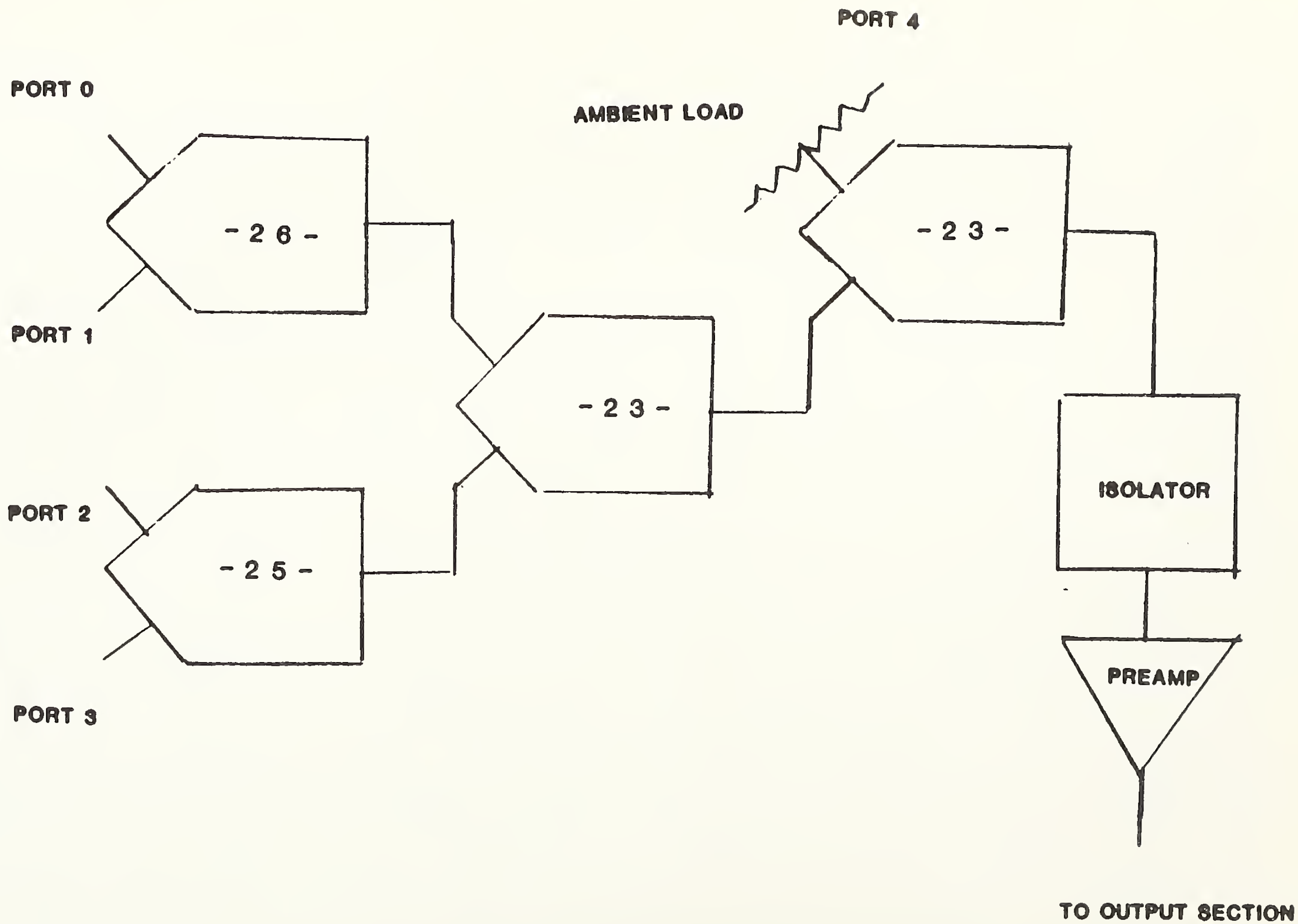
The purpose of the tests was to determine the error to be expected due to port asymmetry of the NBS Automated Radiometer in the 2.0 to 4.0 GHz frequency range.

DESCRIPTION OF TESTS:

The port asymmetry tests are based on an error model created by W. C. Daywitt. To determine port asymmetry using this model requires two noise sources and an ambient load. The noise temperature of the two noise sources need not be known. Refer to Figure 1A. This figure shows the system port arrangement used in the tests. All ports used have type N coaxial connectors as did the ambient load and two noise sources.

To evaluate the error due to port asymmetry, the two noise sources (X1 and X2) are connected to ports 0 and 1 respectively. A special computer program is utilized which provides for the determination of the complex reflection coefficients of the system measurement ports and the two noise sources mentioned previously.

This program also accomplishes the automatic switching of the port switches and measurement of the noise power at ports 0, 4, and 1 in that order. This is done a minimum of 25 times and the ratio of power at port 0 (noise source 1) and the power at port 4 (ambient load) is calculated for each switching cycle. The same ratio is determined for noise power at port 1 (noise source 2) and port 4 (ambient load). At the end of 25 measurements, the average of the two ratios is then calculated and stored. The two noise sources are then interchanged and the



SYSTEM PORT SWITCHES USED IN ASYMMETRY TESTS

FIGURE 1A

process repeated. Upon completion of the second set of measurements , the port asymmetry is calculated as follows:

Refer to Figure 2A.

With source 1 at port 0 and source 2 at port 1:

$$X0=(1-Mag(Gx1)^2)(1-Mag(Gs1)^2) \qquad (1)$$

$$Y0=(1-Gx1Real*Gs1Real+Gx1Imag*Gs1imag)^2 \qquad (2)$$

$$Z0=(Gx1Real*Gs1Imag + Gs1Real*Gx1Imag)^2 \qquad (3)$$

$$Mx1=X0/(Y0+Z0) \qquad (4)$$

Where Gx1=Complex reflection coefficient of the source at port 0

Gs1=Complex reflection coefficient of the system at port 0

$$X1=(1-Mag(Gx2)^2)(1-Mag(Gs2)^2) \qquad (5)$$

$$Y1=(1-Gx2Real*Gs2Real+Gs2Imag*Gx2Imag)^2 \qquad (6)$$

$$Z1=(Gx2Real*Gs2Imag+Gs2Real*Gx2Imag)^2 \qquad (7)$$

$$Mx2=X1/(Y1+Z1) \qquad (8)$$

Where Gx2=complex reflection coefficient of source at port 1

Gs2=complex reflection coefficient of system at port 1

When the noise sources connected to ports 1 and 2 are interchanged, Mx1′ and Mx2′ are calculated using equations (1) through (8). Gx2 is substituted for Gx1 in equations (1) through (3), resulting in Mx1′ when solving equation (4). Gx1 is substituted for Gx2 in equations (5) through (7), resulting in Mx2′ when solving equation (8).

Then:

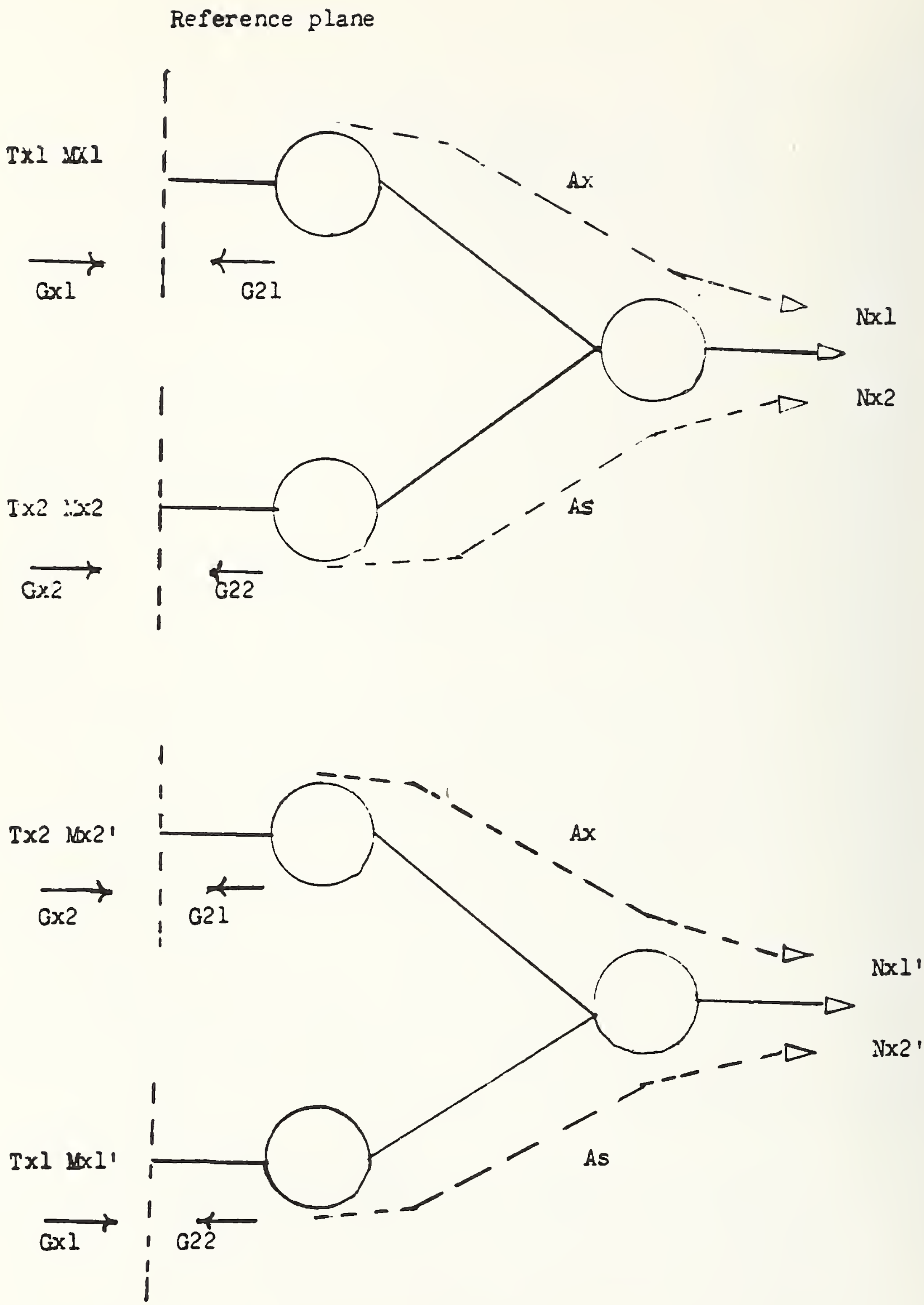
$$[(Mx1*Mx2')/(Mx2*Mx1')]*[(Yx2-1)/(Yx1'-1)]*[(Yx2'-1)/Yx1-1)]=N \qquad (9)$$

$$(Ns/Nx)^2=N \qquad (10)$$

$$Ns/Nx=(N)^1/2 \qquad (11)$$

$$\text{Asymmetry in dB}=10*Ln(Ns/Nx) \qquad (12)$$

Where



SWITCH ASYMMETRY NS/NX

FIGURE 2A

Yx1=Power measured at port 0/Power measured at port 4 (13)

Yx2=Power measured at port 1/Power measured at port 4 (14)

(Power measured at port 4 is ambient power)

And

Yx1′ and Yx2′ are calculated with (13) and (14) after the noise sources are interchanged.

MEASUREMENT RESULTS

Using the above procedures the following measurement results were obtained with type N connectors and no adaptors were used.

FREQUENCY MHZ	PORT ASYMMETRY DECIBELS
2000	0.0044
2250	0.0036
2500	0.0032
2850	0.0012
3000	0.0022
3250	0.0051
3500	-0.0021
3750	0.0017
4000	0.0078
Average	0.0030

These results remain essentially the same regardless of port selection as long as the switches operate properly. Use of various adaptors such as GR900 to N can result in asymmetry as high as 0.015 dB. This suggests that asymmetry should be evaluated for the specific adaptors used. As a part of this test, ports with right angle N adaptors were evaluated, and found to exhibit asymmetry in the range of 0.006 to 0.009 decibel at 2000, 3000, and 4000 Mhz.

APPENDIX II

PROGRAM LISTINGS AND VARIABLE CROSS REFERENCE TABLES

This appendix contains the listing of the measurement program, RAD7EF. This program is currently used to make measurements with the automated radiometer. The program is divided into segments and each segment listed in order. Each segment listing is followed by the cross reference table for the variables referenced.

A. PROGRAM RAD7EF

```
8 SEPTEMBER 1983
RAD7EF

10      ! REV 2 RAD7EF 7 SEPTEMBER 1983    GJC  AVAIL MEM THIS VS 58176
20      ! THIS VS HAS CODE TO UTILIZE PORT 2 FOR UNK AND 3 FOR  STD
30      ! QUANTUM CORRECTION IMPLEMENTED
40      ! RE-STORE"RAD7EF:F8"  ! 6 SEPTEMBER 1983  1015
50       OPTION BASE 1
60       COM F(4,15),Z(1,80),T1,T2,T3,Qr(12),Qi(12),Final(5)
70       COM File,Flag
80       DIM H$[100],C$[100],G$[100],R$[100],V(20),C(16,4,10),Q(3,100)
90 !     OUTPUT 704;"0000000000000000000000000" !CLEAR SYNTH
100      MAT F=ZER
110      MAT Q=ZER
120      MAT Z=ZER
130      PO$="NOM1L7K7"  !SYNTHESIZER POWER TO 2MW
140      Fr=1
150      Cc=1
160      CALL Volt(V(*),Fr,Cc,C(*))
170      Aet=1
180      PRINTER IS 16
190      DISP "INSURE THAT ALL PORTS HAVE DEVICES ATTACHED THEN PRESS CONT"
200       INPUT "AMBIENT TEMP",Tt
210      T2=273.15+Tt
220       INPUT "STANDARD TEMP",T3
230      Tx=0
240      P0=1
250          ! SET SYNTHESIZER TO PROPER FREQUENCY AND LEVEL
260        OUTPUT 704;"00H0G260E0D0C0B0A0N0M2L5K5"
270        OUTPUT 1003;"8","8","?","0","4","2"
280        OUTPUT 1003;"8","8","0","0","4","2"
290        OUTPUT 702;"0","8","7","0"
300        OUTPUT 702;"0","8","0","0"
310      PRINTER IS 16
320      FOR K=1 TO 5
330      CALL Power(P1,P2,P3,P0,Aet)
340      Y1=P1/P2
350      Y3=P3/P2
360      Tx=Tx+(T2+(T3-T2)*(Y1-1)/(Y3-1))
370      T4=(T3-Y3*T2)/(Y3-1)
380      PRINTER IS 16
390      PRINT "T4=";T4,"Tx=";Tx/K
400      G=10*LOG(7.244E13*P2/.95/(T2+T3))  !30Mhz IF
410      PRINT "GAIN=";G;"dB"
420      PRINT P1*1000,P2*1000,P3*1000
430      Ptest=Ptest+P1
440      NEXT K
```

```
450     P1=Ptest/(K-1)
460     PRINTER IS 16
470     PRINT "AVERAGE POWER AT PORT 0 IS ";P1*1000;"MILLIWATTS"
480     PRINT "AVERAGE TEMP AT PORT 0 IS";Tx/(K-1);"KELVINS"
490     PRINT "PAUSE 580"
500     PAUSE
510     MASS STORAGE IS ":F8"
520    LINPUT "AMBIENT STANDARD TEMPERATURE IN C",H$[1,10]
530     H$[1,10]=VAL$(VAL(H$[1,10])+273.15)
540     PRINT H$[1,10]
550     LINPUT "BAROMETRIC PRESSURE",H$[11,20]
560     INPUT "APPROXIMATE VALUE OF UNKNOWN TO BE TESTED",E7
570     INPUT "MAXIMUM DEVIATION FROM NOMINAL TO BE ALLOWED",E8
580     PRINTER IS 16
590   ! OUTPUT 9;"S04:26:15:23:00"          !RESET REAL TIME CLOCK
600     Q=FNS(4)
610     OUTPUT 9;"R"
620     ENTER 9;P$
630     PRINT TAB(15),P$;":1983"
640     CALL Get_parameters(C$,G$,R$,F1,F2,F3,Fn,N3,N8)
650    !
660    ! START CAL OF SYSTEM  DETERMINE PATH LOSS AND START CAL SELFCHECK
670    !
680    Init=1
690     CALL Cal(C(*),P0$,Init)
700    !
710    Aet=1
720    CALL Corr2(C1,C$,G$,R$,E7,E8,Q(*),Aet)
730    !
740    Init=2
750    CALL Cal(C(*),P0$,Init)
760     ! START CAL OF UNKNOWN
770    !
780    Aet=2
790     CALL Out(C1,C$,G$,H$,R$,E7,E8,Q(*),Aet)
800    !
810    ! GOTO 100
820    ! STORE MEAS RESULTS AND DESCRIPTION OF DEVICE
n30    !
840     CALL Descr(P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,Q(*))
850     PRINT "PAUSE 1020  PROGRAM END PRESS CONT TO RESTART"
860     PAUSE
870       GOTO 90
880     END
```

MAIN

Aet	170	330	710	720	780	790
C$	80	640	720	790	840	
C(	80	160	690	750		
C1	720	790				

RAD7EF

Cc	150	160						
E7	560	720	790					
E8	570	720	790					
F(	*	100						
F1	640	840						
F2	640	840						
F3	640	840						
Fn	640							
Fr	140	160						
G	400	410						
G$	80	640	720	790	840			
H$	80	520	530	530	540	550	790	840
Init	680	690	740	750				
K	320	390	440	450	480			
N3	640	840						
N8	640	840						
P$	620	630	840					
P0	240	330						
P0$	130	690	750					
P1	330	340	420	430	450	470		
P2	330	340	350	400	420			
P3	330	350	420					
Ptest	430	430	450					
Q	600							
Q(	80	110	720	790	840			
R$	80	640	720	790	840			
T2	*	210	360	360	370	400		

T3	*	220	360	370	400
T4	370	390			
Tt	200	210			
Tx	230	360	360	390	480
V(	80	160			
Y1	340	360			
Y3	350	360	370	370	
Z(	*	120			

```
890  DEF FNB(Q)                        !!(FNB)
900    OPTION BASE 1
910    COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
920    COM File,Flag
930  FOR I=1 TO Q
940  BEEP
950  WAIT ABS(100*(I-4))
960  NEXT I
970  RETURN 0
980   FNEND
```

FNB(

I	930	950	960
Q	890	930	

RAD7EF

```
990  DEF FNN(Q)                          !!(FNN)
1000   OPTION BASE 1
1010   COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
1020   COM File,Flag
1030 DISP "( =NC):";Q;
1040 LINPUT B$
1050 IF B$[1,1]=" " THEN 1070
1060 RETURN VAL(B$)
1070 RETURN Q
1080  FNEND
```

FNN(

B$	1040	1050	1060
Q	990	1030	1070

```
1090 DEF FNO(P$,Q$)                !!(FNO)
1100   OPTION BASE 1
1110   COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
1120   COM File,Flag
1130 IF I2=0 THEN 1180
1140 PRINT "( =NC)NOW: ";P$;
1150 LINPUT Q$
1160 IF Q$=" " THEN 1240
1170 P$=Q$
1180 PRINT "( =NC)NOW: ";P$
1190 I0=FNS(1)
1200  WAIT 50
1210 LINPUT Q$
1220 IF Q$=" " THEN 1240
1230 P$=Q$
1240 RETURN Q
1250  FNEND
```

FNO(

I0	1190						
I2	1130						
P$	1090	1140	1170	1180	1230		
Q	1240						
Q$	1090	1150	1160	1170	1210	1220	1230

```
1260 DEF FNS(Q)                          !!(FNS)
1270   OPTION BASE 1
1280   COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
1290   COM File,Flag
1300 FOR I=1 TO Q
1310 PRINT
1320 NEXT I
1330 RETURN 0
1340  FNEND
```

FNS(

I	1300	1320
Q	1260	1300

```
1350 SUB Cal(C(*),P0$,Init)
1360  OPTION BASE 1
1370  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
1380  COM File,Flag
1390  DIM D$[50],P(16,4),Pdiode(6,4,21),Zdiode(2,4),Z$[100]
1400  DIM G1(16),G1i(16),G1r(16),Pa(16,7),G1a(16),F$[50]
1410  PRINTER IS 16
1420  !
1430 ! GOTO 1750
1440  FOR Cal=1 TO 2
1450  Prt=Cal
1460 Cal2: !
1470  Recal=0
1480  IF Cal=1 THEN GOTO 1520
1490  PRINT "CAL SEQ FOR STANDARD PORT"
1500  Pout$="3"
1510  GOTO 1540
1520  PRINT "CAL SEQ FOR MEASUREMENT PORT"
1530  Pout$="2"
1540  I1=0
1550  F1=Z(1,37)
1560  F2=Z(1,38)
1570  F3=Z(1,39)
1580  Fn=(F2-F1)/F3+1   !=1
1590  F=F1
1600    GOTO 3130        !THIS PATH FOR READ DATA ONLY
1610  GOSUB Zerdiode
1620  GOTO 1880
1630  ! ******************DIODE ZERO CHECK****************************
1640 Zerdiode: !
1650  PRINTER IS 16
1660  !
1670  Ndiode=4
1680  C=0
1690  Cc=1
1700  Ccc=1
1710 ! ENABLE SINGLE FREQUENCY
1720  F1=(Z(1,38)-Z(1,37))/2+1
1730  Fn=1
1740  PRINT "Fn=",Fn
1750  OUTPUT 1003;"8","8","?",Pout$,"4","2"!30 IF PORT 0 AND 2-4 SYSTEM CC
1760  OUTPUT 1003;"8","8","0",Pout$,"4","0"!30 IF PORT 0 AND 2-4 SYSTEM CC
1770  P=3
1780  P0$="N1M4L9K9"  !MAX ATTEN MIN PWR FROM SYNTH
1790  M=1
1800  PRINT "Dzero"
1810  GOSUB Meas
1820  PRINTER IS 16
1830  PRINT Zdiode(*)
1840 OUTPUT 1003;"0","8","?",Pout$,"4","2"
1850 OUTPUT 1003;"0","8","0",Pout$,"4","2"
1860     IF Recal=1 THEN GOTO Resume
1870     RETURN
1880  ! *******************CAL SEQUENCE*********************************
```

```
1890  !
1900 OUTPUT 1003;"0","8","?",Pout$,"4","2"
1910 OUTPUT 1003;"0","8","0",Pout$,"4","2"
1920     OUTPUT 704;"OOHOG2FOEODOCOBOAONOM4LOK4" !3000 MHZ1.5MW  AT LO
1930     RESET 1022
1940  M=1             !RESET FOR FREQ SUB PROGRAM
1950  C=1  !Enables C MATRIX
1960   Cc=1 !Cal ITEM ID   1=D.U.T 2=OFFSET 3-9=SLIDING SHORT 10-14=
      SLIDING  LOAD 15=AMBIENT  STD (7 SLIDING  SHORT  AND  5 SLIDING
       LOAD POS)
1970  Ccc=3
1980  ! !!!!!!!!!!!!!!!!!!!!!SET  CAL POWER LEVEL!!!!!!!!!!!!!!!!!!
1990  F1=Z(1,37)
2000  F2=Z(1,38)
2010  F3=Z(1,39)
2020  Fn=(F2-F1)/F3+1  !=1
2030  P=3
2040  GOSUB Setpwr
2050  GOTO 2450
2060  ON Cal GOTO 2070,2090
2070  PRINT "PLACE NOISE STANDARD (D. U. T. ) ON PORT";Pout$;"PRESS CONT"
2080 GOTO 2100
2090  PRINT "PLACE CRYO STANDARD ON PORT";Pout$;"PRESS CONT"
2100  Cc=1
2110  P=3
2120  M=1
2130  PRINT "D.U.T    Cc=";Cc
2140  Q=FNB(3)
2150  PAUSE
2160  M1=1
2170  Seq=4
2180  GOSUB Meas
2190  GOTO 3120
2200  M=1
2210  PRINT "PLACE OFFSET ON PORT 0 AND PRESS CONTINUE"
2220 Q=FNB(3)
2230  PAUSE
2240  Seq=3
2250  Cc=2
2260  PRINT "OFFSET Cc=";Cc
2270 GOSUB Meas
2280 ! GOTO 2150
2290  PRINT "PLACE IMPED CK ON PORT AND PRESS CONT"
2300  M=1
2310  Cc=16
2320  Seq=5
2330  Q=FNB(3)
2340  PAUSE
2350  GOSUB Meas
2360  ON Init GOTO 2370,2060
2370  PRINT "PLACE AUXILIARY NOISE SOURCE ON PORT";Pout$;" AND PRESS CONT"
2380  Q=Fnb(3)
2390  M=1
2400  Cc=15
2410  Seq=6
```

```
2420  PAUSE
2430  GOSUB Meas
2440  GOTO 3120
2450 M=1
2460  PRINT "PLACE SLIDING SHORT ON PORT 0 AND PRESS CONTINUE"
2470  Np=1
2480  Cp=1
2490  Cc=3
2500  PRINT "SLIDING SHORT Cc=3 POS 0"
2510  Seq=1
2520  Ss=1         !1ST POSITION
2530  Q=FNB(3)
2540  N1=7
2550  PAUSE
2560  GOSUB Meas
2570 ! SLIDING SHORT ROUTINE 7 POSITIONS
2580  Ss$=VAL$(Ss)
2590  Q$="PRESS CONT"
2600  D$="SLIDE POS"
2610  PRINT D$;" ";Ss$;" ";Q$
2620  Q=FNB(3)
2630  PAUSE
2640  M=1
2650  Cc=Cc+1
2660  Cp=1
2670  Np=1
2680  Ss=Ss+1
2690  PRINT Ss
2700  IF Ss=8 THEN 2740
2710  PRINT "SS POS"&D$&Ss$;"Cc=";Cc
2720  GOSUB Meas
2730  GOTO 2580
2740  ! SLIDING LOAD  5 POSITIONS
2750  M=1
2760  PRINT "PLACE SLIDING LOAD ON PORT 0 AND PRESS CONT"
2770  Np=1
2780   Cp=1
2790  Cc=10
2800  Seq=2
2810  Ss=0
2820  Q=FNB(3)
2830  N2=5
2840  PAUSE
2850  GOSUB Meas
2860  Ss=1
2870  Ss$=VAL$(Ss)
2880  Q$="PRESS CONT"
2890  D$="SLIDE POS"
2900  PRINT D$;" ";Ss$;" ";Q$
2910  Q=FNB(3)
2920  PAUSE
2930  M=1
2940  Cc=Cc+1
2950  Cp=1
2960  Np=1
```

```
2970  Ss=Ss+1
2980  PRINT Ss
2990  IF Ss=6 THEN GOTO 2200
3000  GOSUB Meas
3010  GOTO 2870
3020  Seq=1
3030  GOTO 3130
3040  PRINT "CRYO    STANDARD  PROGRAMMED FOR PORT 2"
3050  OUTPUT 1003;"0","8","?","2","4","0"!30 IF PORT 3 AND 2-4
3060  OUTPUT 1003;"0","8","0","2","4","0"!CC
3070  Q=FNB(3)
3080  Seq=6
3090  Cp=1
3100  Np=1
3110  GOSUB Meas
3120  NEXT Cal
3130 INPUT "CMATRIX FILE NUMBER",Num
3140  MASS STORAGE IS ":F8,1"
3150  Num=INT(Num)
3160  File$="CMAT"&VAL$(Num)
3170  ! CREATE File$,80
3180   ASSIGN #1 TO File$
3190 ! PRINT #1;C(*),Zdiode(*),Z(*)
3200      READ #1;C(*),Zdiode(*),Z(*)
3210  ASSIGN #1 TO *
3220  FOR I=1 TO 15
3230  FOR Fr=1 TO 2*Fn
3240  PRINTER IS 16
3250  PRINT C(I,1,Fr);C(I,2,Fr);C(I,3,Fr);C(I,4,Fr)
3260  NEXT Fr
3270  NEXT I
3280  PRINT
3290 !                  7 SLIDING SHORT AND 5 SLIDING LOAD POS ARE USED
3300  ! *************\
3310  PRINT "CAL#",Cal
3320  PRINT
3330  FOR Cal=1 TO 2
3340  FOR Ck=1 TO 15
3350  FOR Fr=1 TO 2*Fn
3360  PRINT C(Ck,1,Fr),C(Ck,2,Fr),C(Ck,3,Fr),C(Ck,4,Fr)
3370  NEXT Fr
3380  NEXT Ck
3390  PRINT
3400  PRINT
3410  NEXT Cal
3420  PRINTER IS 0
3430  F1=Z(1,37)
3440  F2=Z(1,38)
3450 F3=Z(1,39)
3460  Fn=(F2-F1)/F3+1
3470      Fr=1
3480  GOTO Calz
3490 Sel:     !
3500  A=0
3510  FOR D=10 TO 13       !PROGRAM SCANNER CHANNELS
```

```
3520  IF Ccc<>2 THEN 3550
3530  PRINT "PLACE SLIDING SHORT ON PORT 0--SLIDE FOR MAX VOLTAGE"
3540  PRINT "PRESS CONTINUE WHEN MAX IS OBTAINED"
3550  Di=D-10+1
3560  OUTPUT 1007;D
3570  WAIT 125
3580  IF Ccc=1 THEN GOTO 3610
3590  WAIT 500
3600  GOTO 3620
3610   WAIT 500
3620   CALL Dmm(V1,C(*),Fr,Cc,C,Di)
3630   IF Ccc<>1 THEN GOTO 3660
3640   Zdiode(Cal,Di)=V1
3650   GOTO 3770
3660   IF Cal>1 THEN GOTO 3700
3670   C(Cc,Di,Fr)=V1
3680  C(Cc,Di,Fr)=ABS(C(Cc,Di,Fr)-Zdiode(Cal,Di))
3690   GOTO 3730
3700 C(Cc,Di,Fr+Fn)=V1
3710  C(Cc,Di,Fr+Fn)=ABS(C(Cc,Di,Fr+Fn)-Zdiode(Cal,Di))
3720  PRINTER IS 0
3730  PRINTER IS 16
3740   PRINT Cc,Seq,"FR=";Fr;Cal
3750   PRINT C(Cc,Di,Fr);C(Cc,Di,Fr+Fn)
3760   PRINTER IS 16
3770   NEXT D
3780   RETURN
3790 Meas:     !
3800  PRINT "MEAS",F1,F2,Fn
3810  M1=1
3820  IF Ccc=1 THEN Fn=1
3830  FOR Fr=1 TO Fn
3840  CALL Freq(F,F$,F1$,P0$,M,Ccc)
3850  Q=5
3860  GOSUB Sel
3870  M=2
3880  F=F4=F1*10^6+Fr*F3*10^6
3890  PRINT "F4",F4,"F",F
3900  NEXT Fr
3910  RETURN
3920 Setpwr: !
3930  ON P GOTO 3940,3960,3980,4000,4020,4040,4060
3940  P$="N0M3L6K0"     !-  3DBM  P$="N0M4L0K0
3950  GOTO 4070
3960  P$="N0M3L9K0"     !-6.0DBM
3970  GOTO 4070
3980  P$="N0M4L2K0"      !-13DBM
3990  GOTO 4070
4000  P$="N0M4L5K0"      !-16DBM
4010  GOTO 4070
4020  P$="N0M4L8K0"     !-23DBM
4030  GOTO 4070
4040  P$="N0M5L1K0"     !-26 DBM
4050  GOTO 4070
4060  P$="N0M5L4K0"     !-26 DBM
```

```
4070  PRINT "P, P$";P,P$
4080  PO$=P$
4090  RETURN
4100 Calz:! OPTION BASE 1
4110 !
4130   DIM A(5,5),B(20,5),Cm(5,20),U(8),V(8),W(1,1),X(20,1),Y(10,1),Zm(4,1
4140 !
4150 ! Read real time clock
4160 OUTPUT 9;"R"
4170 ENTER 9;T$
4180 Date=830000+VAL(T$[1,2])*100+VAL(T$[4,5])
4190 Time$=T$[7;5]
4200 ! Fn  "FREQ IN GHZ",Freq    !SET UP MULTIPLE FREQ INDEX Fn=#Fr
4210 ! INPUT "NO. OF SHORT POSITIONS AND LOAD POSITIONS",N1,N2
4220  N1=7
4230  N2=5
4240  Fr=1
4250 O=0
4260 PRINTER IS 16   ! 7 & 9is HPIB, 0 is address of printer
4270 Dvm=1022 ! HPIB + address 22
4280 Scanner=1007  ! HPIB + address 7
4290 INPUT "FREQUENCY # FOR CALCULATION",Set
4300      F1=Z(1,37)-Z(1,39)
4310 F(1,1)=F(2,1)=F1+Set*Z(1,39)
4320  F1=F=F(1,1)
4330 ! ***********************************************************************
4340 ! Index I=1 for D.U.T., 2 FOR OFFSET, 3-9 for sliding short,
      10-14 for sliding load, AND 15 for AMBIENT STD.
4350  PRINTER IS 0
4360  F(Fr,1)=F1
4370  Fz=(Z(1,38)-Z(1,37))/Z(1,39)+1
4380 PRINT "                              DATE:";Date;" TIME:";Time$
4390  PRINTER IS 16
4400   ! *********************************************************************
4410   !
4420   ! Start calibration calculations
4430   Pout$="2"
4440   FOR Prt=1 TO 2
4450   IF Prt=2 THEN Pout$="3"
4460   FOR Cc=1 TO 16
4470   Fn=Fz
4480      Fr=Set
4490   ON Prt GOTO 4500,4550
4500   P(Cc,2)=C(Cc,2,Set)
4510   P(Cc,4)=C(Cc,4,Set)
4520   P(Cc,1)=C(Cc,1,Set)
4530   P(Cc,3)=C(Cc,3,Set)
4540   GOTO 4590
4550   P(Cc,2)=C(Cc,2,Set+Fn)
4560   P(Cc,4)=C(Cc,4,Set+Fn)
4570   P(Cc,1)=C(Cc,1,Set+Fn)
4580   P(Cc,3)=C(Cc,3,Set+Fn)
4590   NEXT Cc
4600 PRINT USING 4610;P(1,4),P(1,1),P(1,3),P(1,2)!P3,P5,P6,P4
4610  IMAGE 4(MDZ.5D11X)
```

```
4620   Cal=1
4630  Fnn=Fn
4640  Fn=1
4650    INPUT "1 FOR OPEN 2 FOR OFFSET",Imped
4660 ! Imped=2
4670   ON Imped GOTO 4680,4700
4680 GOSUB Open
4690  GOTO 4710
4700  GOSUB Gamo
4710  FOR Fr=1 TO Fn
4720  RAD
4730  F=F(Fr,1)
4740  G1=Gr(Fr)
4750  G2=Gi(Fr)
4760  PRINTER IS 0
4770  PRINT "FREQUENCY:";F(Fr,Cal)
4780  PRINT "Real ";G1,"Imag ";G2;"MAG";SQR(G1^2+G2^2);"ANG";Ang(Fr)
4790  NEXT Fr
4800 ! GOSUB Pon           !PUT POWERS IN P ARRAY IN PROPER ORDERAUSE
4810   ! DIODE 1 CHANNEL 10 P5
4820   ! DIODE 2 CHANNEL 11 P4
4830   ! DIODE 3 CHANNEL 12 P6
4840   ! DIODE 4 CHANNEL 13  P3
4850   !
4860   ! SOLVE ELLIPSE FOR SLIDING SHORT
4880 PRINT
4890 O=FNA(A,A(*),B,B(*),Cm,Cm(*),D,E,F,Fr,G,J,K,N,N1,O,P,P(*),Q,W(*),X(*)
     ,Y(*))
4900 ! O=FNA(A,A(*),B,B(*),Cm,Cm(*),D,E,F,G,J,K,N,N1,O,P,P(*),Q,W(*),X(*)
     ,Y(*))
4910 O=FNI(A,B,Cm,F,G,O,W(*),Fr)
4920 PRINT
4940   ! CALC K,L,M,RE&IM(-N/M)
4950 PRINT "ROOT RESIDUES="
4960 O=FNBm(A,A(*),A1,B,B(*),B1,Cm,Cm(*),C1,D,E,F,G,H,I,J,K,L,N1,N2,N3,O,P
     ,P(*),Q,R1,R2,S,S0,S1,S2,T,W1,W2,W3,X(*),Y(*),Zm(*))
4970 PRINT
4980 PRINT "VALUES FOR R1,W1,R2,W2,W3"
4990 PRINT USING 5000;R1,W1,R2,W2,W3
5000 IMAGE 5(MZ.5D2X)
5010 !
5020   ! REDUNDANCY APPLICATION
5030 O=FNL(A,A(*),B,B(*),Cm,Cm(*),Fr,I,J,K,L,N1,N2,O,P,P(*),Q,R1,R2,T,W(*)
     ,W1,W2,W3,X(*),Y(*))
5040 !  O=FNL(A,A(*),B,B(*),Cm,Cm(*),Fr,I,J,K,L,N1,N2,O,P,P(*),Q,R1(*)
     ,R2(*),T,W(*),W1,W2,W3,X(*),Y(*))
5050 PRINT USING 5000;R1,W1,R2,W2,W3
5060 PRINT
5080   ! COMP A1,B1,C1,A2,B2,C2
5090 O=FNC(A,A(*),A1,A2,B,B(*),B1,B2,Cm,Cm(*),C1,C2,D,E,F,G,H,I,J,K,N1,N2,
     N3,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W(*),W1,W2,W3,X(*)
     ,Y(*))
5100 PRINT USING 5110;"VALUES FOR (RCS^2-RS^2),RCSX,RCSY=",A1,B1,C1
5110 IMAGE 34A,3(XZ.5DX)
5120 PRINT USING 5110;"VALUES FOR (RCL^2-RL^2),RCLX,RCLY=",A2,B2,C2
```

```
5130 PRINT USING 5140;"SL APPROX GAMMA=",SQR(ABS((B2^2+C2^2-A2)/SQR(B1^2
     +C1^2-A1)))
5140 IMAGE 16A,XZ.5D
5150 !
5160   ! CALC B,(C/A)
5170 O=FND(A,A1,B,B1,B8,B9,Cm,C1,C8,C9,D,E,F,G,H,I,K,N1,N2,O,P,P(*),P3,P4
     ,P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3)
5180 PRINT USING 5200;SQR(B8^2+B9^2),ATN(B9/B8)
5190 PRINT "TEST";SQR(B8^2+B9^2),ATN(B9/B8)
5200 IMAGE "MAG & ARG B="2(XMZ.5DX)
5210   PRINT USING 5230;SQR(C8^2+C9^2),ATN(C9/C8)
5220   PRINT "TEST 2";SQR(C8^2+C9^2),ATN(C9/C8)
5230 IMAGE "MAG & ARG C/A="2(XMZ.5DX)
5240 !
5250   ! CALC(1/A)
5260 O=FNE(A,A8,A9,B,B8,B9,Cm,C8,C9,D,E,F,G,G1,G2,H,I,K,O,P,P(*),P3,P4,P5
     ,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3,X,Y)
5270 PRINT USING 5280;SQR(A8^2+A9^2)
5280 IMAGE "MAG 1/A="D.5D
5290 !
5300   !   CALC 6-PORT PARAMETERS
5310 O=FNH(A,A8,A9,B,B8,B9,C8,C9,G,H,I,O,R,T,W1,W2,W3,X,Y,Prt,Pout$)
5320 PRINT USING 5330
5330 IMAGE @
5340 ! ***********************************************************
5350 !
5360 ! Start measurements
5370 !
5380 Rcoef: !
5390  PRINTER IS 0
5400  PRINT "FREQUENCY=";Z(1,37);"      PORT =";Pout$
5410 ! -------------------------------
5420 ! Measure Reflection Coefficient
5430 ! GOSUBRefl
5440  ! PRINT "PRESS CONTINUE TO MEASURE MORE REFLECTION"
5450 ! PAUSE
5460  ! GO TO Rcoef
5470   Goto=1
5480 ! Z:INPUT "Z Meas, input ID# other than 1-19 or 3-19 for SS and SL",I1
5490  IF Init=1 THEN GOTO 5530
5500  FOR I1=1 TO 16
5510  IF (I1=15) OR (I1=2) THEN GOTO 5870
5520  GOTO 5550
5530  FOR I1=2 TO 16
5540  IF I1=2 THEN GOTO 5870
5550  It=I1
5560 PRINT !"P(3)","P(5)","P(6)","P(4)"
5570  PRINT I1
5590  P4=P(I1,2)
5600  P3=P(I1,4)
5610  P5=P(I1,1)
5620  P6=P(I1,3)
5630 Cc=I1
5640 O=FNT(A,A8,A9,B,B8,B9,Cm,C8,C9,D,E,F,G,H,I,K,O,P,P(*),P3,P4,P5,P6,Q
      ,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3,X,Y,Z8,Fr,I1,G1i(*),G1r(*),G1(*)
```

```
     ,Gla(*),Pout$)
5650  ON Init GOTO 5660,5760
5660  IF I1<>15 THEN GOTO 5870
5670  F(Prt+2,11)=G1(15)
5680  F(Prt+2,12)=Gla(15)
5690  F(Prt+2,13)=Glr(15)
5700  F(Prt+2,14)=Gli(15)
5710  F(Prt+2,9)=F(Prt,9)
5720  F(Prt+2,7)=F(Prt,7)
5730  F(Prt+2,3)=F(Prt,3)
5740  F(Prt+2,5)=F(Prt,5)
5750  GOTO 5870
5760  F(Prt,11)=G1(1)
5770  F(Prt,12)=Gla(1)
5780  F(Prt,13)=Glr(1)
5790  F(Prt,14)=Gli(1)
5800  IF I1=16 THEN 5820
5810  GOTO 5870
5820 PRINTER IS 0
5830  PRINT "IMPEDANCE CK MAG,ANG,REAL, IMAG"
5840  PRINT G1(16),Gla(16),Glr(16),Gli(16)
5850  PRINT
5860  PRINTER IS 16
5870  NEXT I1
5880 Mismatch1:!
5890  PRINTER IS 0
5900  ON Init GOTO 6360,5910
5910  M1=(1-F(Prt,11)^2)*(1-F(Prt,9)^2)
5920  M2=(1-F(Prt,13)*F(Prt,3)+F(Prt,14)*F(Prt,5))^2+(F(Prt,13)*F(Prt,5)
      +F(Prt,14)*F(Prt,3))^2
5930  F(Prt,15)=M1/M2
5940  IF Prt=1 THEN GOTO 6020
5950   FOR I=1 TO 2
5960   PRINT
5970   PRINT F(I,1),F(I,2),F(I,3),F(I,4)
5980   PRINT F(I,5),F(I,6),F(I,7),F(I,8)
5990   PRINT F(I,9),F(I,10),F(I,11),F(I,12)
6000   PRINT F(I,13),F(I,14),F(I,15)
6010   NEXT I
6020  PRINT
6030  PRINT "SYSTEM  D. U. T.  PORT   2"
6040  PRINT "|Gg|","Ang g","Xg","Yg"
6050  PRINT F(1,11),F(1,12),F(1,13),F(1,14)
6060  PRINT
6070  PRINT "|G2|","ANG 2","X2","Y2"
6080  PRINT F(1,9),F(1,7),F(1,3),F(1,5)
6090  PRINT
6100  Z(1,61)=F(1,13)
6110  Z(1,62)=F(1,14)
6120  Z(1,63)=F(1,12)
6130  Z(1,64)=F(1,11)
6140  IF Prt=2 THEN GOTO 6160
6150  GOTO 6750
6160  PRINT "SYSTEM  STD. PORT 0"
6170  PRINT "|Gg|","Ang g","Xg","Yg"
```

```
6180  PRINT F(2,11),F(2,12),F(2,13),F(2,14)
6190  PRINT
6200  PRINT "|G2|","ANG 2","X2","Y2"
6210  PRINT F(2,9),F(2,7),F(2,3),F(2,5)
6220  PRINT
6230  PRINT "RESULT SET 1 M EQUATION=Mx"
6240  PRINT F(1,15)
6250  PRINT "RESULT SET 2 M EQUATION=Ms"
6260  PRINT F(2,15)
6270  PRINT "MISMATCH FACTOR Ms/Mx"
6280  PRINT F(2,15)/F(1,15)
6290  Final(Set)=F(2,15)/F(1,15)
6300  Z(Set,65)=Final(Set)
6310  Mone=ABS(F(1,13)-F(1,3)-F(2,13)+F(2,3))  !(|xx-x2-xs+x0|)
6320  Mtwo=6*ABS(F(1,14)+F(1,5)-F(2,14)-F(2,5))!6*(|Yx+y2-Ys-y0|)
6330  Z(Set,26)=.4*(Mone+Mtwo) !Mismatch %Error=.4*(Mone+Mtwo)
6340  PRINT
6350  GOTO 6570
6360  PRINT
6370  PRINT
6380  M1=(1-F(Prt+2,11)^2)*(1-F(Prt+2,9)^2)
6390  M2=(1-F(Prt+2,13)*F(Prt+2,3)+F(Prt+2,14)*F(Prt+2,5))^2+(F(Prt+2,13)
      *F(Prt+2,5)+F(Prt+2,14)*F(Prt+2,3))^2
6400  F(Prt+2,15)=M1/M2
6410  IF Prt=1 THEN GOTO 6750
6420  PRINT "AUXILIARY STD #1  PORT   2"
6430  PRINT "|Gg|","Ang g","Xg","Yg"
6440  PRINT F(3,11),F(3,12),F(3,13),F(3,14)
6450  PRINT
6460  PRINT "|G2|","ANG 2","X2","Y2"
6470  PRINT F(3,9),F(3,7),F(3,3),F(3,5)
6480  PRINT
6490  PRINT "AUXILIARY STD #2 PORT 0"
6500  PRINT "|Gg|","Ang g","Xg","Yg"
6510  PRINT F(4,11),F(4,12),F(4,13),F(4,14)
6520  PRINT
6530  PRINT "|G2|","ANG 2","X2","Y2"
6540  PRINT F(4,9),F(4,7),F(4,3),F(4,5)
6550  PRINT
6560  PRINTER IS 16
6570  LINPUT "CAL FREQ #",Cal$
6580  ON Init GOTO 6590,6650
6590  Cal$="AUX"&Cal$
6600  CREATE Cal$,20
6610  ASSIGN #3 TO Cal$
6620  PRINT #3;F(*)
6630  ASSIGN #3 TO *
6640  GOTO 6760
6650  Cal$="Cal"&Cal$
6660  CREATE Cal$,20
6670  ASSIGN #3 TO Cal$
6680  PRINT #3;F(*),Final(*)
6690  ASSIGN #3 TO *
6700  FOR I=1 TO 5
6710  PRINT "FREQ #";I,"MISMATCH FACTOR";Final(I)
```

```
6720  NEXT I
6730 ! RETURN
6740 PRINT
6750  NEXT Prt
6760  SUBEXIT
6770 ! ------------------------
6780 Ntime:! Gets new time from clock
6790 OUTPUT 9;"R"
6800 ENTER 9;Nt$
6810 Newt$=Nt$[7;5]
6820 RETURN
6830  !
6840 Refl:  ! REFLECTION COEFFICIENT MEASUREMENT ROUTINE
6850  IF Recal=1 THEN GOTO 6950
6860  PRINTER IS 16
6870  PRINT "DEVICE TO BE TESTED  (D. U. T. ) ON PORT 0 PRESS CONT"
6880 Q=FNB(6)
6890  PRINT "Zdiode"
6900  PRINT Zdiode(*)
6910  Recal=1
6920  Fr=1
6930  GOTO Zerdiode
6940 Resume: !
6950  OUTPUT 1003;"0","8","?",Pout$,"4","0"!30 IF PORT 3 AND 2-4 REFL
6960  OUTPUT 1003;"0","8","0",Pout$,"4","0"!30 IF PORT 0 AND 2-4 REFL  CC
6970  PRINT "CONNECT DEVICE TO BE MEASURED  AND PRESS CONTINUE"
6980 GOSUB Ntime
6990  PRINTER IS 0
7000 PRINT TAB(40);"DATE:";Date;" TIME:";Newt$
7010  F=F(Fr,1)
7020 LINPUT "DEVICE DESC",P$
7030  PRINT P$
7040  F9=Z(1,37)
7050  F1=F9
7060  F2=F9
7070  Cc=I1=16
7080  F3=1
7090  Fn=1
7100  M=1
7110  Ccc=3
7120  C=1
7130  P=3
7140  GOSUB Setpwr
7150 GOSUB Meas
7160  FOR Di=1 TO 4
7170  V1=C(Cc,Di,Fr)
7180  P(Cc,Di)=V1
7190  PRINTER IS 0
7200  PRINT P(Cc,Di)
7210 O=FNT(A,A8,A9,B,B8,B9,Cm,C8,C9,D,E,F,G,H,I,K,O,P,P(*),P3,P4,P5,P6,Q
     ,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3,X,Y,Z8,Fr,I1,G1i(*),G1r(*),G1(*)
     ,G1a(*),Pout$)
7220  PRINTER IS 16
7230  NEXT Di
7240  RETURN    !!!!!!!!!!!LOOP FREQ IN CALLING ROUTINE
```

```
7260 Open: ! CALCULATES R AND I PARTS AND ANG OF OPEN Z
7270  Fn=1
7280  PRINTER IS 0
7290  PRINT "FREQUENCY=";F(1,1);"MHZ"
7300  Co=.1635*1E-12
7310  FOR I=1 TO Fn
7320  F=F(Prt,1)*1E6
7330  Gr(I)=(1-(50*2*PI*F*Co)^2)/(1+(50*2*PI*F*Co)^2)
7340  Gi(I)=-100*2*PI*F*Co/(1+(50*2*PI*F*Co)^2)
7350  DEG
7360  Ang(I)=ATN(-100*2*PI*F*Co/(1-(50*2*PI*F*Co)^2))
7370  NEXT I
7380  RETURN
7390   !
7400   ! SUB Gamo CALCULATES SKIN DEPTH AND LOSS OF OFFSET SHORT VS FREQUENCY
7410   ! REFLECTION COEFFICIENT; ANGLE; REAL AND IMAGINARY PARTS ARE CALCULATED
         USING THE LOSS.
7420   ! SKD(*)=SKIN DEPTH VS FREQ
7430   ! Ac(*)=LOSS DB/CM VS FREQ
7440   ! Gam(*)=GAMMA OF OFFSET VS FREQ
7450   ! Ang(*)=GAMMA ANGLE OF OFFSET VS FREQ
7460   ! Gr(*)=REAL PART OF GAMMA VS FREQ
7470   ! Gi(*)=IMAGINARY PART OF GAMMA VS FREQ
7480 Gamo:    ! G1,G2=RE&IM Parts of Z-Std
7490  PRINTER IS 16
7500   DIM Skd(105),Ac(105)!,Ang(105),G 1(105),G2(105),Gam(105)
7510 ! Calculations for impedance std (offset short) 6 port reflectometer
7520 ! RE-SAVE"SUBG"!  June 30, 1982 0645
7530  ! ATTENUATION RESULTING FROM CONDUCTOR LOSSES
7540  PRINTER IS 16
7550  PRINT
7560  ! 7mm LINE IS CHARACTERIZED FOR GOLD; 14mm LINE FOR COPPER
7570 ! INPUT "1 FOR 7mm OR 2 FOR 14mm LINE",Line
7580  Line=2
7590  ON Line GOTO 7600,7630
7600  Lineloss=2.21*10^(-6)
7610  PRINT "7mm LINE (GOLD)"
7620  GOTO 7650
7630  Lineloss=1.72*10^(-6)
7640  PRINT "14mm LINE (COPPER)"
7650  I=0
7660  PRINT
7670  PRINT "  FREQ";"       SKIN DEPTH";"       LOSS DB/CM"
7680  PRINT
7690  F=Fc=F(Prt,1)*1E6
7700  Fn=1
7710  FOR Fr=1 TO Fn
7720  I=I+1
7730  Skd(Fr)=5033*SQR(Lineloss)/SQR(F)
7740  Mu=1
7750  E=SQR(1.0005)
7760  Or=1.42875/2
7770  Ir=.6203696/2
7780  Nn1=1/Or         !1/B
7790  Nn2=1+Or/Ir           !1+B/A
```

```
7800  N3=LOG(Or/Ir)              !ln(B/A)
7810  C=299793000*100 !CM/SEC
7820  Ft=F
7830  Ac(Fr)=13.6438*(Skd(Fr)*Mu/(C/Ft))*Nn1*Nn2*(E/N3)
7840  PRINT USING 7850;F/1E6,Skd(Fr),Ac(Fr)
7850  IMAGE 2X,4D,5X,MD.9D,5X,MD.9D
7860  IF I<>10 THEN GOTO 7890
7870  PRINT
7880  I=0
7890  NEXT Fr
7900  PRINT
7910  PRINT
7920  DEG
7930 ! INPUT "LENGTH OF OFFSET IN CM",L
7940  L=29979300000/3000000000/4
7950  FOR Fr=1 TO Fn
7960  Mult=C/Fc/360
7970  Delta=C/Fc/2-2*L
7980  IF Delta>0 THEN GOTO 8020
7990  IF Delta=0 THEN GOTO 8040
8000  Ang(Fr)=0-Delta/Mult
8010  GOTO 8050
8020  Ang(Fr)=0+Delta/Mult
8030  GOTO 8050
8040  Ang(Fr)=0
8050  Fc=F(Prt,1)
8060  NEXT Fr
8070  PRINTER IS 0
8080  PRINT "  FREQ  ";"  GAMMA";"     ANGLE";"        GAMMA R";"    GAMMA i"
8090  PRINT
8100  F=F(Prt,1)
8110  FOR I=1 TO Fn
8120  Loss=Ac(I)*2*L
8130  Gam(I)=10^(-Loss/20)
8140  G1(I)=Gam(I)
8150  G2(I)=Ang(I)
8160  Gr(I)=G1(I)*COS(G2(I))
8170  Gi(I)=G1(I)*SIN(G2(I))
8180  Gmag=SQR(Gr(I)^2+Gi(I)^2)
8190  PRINT USING 8200;F,Gam(I),Ang(I),Gr(I),Gi(I)
8200  IMAGE 2X,4D.DDD,2X,MD.5D,2X,M3D.2D,2X,MD.5D,2X,M3D.2D
8210  PRINT "CALCULATED MAGNITUDE IS:";Gmag
8220          !  F=F1+I*F3
8230  NEXT I
8240  RAD
8250  RETURN
8260  ! !*****************************************************************
8270  ! Calculation Functions
8280  !

S Cal(

A                  3500   4890   4910   4960   5030   5090   5170   5260
                   5310   5640   7210
```

A(	4130	4890	4960	5030	5090				
A1	4960	5090	5100	5130	5170				
A2	5090	5120	5130						
A8	5260	5270	5310	5640	7210				
A9	5260	5270	5310	5640	7210				
Ac(	7500	7830	7840	8120					
Ang(	4780	7360	8000	8020	8040	8150	8190		
B	4890	4910	4960	5030	5090	5170	5260		
	5310	5640	7210						
B'(	4130	4890	4960	5030	5090				
B1	4960	5090	5100	5130	5170				
B2	5090	5120	5130						
B8	5170	5180	5180	5190	5190	5260	5310	5640	
	7210								
B9	5170	5180	5180	5190	5190	5260	5310	5640	
	7210								
C	1680	1950	3620	7120	7810	7830	7960	7970	
C(	1350	3200	3250	3250	3250	3250	3360	3360	
	3360	3360	3620	3670	3680				
	3680	3700	3710	3710	3750	3750	4500	4510	
	4520	4530	4550	4560					
	4570	4580	7170						
C1	4960	5090	5100	5130	5170				
C2	5090	5120	5130						
C8	5170	5210	5210	5220	5220	5260	5310		
	5640	7210							
C9	5170	5210	5210	5220	5220	5260	5310		
	5640	7210							
Cal	1440	1450	1480	2060	3120	3310	3330		
	3410	3640	3660	3680	3710	3740			
	4620	4770							
Cal$	6570	6590	6590	6600	6610	6650	6650	6660	6670
Cal2:	1460								

Calz:	4100	3480							
Cc	1690	1960	2100	2130	2250	2260	2310		
	2400	2490	2650	2650	2710	2790	2940		
	2940	3620	3670	3680	3680	3700	3710		
	3710	3740	3750	3750	4460	4500	4500		
	4510	4510	4520	4520	4530	4530	4550		
	4550	4560	4560	4570	4570	4580	4580		
	4590	5630	7070	7170	7180	7200			
Ccc	1700	1970	3520	3580	3630	3820	3840	7110	
Ck	3340	3360	3360	3360	3360	3380			
Cm	4890	4910	4960	5030	5090	5170	5260	5640	
	7210								
Cm(	4130	4890	4960	5030	5090				
Co	7300	7330	7330	7340	7340	7360	7360		
Cp	2480	2660	2780	2950	3090				
D	3510	3550	3560	3770	4890	4960	5090		
	5170	5260	5640	7210					
D$	1390	2600	2610	2710	2890	2900			
Date	4180	4380	7000						
Delta	7970	7980	7990	8000	8020				
Di	3550	3620	3640	3670	3680	3680	3680		
	3700	3710	3710	3710	3750	3750	7160		
	7170	7180	7200	7230					
Dvm	4270								
E	4890	4960	5090	5170	5260	5640	7210	7750	7830
F	1590	3840	3880	3890	4320	4730	4890	4910	
	4960	5090	5170	5260	5640	7010	7210	7320	
	7330	7330	7340	7340	7360	7360	7690	7730	
	7820	7840	8100	8190					
F$	1400	3840							
F(	*	4310	4310	4320	4360	4730	4770	5670	
	5680	5690	5700	5710	5710	5720	5720	5730	
	5730	5740	5740	5760	5770	5780	5790	5910	
	5910	5920	5920	5920	5920	5920	5920	5920	
	5920	5930	5970	5970	5970	5970	5980	5980	
	5980	5980	5990	5990	5990	5990	6000	6000	
	6000	6050	6050	6050	6050	6080	6080	6080	

	6080	6100	6110	6120	6130	6180	6180	6180
	6180	6210	6210	6210	6210	6240	6260	6280
	6280	6290	6290	6310	6310	6310	6310	6320
	6320	6320	6320	6380	6380	6390	6390	6390
	6390	6390	6390	6390	6390	6400	6440	6440
	6440	6440	6470	6470	6470	6470	6510	6510
	6510	6510	6540	6540	6540	6540	6620	6680
	7010	7290	7320	7690	8050	8100		
F1	1550	1580	1590	1720	1990	2020	3430	3460
	3800	3880	4300	4310	4320	4360	7050	
F1$	3840							
F2	1560	1580	2000	2020	3440	3460	3800	7060
F3	1570	1580	2010	2020	3450	3460	3880	7080
F4	3880	3890						
F9	7040	7050	7060					
Fc	7690	7960	7970	8050				
File$	3160	3180						
Final(	*	6290	6300	6680	6710			
Fn	1580	1730	1740	2020	3230	3350	3460	3700
	3710	3710	3750	3800	3820	3830	4470	4550
	4560	4570	4580	4630	4640	4710	7090	7270
	7310	7700	7710	7950	8110			
Fnb(	2380							
Fnn	4630							
Fr	3230	3250	3250	3250	3250	3260	3350	3360
	3360	3360	3360	3370	3470	3620	3670	3680
	3680	3700	3710	3710	3740	3750	3750	3830
	3880	3900	4240	4360	4480	4710	4730	4740
	4750	4770	4780	4790	4890	4910	5030	5640
	6920	7010	7170	7210	7710	7730	7830	7830
	7840	7840	7890	7950	8000	8020	8040	8060
Ft	7820	7830						
Fz	4370	4470						
G	4890	4910	4960	5090	5170	5260	5310	5640
	7210							
G1	4740	4780	4780	5260				
G1(	8140	8160	8170					

G2	4750	4780	4780	5260				
G2(	8150	8160	8170					
Gam(	8130	8140	8190					
Gamo:	7480	4700						
Gi(	4750	7340	8170	8180	8190			
Gl(	1400	5640	5670	5760	5840	7210		
Gla(	1400	5640	5680	5770	5840	7210		
Gli(	1400	5640	5700	5790	5840	7210		
Glr(	1400	5640	5690	5780	5840	7210		
Gmag	8180	8210						
Goto	5470							
Gr(	4740	7330	8160	8180	8190			
H	4960	5090	5170	5260	5310	5640	7210	
I	3220	3250	3250	3250	3250	3270	4960	5030
	5090	5170	5260	5310	5640	5950	5970	5970
	5970	5970	5980	5980	5980	5980	5990	5990
	5990	5990	6000	6000	6000	6010	6700	6710
	6710	6720	7210	7310	7330	7340	7360	7370
	7650	7720	7720	7860	7880	8110	8120	8130
	8140	8140	8150	8150	8160	8160	8160	8170
	8170	8170	8180	8180	8190	8190	8190	8190
	8230							
Il	1540	5500	5510	5510	5530	5540	5550	5570
	5590	5600	5610	5620	5630	5640	5660	5800
	5870	7070	7210					
Imped	4650	4670						
Init	1350	2360	5490	5650	5900	6580		
Ir	7770	7790	7800					
It	5550							
J	4890	4960	5030	5090				
K	4890	4960	5030	5090	5170	5260	5640	7210
L	4960	5030	7940	7970	8120			

Line	7580	7590						
Lineloss	7600	7630	7730					
Loss	8120	8130						
M	1790	1940	2120	2200	2300	2390	2450	2640
	2750	2930	3840	3870	7100			
M1	2160	3810	5910	5930	6380	6400		
M2	5920	5930	6390	6400				
Meas:	3790	1810	2180	2270	2350	2430	2560	2720
	2850	3000	3110	7150				
Mismatchl:	5880							
Mone	6310	6330						
Mtwo	6320	6330						
Mu	7740	7830						
Mult	7960	8000	8020					
N	4890							
N1	2540	4220	4890	4960	5030	5090	5170	
N2	2830	4230	4960	5030	5090	5170		
N3	4960	5090	7800	7830				
Ndiode	1670							
Newt$	6810	7000						
Nn1	7780	7830						
Nn2	7790	7830						
Np	2470	2670	2770	2960	3100			
Nt$	6800	6810						
Ntime:	6780	6980						
Num	3130	3150	3150	3160				
O	4250	4890	4890	4910	4910	4960	4960	5030
	5030	5090	5170	5170	5260	5260	5310	5310
	5640	5640	7210	7210				
Open:	7260	4680						

Or	7760	7780	7790	7800					
P	1770	2030	2110	3930	4070	4890	4960	5030	
	5090	5170	5260	5640	7130	7210			
P$	3940	3960	3980	4000	4020	4040	4060	4070	
	4080	7020	7030						
P(	1390	4500	4510	4520	4530	4550	4560	4570	
	4580	4600	4600	4600	4600	4890	4960	5030	
	5090	5170	5260	5590	5600	5610	5620	5640	
	7180	7200	7210						
P0$	1350	1780	3840	4080					
P3	5090	5170	5260	5600	5640	7210			
P4	5090	5170	5260	5590	5640	7210			
P5	5090	5170	5260	5610	5640	7210			
P6	5090	5170	5260	5620	5640	7210			
Pa(	1400								
Pdiode(	1390								
Pout$	1500	1530	1750	1760	1840	1850	1900	1910	
	2070	2090	2370	4430	4450	5310	5400	5640	
	6950	6960	7210						
Pout$:	0	4450							
Prt	1450	4440	4450	4490	5310	5670	5680	5690	
	5700	5710	5710	5720	5720	5730	5730	5740	
	5740	5760	5770	5780	5790	5910	5910	5920	
	5920	5920	5920	5920	5920	5920	5920	5930	
	5940	6140	6380	6380	6390	6390	6390	6390	
	6390	6390	6390	6390	6400	6410	6750	7320	
	7690	8050	8100						
Q	2140	2220	2330	2380	2530	2620	2820	2910	
	3070	3850	4890	4960	5030	5090	5170	5260	
	5640	6880	7210	2590	2610	2880	2900	5090	
	5170	5260	5310	5640	7210				
R1	4960	4990	5030	5050	5090	5170	5260	5640	7210
R2	4960	4990	5030	5050	5090	5170	5260	5640	7210
Rcoef:	5380								
Recal	1470	1860	6850	6910					

Refl:	6840								
Resume:	6940	1860							
S	4960	5090	5170	5260	5640	7210			
S0	4960								
S1	4960								
S2	4960								
S3	5090	5170	5260	5640	7210				
S4	5090	5170	5260	5640	7210				
S5	5090	5170	5260	5640	7210				
S6	5090	5170	5260	5640	7210				
Scanner	4280								
Sel:	3490	3860							
Seq	2170	2240	2320	2410	2510	2800	3020	3080	3740
Set	4290	4310	4480	4500	4510	4520	4530	4550	4560
	6300	6330							
Setpwr:	3920	2040	7140						
Skd(	7500	7730	7830	7840					
Ss	2520	2580	2680	2680	2690	2700	2810	2860	
	2870	2970	2970	2980	2990				
Ss$	2580	2610	2710	2870	2900				
T	4960	5030	5090	5170	5260	5310	5640	7210	
T$	4170	4180	4180	4190					
Time$	4190	4380							
U(	4130								
V(	4130								
V1	3620	3640	3670	3700	7170	7180			
W(	4130	4890	4910	5030	5090				
W1	4960	4990	5030	5050	5090	5170	5260	5310	
	5640	7210							

W2	4960	4990	5030	5050	5090	5170	5260	5310
	5640	7210						
W3	4960	4990	5030	5050	5090	5170	5260	5310
	5640	7210						
X	5260	5310	5640	7210				
X(	4130	4890	4960	5030	5090			
Y	5260	5310	5640	7210				
Y(	4130	4890	4960	5030	5090			
Z$	1390							
Z(	1550	1560	1570	1720	1720	1990	2000	
	2010	3200	3430	3440	3450	4300	4300	4310
	4370	4370	4370	5400	6100	6110	6120	6130
	6300	6330	7040					
Z8	5640	7210						
Zdiode(	1390	1830	3200	3640	3680	3710	6900	
Zerdiode:	1640	1610	6930					
Zm(	4130	4960						

```
8290  DEF FNA(A,A(*),B,B(*),Cm,Cm(*),D,E,F,Fr,G,J,K,N,N1,O,P,P(*),Q,W(*)
      ,X(*),Y(*))
8300  ! DEF FNA(A,A(*),B,B(*),C,C(*),D,E,F,G,J,K,N,N1,O,P,P(*),Q,W(*)
      ,X(*),Y(*))
8320  OPTION BASE 1
8330  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
8340  COM File,Flag
8350  REDIM A(3,3),B(7,3),Cm(3,7),X(7,1),Y(3,1)
8360  N1=7
8370  N2=5
8380  F=0
8390  FOR J=1 TO N1
8400  K=J+2
8410  X(J,1)=P(K,2)
8420  F=F+X(J,1)
8430  B(J,1)=P(K,1)
8440  B(J,2)=P(K,3)
8450  B(J,3)=P(K,4)
8460  NEXT J
8470  N=3
8480  GOSUB 8780
8490  D=SQR(Cm(1,1)^2+Cm(2,1)^2+Cm(3,1)^2)
8500  P=Cm(1,1)/Cm(3,1)
8510  Q=Cm(2,1)/Cm(3,1)
8520  REDIM A(5,5),B(N1,5),Cm(5,N1),Y(5,1)
8530  F=0
8540  FOR J=1 TO N1
8550  K=J+2
8560  G=P(K,2)^2
8570  F=F+G
8580  X(J,1)=-G
8590  B(J,1)=P(K,1)^2
8600  B(J,2)=2*P(K,1)*P(K,3)
8610  B(J,3)=P(K,3)^2
8620  B(J,4)=2*P(K,1)*P(K,2)
8630  B(J,5)=2*P(K,3)*P(K,2)
8640  NEXT J
8650  N=5
8660  GOSUB 8780
8670  A=Cm(1,1)
8680  B=Cm(2,1)
8690  Cm=Cm(3,1)
8700  D=Cm(4,1)
8710  E=Cm(5,1)
8720  Ef(Fr)=E
8730  G=SQR(1-4*(A*Cm-B*B)*(1+P*P+Q*Q)/(Cm+Cm*P*P+A+A*Q*Q-2*B*P*Q)^2)
8740  PRINTER IS 16
8750  PRINT USING 8760;SQR((1+Gf(Fr))/(1-Gf(Fr)))
8760  IMAGE "RMAX/RMIN FOR 3D ELLIPSE=",DD.4D
8770  RETURN 0
8780  MAT Cm=TRN(B)
8790  MAT Y=Cm*X
8800  MAT A=Cm*B
8810  MAT A=INV(A)
```

```
8820  REDIM Cm(N,1)
8830  MAT Cm=A*Y
8840  REDIM A(N1,1),Y(1,N1)
8850  MAT A=B*Cm
8860  MAT A=A-X
8870  MAT Y=TRN(A)
8880  MAT W=Y*A
8890  RETURN
8900  !
8910  ! ----------------------------
```

FNA(

A	8290	8670	8730	8730	8730			
A(	8290	8350	8520	8800	8810	8810	8830	8840
	8850	8860	8860	8870	8880			
B	8290	8680	8730	8730	8730			
B(	8290	8350	8430	8440	8450	8520	8590	8600
	8610	8620	8630	8780	8800	8850		
Cm	8290	8690	8730	8730	8730			
Cm(	8290	8350	8490	8490	8490	8500	8500	8510
	8510	8520	8670	8680	8690	8700	8710	8780
	8790	8800	8820	8830	8850			
D	8290	8490	8700					
E	8290	8710	8720					
Ef(	8720							
F	8290	8380	8420	8420	8530	8570	8570	
Fr	8290	8720	8750	8750				
G	8290	8560	8570	8580	8730			
Gf(	8750	8750						
J	8290	8390	8400	8410	8420	8430	8440	8450
	8460	8540	8550	8580	8590	8600	8610	8620
	8630	8640	8290	8400	8410	8430	8440	8450
	8550	8560	8590	8600	8600	8610	8620	8620
	8630	8630						
N	8290	8470	8650	8820				
N1	8290	8360	8390	8520	8520	8540	8840	8840
N2	8370							

O	8290	8380	8770					
P	8290	8500	8730	8730	8730	8730	8730	
P(	8290	8410	8430	8440	8450	8560	8590	8600
	8600	8610	8620	8620	8630	8630		
Q	8290	8510	8730	8730	8730	8730	8730	
W(	8290	8880						
X(	8290	8350	8410	8420	8580	8790	8860	
Y(	8290	8350	8520	8790	8830	8840	8870	8880

```
8920  DEF FNBm(A,A(*),A1,B,B(*),B1,Cm,Cm(*),C1,D,E,F,G,H,I,J,K,L,N1,N2,N3
      ,O,P,P(*),Q,R1,R2,S,S0,S1,S2,T,W1,W2,W3,X(*),Y(*),Zm(*))
8930  OPTION BASE 1
8940  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
8950  COM File,Flag
8960  !  CALC R1,W1,R2,W2,W3--INPUT(A,B,C,D,E)**********************
8970  !  A1=RCS^2-RS^2
8980  !  B1,C1=RCSX,RCSY
8990  !  R1,R2=ZETA&RHO
9000  !  W1,W2,W3=ABS(W1),RE&IM(W2)
9010  F=A*Cm-B*B
9020  G=D
9030  H=E
9040  D=SQR(ABS(A-G*G)/F)
9050  A1=SQR(ABS(Cm-H*H)/F)
9060  A=(B*G-A*H)/F
9070  Cm=(B*H-Cm*G)/F
9080  B=(G*H-B)/F
9090  T=1E50
9100  N3=INT((N1+N2)/2)
9110  REDIM A(4,4),B(N3,4),Cm(4,N3),X(N3,1),Y(4,1)
9120  FOR I=1 TO N3
9130  J=2*I+1
9140  B(I,3)=P(J,4)
9150  B(I,4)=P(J,2)
9160  X(I,1)=P(J,1)
9170  NEXT I
9180  FOR K=1 TO 2
9190  FOR L=1 TO 2
9200  G=(Cm-A1)/(A-D)
9210  C1=(B-D*A1)/(A-D)
9220  H=SQR(C1)
9230  B1=(Cm+A1+2*C1-(A+D)*G)/4/H
9240  C1=SQR((Cm+A1)/2-B1*B1)
9250  FOR I=1 TO N3
9260  J=2*I+1
9270  P=(P(J,1)+H*H*P(J,2)-G*P(J,3))/H
9280  B(I,1)=P
9290  IF J<N1+2.5 THEN 9320
9300  B(I,2)=SQR(ABS(4*P(J,1)*P(J,2)-P*P))
9310  GOTO 9330
9320  B(I,2)=(A1*P(J,2)+P(J,1)-P*B1)/C1
9330  NEXT I
9340  MAT Cm=TRN(B)
9350  MAT Zm=Cm*X
9360  MAT A=Cm*B
9370  MAT A=INV(A)
9380  MAT Y=A*Zm
9390  Q=SQR(ABS(1+(Y(1,1)^2+Y(2,1)^2)/Y(4,1)))
9400  PRINT USING 9410;Q
9410  IMAGE Z.5D
9420  IF Q>T THEN 9490
9430  T=Q
9440  R1=G
```

```
9450  W1=H
9460  W2=Y(1,1)
9470  W3=Y(2,1)
9480  R2=Y(3,1)
9490  S=0
9500  FOR I=2 TO 2+N1+N2
9510  S0=(P(I,1)+H*H*P(I,2)-G*P(I,3))/H
9520  S1=P(I,1)
9530  S2=W2^2+W3^2
9540  S=S+((S0*W2+P(I,4)*R2-P(I,2)*S2-S1)^2-(4*S1*P(I,2)-S0^2)*W3^2)^2
9550  NEXT I
9560  D=-D
9570  NEXT L
9580  A1=-A1
9590  NEXT K
9600  RETURN 0
9610  !
9620  ! ---------------------------------
```

FNBm(

A	8920	9010	9040	9060	9060	9200	9210	9230	
A(	8920	9110	9360	9370	9370	9380			
A1	8920	9050	9200	9210	9230	9240	9320	9580	9580
B	8920	9010	9010	9060	9070	9080	9080	9210	
B(	8920	9110	9140	9150	9280	9300	9320	9340	9360
B1	8920	9230	9240	9240	9320				
C1	8920	9210	9220	9230	9240	9320			
Cm	8920	9010	9050	9070	9070	9200	9230	9240	
Cm(	8920	9110	9340	9350	9360				
D	8920	9020	9040	9200	9210	9210	9230	9560	9560
E	8920	9030							
F	8920	9010	9040	9050	9060	9070	9080		
G	8920	9020	9040	9040	9060	9070	9080	9200	
	9230	9270	9440	9510					
H	8920	9030	9050	9050	9060	9070	9080	9220	
	9230	9270	9270	9270	9450	9510	9510	9510	
I	8920	9120	9130	9140	9150	9160	9170	9250	
	9260	9280	9300	9320	9330	9500	9510	9510	
	9510	9520	9540	9540	9540	9550			

J	8920	9130	9140	9150	9160	9260	9270	9270	
	9270	9290	9300	9300	9320	9320			
K	8920	9180	9590						
L	8920	9190	9570						
N1	8920	9100	9290	9500					
N2	8920	9100	9500						
N3	8920	9100	9110	9110	9110	9120	9250		
O	8920	9600							
P	8920	9270	9280	9300	9300	9320			
P(	8920	9140	9150	9160	9270	9270	9270	9300	
	9300	9320	9320	9510	9510	9510	9520	9540	
	9540	9540							
Q	8920	9390	9400	9420	9430				
R1	8920	9440							
R2	8920	9480	9540						
S	8920	9490	9540	9540					
S0	8920	9510	9540	9540					
S1	8920	9520	9540	9540					
S2	8920	9530	9540						
T	8920	9090	9420	9430					
W1	8920	9450							
W2	8920	9460	9530	9540					
W3	8920	9470	9530	9540					
X(	8920	9110	9160	9350					
Y(	8920	9110	9380	9390	9390	9390	9460	9470	9480
Zm(	8920	9350	9380						

```
9630  DEF FNC(A,A(*),A1,A2,B,B(*),B1,B2,Cm,Cm(*),C1,C2,D,E,F,G,H,I,J,K,N1
      ,N2,N3,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W(*),W1,W2,W3,
      X(*),Y(*))
9640  OPTION BASE 1
9650  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
9660  COM File,Flag
9670  !  SOLVE FOR SLIDING SHORT & LOAD-INPUT P(),D7,D8,D9,E6,E7,E8,E9****
9680  !  OUT(A1,B1,C1,A2,B2,C2)
9700  REDIM A(3,3),B(N1,3),Cm(3,N1),X(N1,1),Y(3,1)
9710  PRINT "SS RESIDUES="
9720  N3=N1
9730  FOR I=3 TO N1+2
9740  J=I-2
9750  GOSUB 10030
9760  PRINT USING 9770;R
9770  IMAGE XD.DDEX
9780  NEXT I
9790  GOSUB 10090
9800  A1=Cm(1,1)
9810  B1=Cm(2,1)
9820  C1=Cm(3,1)
9830  PRINT USING 9840;"SS CIRCLE RESIDUAL="
      ,SQR(W(1,1)/N1)/(B1^2+C1^2-A1)/2
9840  IMAGE 19A,Z.6D
9850  REDIM A(3,3),B(N2,3),Cm(3,N2),X(N2,1),Y(3,1)
9860  N3=N2
9870  PRINT
9880  PRINT "SL RESIDUES="
9890  FOR I=N1+3 TO N1+N2+2
9900  J=I-N1-2
9910  GOSUB 10030
9920  PRINT USING 9770;R
9930  NEXT I
9940  GOSUB 10090
9950  A2=Cm(1,1)
9960  B2=Cm(2,1)
9970  C2=Cm(3,1)
9980  PRINT USING 9840;"SL CIRCLE RESIDUAL="
      ,SQR(W(1,1)/N2)/(B2^2+C2^2-A2)/2
9990  PRINT
10000 RETURN O
10030 O=FNG(A,B,C,D,E,F,G,H,I,K,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4
      ,S5,S6,T,W1,W2,W3,I1)
10040 X(J,1)=G*G+H*H
10050 B(J,1)=-1
10060 B(J,2)=2*G
10070 B(J,3)=2*H
10080 RETURN
10090 MAT Cm=TRN(B)
10100 MAT Y=Cm*X
10110 MAT A=Cm*B
10120 MAT A=INV(A)
10130 REDIM Cm(3,1)
10140 MAT Cm=A*Y
```

```
10150 REDIM A(N3,1),Y(1,N3)
10160 MAT A=B*Cm
10170 MAT A=A-X
10180 MAT Y=TRN(A)
10190 MAT W=Y*A
10200 RETURN
10210 !
10220 ! ------------------------------
```

```
FNC(


A                     9630  10030

A(                    9630   9700   9850  10110  10120  10120  10140  10150
                     10160  10170  10170  10180  10190

A1                    9630    00  10030

P                     9630  10030

P(                    9630  10030

P3                    9630  10030

P4                    9630  10030

P5                    9630  10030

P6                    9630  10030

Q                     9630  10030

R                     9630   9760   9920  10030

R1                    9630  10030

R2                    9630  10030

S                     9630  10030

S3                    9630  10030

S4                    9630  10030

S5                    9630  10030

S6                    9630  10030

T                     9630  10030

W(                    9630   9830   9980  10190

W1                    9630  10030
```

RAD7EF

W2	9630	10030						
W3	9630	10030						
X(	9630	9700	9850	10040	10100	10170		
Y(	9630	9700	9850	10100	10140	10150	10180	10190

```
10230 DEF FND(A,A1,B,B1,B8,B9,Cm,C1,C8,C9,D,E,F,G,H,I,K,N1,N2,O,P
      ,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3)
10240 OPTION BASE 1
10250 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
10260 COM File,Flag
10270 !  CALC B,(C/A)--INPUT(A1,B1,C1,A2,B2,C2)********************
10280 !  1/31/77 THIS MODIFIC FOR USE IF GAMMA SLIDING LOAD IS VERY SMALL**
10290 B8=0
10300 B9=0
10310 !  B8=RE(B),B9=IM(B)
10320 !  C8=RE(C/A),C9=IM(C/A)
10330 FOR I=N1+3 TO N1+N2+2
10340 O=FNG(A,B,Cm,D,E,F,G,H,I,K,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,S5,
      S6,T,W1,W2,W3,I1)
10350 B8=B8+G/N2
10360 B9=B9+H/N2
10370 NEXT I
10380 A=B1-B8
10390 B=B9-C1
10400 Cm=A1-B1*B8-C1*B9
10410 D=B1*B9-C1*B8
10420 E=Cm^2+D^2
10430 C8=(A*Cm+B*D)/E
10440 C9=(B*Cm-A*D)/E
10450 RETURN O
10460 !
10470 ! ----------------------------
```

FND(

A	10230	10340	10380	10430	10440		
A1	10230	10400					
B	10230	10340	10390	10430	10440		
B1	10230	10380	10400	10410			
B8	10230	10290	10350	10350	10380	10400	10410
B9	10230	10300	10360	10360	10390	10400	10410
C1	10230	10390	10400	10410			
C8	10230	10430					
C9	10230	10440					
Cm	10230	10340	10400	10420	10430	10440	
D	10230	10340	10410	10420	10430	10440	

E	10230	10340	10420	10430	10440
F	10230	10340			
G	10230	10340	10350		
H	10230	10340	10360		
I	10230	10330	10340	10370	
I1	10340				
K	10230	10340			
N1	10230	10330	10330		
N2	10230	10330	10350	10360	
O	10230	10340	10450		
P	10230	10340			
P(	10230	10340			
P3	10230	10340			
P4	10230	10340			
P5	10230	10340			
P6	10230	10340			
Q	10230	10340			
R	10230	10340			
R1	10230	10340			
R2	10230	10340			
S	10230	10340			
S3	10230	10340			
S4	10230	10340			
S5	10230	10340			
S6	10230	10340			
T	10230	10340			
W1	10230	10340			

RADZEF

W2	10230	10340
W3	10230	10340

```
10480 DEF FNE(A,A8,A9,B,B8,B9,Cm,C8,C9,D,E,F,G,G1,G2,H,I,K,O,
      P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3,X,Y)
10490 OPTION BASE 1
10500 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
10510 COM File,Flag
10520 !  CALC (1/A) INPUT(B8,B9,C8,C9,G1,G2,); OUT(A8,A9)*****
10530 I=2
10540 ! REVISED SUBROUTINE FOR Z CALC. -- INPUT P(*),B8,B9,C8,C9,D8,D9;
      OUTPUT A,B
10550 ! REVISED 1/28/77
10560 RAD
10570 O=FNG(A,B,Cm,D,E,F,G,H,I,K,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,
      S5, S6,T,W1,W2,W3,I1)
10580 Cm=G-B8
10590 D=H-B9
10600 E=1-G*C8+H*C9
10610 P=-H*C8-G*C9
10620 B=E^2+P^2
10630 A=(Cm*E+D*P)/B
10640 B=(D*E-Cm*P)/B
10650 IF I=2 THEN 10750
10660 X=A*A8-B*A9
10670 Y=A*A9+B*A8
10680 R=SQR(X*X+Y*Y)
10690 T=ATN(Y/X)*180/PI
10700 IF X>0 THEN 10750
10710 IF Y>0 THEN 10740
10720 T=T-180
10730 GOTO 10750
10740 T=T+180
10750 !  A8=RE(1/A),A9=IM(1/A)
10760 Cm=A^2+B^2
10770 A8=(A*G1+B*G2)/Cm
10780 A9=(A*G2-B*G1)/Cm
10790 PRINT "PAUSE 12352 A8;A9";A8,A9
10800 RETURN O
10810 !
10820 ! --------------------------------
```

FNE(

A	10480	10570	10630	10660	10670	10760	10770	10780
A8	10480	10660	10670	10770	10790			
A9	10480	10660	10670	10780	10790			
B	10480	10570	10620	10630	10640	10640	10660	10670
	10760	10770	10780					
B8	10480	10580						
B9	10480	10590						

C8	10480	10600	10610					
C9	10480	10600	10610					
Cm	10480	10570	10580	10630	10640	10760	10770	10780
D	10480	10570	10590	10630	10640			
E	10480	10570	10600	10620	10630	10640		
F	10480	10570						
G	10480	10570	10580	10600	10610			
G1	10480	10770	10780					
G2	10480	10770	10780					
H	10480	10570	10590	10600	10610			
I	10480	10530	10570	10650				
I1	10570							
K	10480	10570						
O	10480	10570	10800					
P	10480	10570	10610	10620	10630	10640		
P(	10480	10570						
P3	10480	10570						
P4	10480	10570						
P5	10480	10570						
P6	10480	10570						
Q	10480	10570						
R	10480	10570	10680					
R1	10480	10570						
R2	10480	10570						
S	10480	10570						
S3	10480	10570						
S4	10480	10570						

S5	10480	10570					
S6	10480	10570					
T	10480	10570	10690	10720	10720	10740	10740
W1	10480	10570					
W2	10480	10570					
W3	10480	10570					
X	10480	10660	10680	10680	10690	10700	
Y	10480	10670	10680	10680	10690	10710	

```
10830 DEF FNF(A,A8,A9,B,B8,B9,Cm,C8,C9,D,E,E4,E5,F,F3,G,G5,H,I,K,N3,
      O,P,P(*),P2,P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3,Z1,
      Z2,Z3)
10840 OPTION BASE 1
10850 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
10860 COM File,Flag
10880 Cm=A8^2+A9^2
10890 D=Cm-C8*C8-C9*C9
10900 Z1=(B8*Cm-C8)/D
10910 Z2=(B9*Cm+C9)/D
10920 Z3=((1-B8*C8+B9*C9)^2+(B8*C9+B9*C8)^2)*Cm/D/D
10930 I=1
10940 O=FNG(A,B,Cm,D,E,F,G,H,I,K,O,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,
      S4,S5,S6,T,
W1,W2,W3)
10950 !  NET POWER IN STD=G5
10960 G5=P2/N3
10970 F3=1-((G-Z1)^2+(H-Z2)^2)/Z3
10980 E4=G5/F/F3
10990 E5=G5/P(1,2)/F3
11000 RETURN O
11010 !SUBROUTINE FOR Z CALC.-INPUT P(*),B8,B9,C8,C9,D8,D9;OUTPUT A,B
11020 !  REVISED 1/28/77
11030 O=FNG(A,B,Cm,D,E,F,G,H,I,K,O,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,
      S5,S6,T,W1,W2,W3)
11040 Cm=G-B8
11050 D=H-B9
11060 E=1-G*C8+H*C9
11070 P=-H*C8-G*C9
11080 B=E^2+P^2
11090 A=(Cm*E+D*P)/B
11100 B=(D*E-Cm*P)/B
11110 IF I=2 THEN 11210
11120 X=A*A8-B*A9
11130 Y=A*A9+B*A8
11140 R=SQR(X*X+Y*Y)
11150 T=ATN(Y/X)*180/PI
11160 IF X>0 THEN 11210
11170 IF Y>0 THEN 11200
11180 T=T-180
11190 GOTO 11210
11200 T=T+180
11210 RETURN
11220 !
11230 ! ------------------------------
```

```
FNF(


A                 10830  10940  11030  11090  11120  11130

A8                10830  10880  11120  11130

A9                10830  10880  11120  11130
```

B	10830	10940	11030	11080	11090	11100	11100	11120
	11130							
B8	10830	10900	10920	10920	11040			
B9	10830	10910	10920	10920	11050			
C8	10830	10890	10890	10900	10920	10920	11060	11070
C9	10830	10890	10890	10910	10920	10920	11060	11070
Cm	10830	10880	10890	10900	10910	10920	10940	11030
	11040	11090	11100					
D	10830	10890	10900	10910	10920	10920	10940	11030
	11050	11090	11100					
E	10830	10940	11030	11060	11080	11090	11100	
E4	10830	10980						
E5	10830	10990						
F	10830	10940	10980	11030				
F3	10830	10970	10980	10990				
G	10830	10940	10970	11030	11040	11060	11070	
G5	10830	10960	10980	10990				
H	10830	10940	10970	11030	11050	11060	11070	
I	10830	10930	10940	11030	11110			
K	10830	10940	11030					
N3	10830	10960						
O	10830	10940	10940	11000	11030	11030		
P	10830	10940	11030	11070	11080	11090	11100	
P(	10830	10940	10990	11030				
P2	10830	10960						
P3	10830	10940	11030					
P4	10830	10940	11030					
P5	10830	10940	11030					
P6	10830	10940	11030					

Q	10830	10940	11030					
R	10830	10940	11030	11140				
R1	10830	10940	11030					
R2	10830	10940	11030					
S	10830	10940	11030					
S3	10830	10940	11030					
S4	10830	10940	11030					
S5	10830	10940	11030					
S6	10830	10940	11030					
T	10830	10940	11030	11150	11180	11180	11200	11200
W1	10830	10940	11030					
W2	10830	10940	11030					
W3	10830	10940	11030					
X	11120	11140	11140	11150	11160			
Y	11130	11140	11140	11150	11170			
Z1	10830	10900	10970					
Z2	10830	10910	10970					
Z3	10830	10920	10970					

```
11240 DEF FNH(A,A8,A9,B,B8,B9,C8,C9,G,H,I,O,R,T,W1,W2,W3,X,Y,Prt,Pout$)
11250 !   CALC ORIG PARAMETERS*************
11260 OPTION BASE 1
11270 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
11280 COM File,Flag
11290 PRINTER IS 16
11300 I=0
11310 PRINTER IS 0
11320 PRINT
11330 PRINT "FREQUENCY =";F(1,1)
11340 X=A9*B9-A8*B8
11350 Y=-A8*B9-A9*B8
11360 Gjc=3
11370 GOSUB 11960
11380 PRINT USING 11390;" Q5=",R,T
11390 IMAGE 11A,XZ.5DX,XM3D.DD
11400 ! PRINT "10285 -B/A Q3REAL AND IMAG"
11410 ! PRINT "REAL";Qr(3);"IMAG";Qi(3)
11420 A=A8*A8+A9*A9
11430 X=-(A8*C8+A9*C9)/A
11440 Y=(A9*C8-A8*C9)/A
11450 ! PRINT X,Y
11460 Gjc=4
11470 GOSUB 11960
11480 PRINT USING 11390;" G 2I=";R,T
11490 IF VAL(Pout$)<>2 THEN GOTO 11560
11500 F(1,9)=R
11510 F(1,7)=T
11520 DEG
11530 F(1,3)=F(1,9)*COS(F(1,7))
11540 F(1,5)=F(1,9)*SIN(F(1,7))
11550 RAD
11560 F(2,9)=R
11570 F(2,7)=T
11580 DEG
11590 F(2,3)=F(2,9)*COS(F(2,7))
11600 F(2,5)=F(2,9)*SIN(F(2,7))
11610 RAD
11620 Gjc=5
11630 G=W1
11640 H=0
11650 GOSUB 11860
11660 Qr(5)=X
11670 Qi(5)=Y
11680 ! PRINT "10553 -F/E Q5 REAL AND IMAG"
11690 ! PRINT "REAL";Qr(5);"IMAG";Qi(5)
11700 PRINT USING 11390;" Q6=";R,T
11710 G=W2
11720 H=W3
11730 Gjc=6
11740 GOSUB 11860
11750 Qr(6)=X
11760 Qi(6)=Y
11770 ! PRINT "10403 -H/G Q6 REAL AND IMAG"
```

```
11780 ! PRINT "REAL";Qr(6);"IMAG";Qi(6)
11790 PRINT USING 11390;" Q3=";R,T
11800 PRINT
11810 PRINTER IS 16
11820 RETURN O
11830 !SUBROUTINE FOR Z CALC.-INPUT P(*),B8,B9,C8,C9,D8,D9;OUTPUT A,B
11840 !REVISED 1/28/79
11850 O=FNG(O)
11860 Cm=G-B8
11870 D=H-B9
11880 E=1-G*C8+H*C9
11890 P=-H*C8-G*C9
11900 B=E^2+P^2
11910 A=(Cm*E+D*P)/B
11920 B=(D*E-Cm*P)/B
11930 IF I=2 THEN 12050
11940 X=A*A8-B*A9
11950 Y=A*A9+B*A8
11960 R=SQR(X*X+Y*Y)
11970 T=ATN(Y/X)*180/PI
11980 Qr(Gjc)=X
11990 Qi(Gjc)=Y
12000 IF X>0 THEN 12050
12010 IF Y>0 THEN 12040
12020 T=T-180
12030 GOTO 12050
12040 T=T+180
12050 RETURN
12060 !
12070 ! ------------------------------
```

FNH(

A	11240	11420	11430	11440	11910	11940	11950	
A8	11240	11340	11350	11420	11420	11430	11440	11940
	11950							
A9	11240	11340	11350	11420	11420	11430	11440	11940
	11950							
B	11240	11900	11910	11920	11920	11940	11950	
B8	11240	11340	11350	11860				
B9	11240	11340	11350	11870				
C8	11240	11430	11440	11880	11890			
C9	11240	11430	11440	11880	11890			
Cm	11860	11910	11920					
D	11870	11910	11920					

E	11880	11900	11910	11920				
F(	*	11330	11500	11510	11530	11530	11530	11540
	11540	11540	11560	11570	11590	11590	11590	11600
	11600	11600						
G	11240	11630	11710	11860	11880	11890		
Gjc	11360	11460	11620	11730	11980	11990		
H	11240	11640	11720	11870	11880	11890		
I	11240	11300	11930					
O	11240	11820	11850	11850				
P	11890	11900	11910	11920				
Pout$	11240	11490						
Prt	11240							
Qi(	*	11670	11760	11990				
Qr(	*	11660	11750	11980				
R	11240	11380	11480	11500	11560	11700	11790	11960
T	11240	11380	11480	11510	11570	11700	11790	11970
	12020	12020	12040	12040				
W1	11240	11630						
W2	11240	11710						
W3	11240	11720						
X	11240	11340	11430	11660	11750	11940	11960	11960
	11970	11980	12000					
Y	11240	11350	11440	11670	11760	11950	11960	11960
	11970	11990	12010					

```
12080 DEF FNI(A,B,Cm,F,G,O,W(*),Fr)
12090 !  CALC&PRINT RMAX/RMIN FOR ELLIPSE INPUT (A,B,C)*********
12100 OPTION BASE 1
12110 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
12120 COM File,Flag
12130 PRINT USING 12140;SQR(W(1,1)/F)
12140 IMAGE "COV ELLIPSE=",Z.5D
12150 RETURN O
12160 !
12170 ! ------------------------------
```

FNI(

A	12080	
B	12080	
Cm	12080	
F	12080	12130
Fr	12080	
G	12080	
O	12080	12150
W(	12080	12130

```
12180 DEF FNL(A,A(*),B,B(*),Cm,Cm(*),Fr,I,J,K,L,N1,N2,O,P,P(*),Q,
      R1,R2,T,W(*),W1,W2,W3,X(*),Y(*))
12190 OPTION BASE 1
12200 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
12210 COM File,Flag
12220 !  SOLVE REDUNDANCY EQUATION************
12230 W3=W3*W3
12240 PRINT "RESIDUAL FROM REDUNDANCY EQN="
12250 REDIM A(5,5),B(1+N1+N2,5),X(1+N1+N2,1),Y(5,1)
12260 T=1E50
12270 FOR K=1 TO 10
12280 FOR I=1 TO 1+N1+N2
12290 J=I+1
12300 A=(R1*P(J,3)-P(J,1))/W1-W1*P(J,2)
12310 B=P(J,1)+(W2*W2+W3)*P(J,2)+A*W2-R2*P(J,4)
12320 Cm=A*A-4*P(J,1)*P(J,2)
12330 P=2*(B*W2+A*W3)
12340 X(I,1)=B*B+W3*Cm
12350 B(I,1)=P*P(J,3)/W1
12360 B(I,2)=P*(-A/W1-2*P(J,2))
12370 B(I,3)=-2*B*P(J,4)
12380 B(I,4)=2*B*(2*W2*P(J,2)+A)
12390 B(I,5)=2*B*P(J,2)+Cm
12400 NEXT I
12410 REDIM A(1,N1+N2+1)
12420 MAT A=TRN(X)
12430 MAT W=A*X
12440 Q=SQR(W(1,1))
12450 PRINT USING 12460;Q
12460 IMAGE Z.5D
12470 IF Q>T THEN 12670
12480 IF Q/T>.99 THEN 12650
12490 T=Q
12500 REDIM A(5,5),Cm(5,1+N1+N2)
12510 L=0
12520 MAT Cm=TRN(B)
12530 MAT Y=Cm*X
12540 MAT A=Cm*B
12550 MAT A=INV(A)
12560 REDIM Cm(5,1)
12570 MAT Cm=A*Y
12580 R1=R1-Cm(1,1)
12590 W1=W1-Cm(2,1)
12600 R2=R2-Cm(3,1)
12610 W2=W2-Cm(4,1)
12620 W3=W3-Cm(5,1)
12630 NEXT K
12640 !  FOR REVERSED P3&P5 CHANGE SIN OF E7
12650 W3=SQR(W3)
12660 RETURN O
12670 L=L+1
12680 IF L>3.5 THEN 12650
12690 R1=R1+C(1,1)/3
12700 W1=W1+Cm(2,1)/3
```

```
12710 R2=R2+Cm(3,1)/3
12720 W2=W2+Cm(4,1)/3
12730 W3=W3+Cm(5,1)/3
12740 GOTO 12280
12750 !
12760 ! ----------------------------
```

FNL(

A	12180	12300	12310	12320	12320	12330	12360	12380
A(	12180	12250	12410	12420	12430	12500	12540	12550
	12550	12570						
B	12180	12310	12330	12340	12340	12370	12380	12390
B(	12180	12250	12350	12360	12370	12380	12390	12520
	12540							
C(	12690							
Cm	12180	12320	12340	12390				
Cm(	12180	12500	12520	12530	12540	12560	12570	12580
	12590	12600	12610	12620	12700	12710	12720	12730
Fr	12180							
I	12180	12280	12290	12340	12350	12360	12370	12380
	12390	12400						
J	12180	12290	12300	12300	12300	12310	12310	12310
	12320	12320	12350	12360	12370	12380	12390	
K	12180	12270	12630					
L	12180	12510	12670	12670	12680			
N1	12180	12250	12250	12280	12410	12500		
N2	12180	12250	12250	12280	12410	12500		
O	12180	12660						
P	12180	12330	12350	12360				
P(	12180	12300	12300	12300	12310	12310	12310	12320
	12320	12350	12360	12370	12380	12390		
Q	12180	12440	12450	12470	12480	12490		
R1	12180	12300	12580	12580	12690	12690		
R2	12180	12310	12600	12600	12710	12710		

T	12180	12260	12470	12480	12490			
W(	12180	12430	12440					
W1	12180	12300	12300	12350	12360	12590	12590	12700
	12700							
W2	12180	12310	12310	12310	12330	12380	12610	12610
	12720	12720						
W3	12180	12230	12230	12230	12310	12330	12340	12620
	12620	12650	12650	12730	12730			
X(	12180	12250	12340	12420	12430	12530		
Y(	12180	12250	12530	12570				

```
12770 DEF FNG(A,B,Cm,D,E,F,G,H,I,K,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,
      S4,S5,S6,T,W1,W2,W3,I1)
12780 OPTION BASE 1
12790 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
12800 COM File,Flag
12810 !APPLY LEAST SQUARES TO DATA, IN(KLMNO),OUT B4^2,RE&IM(B3/B4)
12820 !  F=(B4^2),G,H=RE&IM(B3/B4)
12830 IF I1=1 THEN GOTO 12850
12840 GOTO 12860
12850 I=I1
12860 P3=P(I,1)  ! P5 on 6port
12870 P4=P(I,2)
12880 P5=P(I,3)  ! P6 on 6port
12890 P6=P(I,4)  ! P3 on 6port
12900 IF I>15 THEN 12930
12910 PRINTER IS 16
12920 GOTO 12940
12930 PRINTER IS 16
12940 PRINT P(I,4),P(I,1),P(I,3),P(I,2)
12950 PRINTER IS 16
12960 S=(P3+P4+P5+P6)/100
12970 S3=S+P3
12980 S4=S+P4
12990 S5=S+P5
13000 S6=S+P6
13010 G=(W1+(P3-R1*P5)/P4/W1)/2
13020 H=((W2*W2+W3*W3+(P3-R2*P6)/P4)/2-G*W2)/W3
13030 P3=P3/S3
13040 P4=P4/S4
13050 P5=P5*R1/S5
13060 P6=P6*R2/S6
13070 P=P3*P3+P4*P4+P5*P5+P6*P6
13080 T=1E50
13090 FOR K=1 TO 6
13100 Cm=(G*G+H*H)/S3
13110 D=((G-W1)^2+H*H)/S5
13120 E=((G-W2)^2+(H-W3)^2)/S6
13130 F=P/(Cm*P3+P4/S4+D*P5+E*P6)
13140 Cm=Cm-P3/F
13150 D=D-P5/F
13160 E=E-P6/F
13170 R=SQR(((1-P(I,2)/F)/S4)^2+Cm*Cm+D*D+E*E)/S/25
13180 IF R/T>.99 THEN 13310
13190 T=R
13200 Q=Cm/S3+D/S5+E/S6
13210 A=G*Q-W1*D/S5-W2*E/S6
13220 B=H*Q-W3*E/S6
13230 D=G*P3/S3+(G-W1)*P5/S5+(G-W2)*P6/S6
13240 E=H*P3/S3+H*P5/S5+(H-W3)*P6/S6
13250 Cm=Q+2*((G/S3)^2+((G-W1)/S5)^2+((G-W2)/S6)^2-D*D/P)
13260 D=2*(G*H/S3/S3+(G-W1)*H/S5/S5+(G-W2)*(H-W3)/S6/S6-D*E/P)
13270 E=Q+2*(H*(H/S3/S3+H/S5/S5)+((H-W3)/S6)^2-E*E/P)
13280 G=G-(A*E-B*D)/(Cm*E-D*D)
13290 H=H-(B*Cm-A*D)/(Cm*E-D*D)
```

```
13300 NEXT K
13310 RETURN 0
13320 !
13330 ! -------------------------
```

FNG(

A	12770	13210	13280	13290				
B	12770	13220	13280	13290				
Cm	12770	13100	13130	13140	13140	13170	13170	13200
	13250	13280	13290	13290				
D	12770	13110	13130	13150	13150	13170	13170	13200
	13210	13230	13250	13250	13260	13260	13280	13280
	13280	13290	13290	13290				
E	12770	13120	13130	13160	13160	13170	13170	13200
	13210	13220	13240	13260	13270	13270	13270	13280
	13280	13290						
F	12770	13130	13140	13150	13160	13170		
G	12770	13010	13020	13100	13100	13110	13120	13210
	13230	13230	13230	13250	13250	13250	13260	13260
	13260	13280	13280					
H	12770	13020	13100	13100	13110	13110	13120	13220
	13240	13240	13240	13260	13260	13260	13270	13270
	13270	13270	13290	13290				
I	12770	12850	12860	12870	12880	12890	12900	12940
	12940	12940	12940	13170				
I1	12770	12830	12850					
K	12770	13090	13300					
P	12770	13070	13130	13250	13260	13270		
P(	12770	12860	12870	12880	12890	12940	12940	12940
	12940	13170						
P3	12770	12860	12960	12970	13010	13020	13030	13030
	13070	13070	13130	13140	13230	13240		
P4	12770	12870	12960	12980	13010	13020	13040	13040
	13070	13070	13130					
P5	12770	12880	12960	12990	13010	13050	13050	13070
	13070	13130	13150	13230	13240			

P6	12770	12890	12960	13000	13020	13060	13060	13070
	13070	13130	13160	13230	13240			
Q	12770	13200	13210	13220	13250	13270		
R	12770	13170	13180	13190				
R1	12770	13010	13050					
R2	12770	13020	13060					
S	12770	12960	12970	12980	12990	13000	13170	
S3	12770	12970	13030	13100	13200	13230	13240	13250
	13260	13260	13270	13270				
S4	12770	12980	13040	13130	13170			
S5	12770	12990	13050	13110	13200	13210	13230	13240
	13250	13260	13260	13270	13270			
S6	12770	13000	13060	13120	13200	13210	13220	13230
	13240	13250	13260	13260	13270			
T	12770	13080	13180	13190				
W1	12770	13010	13010	13110	13210	13230	13250	13260
W2	12770	13020	13020	13020	13120	13210	13230	13250
	13260							
W3	12770	13020	13020	13020	13120	13220	13240	13260
	13270							

```
13340 DEF FNT(A,A8,A9,B,B8,B9,Cm,C8,C9,D,E,F,G,H,I,K,O,P,P(*),P3,P4,
      P5,P6,Q,R,R1,R2,S,S3,S4,S5,S6,T,W1,W2,W3,X,Y,Z8,Fr,I1,Gli(*),
      Glr(*),Gl(*),Gla(*),Pout$)
13350 OPTION BASE 1
13360 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
13370 COM File,Flag
13380 IF I1>1 THEN I=I1
13390 GOSUB 13530
13400 PRINTER IS 16
13410 PRINT "  PORT","MAG(REFL COEF)","ARG(REFL COEF)"
13420 PRINT USING 13490;VAL(Pout$),R,T
13430 DEG
13440 Gl(I1)=R
13450 Gla(I1)=T
13460 Glr(I1)=COS(T)*R
13470 Gli(I1)=SIN(T)*R
13480 RAD
13490 IMAGE XM4D,14XZ.5D,11XM3D.3D
13500 Z8=R
13510 PRINTER IS 16
13520 RETURN O
13540 O=FNG(A,B,Cm,D,E,F,G,H,I,K,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,S4,
      S5,S6,T,W1
,W2,W3,I1)
13550 Cm=G-B8
13560 D=H-B9
13570 E=1-G*C8+H*C9
13580 P=-H*C8-G*C9
13590 B=E^2+P^2
13600 A=(Cm*E+D*P)/B
13610 B=(D*E-Cm*P)/B
13620 IF I=2 THEN 13720
13630 X=A*A8-B*A9
13640 Y=A*A9+B*A8
13650 R=SQR(X*X+Y*Y)
13660 T=ATN(Y/X)*180/PI
13670 IF X>0 THEN 13720
13680 IF Y>0 THEN 13710
13690 T=T-180
13700 GOTO 13720
13710 T=T+180
13720 RETURN
13730 !
13740 ! ---------------------------
```

FNT(

A	13340	13540	13600	13630	13640
A8	13340	13630	13640		
A9	13340	13630	13640		

B	13340	13540	13590	13600	13610	13610	13630	13640
B8	13340	13550						
B9	13340	13560						
C8	13340	13570	13580					
C9	13340	13570	13580					
Cm	13340	13540	13550	13600	13610			
D	13340	13540	13560	13600	13610			
E	13340	13540	13570	13590	13600	13610		
F	13340	13540						
Fr	13340							
G	13340	13540	13550	13570	13580			
G1(	13340	13440						
G1a(	13340	13450						
G1i(	13340	13470						
G1r(	13340	13460						
H	13340	13540	13560	13570	13580			
I	13340	13380	13540	13620				
I1	13340	13380	13380	13440	13450	13460	13470	13540
K	13340	13540						
O	13340	13520	13540					
P	13340	13540	13580	13590	13600	13610		
P(	13340	13540						
P3	13340	13540						
P4	13340	13540						
P5	13340	13540						
P6	13340	13540						
Pout$	13340	13420						
Q	13340	13540						

R	13340	13420	13440	13460	13470	13500	13540	13650
R1	13340	13540						
R2	13340	13540						
S	13340	13540						
S3	13340	13540						
S4	13340	13540						
S5	13340	13540						
S6	13340	13540						
T	13340	13420	13450	13460	13470	13540	13660	13690
	13690	13710	13710					
W1	13340	13540						
W2	13340	13540						
W3	13340	13540						
X	13340	13630	13650	13650	13660	13670		
Y	13340	13640	13650	13650	13660	13680		
Z8	13340	13500						

```
13750 DEF FNU(A,B,Cm,D,E,F,F3,G,H,I,K,O,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,
      S,S3,S4,S5,S6,T,W1,W2,W3,Z1,Z2,Z3)
13760 OPTION BASE 1
13770 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
13780 COM File,Flag
13790 !  SOLUTION FOR NET POWER
13800 O=FNG(A,B,Cm,D,E,F,G,H,I,K,O,P,P(*),P3,P4,P5,P6,Q,R,R1,R2,S,S3,
      S4,S5,S6,T,W1,W2,W3)
13810 F3=1-((G-Z1)^2+(H-Z2)^2)/Z3
13820 RETURN O
13830 RE-SAVE "CORR",13830,15760!22 MARCH 1983 0930 GJC
```

FNU(

A	13750	13800	
B	13750	13800	
Cm	13750	13800	
D	13750	13800	
E	13750	13800	
F	13750	13800	
F3	13750	13810	
G	13750	13800	13810
H	13750	13800	13810
I	13750	13800	
K	13750	13800	
O	13750	13800	13800
P	13750	13800	
P(	13750	13800	
P3	13750	13800	
P4	13750	13800	
P5	13750	13800	
P6	13750	13800	
Q	13750	13800	
R	13750	13800	

RAD7EF

R1	13750	13800
R2	13750	13800
S	13750	13800
S3	13750	13800
S4	13750	13800
S5	13750	13800
S6	13750	13800
T	13750	13800
W1	13750	13800
W2	13750	13800
W3	13750	13800
Z1	13750	13810
Z2	13750	13810
Z3	13750	13810

```
13840 SUB Corr1(C1,P0,E7,E8,Q(*),Aet)
13850 OPTION BASE 1
13860 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
13870  COM File,Flag
13880  DIM A$[100]
13890  F1=Z(1,37)
13900  F2=Z(1,38)
13910  F3=Z(1,39)
13920  N3=5
13930  N8=2
13940  PRINT N8,N3,"N8,N3"
13950  PRINTER IS 0
13960  PRINT "*****************************************************************"
13970 PRINT
13980 IF P0=2 THEN GOTO 14000
13990 PRINT "PLACE STANDARDS ON PORTS 2 AND 0,PRESS CONTINUE"
14000 OUTPUT 9;"R"
14010 ENTER 9;P$
14020 PRINT TAB(20),"DATE:";P$[1,2];"-";P$[4,5];"-1982";"    TIME:";P$[7,14]
14030 PRINT
14040 PRINTER IS 16
14050 Z9=T7=T8=T9=P7=P8=P9=0
14060 W4=W5=W6=0
14070 !
14080 C=0
14090 M=1  !SET VALUE FOR Freq SUBROUTINE
14100  Fn=(Z(1,38)-Z(1,37))/Z(1,39)+1
14110  PRINT Fn
14120 P0$="N0M2L5K5"
14130 F1=F1*10^6
14140 F=F1
14150 OUTPUT 704;"00H0"&VAL$(F1)&P0$
14160 ! CALL Freq(F,F$,F1$,P0$,M,Ccc)
14170 PRINT F,F1
14180 M=2
14190 X8=V2=T1=T8=T9=T7=P7=P8=P9=P4=P5=P6=W4=W5=W6=W1=W2=W3=Z=0
14200 FOR J8=1 TO N8+1
14210 T1=T4=V2=P4=P5=P6=W1=W2=W3=0
14220 PRINTER IS 0
14230 FOR Z2=1 TO N3
14240 IF P0=0 THEN P0=1
14250 CALL Power(P1,P2,P3,P0,Aet)            !CALL POWER SUBROUTINE
14260 Y1=P1/P2
14270 Y3=P3/P2
14280 X8=(Y3-1)/(Y1-1)
14290 IF J8=1 THEN GOTO 14380
14300 IF ABS(X8-E9)>.560 THEN GOTO 14330
14310 GOTO 14350
14320 PRINTER IS 16
14330 PRINT "DEV EXCEEDS";E9;"REPEATING MEASUREMENT"
14340 GOTO 14250
14350 PRINTER IS 16
14360 PRINT E9
14370 PRINTER IS 0
```

```
14380 PRINT X8;P1*1000;P2*1000;P3*1000
14390 IF J8=1 THEN 14430
14400 Z=Z-1
14410 ! PAUSE
14420 PRINTER IS 0
14430 T1=T1+X8                                    !SUM OF Tx
14440 T4=T4+(T3-Y3*T2)/(Y3-1)                      !SUM OF Te
14450 DISP "T4",T4
14460 V2=V2+X8*X8                                 !SUM Tx^2
14470 P4=P4+P1                                    !SUM P1
14480 P5=P5+P2                                    !SUM P2
14490 P6=P6+P3                                    !SUM P3
14500 W1=W1+P1*P1                                 !SUM P1^2
14510 W2=W2+P2*P2                                 !SUM P2^2
14520 W3=W3+P3*P3                                 !SUM P3^2
14530 NEXT Z2
14540 T4=T4/N3                                    !AVE Te
14550 S=SQR((V2-T1*T1/N3)/(N3-1))                 !S.D. OF Tx
14560 T1=T1/N3                                    !AVE Tx  SET OF 5
14570 E9=T1
14580 !
14590 ! PLOT AVERAGE OF 5 MEASUREMENTS
14600 !
14610 PRINTER IS 0
14620 IF J8>1 THEN 14940
14630 I6=T1
14640 Q5=100
14650 I5=Q5/25
14660 IMAGE 5X,"TX(K) =",M7D. ,"SIG(K) =",M5D.
14670 IMAGE /,/,/,/
14680 D9=1
14690 Q=FNS(2)
14700 F=F(1,1) ! Z(1,37)-30
14710 PRINT F;"MHZ","I.F. FREQUENCY MHZ: 30","LO FREQ MHZ:";F
14720 PRINT USING 14670
14730 IMAGE 17X,"# OF PTS IN AVE =",M3D
14740 IMAGE 7X,"UNIT =",M9D.D,"PWR RATIO",/
14750 PRINT USING 14730;N3
14760 PRINT USING 14740;I5
14770 PRINT
14780 IF Q5>=10 THEN 14830
14790 PRINT USING 14820;-Q5,-3*Q5/5,-Q5/5,Q5/5,3*Q5/5,Q5
14800 GOTO 14840
14810 IMAGE 4X,M5D ,4X,M5D ,4X,M5D ,4X,M5D ,4X,M5D ,4X,M5D ," KELVINS"
14820 IMAGE 5X,M1DE,4X,M1DE,4X,M1DE,4X,M1DE,4X,M1DE,4X,M1DE," KELVINS"
14830 PRINT USING 14810;-Q5,-3*Q5/5,-Q5/5,Q5/5,3*Q5/5,Q5
14840 A$="!....!....!....!....!....!....!....!....!....!....!"
14850 PRINT TAB(8),A$
14860 IMAGE "#/TIME",21X,"ZERO=",M5D ," PWR RATIO"
14870 IF (T1>=100) AND (T1<=1E5) THEN 14910
14880 PRINT USING 14890;I6
14890 IMAGE "#/TIME",21X,"ZERO=",M1D.2DE," PWR RATIO"
14900 GOTO 14930
14910 PRINTER IS 0
14920 PRINT USING 14860;I6
```

```
14930 GOTO 15010
14940 I6=T1
14950 IMAGE M3D ,4X
14960 PRINTER IS 0
14970 PRINT USING 14950;J8-1
14980 PRINT USING 14990;T1,S
14990 IMAGE 2X,M5D ,2X,M5D
15000   GOTO 15040
15010 PRINT TAB(8),A$
15020 IF J8>1 THEN 15040
15030 GOTO 15140
15040 T1=T1*N3
15050 T8=T8+T1                                    !SUM OF T1
15060 T9=T9+T4                                    !SUM OF T4
15070 T7=T7+V2                                    !SUM OF T1^2
15080 P7=P7+P4                                    !SUM OF P1
15090 P8=P8+P5                                    !SUM OF P2
15100 P9=P9+P6                                    !SUM OF P3
15110 W4=W4+W1                                    !SUM OF P1^2
15120 W5=W5+W2                                    !SUM OF P2^2
15130 W6=W6+W3                                    !SUM OF P3^2
15140 NEXT J8
15150 T1=T8/(N8*N3)                               !AVE VALUE TX 1 FULL SET
15160 T4=T9/N8                                    !AVE VALUE Te 1 FULL SET
15170 S1=SQR((T7-T8*T8/(N8*N3))/(N8*N3-1))            !S.D Tx 1 FULL SET
15180 IF P0=1 THEN 15330
15190 !
15200 ! STORE VALUES IN Z MATRIX
15210 !
15220 Z(1,7)=T2
15230 Z(1,8)=T3                                   !SET 2
15240 Z(1,9)=T1
15250 Z(1,10)=S1
15260 Z(1,11)=T4
15270 Z(1,12)=P8/(N8*N3)
15280 B6=T7                                       !SUM OF SQRS TX SET 2
15290 Z(1,41)=B6
15300 B8=T8                                       !SUM OF Tx SET 2
15310 Z(1,42)=B8
15320 GOTO 15480
15330 Z(1,1)=T2
15340 Z(1,2)=T3
15350 Z(1,3)=T1                                   !SET 1
15360 Z(1,4)=S1
15370 Z(1,5)=T4
15380 Z(1,6)=P8/(N3*N8)
15390 B5=T7                                       !SUM OF SQRS TX SET 1
15400 B7=T8                                       !SUM OF TX SET 1
15410 Z(1,43)=B5
15420 Z(1,44)=B7
15430 ! REM B5 AND B6=SUM OF SQRS-B7 AND B8=SUM OF T1
15440 !
15450 ! PRINT RESULTS OF FULL SET
15460 !
15470 PRINTER IS 0
```

```
15480 PRINT "      RATIO AVE       STD DEV       "
15490 PRINT
15500 PRINT USING 15510;T1,S1
15510 IMAGE 5X, 1D.5D,2X,7D.5D
15520 PRINT
15530 PRINT
15540 PRINT "P1 AVE MW=";P7/(N3*N8);"P2 AVE MW=";P8/(N3*N8);
      "P3 AVE MW=";P9/(N3*N8)
15550 PRINT
15560 PRINT "STANDARD ERROR OF MEAN=";S1/SQR(N8*N3)
15570 PRINT
15580 PRINT
15590 Z=3*S1
15600 PRINTER IS 16
15610 IF P0=2 THEN 15650
15620 Z(1,45)=P7/(N3*N8)                          !AVE    P1 SET 1
15630 Z(1,46)=P8/(N3*N8)                          !AVE OF P2 SET 1
15640 Z(1,47)=P9/(N3*N8)                          !AVE OF P3 SET 1
15650 IF P0=1 THEN 15710
15660 ! B5 AND B6 = SUM OF SQRS T1; B7 AND B8=SUM OF T1
15670 Z(1,48)=P7/(N3*N8)                           !AVE OF P1 SET 2
15680 Z(1,49)=P8/(N3*N8)                           !AVE OF P2
15690 Z(1,50)=P9/(N3*N8)                           !AVE OF P3
15700 Q=FNB(1)
15710 Z8=1
15720 IF P0=2 THEN GOTO 15750
15730   PRINT "INTERCHANGE DEVICES ON PORTS AND PRESS CONT"
15740   PAUSE
15750 M=2
15760 SUBEND
15770 RE-SAVE "Corr2",15780,16970
```

S Corr1(

A$	13880	14840	14850	15010
Aet	13840	14250		
B5	15390	15410		
B6	15280	15290		
B7	15400	15420		
B8	15300	15310		
C	14080			
C1	13840			
D9	14680			
E7	13840			

E8	13840							
E9	14300	14330	14360	14570				
F	14140	14170	14700	14710	14710			
F(	*	14700						
F1	13890	14130	14130	14140	14150	14170		
F2	13900							
F3	13910							
Fn	14100	14110						
I5	14650	14760						
I6	14630	14880	14920	14940				
J8	14200	14290	14390	14620	14970	15020	15140	
M	14090	14180	15750					
N3	13920	13940	14230	14540	14550	14550	14560	14750
	15040	15150	15170	15170	15270	15380	15540	15540
	15540	15560	15620	15630	15640	15670	15680	15690
N8	13930	13940	14200	15150	15160	15170	15170	15270
	15380	15540	15540	15540	15560	15620	15630	15640
	15670	15680	15690					
P$	14010	14020	14020	14020				
P0	13840	13980	14240	14240	14250	15180	15610	15650
	15720							
P0$	14120	14150						
P1	14250	14260	14380	14470	14500	14500		
P2	14250	14260	14270	14380	14480	14510	14510	
P3	14250	14270	14380	14490	14520	14520		
P4	14190	14210	14470	14470	15080			
P5	14190	14210	14480	14480	15090			
P6	14190	14210	14490	14490	15100			
P7	14050	14190	15080	15080	15540	15620	15670	
P8	14050	14190	15090	15090	15270	15380	15540	15630
	15680							

P9	14050	14190	15100	15100	15540	15640	15690	
Q	14690	15700						
Q(	13840							
Q5	14640	14650	14780	14790	14790	14790	14790	14790
	14790	14830	14830	14830	14830	14830	14830	
S	14550	14980						
S1	15170	15250	15360	15500	15560	15590		
T1	*	14190	14210	14430	14430	14550	14550	14560
	14560	14570	14630	14870	14870	14940	14980	15040
	15040	15050	15150	15240	15350	15500		
T2	*	14440	15220	15330				
T3	*	14440	15230	15340				
T4	14210	14440	14440	14450	14540	14540	15060	15160
	15260	15370						
T7	14050	14190	15070	15070	15170	15280	15390	
T8	14050	14190	15050	15050	15150	15170	15170	15300
	15400							
T9	14050	14190	15060	15060	15160			
V2	14190	14210	14460	14460	14550	15070		
W1	14190	14210	14500	14500	15110			
W2	14190	14210	14510	14510	15120			
W3	14190	14210	14520	14520	15130			
W4	14060	14190	15110	15110				
W5	14060	14190	15120	15120				
W6	14060	14190	15130	15130				
X8	14190	14280	14300	14380	14430	14460	14460	
Y1	14260	14280						
Y3	14270	14280	14440	14440				
Z	14190	14400	14400	15590				

Z(	*	13890	13900	13910	14100	14100	14100	15220
	15230	15240	15250	15260	15270	15290	15310	15330
	15340	15350	15360	15370	15380	15410	15420	15620
	15630	15640	15670	15680	15690			
Z2	14230	14530						
Z8	15710							
Z9	14050							

```
15780 SUB Corr2(C1,C$,G$,R$,E7,E8,Q(*),Aet)
15790 OPTION BASE 1
15800 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
15810  COM File,Flag
15820 PRINTER IS 16
15830 F1=Z(1,37)
15840 F2=Z(1,38)
15850 F3=Z(1,39)
15860 N3=Z(1,25)
15870 N8=Z(1,40)
15880  Fn=(F2-F1)/F3+1
15890 Q=FNS(4)
15900 F1=F1-F3
15910 FOR Fr=1 TO Fn
15920 F=F1+Fr*F3*1E6
15930 FOR P0=1 TO 2
15940 ON P0 GOTO 15970,16030
15950 !
15960 !
15970 PRINT "STARTING PROGRAM CORR2 15730"
15980 REM LEVEL LOOP
15990 ! N3=Z(1,25)
16000 ! N8=Z(1,40)
16010 N3=5
16020 N8=2
16030 N=N3*N8*2
16040 Z(1,31)=N
16050 CALL Corr1(C1,P0,E7,E8,Q(*),Aet)    !MEASUREMENT OF THE TEMP OF UNKNOWN
16060 NEXT P0
16070 ! !!!!!!!!READ DATA FROM CAL MATRIX HERE!!!!!!!!!!!!!!
16080 MASS STORAGE IS ":F8,1"
16090 LINPUT "FILE #",Fcal$
16100 Cal$="AUX "&Fcal$
16110 ASSIGN #1 TO Cal$
16120 READ #1;F(*)
16130 Prt=1
16140 T1ave=(Z(1,3)+Z(1,9))/2  !AVE VALUE OF T1
16150 M1=(1-F(3,11)^2)*(1-F(3,9)^2)
16160 M2=(1-F(3,13)*F(3,3)+F(3,14)*F(3,5))^2+(F(3,13)*F(3,5)+F(3,14)*F(3,3))^2
16170 Mx1=M1/M2
16180 Prt=2
16190 M1=(1-F(4,11)^2)*(1-F(4,9)^2)
16200 M2=(1-F(4,13)*F(4,3)+F(4,14)*F(4,5))^2+(F(4,13)*F(4,5)+F(4,14)*F(4,3))^2
16210 Mx2=M1/M2
16220 M1=(1-F(4,11)^2)*(1-F(3,9)^2)
16230 M2=(1-F(4,13)*F(3,3)+F(4,14)*F(3,5))^2+(F(4,13)*F(3,5)+F(4,14)*F(3,3))^2
16240 Mx3=M1/M2
16250 M1=(1-F(3,11)^2)*(1-F(4,9)^2)
16260 M2=(1-F(3,13)*F(4,3)+F(3,14)*F(4,5))^2+(F(3,13)*F(4,5)+F(3,14)*F(4,3))^2
16270 Mx4=M1/M2
16280 Result=SQR(Mx1*Mx3/(Mx2*Mx4)*Z(1,3)*Z(1,9))
16290 Z(1,57)=Aetaratio=Result
16300 T2ave=(Z(1,1)+Z(1,7))/2
16310!
```

```
16320 REM PRELIMINARY RESULTS!
16330 ! A$="------------------------------------------------------------"!
16340 N=N3*N8*2
16350 PRINTER IS 0
16360 ! PRINT PAGE
16370  Q=FNS(10)
16380 PRINT TAB(23),"MEASUREMENT RECAP"
16390 Q=FNS(10)
16400 PRINT
16410 PRINT TAB(6),"FREQUENCY=";F(1,1);"MHZ   IF FREQUENCY=30";"MHZ"
16420 Z(1,58)=F=F(1,1)
16430 PRINT
16440 PRINT TAB(6),A$
16450 Q=FNS(2)
16460 PRINT TAB(11),"Mx1,Mx2,Mx1′,Mx2′"
16470 FIXED 11
16480 PRINT TAB(11),Mx1;"   ";Mx2;"    ";Mx3;"    ";Mx4
16490 PRINT
16500 PRINT TAB(11),"Aeta ratio";TAB(26),"Sa"
16510 FIXED 5
16520 PRINT TAB(6),"   --------     -------- "
16530 PRINT TAB(8),Z(1,3);TAB(26),Z(1,4)
16540 PRINT TAB(8),Z(1,9);TAB(26),Z(1,10)
16550 PRINT
16560 PRINT "Aeta Ratio WITH Mismatch Terms="
16570 PRINT "[Mx1/Mx2)(Mx1′/Mx2′)(Yx2-1)/(Yx1-1)(Yx2′-1)/Yx1′-1)]^1/2="
          ;Result
16580 PRINT "DB FOR RATIO=";10*LGT(Result)
16590 PRINT TAB(6),"3 * SEM FOR ENTIRE SET OF MEASUREMENTS WAS ";Z(1,13)
16600 PRINT TAB(6),A$
16610 PRINT
16620 STANDARD
16630 N9=Z(1,31)
16640 PRINT TAB(6),"AVE POWER IN MILLIWATTS P1,P2,P3 DEV 1"
16650 PRINT TAB(6),Z(1,45)*1000,Z(1,46)*1000,Z(1,47)*1000
16660 PRINT TAB(6),"AVE POWER IN MILLIWATTS P1,P2,P3 DEV 2"
16670 PRINT TAB(6),Z(1,48)*1000,Z(1,49)*1000,Z(1,50)*1000
16680 FIXED 4
16690 PRINT TAB(6),A$
16700 PRINT
16710 PRINT "AMBIENT STANDARD TEMPERATURE:  ";T2
16720 PRINT
16730 Aeta=Z(1,57)=Result
16740 N1=N3*N8
16750 Y1a=Z(1,45)/N1/(Z(1,46)/N1)   ! RATIO DEVICE 1 TO AMBIENT PORT 2 SET 1
16760 Y1b=Z(1,48)/N1/(Z(1,49)/N1)   ! RATIO DEVICE 2 TO AMBIENT PORT 2 SET 2
16770 Y1c=Z(1,47)/N1/(Z(1,46)/N1)   ! RATIO DEVICE 2 TO AMBIENT PORT 3 SET 1
16780 Y1d=Z(1,50)/N1/(Z(1,49)/N1) ! RATIO DEVICE 1 TO AMBIENT PORT 3 SET 2
16790 PRINT " END OF MEASUREMENT  "
16800 FIXED 0
16810 MASS STORAGE IS ":F8,1"
16820 PRINT "PLACE CAL DISC IN F8,1 PRESS CONT"
16830 PAUSE
16840 LINPUT "FILE NAME, CORR+# ",Corr$
```

```
16850   CREATE Corr$,10
16860 ASSIGN #1 TO Corr$
16870 Pa1=Z(1,46)/N1!PWR A SET 1
16880 Pa2=Z(1,49)/N1!PWR A SET 2
16890 Pc1=Z(1,45)/N1 !PWR PORT 2 SET 1
16900 Pc2=Z(1,48)/N1 !PWR PRT 2 SET 2
16910 Pc3=Z(1,47)/N1  !PWR PORT 3 SET 1
16920 Pc4=Z(1,50)/N1  !PWR PORT 3 SET 2
16930 PRINT #1;Aeta,Y1a,Y1b,Y1c,Y1d,Pa1,Pa2,Pc1,Pc2,Pc3,Pc4
16940 ASSIGN #1 TO *
16950 SUBEXIT
16960 PRINTER IS 16
16970 SUBEND
16980 RE-SAVE "SData ",16980,19110!JANUARY 15, 1982 0832
```

S Corr2(

A$	16440 16600 16690
Aet	15780 16050
Aeta	16730 16930
Aetaratio	16290
C$	15780
C1	15780 16050
Cal$	16100 16110
Corr$	16840 16850 16860
E7	15780 16050
E8	15780 16050
F	15920 16420
F(	* 16120 16150 16150 16160 16160 16160 16160 16160 16190 16200 16200 16200 16200 16200 16200 16200 16230 16230 16230 16230 16230 16230 16230 16250 16260 16260 16260 16260 16260 16410 16420
F1	15830 15880 15900 15900 15920
F2	15840 15880
F3	15850 15880 15900 15920
Fcal$	16090 16100
Fn	15880 15910

Fr	15910	15920						
G$	15780							
M1	16150	16170	16190	16210	16220	16240	16250	16270
M2	16160	16170	16200	16210	16230	16240	16260	16270
Mx1	16170	16280	16480					
Mx2	16210	16280	16480					
Mx3	16240	16280	16480					
Mx4	16270	16280	16480					
N	16030	16040	16340					
N1	16740	16750	16750	16760	16760	16770	16770	16780
	16780	16870	16880	16890	16900	16910	16920	
N3	15860	16010	16030	16340	16740			
N8	15870	16020	16030	16340	16740			
N9	16630							
P0	15930	15940	16050	16060				
Pa1	16870	16930						
Pa2	16880	16930						
Pc1	16890	16930						
Pc2	16900	16930						
Pc3	16910	16930						
Pc4	16920	16930						
Prt	16130	16180						
Q	15890	16370	16390	16450				
Q(	15780	16050						
R$	15780							
Result	16280	16290	16570	16580	16730			
T1ave	16140							
T2	* 16710							
T2ave	16300							

Y1a	16750	16930						
Y1b	16760	16930						
Y1c	16770	16930						
Y1d	16780	16930						
Z(	*	15830	15840	15850	15860	15870	16040	16140
	16140	16280	16280	16290	16300	16300	16420	16530
	16530	16540	16540	16590	16630	16650	16650	16650
	16670	16670	16670	16730	16750	16750	16760	16760
	16770	16770	16780	16780	16870	16880	16890	16900
	16910	16920						

```
16990 SUB Report(P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,Q(*),Set)
17000  OPTION BASE 1
17010  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
17020  COM File,Flag
17030  DIM A$[100]
17040  Set=1
17050 ! GOTO 17590
17060 ! MASS STORAGE IS ":F8,1"
17070 ! INPUT "TAPE #,FILE NAME ",T,Q$
17080 ! ASSIGN #1 TO Q$
17090 ! READ #1;P$,C$,G$,R$,H$,F1,F2,F3,N5,N8,C1,C2,Z(*),Q(*),F(*)
17100 ! ASSIGN #1 TO *
17110 REM PRELIMINARY RESULTS
17120 A$="----------------------------------------------------------"
17130 PRINTER IS 0
17140 ! PRINT PAGE
17150 Set=1
17160   FIXED 2
17170 PRINT
17180 OUTPUT 9;"R"
17190 ENTER 9;P$
17200 PRINT TAB(20),"DATE:";P$[1,2];"-";P$[4,5];"-1983";"     TIME:";P$[7,14]
17210 PRINT
17220 PRINT TAB(6),A$
17230 ! PRINT TAB(6),"TAPE #:";T,"FILE:";Q$;TAB(50);R$[1,19]
17240 PRINT TAB(6),"TEMPERATURE OF WATER BATH";H$[1,10]
17250 PRINT TAB(6),"BAROMETRIC PRESSURE MM MERCURY:";H$[11,20]
17260 FOR I=1 TO 8
17270 PRINT
17280 NEXT I
17290 PRINT TAB(23),"MEASUREMENT RECAP"
17300 PRINT TAB(30),"AND"
17310 PRINT TAB(22),"PRELIMINARY RESULTS"
17320 FOR I=1 TO 7
17330 PRINT
17340 NEXT I
17350 Z(1,34)=F(Set,1)
17360 K=Set
17370 PRINT TAB(8),"FREQUENCY=";F(K,1)/1000;"GHZ"
17380 PRINT
17390 PRINT
17400 PRINT TAB(6),A$
17410 PRINT TAB(11),"TX";TAB(21),"SX";TAB(34),"TE"
17420 PRINT TAB(6),"   --------   --------     --------"
17430 PRINT TAB(8),Z(K,3);TAB(20),Z(K,4);TAB(32),Z(K,5);"(1ST 50
      MEASUREMENTS)"
17440 PRINT TAB(8),Z(K,9);TAB(20),Z(K,10);TAB(32),Z(K,11);"(2ND 50
      MEASUREMENTS)"
17450 PRINT
17460 PRINT TAB(6),A$
17470 PRINT
17480 PRINT TAB(8),"AVE Tna      ","AVE Tne"
17490 FIXED 0
17500 PRINT TAB(8),(Z(K,3)+Z(K,9))/2,(1-Mga^2)*Z(1,35)
```

```
17510 PRINT
17520 FIXED 4
17530 PRINT TAB(8)," REFLECTION COEFFICIENT MAGNITUDE OF DEVICE
      TESTED=";Z(Set,64)
17540 FIXED 2
17550 PRINT TAB(8)," REFLECTION COEFFICIENT ANGLE OF DEVICE TESTED=";
      Z(Set,63);"DEGREES"
17560 PRINT
17570 PRINT "        STANDARD CK 1=";Z(1,66);"K"
17580 PRINT "        STANDARD CK 2=";Z(1,67);"K"
17590 PRINT TAB(6),A$
17600 STANDARD
17610 N9=Z(K,31)
17620 N=N9
17630 FIXED 2
17640 PRINT TAB(9),"AVE POWER IN MILLIWATTS P1,P2,P3"
17650 PRINT USING 17660;Z(1,45)/N9*1000,Z(1,46)/N9*1000,Z(1,47)/N9*1000
17660 IMAGE 8X,MD.4D,5X,MD.4D,5X,MD.4D
17670 S1=.000006!SQR((Z(K,48)-Z(K,45)*Z(K,45)/N)/(N-1))
17680 S2=.0000006!SQR((Z(K,49)-Z(K,46)*Z(K,46)/N)/(N-1))
17690 S3=.0000007!SQR((Z(K,50)-Z(K,47)*Z(K,47)/N)/(N-1))
17700 FIXED 8
17710 PRINT USING 17720;Z(K,31),S1*1000,S2*1000,S3*1000
17720 IMAGE 8X,"SD P1,P2,P3 (# OF MEAS=",MDDD/ 8X,MD.DDDD,3X,MD.DDDD,
      3X,MD.DDD
17730 PRINT TAB(6),A$
17740 PRINT
17750 PRINT
17760 Q=FNS(8)
17770       Tna=Z(Set,35)
17780       Mga=SQR(Z(Set,61)^2+Z(Set,62)^2)  !|GAMMA|
17790 Z(Set,34)=Tne=Tna*(1-Mga^2)
17800 PRINT USING 17810
17810 IMAGE "FREQ GHZ",5X,"Tna K",5X,"Tne K",5X,"E1 K",5X,"3Sx K",5X,
      "ENR DB",5X,"E2 DB"
17820 PRINT USING 17830
17830 IMAGE "--------",5X,"-----",5X,"-----",5X,"----",5X,"-----",5X,
      "------",5X,"-----"
17840 K$=VAL$(INT(Tna))
17850 IF Tna-10000<0 THEN GOTO 17930
17860 IF VAL(K$[5,5])>=5 THEN GOTO 17890
17870  K$[5,5]="0"
17880  GOTO 17910
17890 K$[5,5]="0"
17900 K$[4,4]=VAL$(VAL(K$[4,4])+1)
17910 K=VAL(K$)
17920 GOTO 17990
17930 IF VAL(K$[4,4])>=5 THEN GOTO 17960
17940 K$[4,4]="0"
17950 GOTO 17980
17960 K$[4,4]="0"
17970 K$[1,3]=VAL$(VAL(K$[1,3])+1)
17980 K=VAL(K$)
17990 L$=VAL$(Z(1,36))
18000 IF VAL(L$[3,3])>5 THEN GOTO 18020
```

```
18010 GOTO 18050
18020 L$[3,3]="0"
18030 L$[3,3]=VAL$(VAL(L$[3,3])+1)
18040 GOTO 18070
18050 IF VAL(L$[3,3])>0 THEN L$[3,3]="5"
18060 IF VAL(L$[3,3])=0 THEN L$[3,3]="0"
18070 L=VAL(L$)
18080 N$=VAL$(INT(Tne))
18090 IF Tne-10000<0 THEN GOTO 18190
18100 IF VAL(N$[5,5])>=5 THEN GOTO 18130
18110 N$[5,5]="0"
18120 GOTO 18150
18130 N$[5,5]="0"
18140 N$[4,4]=VAL$(VAL(N$[4,4])+1)
18150 Ne=VAL(N$)
18160 IF VAL(N$[4,4])>=5 THEN GOTO 18190
18170 N$[4,4]="0"
18180 GOTO 18210
18190 N$[4,4]="0"
18200 N$[3,3]=VAL$(VAL(N$[3,3])+1)
18210 Ne=VAL(N$)
18220 F=F(Set,1)/1000
18230 F=F(Set,1)/1000
18240 PRINT USING 18250;F,K,Ne,L,Z(1,13),Z(1,14),Z(1,15)
18250 IMAGE    MD.2D,7X,M5D,4X,M5D,4X,M3D,5X,M2D,8X,M2D.2D,3X,M2D.2D
18260 PRINT
18270 PRINT TAB(6),A$
18280 PRINT USING 18290
18290 IMAGE "GAMMA OF D.U.T.-- REAL      IMAGINARY"
18300 PRINT "                 -----      -----"
18310 PRINT USING 18320;Z(Set,61),Z(Set,62)
18320 IMAGE 16X,M.DDDD,5X,M.DDDD
18330 PRINT
18340 FIXED 2
18350 PRINT
18360 PRINT F(1,1);Z(1,35);Z(1,34);Z(1,36);Z(1,13);Z(1,14);Z(1,15)
18380 PAUSE
18390 ! PRINT PAGE
18400 F=Z(1,37)
18410 PRINT USING 18420;F
18420 IMAGE 25X,"FREQUENCY =",M4D.,"MHZ"
18430 If=30
18440 PRINT TAB(26),"I. F. FREQUENCY= 30 MHZ"
18450 ! PRINT TAB(26), "I. F. FREQUENCY= 5 MHZ"
18460 PRINT
18470 PRINT
18480 K=Set
18490 PRINT USING 18500;Z(K,35),Z(K,36),Z(K,13)
18500 IMAGE 10X,"NOISE TEMPERATURE =",M5D.2D,"K  +-",M3D.2D,
      "K(BIAS) +-",M3D.2D,"K (3*SEM)"
18510 IF Z(K,52)<220 THEN 18540
18520 PRINT USING 18530;Z(K,14),Z(K,15)
18530 IMAGE 10X,"EXCESS NOISE RATIO=",M3D.2D ,"DB   +-",MD.2D ,
      "DB(BIAS+3*SEM)"
18540 PRINT USING 18550;Z(K,16)
```

```
18550 IMAGE 10X,"RADIOMETER SYSTEM TEMPERATURE =",4D,"K"
18560 PRINT USING 18570;Z(K,18)
18570 IMAGE 10X,"RADIOMETER GAIN =",M3D.1D ,"DB"
18580 FIXED 2
18590 PRINT "           RADIOMETER NOISE BANDWIDTH=";Z(K,56);"MHZ"
18600 PRINT
18610 PRINT
18620 PRINT
18630 PRINT TAB(28),"ERROR SUMMARY"
18640 PRINT
18650 PRINT TAB(5),"SOURCE OF ERROR";TAB(35)," SOURCE";TAB(58),"% ERROR IN"
18660 PRINT TAB(34),"UNCERTAINTY";TAB(55),"NOISE TEMPERATURE"
18670 PRINT
18680 PRINT USING 18690;Z(1,20)
18690 IMAGE 6X,"CRYOGENIC STANDARD",10X,".77K",16X,M4D.3D
18700 PRINT USING 18710;Z(1,22)
18710 IMAGE 6X, "AMBIENT STANDARD",12X,"0.50K",15X, M4D.3D
18720 PRINT USING 18730;Z(1,24)
18730 IMAGE 6X,"POWER RATIO",17X,"0.01DB",14X,M4D.3D
18740 PRINT USING 18750;Z(1,26)
18750 IMAGE 6X,"MISMATCH",20X,"0.005+0.005J",12X,M  .3D
18760 PRINT USING 18770;Z(1,28)
18770 IMAGE 6X,"NON-LINEARITY",14X," 1.42E-8",13X,M4D.3D
18780 PRINT USING 18790;Z(1,29)

18920 PRINT TAB(6),"CUSTOMER'S STATION:";TAB(30),C$[30,60]
18930 PRINT TAB(6),"CUSTOMER'S ADDRESS:";TAB(30),C$[61,99]
18940 PRINT
18950 PRINT TAB(6),"SOURCE MANUFACTURER:";TAB(30),G$[1,39]
18960 PRINT TAB(6),"SOURCE TYPE:";TAB(30),G$[40,79]
18970 PRINT TAB(6),"SOURCE MODEL:";TAB(30),G$[80,89]
18980 PRINT TAB(6),"SOURCE SERIAL:";TAB(30),G$[90,99]
18990 PRINT
19000 PRINT TAB(6),"DATE OF CALIBRATION:";TAB(30),R$[1,19]
19010 PRINT TAB(6),"CALIBRATION TEST #:";TAB(30),R$[20,39]
19020 PRINT TAB(6),"REQ OR REF #:";TAB(30),R$[40,69]
19030 PRINT
19040 PRINT "PAUSE 19172"
19050 PAUSE
19060 Z6=1
19070 MASS STORAGE IS ":F8,1"
19080 PRINT PAGE
19090 CALL Descr(P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,Q(*),Set)
19100 SUBEXIT
19110 SUBEND
19120  RE-SAVE "Freq",19120,19600!15 JANUARY 1982 0840
```

S Report(

A$	17030	17120	17220	17400	17460	17590	17730	18270
C$	16990	18910	18920	18930	19090			
F	18220	18230	18240	18400	18410			

F(	*	17350	17370	18220	18230	18360		
F1	16990	19090						
F2	16990	19090						
F3	16990	19090						
G$	16990	18950	18960	18970	18980	19090		
H$	16990	17240	17250	19090				
I	17260	17280	17320	17340				
If	18430							
K	17360	17370	17430	17430	17430	17440	17440	17440
	17500	17500	17610	17710	17910	17980	18240	18480
	18490	18490	18490	18510	18520	18520	18540	18560
	18590							
K$	17840	17860	17870	17890	17900	17900	17910	17930
L	18070	18240						
L$	17990	18000	18020	18030	18030	18050	18050	18050
Mga	17500	17780	17790					
N	17620							
N$	18080	18100	18110	18130	18140	18140	18150	18160
	18170	18190	18200	18200	18210			
N3	16990	19090						
N8	16990	19090						
N9	17610	17620	17650	17650	17650			
Ne	18150	18210	18240					
P$	16990	17190	17200	17200	17200	19090		
Q	17760							
Q(	16990	19090						
R$	16990	19000	19010	19020	19090			
S1	17670	17710						
S2	17680	17710						

S3	17690	17710						
Set	16990	17040	17150	17350	17360	17530	17550	17770
	17780	17780	17790	18220	18230	18310	18310	18480
	19090							
Tna	17770	17790	17840	17850				
Tne	17790	18080	18090					
Z(	*	17350	17430	17430	17430	17440	17440	17440
	17500	17500	17500	17530	17550	17570	17580	17610
	17650	17650	17650	17710	17770	17780	17780	17790
	17990	18240	18240	18240	18310	18310	18360	18360
	18360	18360	18360	18360	18400	18490	18490	18490
	18510	18520	18520	18540	18560	18590	18680	18700
	18720	18740	18760	18780	18800	18830	18850	18850
	18880							
Z6	19060							

```
19130 SUB Freq(F,F$,H$,PO$,M,Ccc)
19140 OPTION BASE 1
19150 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
19160 COM File,Flag
19170 DIM FO$[50],SO$[50]
19180 PRINTER IS 16
19190 F1=Z(1,37)
19200 F2=Z(1,38)
19210 F3=Z(1,39)
19220 ! IF Ccc<3 THEN GOTO 15010
19230 IF Fn=0 THEN Fn=1
19240 !
19250 ! SET START FREQ
19260 !
19270 IF M>1 THEN 19380
19280 H=F2-10000
19290 IF H>0 THEN H=1
19300 IF H<0 THEN H=0
19310 H$="H"&VAL$(H)                            !SET 10 GHZ BIT
19320 ! PO$="NOM2L7K4"                            !POWER OUT OF 2MW FROM SYNTH
19330 F4=F1*1000000
19340 IF F4<1000000000 THEN GOTO 19370
19350 SO$="00"&H$&VAL$(F4)&PO$                  !SET START FREQ +POWER STRING
19360 GOTO 19380
19370 SO$="00"&H$&"0"&VAL$(F4)&PO$
19380 ON M GOTO 19390,19440
19390 F=0      !SET F TO 0 1ST TIME THROUGH USE 2-n TIMES WITHOUT RESET
19400 OUTPUT 704;"00H0G0F0E0D0C0B0A0N0M2L7K4"
19410 OUTPUT 704;SO$
19420 WAIT 1000
19430  SUBEXIT
19440 PRINT F
19450 !
19460 ! FREQ LOOP
19470 !
19480 FO=F
19490 IF F<1000000000 THEN GOTO 19520
19500 FO$="00"&H$&VAL$(F)
19510 GOTO 19550
19520 FO$="00"&H$&"0"&VAL$(F)
19530 GOTO 19550
19540 PRINT FO
19550 F$="00"&H$&"G"&FO$[5,5]&"F"&FO$[6,6]&"E"&FO$[7,7]&"D"&FO$[8,8]
      &"C"&FO$[9,9]&"B"&FO$[10,10]&"A"&FO$[11,11]  !100 MHZ OR MORE
19560 PRINT F$
19570 OUTPUT 704;F$
19580 WAIT 1000
19590 SUBEXIT
19600 SUBEND
19610   RE-SAVE "SUB G",19610,20550!JANUARY 15, 1982 0840
```

S Freq(

Ccc	19130							
F	19130	19390	19440	19480	19490	19500	19520	
F$	19130	19550	19560	19570				
FO	19480	19540						
FO$	19170	19500	19520	19550	19550	19550	19550	19550
	19550	19550						
F1	19190	19330						
F2	19200	19280						
F3	19210							
F4	19330	19340	19350	19370				
Fn	19230	19230						
H	19280	19290	19290	19300	19300	19310		
H$	19130	19310	19350	19370	19500	19520	19550	
M	19130	19270	19380					
PO$	19130	19350	19370					
SO$	19170	19350	19370	19410				
Z(	*	19190	19200	19210				

```
19620 SUB Get_parameters(C$,G$,R$,F1,F2,F3,Fn,N3,N8)!
19630 OPTION BASE 1!
19640 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
19650 COM File,Flag
19660 DIM P$[100],Q$[100]
19670 PRINT
19680 PRINT
19690 PRINTER IS 16
19700 LINPUT "0 TO SKIP , SPACE TO CONTINUE",Q$
19710 IF Q$="0" THEN 20360
19720 IF Q$=" " THEN 19730
19730 PRINT "CUSTOMER?"
19740 P$=C$[1,29]
19750 IF I2=0 THEN 19820
19760 PRINT "NOW: ";P$;
19770 LINPUT Q$
19780 IF Q$="0" THEN 20320
19790 IF Q$=" " THEN 19870
19800 C$[1,29]=Q$
19810 GOTO 19880
19820 PRINT "NOW: ";P$
19830 LINPUT Q$
19840 IF Q$="0" THEN 20320
19850 IF Q$=" " THEN 19870
19860 C$[1,29]=Q$
19870 ! Q=FNS(1)
19880 PRINT "CUST'S ADDRESS--STREET  ?"
19890 P$=C$[30,60]
19900 Q=FNO(P$,Q$)
19910 C$[30,60]=P$
19920 Q=FNS(1)
19930 PRINT "CUST'S ADDRESS?--CITY,STATE,ZIP   ?";
19940 P$=C$[61,99]
19950 Q=FNO(P$,Q$)
19960 C$[61,99]=P$
19970 Q=FNS(1)
19980 PRINT "SOURCE MANUFTR?";
19990 P$=G$[1,39]
20000 Q=FNO(P$,Q$)
20010 G$[1,39]=P$
20020 Q=FNS(1)
20030 PRINT "SOURCE TYPE ?  ";
20040 P$=G$[40,79]
20050 Q=FNO(P$,Q$)
20060 G$[40,79]=P$
20070 Q=FNS(1)
20080 PRINT "SOURCE MODL # ?";
20090 P$=G$[80,89]
20100 Q=FNO(P$,Q$)
20110 G$[80,89]=P$
20120 Q=FNS(1)
20130 PRINT "SOURCE SER. # ?";
20140 P$=G$[90,99]
20150 Q=FNO(P$,Q$)
```

```
20160 G$[90,99]=P$
20170 Q=FNS(1)
20180 PRINT "DATE OF CALIBRATION"
20190 P$=R$[1,19]
20200 Q=FNO(P$,Q$)
20210 R$[1,19]=P$
20220 Q=FNS(1)
20230 PRINT "CALIB. TEST # ?";
20240 P$=R$[20,39]
20250 Q=FNO(P$,Q$)
20260 R$[20,39]=P$
20270 Q=FNS(1)
20280 PRINT "REQ OR REF # ? ";
20290 P$=R$[40,69]
20300 Q=FNO(P$,Q$)
20310 R$[40,69]=P$
20320 I2=I2+1
20330 IF I2=1 THEN 19670
20340 Z1=Z1+1
20350 Q=FNS(2)+FNB(1)
20360 !   GET PARAMETERS                          (FNJ2)
20370 Q=FNS(2)
20380 INPUT "START, STOP, AND STEP FREQ IN MHZ",F1,F2,F3
20390 Fn=(F2-F1)/F3+1
20400 F0=1
20410 FOR I=1 TO Fn
20420 Q=FNS(1)
20430 N3=5
20440 N8=10
20450 Z(I,37)=F1
20460 Z(I,38)=F2
20470 Z(I,39)=F3
20480 Z(I,25)=N3
20490 Z(I,40)=N8
20500 Z(I,31)=N3*N8*2
20510 Z(1,55)=3.6      !BANDWIDTH 5MHzIF
20520 Z(1,56)=.95      !BANDWIDTH  30MHz IF
20530 Z(1,27)=1.418426E-8
20540 NEXT I
20550 SUBEND
20560   ! SAVE "SUB M",16560,19080!15 JANUARY 1983 0855
```

S Get_parameters(

C$	19620 19740 19800 19860 19890 19910 19940 19960
F0	20400
F1	19620 20380 20390 20450
F2	19620 20380 20390 20460
F3	19620 20380 20390 20470

Fn	19620	20390	20410					
G$	19620	19990	20010	20040	20060	20090	20110	20140
	20160							
I	20410	20450	20460	20470	20480	20490	20500	20540
I2	19750	20320	20320	20330				
N3	19620	20430	20480	20500				
N8	19620	20440	20490	20500				
P$	19660	19740	19760	19820	19890	19900	19910	19940
	19950	19960	19990	20000	20010	20040	20050	20060
	20090	20100	20110	20140	20150	20160	20190	20200
	20210	20240	20250	20260	20290	20300	20310	
Q	19900	19920	19950	19970	20000	20020	20050	
	20070	20100	20120	20150	20170	20200	20220	
	20250	20270	20300	20350	20370	20420		
Q$	19660	19700	19710	19720	19770	19780	19790	
	19800	19830	19840	19850	19860	19900	19950	
	20000	20050	20100	20150	20200	20250	20300	
R$	19620	20190	20210	20240	20260	20290	20310	
Z(	*	20450	20460	20470	20480	20490	20500	
	20510	20520	20530					
Z1	20340	20340						

```
20570 SUB Meas(C1,P0,E7,E8,Q(*),I,Aet)
20580 OPTION BASE 1
20590 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
20600  COM File,Flag
20610  DIM A$[100]
20620  F1=Z(1,37)
20630  F2=Z(1,38)
20640  F3=Z(1,39)
20650  N3=Z(1,25)
20660  N8=Z(1,40)
20670  PRINTER IS 0,
20680  PRINT "****************************************************************"
20690 PRINT
20700 OUTPUT 9;"R"
20710 ENTER 9;P$
20720 PRINT TAB(20),"DATE:";P$[1,2];"-";P$[4,5];"-1982";" TIME:";P$[7,14]
20730 PRINT
20740 PRINTER IS 16
20750 IF E7>0 THEN GOTO 20790  !NOMINAL VALUE OF TX USED IN MAX DEVIATION
      ROUTINE
20760 E8=600                   !MAX DEVIATION ALLOWED IN DEV ROUTINE
20770 E7=9600
20780 PRINT "DEFAULT VALUE OF E7 BEING USED )"
20790 Z9=T7=T8=T9=P7=P8=P9=0
20800 W4=W5=W6=0
20810 INPUT "TEMPERATURE OF AMBIENT STANDARD IN DEGREES CELCIUS",T2
20820 T2=T2+273.15
20830 Qua=.0479932*F(1,1)/T2
20840 Quaa=Qua/(EXP(Qua)-1)*T2
20850 C=0
20860 T=55
20870 B1=8.394409444E3
20880 B2=-1.890045259E3
20890 B3=-7.282229165
20900 B4=1.022850966E-2
20910 B5=5.556063825E-4
20920 B6=-5.944544662E-6
20930 B7=2.715433932E-8
20940 B8=-4.879535904E-11
20950 B9=5.095360824E2
20960 INPUT "PRESSURE IN MM OF HG",Pressure
20970 T0=55
20980 FOR N=1 TO 30
20990 P=EXP(B1/T+B2+B3*T+B4*(126.2-T)^1.95+B5*T^3+B6*T^4+B7*
      T^5+B8*T^6+B9*LOG(T))
21000 P=760*P
21010 P=P-Pressure
21020 T0=T0+(85-T0)*ABS(P)/(ABS(P)+1718.05458298)
21030 T=T0
21040 NEXT N
21050    T3=INT(100*(T0+.005))/100   !CRYO STD TEMP
21060    Qua=.0479932*F(1,1)/T3
21070    Quas=Qua/(EXP(Qua)-1)
21080    F=F(1,1)
```

```
21090     Ta=300
21100     Td1=2.64E-3*SQR(F)*F(2,11)^2*(Ta-T3)
21110     Td2=.611-2.55E-3*(T3-76)+3.82E-3*(Ta-297)
21120     Td3=(.6*SQR(F)+.011*F)/.611
21130     Tdelta=Td1+Td2*Td3
21140     Tn=Quas*(T3+Tdelta)
21150     T3=Tn
21160 PRINT "NITROGEN TEMP IS";T3;"KELVIN"
21170 PRINT
21180 PRINT T2,T3
21190 LINPUT "ENTER 4 FOR 30MHzIF,0 FOR 5MHz IF",Iff$
21200 M=1  !SET VALUE FOR Freq SUBROUTINE
21210   Fn=(Z(1,38)-Z(1,37))/Z(1,39)+1
21220   PRINT Fn
21230   LINPUT "ENTER CORR FILE ,CORR+#",Fr$
21240   MASS STORAGE IS ":F8,1"
21250   ! OTO 21390
21260   ASSIGN #1 TO Fr$
21270   READ #1;Aeta,Y1a,Y1b,Y1c,Y1d,Pa1,Pa2,Pc1,Pc2,Pc3,Pc4
21280    ASSIGN #1 TO *
21290    LINPUT "ENTER CAL FILE Cal+#",Fr$
21300    ASSIGN #1 TO Fr$
21310    READ #1;F(*),Final
21320    Mismatch=Final
21330 PO$="NOM2L5K5"
21340 F1=Z(1,37)
21350 F=F1
21360   CALL Freq(F,F$,H$,PO$,M,Ccc)
21370 OUTPUT 704;"OOHO"&"2600000000"&PO$
21380 !
21390 M=2
21400 X8=V2=T1=T8=T9=T7=P7=P8=P9=P4=P5=P6=W4=W5=W6=W1=W2=W3=Z=0
21410 FOR J8=1 TO N8+1
21420 T1=T4=V2=P4=P5=P6=W1=W2=W3=0
21430 PRINTER IS 0
21440 FOR Z2=1 TO N3
21450 CALL Power(P1,P2,P3,P0,Aet,Iff)          !CALL POWER SUBROUTINE
21460 IF J8=1 THEN GOTO 21560
21470 Z=Z+1
21480 IF P0>1 THEN GOTO 21530
21490 Q(1,Z)=P1
21500 Q(2,Z)=P2
21510 Q(3,Z)=P3
21520 GOTO 21560
21530 Q(1,Z+N3*N8)=P1
21540 Q(2,Z+N3*N8)=P2
21550 Q(3,Z+N3*N8)=P3
21560 Y1=P1/P2
21570 Y3=P3/P2
21580 T2=Quaa
21590 X8=T2+Mismatch*((T3-T2)*(Y1-1)/(Y3-1)*Aeta)!TEMPERATURE T1 IS X8
21600 PRINTER IS 0
21610 PRINT X8;P1*1000;P2*1000;P3*1000
21620 IF J8=1 THEN 21730
21630 E6=X8-9600
```

```
21640 IF ABS(E6)<=600 THEN 21730
21650 DISP "DEV EXCEEDS MAX--REDO LAST TEMP"
21660 PRINTER IS 16
21670 PRINT E6,E7,E8
21680 PRINT X8,E7
21690 Z=Z-1
21700 ! PAUSE
21710 PRINTER IS 0
21720 GOTO 21450
21730 T1=T1+X8                                    !SUM OF Tx
21740 T4=T4+(T3-Y3*T2)/(Y3-1)                      !SUM OF Te
21750 DISP "T4",T4
21760 V2=V2+X8*X8                                 !SUM Tx^2
21770 P4=P4+P1                                    !SUM P1
21780 P5=P5+P2                                    !SUM P2
21790 P6=P6+P3                                    !SUM P3
21800 W1=W1+P1*P1                                 !SUM P1^2
21810 W2=W2+P2*P2                                 !SUM P2^2
21820 W3=W3+P3*P3                                 !SUM P3^2
21830 NEXT Z2
21840 T4=T4/N3                                    !AVE Te
21850 S=SQR((V2-T1*T1/N3)/(N3-1))                 !S.D. OF Tx
21860 T1=T1/N3                                    !AVE Tx  SET OF 5
21870 !
21880 ! PLOT AVERAGE OF 5 MEASUREMENTS
21890 !
21900 PRINTER IS 0
21910 IF J8>1 THEN 22230
21920 I6=T1
21930 Q5=100
21940 I5=Q5/25
21950 IMAGE 5X,"TX(K) =",M7D. ,"SIG(K) =",M5D.
21960 IMAGE /,/,/,/
21970 D9=1
21980 Q=FNS(2)
21990 F=3250   ! Z(1,37)-30
22000 PRINT F;"MHZ","I.F. FREQUENCY MHZ: 30","LO FREQ MHZ: 3220"
22010 PRINT USING 21960
22020 IMAGE 17X,"# OF PTS IN AVE =",M3D
22030 IMAGE 7X,"UNIT =",M9D.D," KELVINS",/
22040 PRINT USING 22020;N3
22050 PRINT USING 22030;I5
22060 PRINT
22070 IF Q5>=10 THEN 22120
22080 PRINT USING 22110;-Q5,-3*Q5/5,-Q5/5,Q5/5,3*Q5/5,Q5
22090 GOTO 22130
22100 IMAGE 4X,M5D ,4X,M5D ,4X,M5D ,4X,M5D ,4X,M5D ,4X,M5D ," KELVINS"
22110 IMAGE 5X,M1DE,4X,M1DE,4X,M1DE,4X,M1DE,4X,M1DE,4X,M1DE," KELVINS"
22120 PRINT USING 22100;-Q5,-3*Q5/5,-Q5/5,Q5/5,3*Q5/5,Q5
22130 A$="!....!....!....!....!....!....!....!....!....!....!"
22140 PRINT TAB(8),A$
22150 IMAGE "#/TIME",21X,"ZERO=",M5D ," KELVINS",16X,"TX(K)  ",3X,"SIG(K)"
22160 IF (T1>=100) AND (T1<=1E5) THEN 22200
22170 PRINT USING 22180;I6
22180 IMAGE"#/TIME",21X,"ZERO=",MD.2DE," KELVIN",15X,"TX(K)",3X,"SIG(K)"
```

```
22190 GOTO 22220
22200 PRINTER IS 0
22210 PRINT USING 22150;I6
22220 GOTO 22560
22230 I6=T1
22240 IMAGE M3D ,4X
22250 PRINTER IS 0
22260 PRINT USING 22240;J8-1
22270 X3=INT((T1-I6)/I5)+25
22280 X4=INT(S/I5)
22290 IF X3>0 THEN 22320
22300 PRINT "<---";TAB(51),
22310 GOTO 22480
22320 IF X3<50 THEN 22350
22330 PRINT TAB(47),"--->";
22340 GOTO 22480
22350 X3=X3
22360 IF (X3-X4>0) AND (X3+X4<50) THEN 22380
22370 GOTO 22400
22380 PRINT TAB(X3-X4),"!";TAB(X3),"+";TAB(X3+X4),"!";TAB(51),
22390 GOTO 22480
22400 IF (X3-X4>0) AND (X3<50) THEN 22420
22410 GOTO 22440
22420 PRINT TAB(X3-X4),"!";TAB(X3),"+";TAB(51),
22430 GOTO 22480
22440 IF (X3>0) AND (X3+X4<50) THEN 22470
22450 PRINT TAB(X3),"X";TAB(51),
22460 GOTO 22480
22470 PRINT TAB(X3),"+";TAB(X3+X4),"!";TAB(51),
22480 IF (T1>=100) AND (T1<=1E5) THEN 22520
22490 IMAGE 2X,M1D.2DE,2X,M1D.2DE
22500 PRINT USING 22490;T1,S
22510 GOTO 29748
22520 PRINT USING 22530;T1,S
22530 IMAGE 2X,M5D ,2X,M5D
22540 ! IF (J8-1)/20-INT((J8-1)/20)>0 THEN 20359
22550   GOTO 22590
22560 PRINT TAB(8),A$
22570 IF J8>1 THEN 22590
22580 GOTO 22690
22590 T1=T1*N3
22600 T8=T8+T1                                          !SUM OF T1
22610 T9=T9+T4                                          !SUM OF T4
22620 T7=T7+V2                                          !SUM OF T1^2
22630 P7=P7+P4                                          !SUM OF P1
22640 P8=P8+P5                                          !SUM OF P2
 2650 P9=P9+P6                                          !SUM OF P3
22660 W4=W4+W1                                          !SUM OF P1^2
22670 W5=W5+W2                                          !SUM OF P2^2
22680 W6=W6+W3                                          !SUM OF P3^2
22690 NEXT J8
22700 T1=T8/(N8*N3)                                     !AVE VALUE TX 1 FULL SET
22710 T4=T9/N8                                          !AVE VALUE Te 1 FULL SET
22720 S1=SQR((T7-T8*T8/(N8*N3))/(N8*N3-1))                  !S.D Tx 1 FULL SET
22730 IF P0=1 THEN 22880
```

```
22740 !
22750 ! STORE VALUES IN Z MATRIX
22760 !
22770 Z(I,7)=T2
22780 Z(I,8)=T3                                   !SET 2
22790 Z(I,9)=T1
22800 Z(I,10)=S1
22810 Z(I,11)=T4
22820 Z(I,12)=P8/(N8*N3)
22830 B6=T7                                       !SUM OF SQRS TX SET 2
22840 Z(I,41)=B6
22850 B8=T8                                       !SUM OF Tx SET 2
22860 Z(I,42)=B8
22870 GOTO 23030
22880 Z(I,1)=T2
22890 Z(I,2)=T3
22900 Z(I,3)=T1                                   !SET 1
22910 Z(I,4)=S1
22920 Z(I,5)=T4
22930 Z(I,6)=P8/(N3*N8)
22940 B5=T7                                       !SUM OF SQRS TX SET 1
22950 B7=T8                                       !SUM OF TX SET 1
22960 Z(I,43)=B5
22970 Z(I,44)=B7
22980 ! REM B5 AND B6=SUM OF SQRS-B7 AND B8=SUM OF T1
23000 ! PRINT RESULTS OF FULL SET
23020 PRINTER IS 0
23030 PRINT "         TX AVE        STD DEV      TE"
23040 PRINT
23050 PRINT USING 23060;T1,S1,T4
23060 IMAGE 5X,10D.D,5X,7D.2D,5X,7D.2D
23070 PRINT
23080 PRINT
23090 PRINT "P1 AVE MW=";P7/(N3*N8);"P2 AVE MW=";P8/(N3*N8);
      "P3 AVE MW=";P9/(N3*N8)
23100 PRINT
23110 Se1=S1/SQR(N8*N3)
23120 PRINT "STANDARD ERROR OF MEAN=";Se1
23130 Z(1,13)=Se1
23140 PRINT
23150 PRINT
23160 Z=3*S1
23170 Mismatchck1=F(1,15)/F(3,15)
23180 Mismatchck2=F(1,15)/F(4,15)
23190 M1a=(1-F(3,11)^2)*(1-F(4,9)^2)
23200 M2a=(1-F(3,13)*F(4,3)+F(3,14)*F(4,5))^2+(F(3,13)*F(4,5)
      +F(3,14)*F(4,3))^2
23210 M1b=(1-F(4,11)^2)*(1-F(3,9)^2)
23220 M2b=(1-F(4,13)*F(3,3)+F(4,14)*F(3,5))^2+(F(4,13)*F(3,5)
      +F(4,14)*F(3,3))^2
23230 M1f=M1a/M2a
23240 M2f=M1b/M2b
23250 Mismatchck3=F(1,15)/M1f
23260 Mismatchck4=F(1,15)/M2f
23270 PRINTER IS 16
```

```
23280 IF P0=2 THEN 23380
23290 Z(1,2)=T3
23300 Z(1,1)=T2
23310 Z(I,45)=P7                                   !SUM OF P1 SET 1
23320 Z(I,46)=P8                                   !SUM OF P2
23330 Z(I,47)=P9                                   !SUM OF P3
23340 Z(1,71)=P7/(N3*N8)/(P8/(N3*N8))!RATIO P1/P2 SET 1
23350 Z(I,48)=W4                                   !SUM OF P1^2 SET 1
23360 Z(I,49)=W5                                   !SUM OF P2^2
23370 Z(I,50)=W6                                   !SUM OF P3^2
23380 IF P0=1 THEN 23510
23390 ! B5 AND B6 = SUM OF SQRS T1; B7 AND B8=SUM OF T1
23400 Z(1,8)=T3
23410 Z(1,7)=T2
23420 Z(I,73)=P7                                   !SUM OF P1 SET 2
23430 Z(I,74)=P8                                   !SUM OF P2
23440 Z(I,75)=P9                                   !SUM OF P3
23450 Z(I,76)=W4                                   !SUM OF P1^2 SET 2
23460 Z(I,77)=W5                                   !SUM OF P2^2
23470 Z(I,78)=W6                                   !SUM OF P3^2
23480 Z(1,79)=P7/(N3*N8)/(P8/(N3*N8))  !RATIO P1/P2 SET 2
23490 IF P0=1 THEN GOTO 23510
23500 Q=FNB(1)
23510 PRINT
23520 Y3c=Z(1,71)
23530 Ck1=T2+Mismatchck1*((Z(1,3)-T2)*(Y1a-1)/(Y3c-1))*Aeta !Aux1 SET1
23540 Ck2=T2+Mismatchck2*((Z(1,3)-T2)*(Y1c-1)/(Y3c-1))*Aeta !AUX2 SET1
23550 IF P0=1 THEN GOTO 23590
23560 Y3c=Z(1,79)
23570 Ck3=T2+Mismatchck3*((Z(1,9)-T2)*(Y1d-1)/(Y3c-1))*Aeta !AUX1 SET2
23580 Ck4=T2+Mismatchck4*((Z(1,9)-T2)*(Y1b-1)/(Y3c-1))*Aeta !AUX2 SET2
23590 Z(1,66)=Ck1
23600 Z(1,67)=Ck2
23610 PRINTER IS 0
23620 IF P0=1 THEN GOTO 23670
23630 Z(1,68)=Ck3
23640 Z(1,69)=Ck4
23650 PRINT "STANDARDS Ck 3=";Z(1,68);"STANDARDS Ck 4=";Z(1,69)
23660 Z(1,13)=3*(Z(1,13)/2)
23670 PRINT "STANDARDS Ck 1=";Z(1,66);"STANDARDS CK 2=";Z(1,67)
23680 PRINTER IS 16
23690 Z8=1
23700 ! INPUT "ENTER 0 TO REPEAT 1 TO CONTINUE",Z8
23710 ! IF Z8=0 THEN 6311
23720 M=2
23730 ! NEXT Fr
23740 SUBEXIT
23750 SUBEND
23760   RE-SAVE "SUBO",23760,25460!MARCH   15 1983 0900
```

S Meas(

A$ 20610 22130 22140 22560

Aet	20570	21450						
Aeta	21270	21590	23530	23540	23570	23580		
B1	20870	20990						
B2	20880	20990						
B3	20890	20990						
B4	20900	20990						
B5	20910	20990	22940	22960				
B6	20920	20990	22830	22840				
B7	20930	20990	22950	22970				
B8	20940	20990	22850	22860				
B9	20950	20990						
C	20850							
C1	20570							
Ccc	21360							
Ck1	23530	23590						
Ck2	23540	23600						
Ck3	23570	23630						
Ck4	23580	23640						
D9	21970							
E6	21630	21640	21670					
E7	20570	20750	20770	21670	21680			
E8	20570	20760	21670					
F	21080	21100	21120	21120	21350	21360	21990	22000
F$	21360							
F(	*	20830	21060	21080	21100	21310	23170	23170
	23180	23180	23190	23190	23200	23200	23200	23200
	23200	23200	23200	23200	23210	23210	23220	23220
	23220	23220	23220	23220	23220	23220	23250	23260
F1	20620	21340	21350					

F2	20630							
F3	20640							
Final	21310	21320						
Fn	21210	21220						
Fr$	21230	21260	21290	21300				
H$	21360							
I	20570	22770	22780	22790	22800	22810	22820	22840
	22860	22880	22890	22900	22910	22920	22930	22960
	22970	23310	23320	23330	23350	23360	23370	23420
	23430	23440	23450	23460	23470			
I5	21940	22050	22270	22280				
I6	21920	22170	22210	22230	22270			
Iff	21450							
Iff$	21190							
J8	21410	21460	21620	21910	22260	22570	22690	
M	21200	21360	21390	23720				
M1a	23190	23230						
M1b	23210	23240						
M1f	23230	23250						
M2a	23200	23230						
M2b	23220	23240						
M2f	23240	23260						
Mismatch	21320	21590						
Mismatchck1	23170	23530						
Mismatchck2	23180	23540						
Mismatchck3	23250	23570						
Mismatchck4	23260	23580						
N	20980	21040						
N3	20650	21440	21530	21540	21550	21840	21850	21850
	21860	22040	22590	22700	22720	22720	22820	22930

	23090	23090	23090	23110	23340	23340	23480	23480
N8	20660	21410	21530	21540	21550	22700	22710	22720
	22720	22820	22930	23090	23090	23090	23110	23340
	23340	23480	23480					
P	20990	21000	21000	21010	21010	21020	21020	
P$	20710	20720	20720	20720				
P0	20570	21450	21480	22730	23280	23380	23490	23550
	23620							
P0$	21330	21360	21370					
P1	21450	21490	21530	21560	21610	21770	21800	21800
P2	21450	21500	21540	21560	21570	21610	21780	21810
	21810							
P3	21450	21510	21550	21570	21610	21790	21820	21820
P4	21400	21420	21770	21770	22630			
P5	21400	21420	21780	21780	22640			
P6	21400	21420	21790	21790	22650			
P7	20790	21400	22630	22630	23090	23310	23340	23420
	23480							
P8	20790	21400	22640	22640	22820	22930	23090	23320
	23340	23430	23480					
P9	20790	21400	22650	22650	23090	23330	23440	
Pa1	21270							
Pa2	21270							
Pc1	21270							
Pc2	21270							
Pc3	21270							
Pc4	21270							
Pressure	20960	21010						
Q	21980	23500						
Q(	20570	21490	21500	21510	21530	21540	21550	
Q5	21930	21940	22070	22080	22080	22080	22080	22080

	22080	22120	22120	22120	22120	22120	22120	
Qua	20830	20840	20840	21060	21070	21070		
Quaa	20840	21580						
Quas	21070	21140						
S	21850	22280	22500	22520				
Sl	22720	22800	22910	23050	23110	23160		
Sel	23110	23120	23130					
T	20860	20990	20990	20990	20990	20990	20990	20990
	20990	21030						
T0	20970	21020	21020	21020	21030	21050		
Tl	*	21400	21420	21730	21730	21850	21850	21860
	21860	21920	22160	22160	22230	22270	22480	22480
	22500	22520	22590	22590	22600	22700	22790	22900
	23050							
T2	*	20810	20820	20820	20830	20840	21180	21580
	21590	21590	21740	22770	22880	23300	23410	23530
	23530	23540	23540	23570	23570	23580	23580	
T3	*	21050	21060	21100	21110	21140	21150	21160
	21180	21590	21740	22780	22890	23290	23400	
T4	21420	21740	21740	21750	21840	21840	22610	22710
	22810	22920	23050					
T7	20790	21400	22620	22620	22720	22830	22940	
T8	20790	21400	22600	22600	22700	22720	22720	22850
	22950							
T9	20790	21400	22610	22610	22710			
Ta	21090	21100	21110					
Tdl	21100	21130						
Td2	21110	21130						
Td3	21120	21130						
Tdelta	21130	21140						
Tn	21140	21150						
V2	21400	21420	21760	21760	21850	22620		

W1	21400	21420	21800	21800	22660			
W2	21400	21420	21810	21810	22670			
W3	21400	21420	21820	21820	22680			
W4	20800	21400	22660	22660	23350	23450		
W5	20800	21400	22670	22670	23360	23460		
W6	20800	21400	22680	22680	23370	23470		
X3	22270	22290	22320	22350	22350	22360	22360	22380
	22380	22380	22400	22400	22420	22420	22440	22440
	22450	22470	22470					
X4	22280	22360	22360	22380	22380	22400	22420	22440
	22470							
X8	21400	21590	21610	21630	21680	21730	21760	21760
Y1	21560	21590						
Y1a	21270	23530						
Y1b	21270	23580						
Y1c	21270	23540						
Y1d	21270	23570						
Y3	21570	21590	21740	21740				
Y3c	23520	23530	23540	23560	23570	23580		
Z	21400	21470	21470	21490	21500	21510	21530	21540
	21550	21690	21690	23160				
Z(	*	20620	20630	20640	20650	20660	21210	21210
	21210	21340	22770	22780	22790	22800	22810	22820
	22840	22860	22880	22890	22900	22910	22920	22930
	22960	22970	23130	23290	23300	23310	23320	23330
	23340	23350	23360	23370	23400	23410	23420	23430
	23440	23450	23460	23470	23480	23520	23530	23540
	23560	23570	23580	23590	23600	23630	23640	23650
	23650	23660	23660	23670	23670			
Z2	21440	21830						
Z8	23690							
Z9	20790							

```
23770 SUB Out(C1,C$,G$,H$,R$,E7,E8,Q(*),Aet,Iff$)
23780  OPTION BASE 1
23790  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
23800  COM File,Flag
23810  DIM A$[100]
23820 PRINTER IS 16
23830 F1=F=Z(1,37)
23840 F2=Z(1,38)
23850 F3=Z(1,39)
23860 N3=Z(1,25)
23870 N8=Z(1,40)
23880  Fn=(F2-F1)/F3+1
23890 Q=FNS(4)
23900 Startmeas:!
23910 INPUT " CALIBRATION FREQUENCY NUMBER",Fr
23920 F=Z(Fr,37)
23930 FOR P0=1 TO 2
23940 ON P0 GOTO 23970,24010
23950 !
23960 !
23970 PRINT "STARTING PROGRAM OUT"
23980 I=1
23990 N3=Z(I,25)
24000 N8=Z(I,40)
24010 N=N3*N8*2
24020 Z(I,31)=N
24030 CALL Meas(C1,P0,E7,E8,Q(*),I,Aet) !MEASUREMENT UNKNOWN TEMP
24040 NEXT P0
24050 I=1
24060 T1ave=(Z(I,3)+Z(I,9))/2  !AVE VALUE OF T1
24070 Z(I,52)=Z(I,35)=Tx=T1=T1ave
24080 T2ave=(Z(I,1)+Z(I,7))/2
24090 Z(I,53)=T2ave
24100 T3ave=(Z(I,2)+Z(I,8))/2
24110 Z(I,19)=.77! CRYO SOURCE ERROR
24120 R9=T3ave/T1ave*ABS((T1ave-T2ave)/(T3ave-T2ave))
24130 Z(1,20)=Z(1,19)*R9*100/T3ave
24140 Z(I,21)=.5  !AMB S OURCE ERROR
24150 R8=T2ave/T1ave*ABS(1-(T1ave-T2ave)/(T3ave-T2ave))
24160 R9=Z(1,21)/297*100      !Dta/Ta=.17
24170 Z(1,22)=R8*R9
24180 Z(I,23)=.01
24190 Z(I,54)=T3ave
24200 IF VAL(Iff$)>0 THEN GOTO 24240
24210 Ifreq=5
24220 Bw=Z(1,55)
24230 GOTO 24260
24240 Ifreq=30
24250 Bw=Z(1,56)
24260 T4ave=Z(I,16)=(Z(I,5)+Z(I,11))/2
24270 T7=Z(1,41)+Z(1,43)
24280 T8=Z(1,42)+Z(1,44)
24290 T8=T8^2/N
24300 S1=(T7-T8)/(N-1)
```

```
24310 S1=SQR(S1)
24320 Z(I,13)=3*(S1/SQR(N))
24330 Z(I,14)=10*LGT((T1ave-290)/290)
24340 Z(I,16)=T4ave
24350 Q=.0023
24360 Q0=1+Z(I,16)/Z(I,52)                !1+Te/Tx
24370 Q1=1-Z(I,53)/Z(I,52)                !1-TA/TX
24380 Q2=(Z(I,54)+Z(I,16))/(Z(I,54)-Z(I,53))     !![TS+TE]/[TS-TA]
24390 Q3=.23*(Q0-Q1*Q2)
24400 Z(I,23)=.01    !SOURCE ERROR PWR RATIO
24410 Z(I,24)=Q3     !%ERROR POWER RATIO
24420 Rnoisefig=10*LGT(1+T4ave/290)      ! SYSTEM N.F. IN dB
24430 PRINT "PAUSE  24500"
24440 PAUSE
24450 Z(I,17)=Rnoisefig
24460 Gain=7.244E13*T2ave*Bw/(T2ave+T4ave)
24470 Gaindb=10*LGT(Gain)                        !SYSTEM GAIN IN dB
24480 Z(I,18)=Gaindb
24490 Nlin=(T1ave-T2ave)*(T1ave-T3ave)*Z(1,27)*100/T1ave
24500 Z(1,28)=Nlin    !NON-LINEARITY %ERROR
24510 Z(1,32)=Z(1,13)/Z(1,52)*100  !%ERROR 3*SEM
24520 A=1+T4ave/T1ave
24530 B=1-T2ave/T1ave
24540 C=(T3ave+T4ave)/(T3ave-T2ave)
24550 Z(1,29)=.23*ABS(B)*ABS(A-B*C)  !%ERROR SWTCH ASYMMETRY
24560 Set=1
24570 Z(1,26)=0 !%ERROR FOR MISMATCH
24580 Isolator=.0258*ABS((T1ave-T2ave)/Tx)+.0193*ABS((T1ave-T3ave)/Tx)
      +ABS(143.6*Z(1,61)/Tx)     !%ERROR ISOLATOR
24590 Z(I,59)=Isolator!ERROR IN PERCENT
24600 Z(I,60)=Z(I,26)+Z(I,24)
24610 Z(I,30)=Z(I,20)+Z(I,22)+Z(I,24)+Z(I,28)+Z(I,59)+Z(1,26)+Z(1,29)
24620 Z(I,33)=Z(I,32)+Z(I,30)     !SUM OF BIAS +3SEM=LINEAR SUM%
24630 Z(1,36)=Z(1,30) !BIAS ERROR SUM %
24640 Temp=T1ave*Z(1,30)/100
24650 Temp1=Temp/(Z(1,52)-290)
24660 Temp2=1+ABS(Temp1)
24670 Z(I,15)=10*LGT(Temp2)      ! LINEAR SUM IN DB
24680 ! PRINT PAGE
24690 Q=FNS(3)
24700 REM PRELIMINARY RESULTS!
24710 A$="-----------------------------------------------------------"!
24720 N=N3*N8*2
24730 PRINTER IS 16
24740 PRINT PAGE
24750  Q=FNS(10)
24760 PRINT TAB(23),"MEASUREMENT RECAP"
24770 PRINT TAB(30),"AND"
24780 PRINT TAB(22),"PRELIMINARY RESULTS"
24790 Q=FNS(5)
24800  IF T1<220 THEN GOTO 24830
24810  PRINT TAB(6),"AVERAGE VALUE OF Tx=";Tx
24820 PRINT TAB(6),"EXCESS NOISE RATIO=";Z(1,14)
24830 PRINT
24840 PRINT TAB(6),"RADIOMETER SYSTEM TEMPERATURE=";Z(1,16)
```

```
24850 PRINT TAB(6),"RADIOMETER GAIN dB=";Z(1,18)
24860 PRINT TAB(6),"RADIOMETER NOISE BANDWIDTH =";Bw;"MHZ"
24870 PRINT
24880 PRINT
24890 PRINT TAB(6),"FREQUENCY=";F1;"MHZ   IF FREQUENCY=";Ifreq;"MHZ"
24900 PRINT TAB(28),"L. O. FREQUENCY=";Fl
24910 Z(I,58)=F1
24920 PRINT
24930 PRINT TAB(6),A$
24940 Q=FNS(2)
24950 PRINT TAB(11),"TX";TAB(21),"SX";TAB(34),"TE"," AVERAGE TX"
24960 FIXED 2
24970 PRINT TAB(6),"  --------   --------    --------  ----------"
24980 PRINT TAB(8),Z(I,3);TAB(20),Z(I,4);TAB(32),Z(I,5);(Z(I,3)+Z(I,9))/2
24990 PRINT TAB(8),Z(I,9);TAB(20),Z(I,10);TAB(32),Z(I,11)
25000 PRINT
25010 PRINT TAB(6),"3 * SEM FOR ENTIRE SET OF MEASUREMENTS WAS ";Z(I,13)
25020 PRINT TAB(6),A$
25030 PRINT
25040 STANDARD
25050 N=N9=Z(I,31)
25060 PRINT TAB(6),"AVE POWER IN MILLIWATTS P1,P2,P3"
25070 PRINT TAB(6),Z(I,45)/N*1000,Z(I,46)/N*1000,Z(I,47)/N*1000
25080 Y=Z(1,45)/Z(1,46)
25090 S1=SQR((Z(I,48)-Z(I,45)*Z(I,45)/N)/(N-1))
25100 S2=SQR((Z(I,49)-Z(I,46)*Z(I,46)/N)/(N-1))
25110 S3=SQR((Z(I,50)-Z(I,47)*Z(I,47)/N)/(N-1))
25120 FIXED 4
25130 PRINT TAB(6),"SD P1,P2,P3 (# OF MEAS=";N;")";S1*1000;S2*1000;S3*1000
25140 PRINT TAB(6),A$
25150 PRINT
25160 PRINT "       AMBIENT STANDARD TEMPERATURE:  ";T2
25170 PRINT "       TRANSFER STANDARD TEMPERATURE: ";T3
25180 PRINT "       STANDARDS CK 1;2;3;4"
25190 PRINT "      ";Z(1,66),Z(1,67),Z(1,68),Z(1,69)
25200 PRINT TAB(6),A$
25210 PRINT
25220 PRINT TAB(6),"CUSTOMER:";TAB(30),C$[1,29]
25230 PRINT TAB(6),"CUSTOMER'S STATION:";TAB(30),C$[30,59]
25240 PRINT TAB(6),"CUSTOMER'S ADDRESS:";TAB(30),C$[60,99]
25250 PRINT
25260 PRINT TAB(6),"SOURCE MANUFACTURER:";TAB(30),G$[1,39]
25270 PRINT TAB(6),"SOURCE TYPE:";TAB(30),G$[40,79]
25280 PRINT TAB(6),"SOURCE MODEL:";TAB(30),G$[80,89]
25290 PRINT TAB(6),"SOURCE SERIAL:";TAB(30),G$[90,99]
25300 PRINT
25310 PRINT TAB(6),"DATE OF CALIBRATION:";TAB(30),R$[1,19]
25320 PRINT TAB(6),"CALIBRATION TEST #:";TAB(30),R$[20,39]
25330 PRINT TAB(6),"REQ OR REF #:";TAB(30),R$[40,69]
25340 PRINT
25350 Q=FNS(8)
25360 PRINT TAB(6),A$
25370 PRINT
25380 F=F+F3
25390 PRINTER IS 16
```

```
25400 PRINT " END OF MEASUREMENT  PRESS CONTINUE FOR FULL REPORT"
25410 PAUSE
25420 PRINTER IS 16
25430 CALL Report(P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,Q(*),Set)
25440 GOTO Startmeas
25450 SUBEXIT
25460 SUBEND
25470   RE-SAVE " PWRFL"              !AUGUST 5 1982    1212 GJC
25480   ! USES HPIB ADDRESS 1003 FOR SWITCH DRIVERS
25490   ! USES NEW FLUKE PWR ROUTINE
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S Out(

A	24520	24550						
A$	23810	24710	24930	25020	25140	25200	25360	
Aet	23770	24030						
B	24530	24550	24550					
Bw	24220	24250	24460	24860				
C	24540	24550						
C$	23770	25220	25230	25240	25430			
C1	23770	24030						
E7	23770	24030						
E8	23770	24030						
F	23830	23920	25380	25380				
F1	23830	23880	24890	24900	24910	25430		
F2	23840	23880	25430					
F3	23850	23880	25380	25430				
Fn	23880							
Fr	23910	23920						
G$	23770	25260	25270	25280	25290	25430		
Gain	24460	24470						
Gaindb	24470	24480						
H$	23770	25430						
I	23980	23990	24000	24020	24030	24050	24060	24060

	24070	24070	24080	24080	24090	24100	24100	24110
	24140	24180	24190	24260	24260	24260	24330	24340
	24360	24360	24370	24370	24380	24380	24380	24380
	24400	24410	24450	24480	24590	24600	24600	24600
	24610	24610	24610	24610	24610	24610	24620	24620
	24620	24670	24910	24980	24980	24980	24980	24980
	24990	24990	24990	25010	25050	25070	25070	25070
	25090	25090	25090	25100	25100	25100	25110	25110
	25110							
Iff$	23770	24200						
Ifreq	24210	24240	24890					
Isolator	24580	24590						
N	24010	24020	24290	24300	24320	24720	25050	25070
	25070	25070	25090	25090	25100	25100	25110	25110
	25130							
N3	23860	23990	24010	24720	25430			
N8	23870	24000	24010	24720	25430			
N9	25050							
Nlin	24490	24500						
P$	25430							
PO	23930	23940	24030	24040				
Q	23890	24350	24690	24750	24790	24940	25350	
Q(	23770	24030	25430					
Q0	24360	24390						
Q1	24370	24390						
Q2	24380	24390						
Q3	24390	24410						
R$	23770	25310	25320	25330	25430			
R8	24150	24170						
R9	24120	24130	24160	24170				
Rnoisefig	24420	24450						
S1	24300	24310	24310	24320	25090	25130		
S2	25100	25130						

S3	25110	25130						
Set	24560	25430						
Startmeas:	23900	25440						
T1	*	24070	24800					
T1ave	24060	24070	24120	~~24120~~	24150	24150	24330	24490
	24490	24490	24520	24530	24580	24580	24640	
T2	*	25160						
T2ave	24080	24090	24120	24120	24150	24150	24150	24460
	24460	24490	24530	24540	24580			
T3	*	25170						
T3ave	24100	24120	24120	24130	24150	24190	24490	24540
	24540	24580						
T4ave	24260	24340	24420	24460	24520	24540		
T7	24270	24300						
T8	24280	24290	24290	24300				
Temp	24640	24650						
Temp1	24650	24660						
Temp2	24660	24670						
Tx	24070	24580	24580	24580	24810			
Y	25080							
Z(	*	23830	23840	23850	23860	23870	23920	23990
	24000	24020	24060	24060	24070	24070	24080	24080
	24090	24100	24100	24110	24130	24130	24140	24160
	24170	24180	24190	24220	24250	24260	24260	24260
	24270	24270	24280	24280	24320	24330	24340	24360
	24360	24370	24370	24380	24380	24380	24380	24400
	24410	24450	24480	24490	24500	24510	24510	24510
	24550	24570	24580	24590	24600	24600	24600	24610
	24610	24610	24610	24610	24610	24610	24610	24620
	24620	24620	24630	24630	24640	24650	24670	24820
	24840	24850	24910	24980	24980	24980	24980	24980
	24990	24990	24990	25010	25050	25070	25070	25070
	25080	25080	25090	25090	25090	25100	25100	25100
	25110	25110	25110	25190	25190	25190	25190	

```
25500 SUB Power(P1,P2,P3,P0,Aet,Iff$)
25510  OPTION BASE 1
25520 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
25530  COM File,Flag
25540 DIM Po(6)
25550 PRINTER IS 16
25560 Q=0
25570 Pout$="2"                    !Q=FNX(Q7)
25580 ON Aet GOTO 25600,25590
25590 ON P0 GOTO 25600,25640
25600 OUTPUT 702;"0","1","7","3"             !0 POWER TO MOUNT
25610 WAIT 50
25620 OUTPUT 702;"0","1",">","3"             !CCONTROL
25630 GOTO 25670
25640 OUTPUT 702;"3","1","7","3"             !0 POWER TO MOUNT
25650 WAIT 50
25660 OUTPUT 702;"3","1",">","3"             !0 POWER TO MOUNT
25670 OUTPUT 1003;"8","8","?",Pout$,Iff$,"2"
25680 WAIT 50
25690 OUTPUT 1003;"8","8","0","Pout$",Iff$,"2"!CCONTROL
25700 WAIT 250
25710 OUTPUT 709;"C"  !CLEAR SCANNER
25720 OUTPUT 709;15  !CHANNEL 15
25730 OUTPUT 701;"VRF2T2H0?" !VOLTS FILTER #SA
25740 ENTER 701;V0  !VALUE OF BRIDGE POWER OFF
25750  PRINT "BRIDGE PWR OFF=";V0
25760 ! OUTPUT 709;16   !CHANNEL 16
25770 ! WAIT 300
25780 ! OUTPUT 701;"VRF2S5?"    !OUTPUT FLUKE
25790 ! ENTER 701;V1      !VALUE OF REF
25800 ! PRINT "VALUE OF REF=";V1
25810 ! PAUSE
25820 OUTPUT 709;17
25830 WAIT 300
25840 OUTPUT 701;"VRF2T2H0?"
25850 ENTER 701;V3  !BRIDGE -REF WITH NO POWER
25860 PRINT "BRIDGE -REF NO PWR=";V3
25870 FOR Loop=1 TO 3
25880 ON Loop GOTO 25890,25910,25930
25890 Pout$="2"                               ! UNKNOWN PORT
25900 GOTO 25940
25910 Pout$="4"                                ! AMBIENT PORT
25920 GOTO 25940
25930 Pout$="3"                                 ! TRANSFER STD PORT
25940 OUTPUT 1003;"8","8","?",Pout$,Iff$,"2"!SYS,2-4,STR,PORT,30 IF
25950 WAIT 50
25960 OUTPUT 1003;"8","8","0",Pout$,Iff$,"2"!CC
25970 ON Aet GOTO 25990,25980
25980 ON P0 GOTO 25990,26020
25990 OUTPUT 702;"0","0","7","3"       !POWER APPLIED TO MOUNT
26000 OUTPUT 702;"0","0",">","3"    !CCONTROL
26010 GOTO 26050
26020 OUTPUT 702;"3","0","7","3"       !POWER APPLIED TO MOUNT
26030 WAIT 50
```

```
26040 OUTPUT 702;"3","0",">","3"     !CCONTROL
26050 WAIT 150
26060 OUTPUT 701;"VRF2T2HO?" !OUTPUT FLUKE
26070 ! WAIT 600
26080 ENTER 701;V4 !ENTER BRIDGE -REF WITH POWER
26090 PRINT "BRIDGE -REF PWR=";V4
26100 Po(Loop)=V4
26110 NEXT Loop
26120 Pout$="0"
26130 OUTPUT 702;"0","1","7","0"  !POWER REMOVED FROM MOUNT
26140 WAIT 150
26150 OUTPUT 702;"0","1",">","0"
26160 OUTPUT 1003;"8","8","?",Pout$,Iff$,"2"  !SET PORT TO 0
26170 OUTPUT 1003;"8","8","0",Pout$,Iff$,"2"  !CCONTROL
26180 WAIT 150
26190 OUTPUT 701;"VRF2T2HO?"  !OUTPUT FLUKE
26200 ENTER 701;V5!       RECHECK BRIDGE -REF PWR OFF
26210 PRINT "BRIDGE -REF PWR OFF";V5
26220 OUTPUT 709;15
26230 WAIT 300
26240 ! OUTPUT 701;"VRF2T2HO?" !OUTPUT FLUKE
26250 ! WAIT 600
26260 ! ENTER 701;V6!RECHECK BRIDGE WITH POWER OFF
 6270 V6=V0
26280 DISP "BRIDGE NO PWR";V6
26290 !
26300 ! OUTPUT POWER FROM VOLTAGE
26310 !
26320 E6=V0+V6
26330 DISP "E6=";E6
26340 E7=(V3+V5)/2
26350 DISP "E7=";E7
26360 FOR I=4 TO 6
26370 E8=E6-Po(I-3)+E7
26380 DISP "E8=";E8
26390 E9=Po(I-3)-E7
26400 DISP "E9=";E9
26410 Po(I)=E8*E9/200
26420 NEXT I
26430 P1=Po(4)
26440 P2=Po(5)
26450 P3=Po(6)
26460 PRINTER IS 0
26470 SUBEND
26480 RE-SAVE "SUB V",26480,26920! JAN 13 1982 1430
```

S Power(

Aet	25500	25580	25970	
E6	26320	26330	26370	
E7	26340	26350	26370	26390

E8	26370	26380	26410					
E9	26390	26400	26410					
I	26360	26370	26390	26410	26420			
Iff$	25500	25670	25690	25940	25960	26160	26170	
Loop	25870	25880	26100	26110				
P0	25500	25590	25980					
P1	25500	26430						
P2	25500	26440						
P3	25500	26450						
Po(	25540	26100	26370	26390	26410	26430	26440	26450
Pout$	25570	25670	25890	25910	25930	25940	25960	26120
	26160	26170						
Q	25560							
V0	25740	25750	26270	26320				
V3	25850	25860	26340					
V4	26080	26090	26100					
V5	26200	26210	26340					
V6	26270	26280	26320					

```
26490 SUB Volt(V(*),Fr,Cc,C(*))
26500 PRINTER IS 16
26510  OPTION BASE 1
26520  COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
26530  COM File,Flag
26540 OUTPUT 1007;C
26550 CLEAR 1022
26560 FOR I=20 TO 27
26570 OUTPUT 1007;I
26580 PRINT I
26590 WAIT 50
26600 C=0
26610 CALL Dmm(V1,C(*),Fr,Cc,C,Di)
26620 V(I-19)=V1
26630 NEXT I
26640 OUTPUT 9;"R"
26650 ENTER 9;Y$
26660 PRINTER IS 0
26670 PRINT
26680 PRINT
26690 PRINT "DATE AND TIME:";Y$,"      YEAR  1982        FREQ=";F;"MHZ"
26700 PRINT
26710 PRINT
26720 IMAGE 1X,"VOLTMETER ZERO CHECK ",21X,DD.DDD,5X,"CHANNEL 28"
26730 IMAGE 1X,"15 VOLT SUPPLY (PREAMP 2-4)",15X,DD.DDD,5X,"CHANNEL 20"
26740 IMAGE 1X,"20 VOLT SUPPLY ANZAC AMPS",17X,DD.DDD,5X,"CHANNEL 21"
26750 IMAGE 1X,"28 VOLT SUPPLY AVENTEK I",18X,DD.DDD,5X,"CHANNEL 22"
26760 IMAGE 1X,"28 VOLT SUPPLY AVENTEK II",17X,DD.DDD,5X,"CHANNEL 23"
26770 IMAGE 1X,"15 VOLT SUPPLY SW. DR. TABLE",14X,DD.DDD,5X,"CHANNEL 24"
26780 IMAGE 1X,"28 VOLT SUPPLY TRANSCO SWITCH",12X,DDD.DDD,5X,"CHANNEL 25"
26790 IMAGE 1X,"15 VOLT SUPPLY SW. DR. OUTPUT",13X,DD.DDD,5X,"CHANNEL 26"
26800 IMAGE 1X,"15 VOLT SUPPLY SW. DR. OUTPUT",13X,DD.DDD,5X,"CHANNEL 26"
26810 IMAGE 1X,"25 VOLT SUPPLY WEINSCHEL ATTN.",12X,DD.DDD,5X,"CHANNEL 27"
26820 PRINTER IS 0
26830 ! PRINT USING 9810;V(9)
26840 PRINT USING 26730;V(1)
26850 PRINT USING 26740;V(2)
26860 PRINT USING 26750;V(3)
26870 PRINT USING 26760;V(4)
26880 PRINT USING 26770;V(5)
26890 PRINT USING 26780;V(6)
26900 PRINT USING 26800;V(7)
26910 PRINT USING 26810;V(8)
26920 SUBEND
26930   RE-SAVE "DESCR",26930,27080 !JANUARY 15 1982 0905
```

S Volt(

C	26540	26600	26610
C(	26490	26610	
Cc	26490	26610	

Di	26610							
F	26690							
Fr	26490	26610						
I	26560	26570	26580	26620	26630			
V(	26490	26620	26840	26850	26860	26870	26880	26890
	26900	26910						
V1	26610	26620						
Y$	26650	26690						

```
26940 SUB Descr(P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,Q(*),Set)
26950 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
26960 COM File,Flag
26970 LINPUT "DESCRIPTION FILE   MEAS+ #",Desc$
26980 MASS STORAGE IS ":F8,1"
26990 CREATE Desc$,80
27000 OUTPUT 9;"R"
27010 ENTER 9;P$
27020 ASSIGN #3 TO Desc$
27030 PRINT #3;P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,C1,C2,Z(*),Q(*),F(*)
27040 ASSIGN #3 TO *
27050 ASSIGN #3 TO Desc$
27060 READ #3;P$,C$,G$,R$,H$,F1,F2,F3,N3,N8,C1,C2,Z(*),Q(*),F(*)
27070 PRINT P$;":1983"
27080 SUBEND
27090  RE-SAVE "DMM",27090,27310!21 JANUARY 1982 GJC  1330
```

S Descr(

C$	26940	27030	27060		
C1	27030	27060			
C2	27030	27060			
Desc$	26970	26990	27020	27050	
F(	*	27030	27060		
F1	26940	27030	27060		
F2	26940	27030	27060		
F3	26940	27030	27060		
G$	26940	27030	27060		
H$	26940	27030	27060		
N3	26940	27030	27060		
N8	26940	27030	27060		
P$	26940	27010	27030	27060	27070
Q(	26940	27030	27060		
R$	26940	27030	27060		
Set	26940				
Z(	*	27030	27060		

```
27100 SUB Dmm(V1,C(*),Fr,Cc,C,Di)
27110 OPTION BASE 1
27120 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
27130 COM File,Flag
27140 DIM Rv$(100),Va(50)
27150 MAT Va=ZER
27160 RESET 1022
27170 FOR V=1 TO 5
27180 OUTPUT 1022;"S0 F1 R1 T4 L1 RS1 SM020 QX1"
27190 TRIGGER 1022
27200 ENTER 1022 BINT NOFORMAT;Rv$(V)
27210 STATUS 1022;S
27220 IF S=0 THEN 27250
27230 PRINT "PAUSE  1720"
27240 PAUSE
27250 Va(V)=VAL(Rv$(V))
27260 NEXT V
27270 V1=SUM(Va)/5
27280 MAT Va=ZER
27290 IF C=0 THEN 27310
27300 ! C(Cc,Di,Fr)=V1
27310 SUBEND
27320  RE-SAVE "SUB Vt     :F8,1",27320,27680 !JUNE 1, 1982 1545 GJC
```

S Dmm(

C	27100 27290
C(	27100
Cc	27100
Di	27100
Fr	27100
Rv$(	27140 27200 27250
S	27210 27220
V	27170 27200 27250 27250 27260
V1	27100 27270
Va(	27140 27150 27250 27270 27280

```
27330 SUB Vt(C(*),Fr,Cc,C,Di,Mean,Ret)
27340 OPTION BASE 1
27350 COM F(*),Z(*),T1,T2,T3,Qr(*),Qi(*),Final(*)
27360 COM File,Flag
27370 DIM In$[128],Out(32)
27380 IF Ret>1 THEN GOTO 27410
27390 OUTPUT 1022;"P1F1R40STD 10STI32 STNS01T3"
27400 GOTO 27420
27410 OUTPUT 1022;"P1F1R30STD FL1 10STI32 STNS01T3"
27420 ENTER 1022 BFHS 128 NOFORMAT;In$
27430 CALL Unpk56(In$,Out(*))
27440 FOR I=1 TO 32
27450 ! PRINT "NUMBER";I,"VOLTAGE READING";Out(I)
27460 NEXT I
27470 Mean=SUM(Out)/32
27480 PRINT Mean
27490 IF C=0 THEN GOTO 26980
27500 C(Di,Fr,Cc)=Mean
27510 SUBEXIT
27520 SUBEND
```

S Vt(

C	27330	27490		
C(	27330	27500		
Cc	27330	27500		
Di	27330	27500		
Fr	27330	27500		
I	27440	27460		
In$	27370	27420	27430	
Mean	27330	27470	27480	27500
Out(	27370	27430	27470	
Ret	27330	27380		

```
27530 SUB Unpk56(In$,Out(*))
27540 INTEGER N,J,I,B1,B2,B3,B4
27550 N=LEN(In$)
27560 J=0
27570 FOR I=1 TO N STEP 4
27580 J=J+1
27590 B1=NUM(In$[I])
27600 B2=NUM(In$[I+1])
27610 B3=NUM(In$[I+2])
27620 B4=NUM(In$[I+3])
27630 Out(J)=.1*BIT(B1,0)+.01*SHIFT(B2,4)+.001*BINAND(B2,15)
      +.0001*SHIFT(B3,4)+.00001*BINAND(B3,15)+.000001*SHIFT(B4,4)
      +.0000001*BINAND(B4,15)
27640 Out(J)=Out(J)*(1-2*BIT(B1,1))*10^((1-2*BIT(B1,7))
      *SHIFT(BINAND(B1,124),2))
27650 NEXT I
27660 RESET 1022
27670 SUBEXIT
27680 SUBEND
```

S Unpk56(

B1	27540	27590	27630	27640	27640	27640	
B2	27540	27600	27630	27630			
B3	27540	27610	27630	27630			
B4	27540	27620	27630	27630			
I	27540	27570	27590	27600	27610	27620	27650
In$	27530	27550	27590	27600	27610	27620	
J	27540	27560	27580	27580	27630	27640	27640
N	27540	27550	27570				
Out(	27530	27630	27640	27640			

GLOBAL NAMES

* F(	60	910	1010	1110	1280	1370	8330	8940
	9650	10250	10500	10850	11270	12110	12200	12790
	13360	13770	13860	15800	17010	19150	19640	20590
	23790	25520	26520	26950	27120	27350		
* File	70	920	1020	1120	1290	1380	8340	8950
	9660	10260	10510	10860	11280	12120	12210	12800
	13370	13780	13870	15810	17020	19160	19650	20600
	23800	25530	26530	26960	27130	27360		
* Final(	60	910	1010	1110	1280	1370	8330	8940
	9650	10250	10500	10850	11270	12110	12200	12790
	13360	13770	13860	15800	17010	19150	19640	20590
	23790	25520	26520	26950	27120	27350		
* Flag	70	920	1020	1120	1290	1380	8340	8950
	9660	10260	10510	10860	11280	12120	12210	12800
	13370	13780	13870	15810	17020	19160	19650	20600
	23800	25530	26530	26960	27130	27360		
* Qi(	60	910	1010	1110	1280	1370	8330	8940
	9650	10250	10500	10850	11270	12110	12200	12790
	13360	13770	13860	15800	17010	19150	19640	20590
	23790	25520	26520	26950	27120	27350		
* Qr(	60	910	1010	1110	1280	1370	8330	8940
	9650	10250	10500	10850	11270	12110	12200	12790
	13360	13770	13860	15800	17010	19150	19640	20590
	23790	25520	26520	26950	27120	27350		
* T1	60	910	1010	1110	1280	1370	8330	8940
	9650	102 13540	13800					
FNH(	11240	5310						
FNI(	12080	4910						
FNL(	12180	5030						
FNN(	990							
FNO(	1090	19900	19950	20000	20050	20100	20150	20200
	20250	20300						
FNS(	1260	600	1190	14690	15890	16370	16390	16450
	17760	19920	19970	20020	20070	20120	20170	20220
	20270	20350	20370	20420	21980	23890	24690	24750
	24790	24940	25350					
FNT(	13340	5640	7210					

FNU(	13750			
S Cal(	1350	690	750	
S Corr1(	13840	16050		
S Corr2(	15780	720		
S Descr(	26940	840	19090	
S Dmm(	27100	3620	26610	
S Freq(	19130	3840	21360	
S Get_parameter	19620	640		
S Meas(	20570	24030		
S Out(	23770	790		
S Power(	25500	330	14250	21450
S Report(	16990	25430		
S Unpk56(	27530	27430		
S Volt(	26490	160		
S Vt(	27330			

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5. AUTHOR(S) George J. Counas

6. PERFORMING ORGANIZATION (*If joint or other than NBS, see instructions*)

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here*)

The equipment described by this manual is the 2.0 to 4.0 GHz subsystem of the automated radiometer. This section of the multiband automated radiometer is a coaxial total power radiometer which implements a six-port reflectometer for impedance characterization and correction and utilizes a newly developed broadband cryogenic noise standard. NBS noise measurement capability in this frequency band has been expanded by the addition of this system which adds continuous frequency coverage to existing services along with the capability to measure cryogenic noise sources. This manual describes the 2.0 to 4.0 GHz frequency band of the NBS automated radiometer and provides operation and service information.

12. KEY WORDS (*Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons*)

automated; broadband cryogenic noise standard; six-port reflectometer; total power radiometer.

13. AVAILABILITY

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