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NISTIR 5016

NIST MODEL PM2 POWER MEASUREMENT SYSTEM FOR 1 mW AT 1 GHz

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December 1993

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TRADE NAME DISCLAIMER

Certain commercial components used in the measurement system are identified in this document in order clearly to instruct the operator in the use of the system. The instructions refer to specific models of specific instruments, and to their controls to ensure that there are no ambiguities. Such use and identification does not imply recommendation or endorsement by NIST, nor does it imply that the identified items are necessarily the best available for the purpose.

NIST MODEL PM2 POWER MEASUREMENT SYSTEM FOR 1 mW AT 1 GHz

Fred R. Clague

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The design and operation of an automated measurement system designed to measure power accurately at the level of 1 mW and at the frequency of 1 GHz are described. The system consists of commercial IEEE Std-488 bus-controlled instruments, a computer controller, and software. The results of a series of measurements are output to the computer display and, optionally, to a printer. The results are the mean of the measurement series and an estimate of the Type A (here random) and Type B (here systematic) uncertainty. The estimated total expanded uncertainty for the average of six consecutive measurements of a nominal 1 mW, 1 GHz source is typically less than 1 percent. The system can measure any power from 0.1 to 10 mW at any microwave frequency by making appropriate changes to the software and, possibly, the hardware.

Key words: automated measurement; microwave; microwave power measurement; power; power measurement; power measurement system.

1. INTRODUCTION

This system is designed to accurately measure microwave power at the level of 1 mW and the frequency of 1 GHz. Specifically, it supports the calibration of the Wavetek 8502A pulse power meter, which has a 1 mW, 1 GHz calibrator output port. The manufacturer's specification on the power output accuracy is ±1.5 percent. Use of the system is not restricted to this specific application; relatively simple modifications to the software would make it possible to measure other power levels and frequencies.

The microwave power measurement method is based on the dc substitution technique. The system is implemented using a commercial version of the NIST-developed Type IV microwave power meter, a commercial coaxial thermistor mount, a digital voltmeter (DVM), and a dedicated computer controller. The Type IV power meter is not direct reading; the substituted dc power is calculated using readings obtained from the DVM. The computer controls the measurement process, calculates the results, and prints them out. Measurement results include an estimate of uncertainty for each data set. Automation also allows use of a procedure that adequately corrects for drift of the thermistor mount caused by external temperature changes. The system is packaged in a single operating case with a storage drawer containing all necessary cables, two thermistor mounts, system software, and the operating manuals.

2. OPERATION

2.1 Initial Steps, Hardware

1. Connect the supplied ac power cables to the DVM and power meter.

2. Connect the supplied IEEE 488 bus cable to the power measurement system and the IEEE 488 bus card in the PC.

3. Connect the thermistor mount to the Type IV power meter. The end of the cable with the single connector goes to the thermistor mount, while the connector marked with an "A" goes to "Channel A" on the power meter and the unmarked connector goes to "Channel B."

4. Depress the input selector switch on the DVM to connect the rear panel input.

5. Turn on all the instruments. The output of the Wavetek 8502A calibrator is more stable after a 2-h warmup, rather than the 30 min specified by the manual. The 2-h warmup period is recommended for both the 8502A and the power measurement system. Also, the thermistor mount should be attached to the calibrator output for at least 30 min before making the measurement. This will reduce the temperature drift of the mount, improving the measurement accuracy. Be sure to note the serial number of the mount selected.

2.2 Software Installation

The software includes an installation program that will create a directory and copy all needed files to the hard drive. The drive must have at least 1 MB of free space and TransEra HTBasic 3.0 or higher already installed.

1. Turn on the power to the computer and allow DOS to load. At the DOS prompt, type `CD\HTB386` (or other directory where the BASIC system is located) and press ENTER. Then type `HTB386C` and again press ENTER. At this point HTBasic should be loaded as indicated by the BASIC soft keys appearing at the bottom of the screen.

2. Insert the disk labeled PM2 MEASUREMENT SYSTEM in the 3.5-in drive and type `LOAD "drive:INSTALL",1` where `drive` is the name of the drive where the PM2 MEASUREMENT SYSTEM disk is located; for example, `LOAD "B:INSTALL",1` and press ENTER. Be sure to type the quotation marks as shown.

3. The first screen lists the software and computer requirements and asks if you want to continue. Type `Y` and press ENTER to continue or `N` and press ENTER to terminate the installation.

4. The name of the source drive (drive from which the files are copied) is requested; press ENTER to accept the default (`B:`) or type another drive letter and press ENTER.

5. The destination drive (drive to which the files are copied) is requested; press ENTER to accept the default (`C:\`) or enter another drive. Note: the installation program will create its own directory named NIST_PM2 on the destination drive.

6. The location of the BASIC system files is requested: press ENTER to accept the default (`C:\HTB386`) or enter another drive and directory. Then the directory NIST_PM2 is created, and the program and support files copied.

7. The program asks if you want to use the supplied AUTOST program. It will activate the IEEE 488 bus card and the system printer, and then load and run the measurement program. The AUTOST program includes code lines as described below. Type `Y` and press ENTER to use the supplied AUTOST.

8. Finally you will be asked if the PC has the Morse KP 800/16 VGA graphics adapter, and the if the 800x600 display mode is desired. Type `Y` and press ENTER to use the 800x600 display mode.

9. This completes the software installation. Type `QUIT` and press ENTER to leave HTBasic and then, if you have HTBasic version 3.0, reboot the computer (this is necessary to avoid an out-of-memory error that may occur when you try to run the program).

The supplied AUTOST program is a modified version of the example supplied with HTBasic. The following lines in the example program have been changed:

310 !LOAD BIN "GPIBN;BOARD AT-GPIB" ! NATIONAL INST
is un-commented (! removed) to read:
310 LOAD BIN "GPIBN;BOARD AT-GPIB" ! NATIONAL INST

730 LOAD "DEMO",1
is commented out (! added) to read:
730 !LOAD "DEMO",1

If the your PC is configured differently than the one on which the prototype system was tested, additional or different changes may be required.

2.3 Measurement Software and Procedure

To run the program follow the directions for starting HTBasic under item 1 in the previous section. If the supplied AUTOST has been installed, the measurement program will load and run automatically. Otherwise, type `LOAD "PWR_MTR2",1` and press ENTER to load and start the program. If the power meter or the DVM is not turned on, the program will report it can not find the power meter at address 713 or the DVM at address 722. Pressing ENTER after each statement will let the program run, but measurements can not be made.

The remainder of this section describes the various software options that are available. The screens and menus as seen on the CRT are shown in figures 2.1 through 2.9. Numbered soft keys, corresponding to the keyboard function keys, are along the bottom of the menus. For quick reference, a menu tree is shown in appendix A.

The first screen displayed by the program is shown in figure 2.1. Additional detail on each item is in later sections of this chapter.

Press F1 to change the thermistor mount to be used in the measurement, or the stored data (such as after a thermistor mount recalibration). The serial number of the selected mount is shown.

Press F2 to enter the serial number of the Wavetek 8502A being measured. The serial number is then displayed and printed with the measurement result.

Press F3 to change the number of repeated measurements to be averaged in a set (at least 6 to 10 is recommended). The present setting is shown.

Press F4 to see instructions on how to operate the Wavetek 8502A (turn the calibrator output on and off).

Press F5 to begin the measurement set.

Press F10 to exit the program.

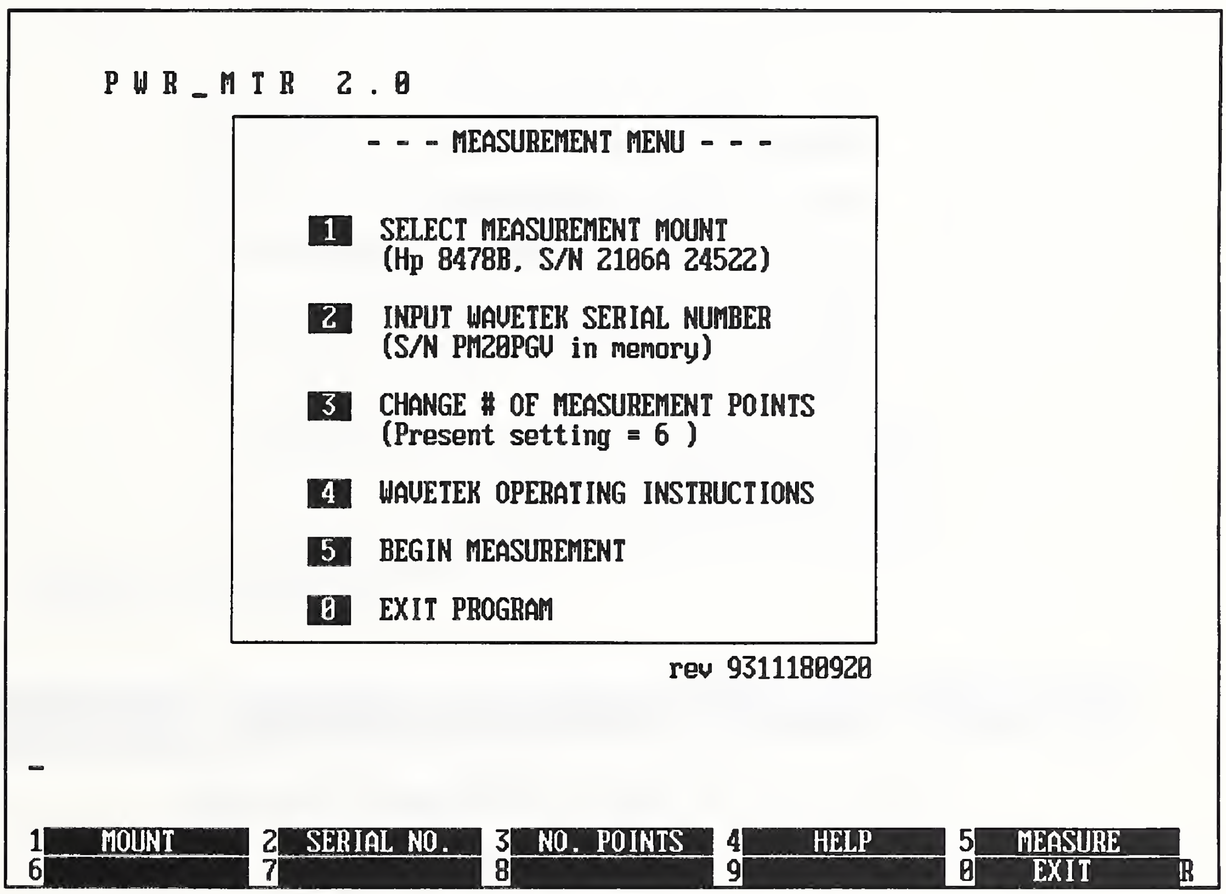

Figure 2.1. Screen display of the measurement menu.

2.3.1 Select Measurement Mount

Figure 2.2 shows the screen after selecting option 1 from the previous menu. Two bolometer mounts are supplied with each system. The calibration data (as listed in the NIST report of calibration) for both mounts is stored in a file called "CALDATA" that is read when the program is started.

Press F1 or F2 to select the active mount.

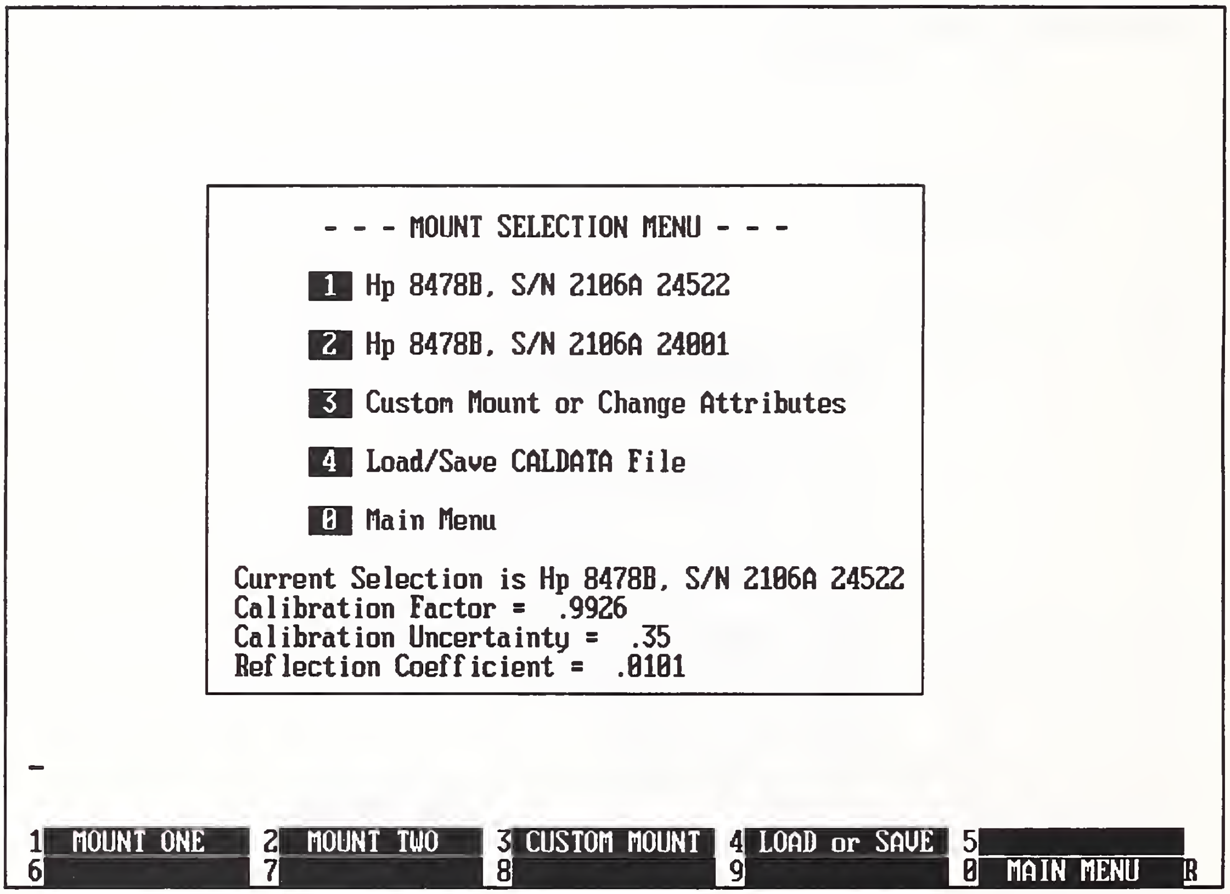

Figure 2.2. Screen display of the mount selection menu.

Press F3 in the Mount Selection Menu (figure 2.2) to change any entries in the CALDATA file (for a new mount or for the existing mounts if they have been recalibrated).

Figure 2.3 shows the screen that appears after pressing F3. You can change any of the four data entries (mount serial number, calibration factor, calibration uncertainty, or the mount reflection coefficient) in sequence. If there is no change for a particular entry, just press ENTER, and the original data will be retained. At each request for input you can abort the process and return to the mount selection menu. When all the changes have been entered, you are asked if you want to permanently save them to the CALDATA file and if the data is for mount 1 or mount 2.

```
        CURRENT MOUNT

        Model/Serial Number: Hp 8478B, S/N 2106A 24522

        Calibration Factor =  .9989

        Calibration Uncertainty in Percent =  .38

        Reflection Coefficient =  .0174



Enter Mount Model/Serial Number
Hp 8478B, S/N 2106A 24522

                                                              R
```

Figure 2.3. Screen display for changing stored calibration data.

Figure 2.4 is the last of the series of screens that appear after pressing F3 in the Mount Selection Menu. It asks for a path and file name for saving the mount data. Note: the name must be "CALDATA" for the file to load automatically when the program is started.

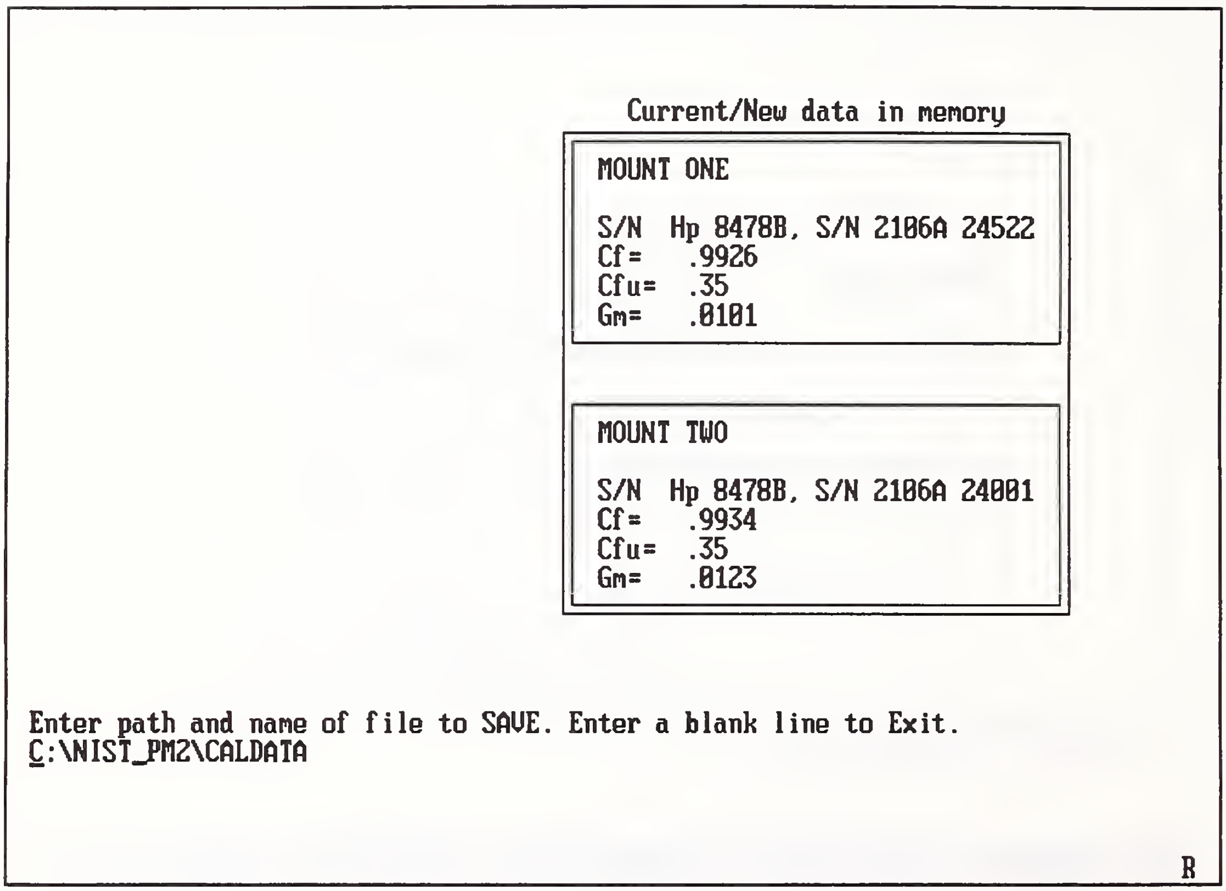

Figure 2.4. Screen display for saving the CALDATA file.

Press F4 in the Mount Selection Menu (figure 2.2) to load or save a CALDATA file.

The menu changes as seen in figure 2.5. If "S" is entered, the data presently in memory for the two mounts will be stored in CALDATA. Again, there is an opportunity to change the path or file name before it is saved, as the screen shown in figure 2.4 is repeated.

```
              - - - MOUNT SELECTION MENU - - -

              1 Hp 8478B, S/N 2106A 24522

              2 Hp 8478B, S/N 2106A 24001

              3 Custom Mount or Change Attributes

              4 Load/Save CALDATA File

              0 Main Menu

         Current Selection is Hp 8478B, S/N 2106A 24522
         Calibration Factor =  .9926
         Calibration Uncertainty =  .35
         Reflection Coefficient =  .0101
(L)oad or (S)ave 'CALDATA'. Press 'ESC' to abort.
_
                                                              R
```

Figure 2.5. Mount selections screen after choosing the fourth item.

If for some reason it is necessary to restore the original calibration data, the initial calibration reports are included with the system, and the data could be re-entered. As an added precaution, a backup version of the original CALDATA file, called "CALDATA.ORG", is on the distribution disk. It can be loaded by pressing F4 in the Mount Selection Menu (figure 2.2), entering the "L" for load, and then the file name as shown in figure 2.6.

```
                                          Current/New data in memory

                                        MOUNT ONE

                                        S/N  Hp 8478B, S/N 2106A 24522
                                        Cf=    .9926
                                        Cfu=   .35
                                        Gm=    .0101

                                        MOUNT TWO

                                        S/N  Hp 8478B, S/N 2106A 24001
                                        Cf=    .9934
                                        Cfu=   .35
                                        Gm=    .0123

Enter path and name of file to LOAD. Enter a blank line to Exit.
C:\NIST_PM2\CALDATA.ORG

                                                                        R
```

Figure 2.6. Mount selection screen when loading a CALDATA file.

2.3.2 Input Wavetek Serial Number

Pressing F2 in the Measurement Menu (figure 2.1) will let you input the serial number of the Wavetek power meter being calibrated. The serial number will then be printed on the measurement report as part of the permanent record.

2.3.3 Change Number of Measurement Points

Pressing F3 in the Measurement Menu (figure 2.1) will let you change the number of repeated measurements made during the calibration. No less than the default six measurements should be made; more than six will slightly reduce the total uncertainty because of a smaller standard uncertainty with additional repeat measurements.

2.3.4 Wavetek Operating Instructions

Pressing F4 in the Measurement Menu (figure 2.1) results in the screen that appears in figure 2.7. It gives brief instructions for manually controlling the 8502A calibrator output based on information given in the instrument's operating manual. The four numbered steps shown on the screen should be carried out before proceeding with the measurement. Press F10 to return to the main menu.

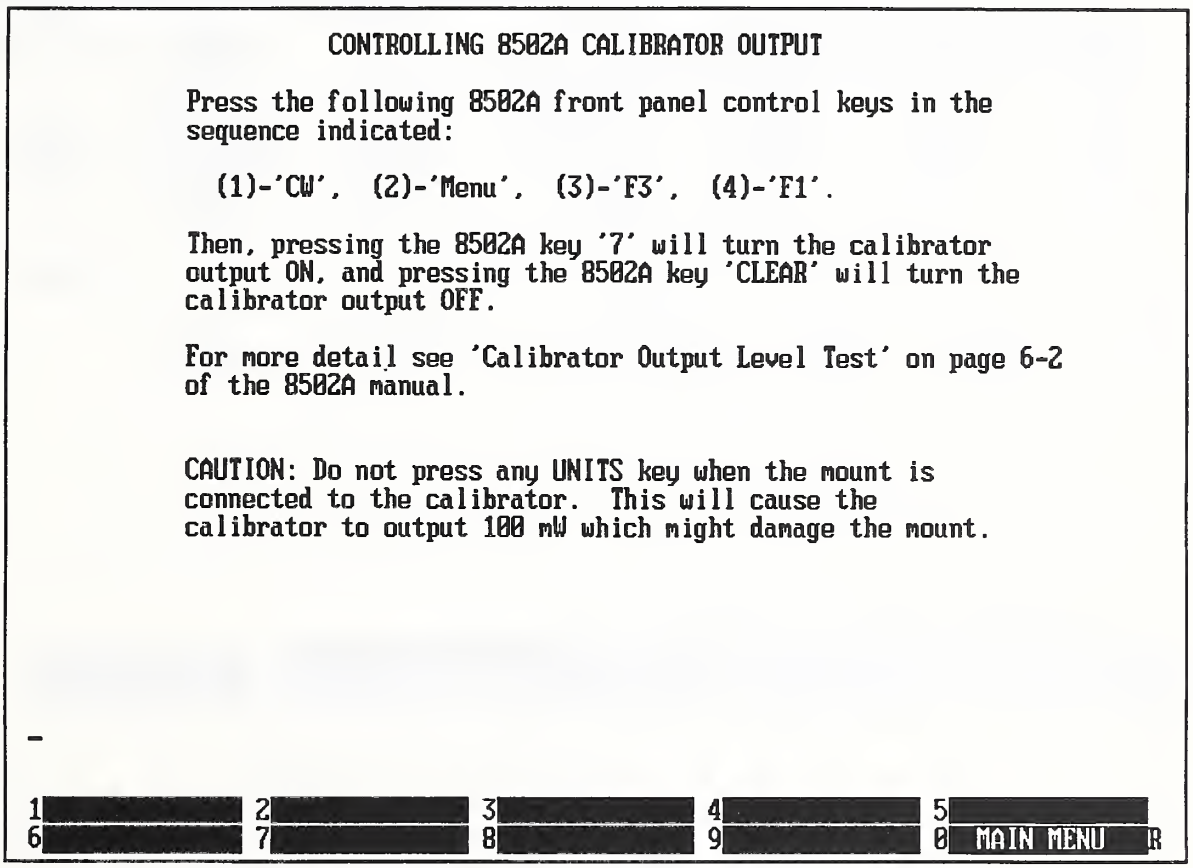

Figure 2.7. Screen display of operating instructions for the calibrator output.

2.3.5 Begin Measurement

Pressing F5 in the Measurement Menu (figure 2.1) leads to the screen that appears in figure 2.8. (Before starting the measurement, check the mount serial number to be sure the mount in use is the one shown on the screen.) Just before the message `TURN RF ON (PRESS 8502A KEY '7')` is displayed, the computer will beep once. At that point press key 7 on the 8502A to turn the rf on and wait for a pair of beeps from the computer. The message will change to `TURN RF OFF (PRESS 8502A 'CLEAR')`. After pressing the CLEAR key on the 8502A, wait until a single beep sounds again before pressing key 7 to begin the next measurement in the set. This sequence will be automatically repeated until all the measurements making up the set have been completed. As indicated, the measurement series can be aborted by pressing the ESCAPE key.

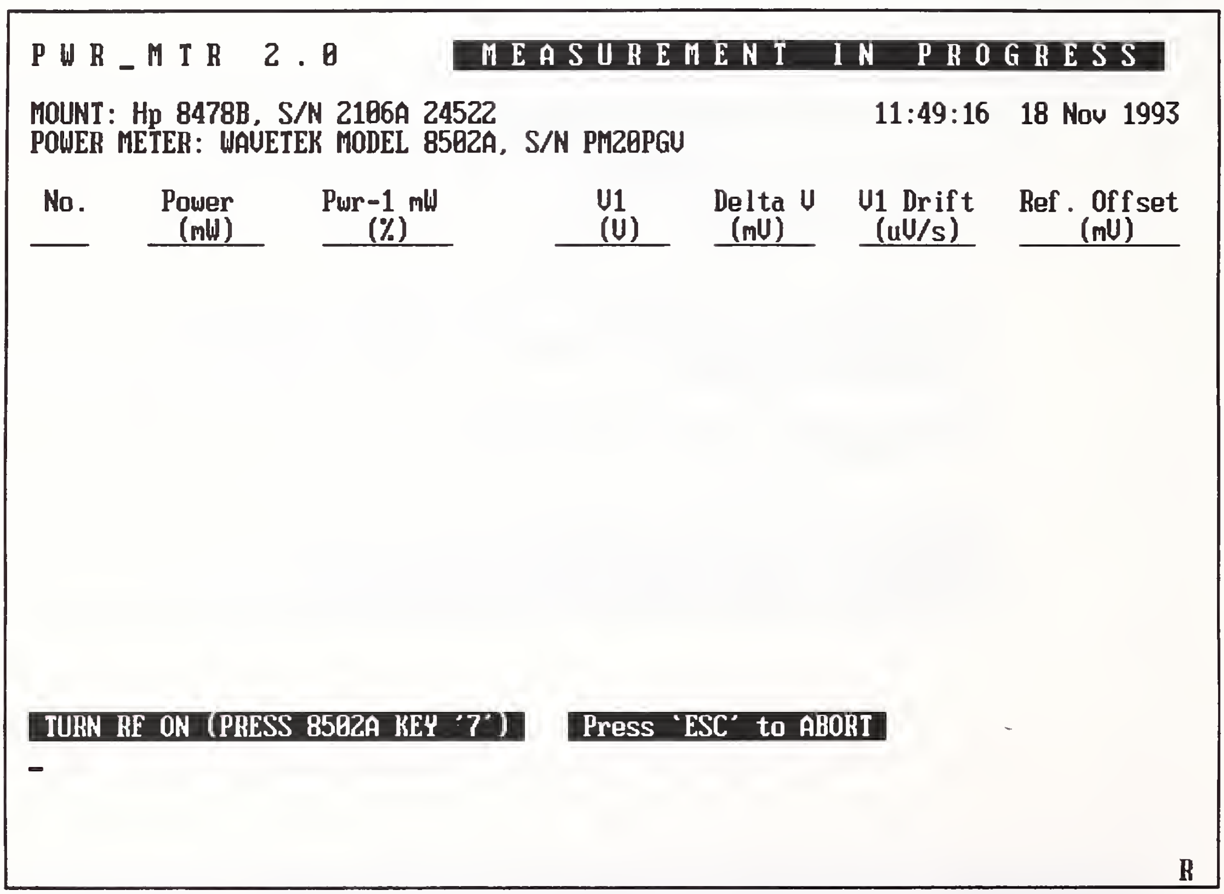

Figure 2.8. Screen display at the start of the measurement.

When the desired number of measurements is complete, the screen shown in figure 2.9 is displayed. The upper half of the screen shows a summary of each measurement in the set as explained in table 2.1 below. The final results are displayed on the lower half of the screen below the horizontal dashed line. The explanation of each column is given in table 2.2.

Press F1 to dump this screen to the system printer. A more detailed report is also available and can be printed or sent to a file, as explained in the paragraph following table 2.2.

```
P W R _ M T R   2 . 0        M E A S U R E M E N T   C O M P L E T E

MOUNT: Hp 8478B, S/N 2106A 24522                       11:49:16  18 Nov 1993
POWER METER: WAVETEK MODEL 8502A, S/N PM20PGV

 No.     Power      Pwr-1 mW        V1        Delta V   V1 Drift   Ref. Offset
         (mW)         (%)           (V)        (mV)      (uV/s)       (mV)
 ___   _________   _________    _________   ________   ________   ___________
  1     0.99390     -0.610      2.249627    44.290       1.4        -2.429
  2     0.99474     -0.526      2.249636    44.328       0.7        -2.429
  3     0.99459     -0.541      2.249644    44.320       0.3        -2.428
  4     0.99427     -0.573      2.249646    44.306       0.1        -2.428
  5     0.99461     -0.539      2.249649    44.321       0.5        -2.427
  6     0.99424     -0.576      2.249650    44.304       0.3        -2.425
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RESULTS:
        AVG PWR     AVG-1 mW        MAX DEV        STD DEV   W/C UNC   EXP UNC
         (mw)         (%)             (%)            (%)       (%)       (%)
        0.99439     -0.561      +0.036,-0.049      0.013     0.835     0.558

-

1 DUMP SCREEN   2 PRINT REPORT   3REPORT TO FILE 4               5
6               7                8               9               0  MAIN MENU
```

Figure 2.9. Screen display of the measurement results.

Table 2.1. Explanation of the upper part of the measurement screen	
Column Heading	Explanation
No.	Number of the power measurement.
Power	Result of the individual power measurement in mW.
Pwr - 1 mW	Normalized deviation of the measured power from 1 mW, percent.
V1	Power meter voltage with the rf off (see section 3.1).
Delta V	Change that occurs in the power meter voltage when the rf is turned on.
V1 Drift	Drift of V_1 in μV/s that occurred from the beginning of the measurement until it was complete. Note that if the drift is greater than 10 μV/s the measurement should be repeated after waiting a period of time for the mount temperature to further stabilize.
Ref. Offset	The compensation element channel is used as the voltage reference; this column shows the voltage difference between the measurement thermistor channel and the compensation thermistor channel when the rf is off.

Table 2.2. Explanation of the results section of the measurement screen	
Column Heading	Explanation
AVG PWR	Average power in mW, computed from the measured data set.
AVG - 1mW	Percent deviation of the average power level from 1 mW.
MAX DEV	The maximum positive and negative deviations from the average.
STD DEV	The standard deviation of the mean.
W/C UNC	Worst-case uncertainty; the total uncertainty in the measurement when all components are simply added.
EXP UNC	Expanded uncertainty; the RSS combination of all uncertainty components multiplied by a coverage factor (k) of two. For a discussion of standard and expanded uncertainty see section 4 and reference [1].

Press F3 in the measurement results screen (figure 2.9) to print a copy of the detailed measurement report which can be used as a permanent record. Press F4 to save the report to a DOS text file that can be imported into a word processor. This report, which is not displayed on the CRT, shows the individual measurements, summarizes the results, and lists the uncertainty components. Figure 2.10 is an example of the report.

The top section of the report essentially duplicates what was shown in the results screen of figure 2.9.

The lower section of the report contains a table listing the uncertainties in the measurement. Each uncertainty component discussed in section 4 is shown, followed by a pair of values. The uncertainty limits column contains values which can be considered the traditional systematic and random components that are added to give the worst case sum. The standard uncertainty column contains the values needed for the method of expressing uncertainty in measurement recommended by the CIPM (International Committee for Weights and Measures) and required by NIST [1]. The final expanded uncertainty is twice the square root of the sum of the squares (RSS) of the standard uncertainties. Section 4 and reference [1] (also listed in the report) give more detail. The two columns make available a choice of uncertainty expression and uncertainty components to meet the user's requirement.

MEASUREMENT DATA

FOR POWER METER: WAVETEK MODEL 8502A, S/N PM20PGV

USING MOUNT: Hp 8478B, S/N 2106A 24522 11:49:16 18 Nov 1993

	Power (mW)	Pwr-1 mW (%)	V1 (V)	Delta V (mV)	V1 Drift (μV/s)	Ref. Offset (mV)
1	0.99390	-0.610	2.249627	44.848	1.4	-2.429
2	0.99474	-0.526	2.249636	44.328	0.7	-2.429
3	0.99459	-0.541	2.249644	44.320	0.3	-2.428
4	0.99427	-0.573	2.249646	44.306	0.1	-2.428
5	0.99461	-0.539	2.249649	44.321	0.5	-2.427
6	0.99424	-0.576	2.249650	44.304	0.3	-2.425

MEASUREMENT RESULTS

The mean of the 6 measurements is 0.99439 mW with 0.008 percent standard deviation of the mean. The maximum deviation from the mean is +0.036 and -0.049 percent. The mean is 0.561 percent less than 1 mW.

The table below shows the values of the major uncertainty components. The total uncertainty is expressed as both the worst case sum and the expanded uncertainty. For a discussion of standard and expanded uncertainty see NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

Value of uncertainty components in percent at 1 GHz.		
Uncertainty factor	Uncertainty limits	Standard uncertainty
DVM	0.033	0.0[illegible]
Mount calibration factor	0.350	0.202
Mismatch (mount reflection coefficient = 0.0101)	0.113	0.080
Dual element	0.300	0.173
Random effects (standard deviation of the mean)	0.039	0.0[illegible]
Worst case sum	0.835	
Combined standard uncertainty (RSS)		0.279
Expanded uncertainty (coverage factor = 2)		0.558

Figure 2.10. Sample of the hardcopy output.

3. SYSTEM DESCRIPTION

3.1 Theory of Operation

The NIST Type IV power meter is not a direct reading instrument. An external precision dc voltmeter must be connected to the power meter, and the power calculated from the voltmeter readings. For this system, the microwave power P is given by

$$P = \frac{1}{K_b R_0}\left(V_1^2 - V_2^2\right), \tag{3.1}$$

where V_1 is the output voltage without rf power, V_2 is the voltage with rf power, R_0 is the operating resistance of the mount, and K_b is the mount calibration factor. Note that the power is proportional to the "bolometric power," which is simply the change of the mount dc bias power as rf power is applied and removed.

Equation (3.1) shows that, as the rf power becomes small, V_2 approaches V_1. Because of the uncertainty "magnification" that occurs in the computed difference of two nearly equal numbers, the power measurement uncertainty becomes very large as the power decreases. The solution to this problem is to measure the difference between V_1 and V_2 directly. This requires a reference voltage generator (RVG) which is set nominally equal to V_1 and, in effect, stores V_1.

When an RVG is used, the expression for calculating power from measured voltages becomes

$$P = \frac{1}{K_b R_0}\left(2V_1 - \Delta V\right)\Delta V, \tag{3.2}$$

where V_1, R_0, and K_b were previously defined, and ΔV is the change in the power meter voltage when rf is applied; that is, V_1-V_2. In providing for a first-order correction of mount drift, the value of V_1 and ΔV are estimated by assuming linear drift and taking several other readings while the rf is off, as shown in figure 3.1.

The diagram in figure 3.1 depicts the outputs of the power meter and RVG as a function of time while the rf is cycled on and off. The measurement sequence of five voltage and time readings used to calculate the power and correct for the mount drift is also shown. Note that the reference voltage generator is not set equal to V_1, nor is it constant with time. This is because it is convenient to use the compensation element of the mount, biased by the second power meter channel, as the reference voltage generator. Thus the RVG does drift

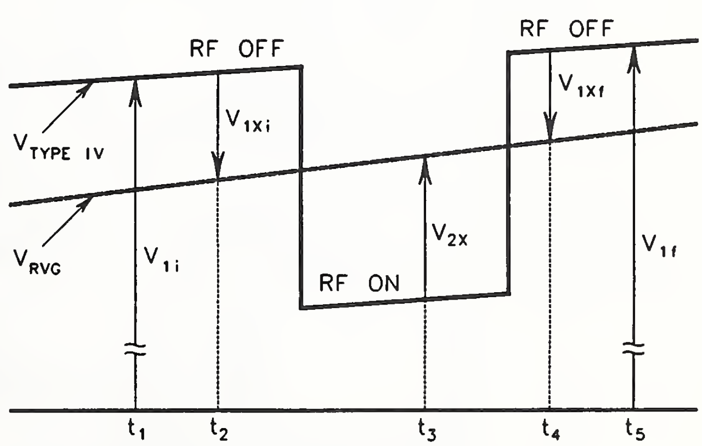

Figure 3.1. Measured power meter voltages vs time.

during the measurement, but this change is also corrected, to first order, by the measurement series.

In terms of the measured voltages, the values to be used in eq (3.2) are given by

$$V_1 = V_{1i} + \left(\frac{t_3 - t_1}{t_5 - t_1}\right)(V_{1f} - V_{1i}) \tag{3.3}$$

and

$$\Delta V = V_{2X} - \left[V_{1Xi} + \left(\frac{t_3 - t_2}{t_4 - t_2}\right)(V_{1Xf} - V_{1Xi})\right]. \tag{3.4}$$

3.2 Hardware

The system block diagram is shown in figure 3.2. The input switching to the digital voltmeter (DVM) is done with the multiplexer internal to the DVM. The controller is user supplied. The generic specifications for the instruments are given in appendix B.

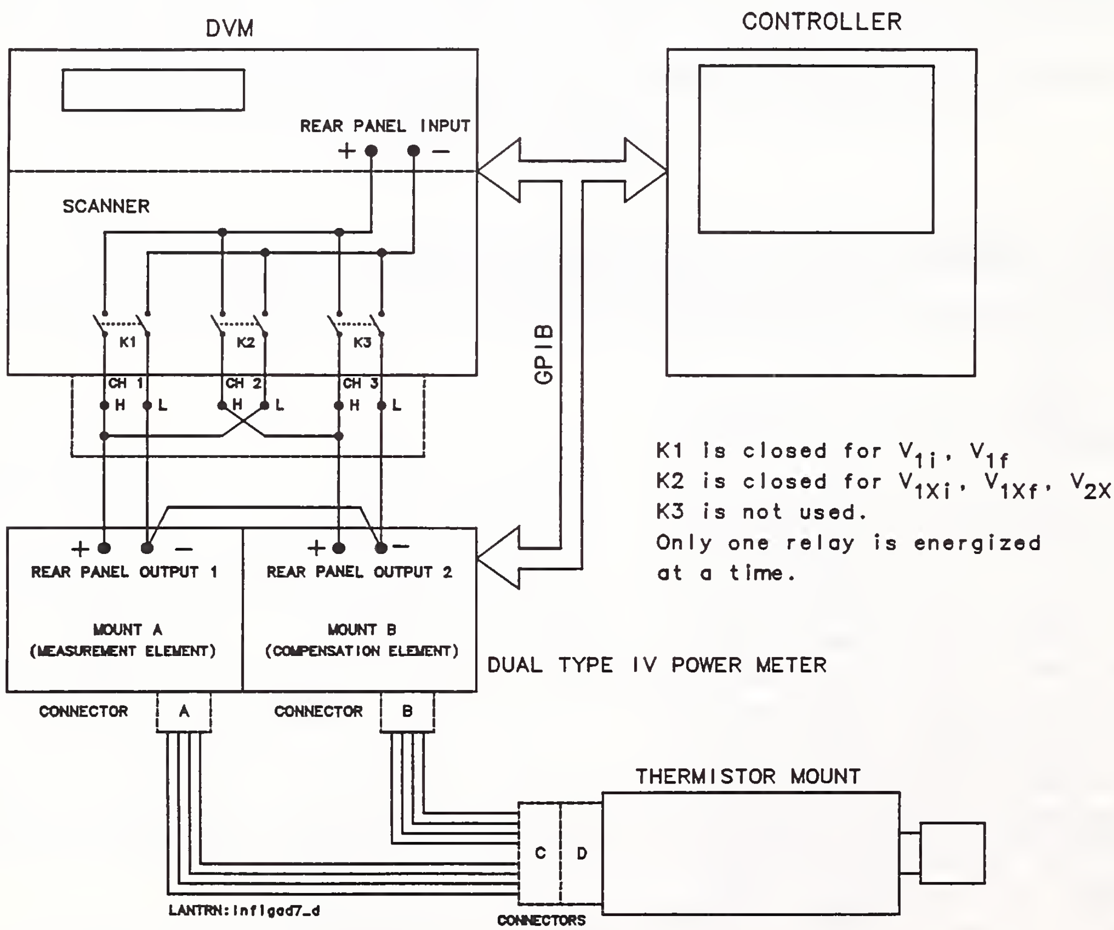

Figure 3.2. System block diagram.

The internal wiring of the thermistor mount as received from the factory is shown in figure 3.3.

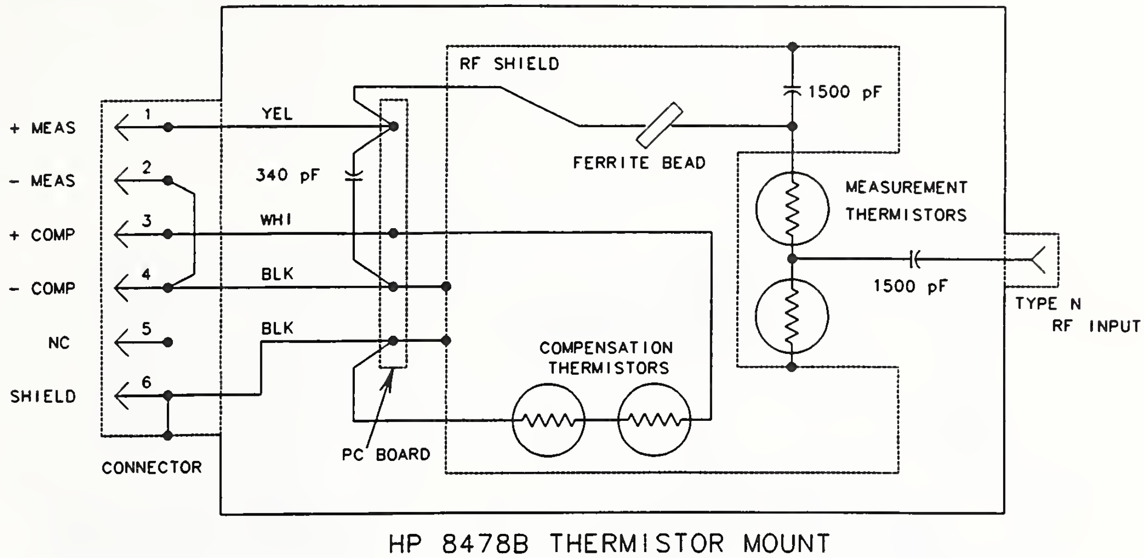

Figure 3.3. Original mount wiring.

Figure 3.4 shows the internal wiring diagram of the thermistor mount as modified for this application. The mount bias connector is replaced and internal wiring changes are made. These changes provide four-wire connections to the measurement and compensation thermistors, which eliminate lead and connector contact resistance errors. Only the modified mounts can be used with the system.

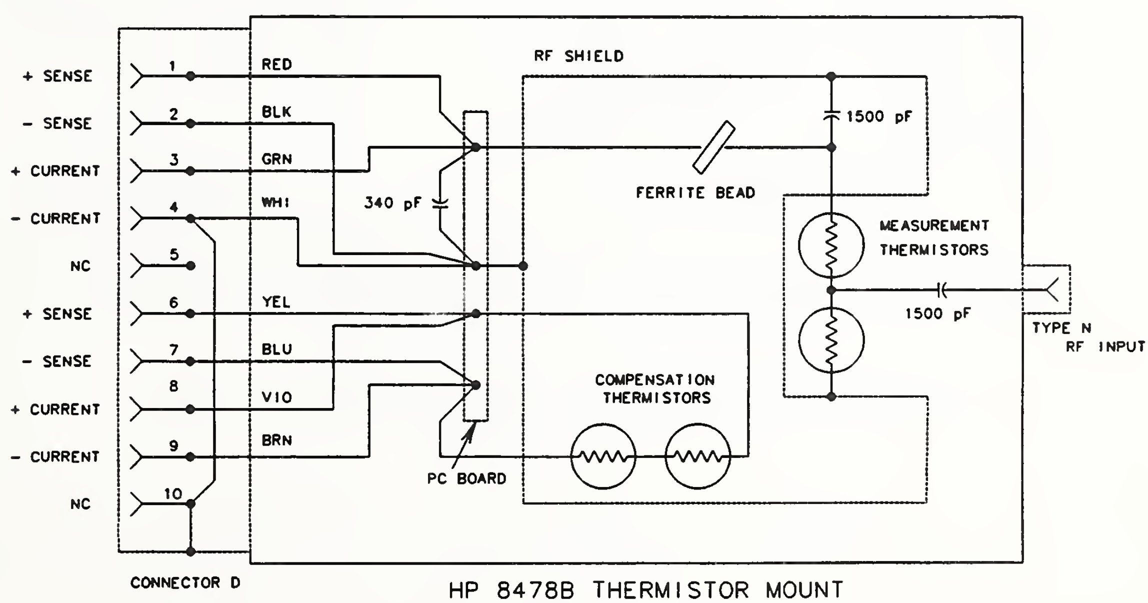

Figure 3.4. Modified mount wiring.

Figure 3.5 is a diagram showing the physical layout of the pc board in the mount with the attachment points for the wires leading to the connector and the thermistor elements.

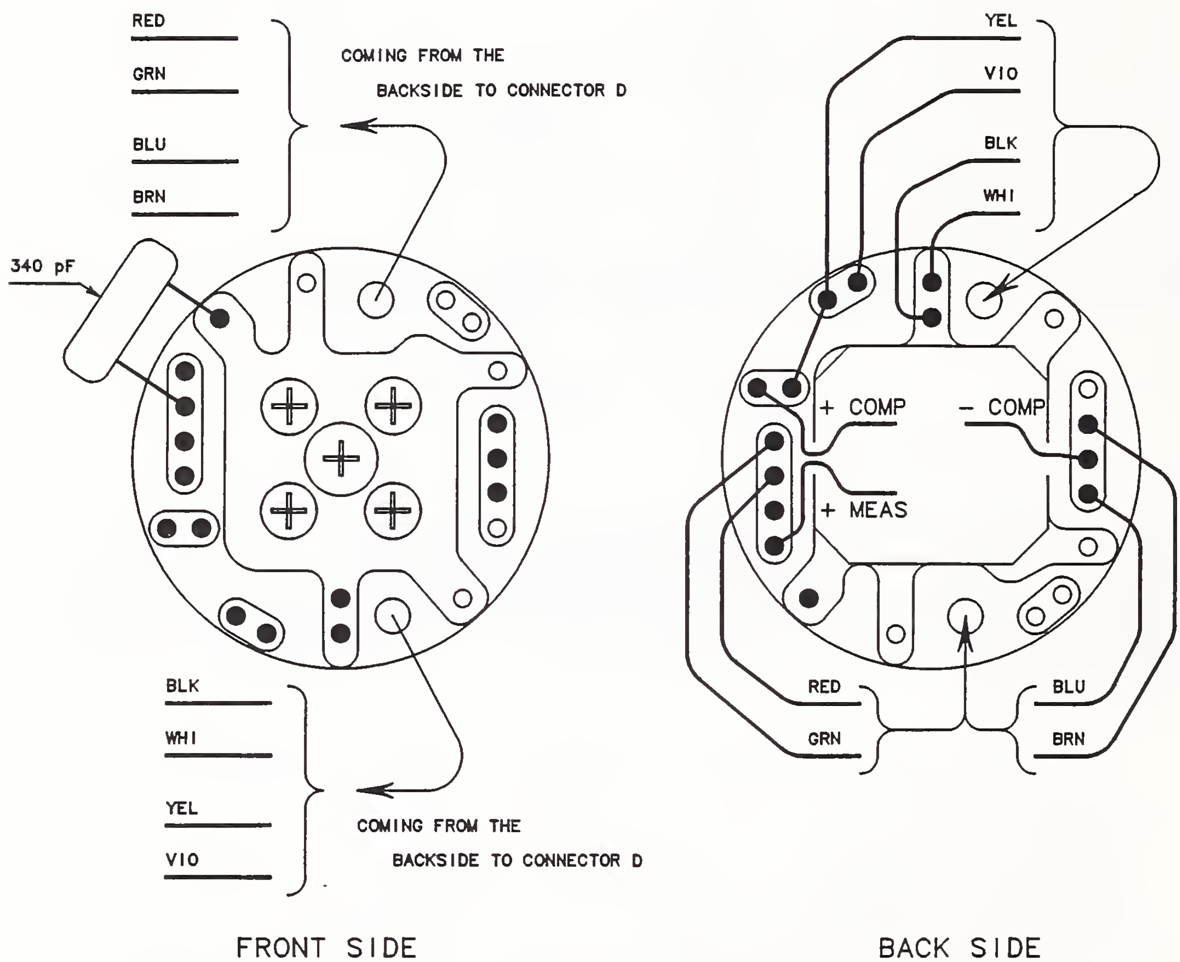

Figure 3.5. HP 8478B thermistor mount pc board layout with modified wiring.

Figure 3.6 is the wiring diagram for the cable that connects the mount to the power meter.

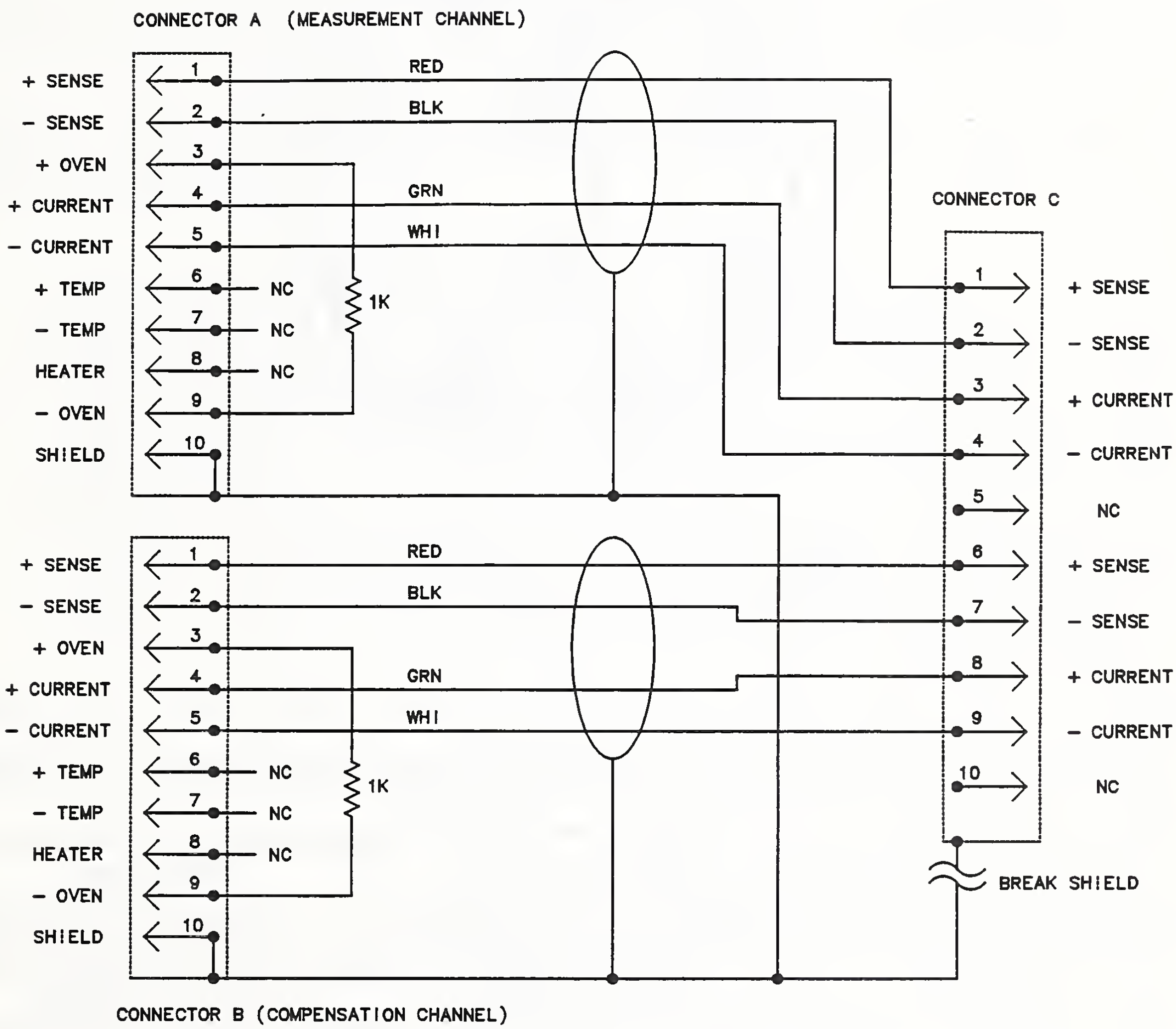

Figure 3.6. Thermistor mount connecting cable wiring diagram.

Figure 3.7 is a view of the cable end of the connector showing the pin-out. The specific connectors used are listed in Table 3.1.

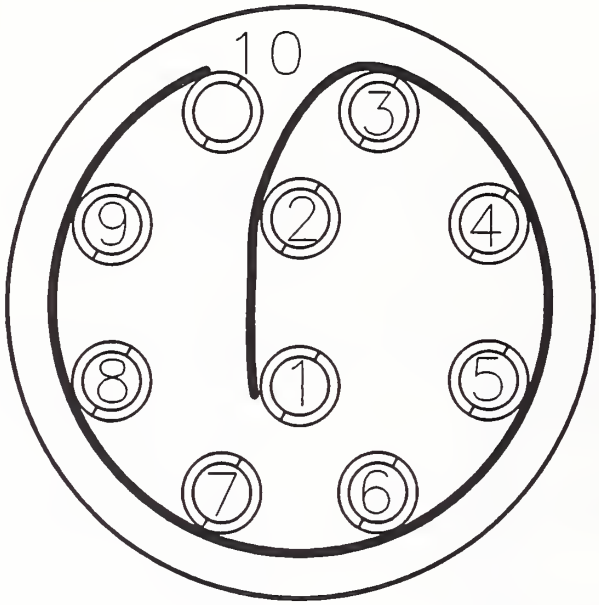

Figure 3.7. Connector pin-out (Male cable connector as seen from cable end).

Table 3.1. Connectors		
Connector designation	Connector model NO.	Manufacturer
Connectors A, B, C	FGG.2B.310.CNAD72Z	Lemo USA INC P.O. Box 11488 Santa Rosa, CA 95406
Connector D	EHG.2B.310.CNL	

3.3 Software

A software listing is included as appendix C. Comments at the beginning of the code define the variables (and their location) that one might want to change for other applications such as a different power level. However, if changes are made, the user is responsible for the results. NIST cannot support modified code.

4. UNCERTAINTY ANALYSIS

The uncertainties associated with the measurement are grouped in two categories according to the method used to estimate their numerical values [1]. The Type A evaluations of standard uncertainty are based on statistical analysis of measurement results. The Type B evaluations of standard uncertainty are based on other methods, such as manufacturer's instrument specifications, measurement results, and scientific judgement. The standard uncertainties obtained by either the Type A or the Type B evaluations are the equivalent of a standard deviation.

The factors listed below contribute to the total measurement uncertainty and are included in the analysis. The standard uncertainty for each component is determined by either a Type A or a Type B evaluation as appropriate.

1. Uncertainty in the dc voltage measurements.
2. Uncertainty in the thermistor mount effective efficiency calibration.
3. Mismatch uncertainty due to the source (8502A calibrator output) reflection coefficient and the thermistor mount reflection coefficient.
4. The "dual element substitution error" associated with the coaxial thermistor mount.
5. Random effects.
6. Type IV power meter uncertainty. There are four sources of possible error internal to the power meter. They are the reference resistors, the operational amplifier open loop gain, input offset voltages, and input bias currents. The Type IV error analysis [2] indicates that all of them are negligible compared to the four factors listed above.

The first five of these items are considered individually in the following sections. An example of the results is summarized in a concluding table.

4.1 Voltmeter Uncertainty

The effect of uncertainty in the individual voltmeter readings can be determined by taking the total differential of the expression for power, eq (3.2),

$$\mathrm{d}P = \frac{2}{K_b\, R_0}\left[\Delta V\,\mathrm{d}V_1 + (V_1 - \Delta V)\,\mathrm{d}\Delta V\right]. \tag{4.1}$$

Let

$$T_{1f} \equiv \frac{t_3 - t_1}{t_5 - t_1} \tag{4.2}$$

and

$$T_{2f} \equiv \frac{t_3 - t_2}{t_4 - t_2}. \tag{4.3}$$

Thus, in terms of the measured parameters,

$$dV_1 = \left(1 - T_{1f}\right) \delta V_{1i} + T_{1f}\, \delta V_{1f} \tag{4.4}$$

and

$$d\Delta V = \delta V_{2X} + \left(1 - T_{2f}\right) \delta V_{1Xi} - T_{2f}\, \delta V_{1Xf}. \tag{4.5}$$

The quantities δV_{1i}, δV_{1f}, δV_{1Xi}, δV_{1Xf}, and δV_{2X}, are the uncertainties in the measured values of V_{1i}, V_{1f}, V_{1Xi}, V_{1Xf}, and V_{2X}. These uncertainties in the measured voltages are based on the voltmeter specifications, which are usually given in two parts as a fraction of reading term, α, and a fraction of full scale term β. The general expression for the voltmeter uncertainty is given by

$$\delta V = \alpha\, V_{reading} + \beta\, V_{fullscale}. \tag{4.6}$$

Figure 4.1 shows the uncertainty in power measurement as a function of power level near 1 mW, as calculated using the above procedure for the voltmeter, power meter, and measurement configuration used in this system. In the calculations, the signs of the independent terms are chosen to give the maximum contribution to the total uncertainty. This uncertainty is obtained from a Type B evaluation and has a rectangular distribution.

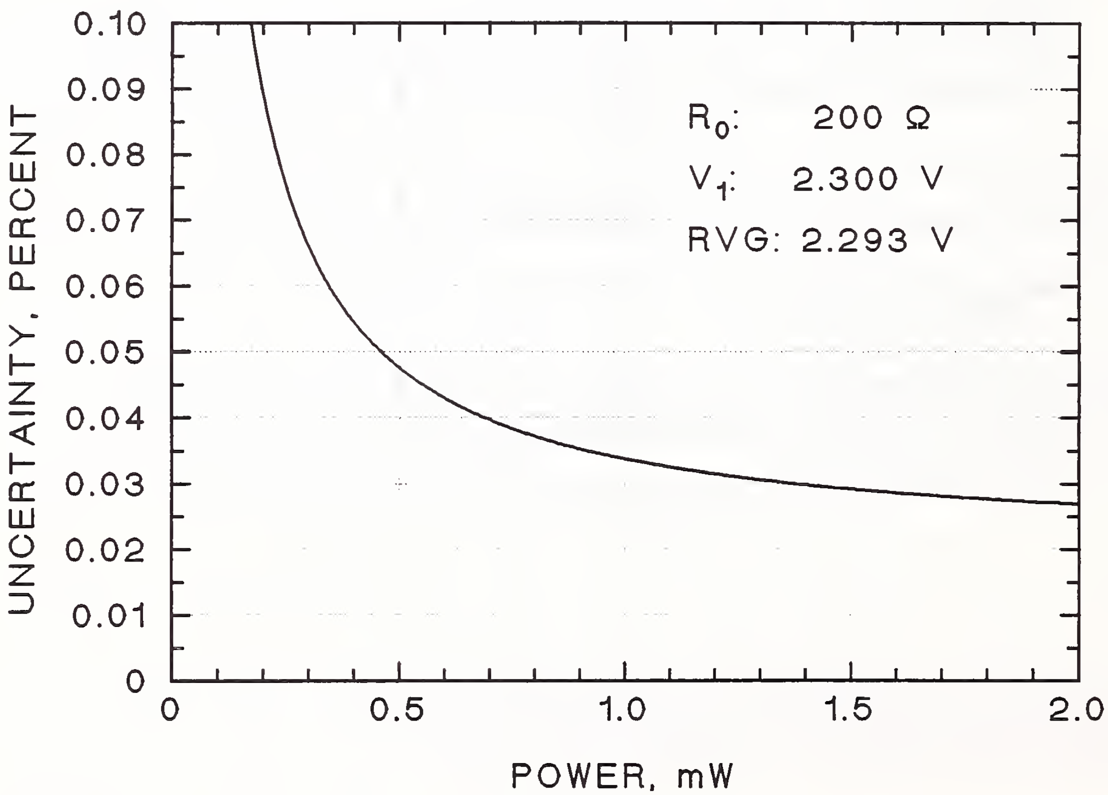

Figure 4.1. Power measurement uncertainty from the DVM.

4.2 Uncertainty in Thermistor Mount Effective Efficiency

This is the uncertainty of the NIST thermistor mount calibration. The NIST calibration also gives a value for the mount calibration factor C_f, which is the factor used in this measurement rather than effective efficiency alone. It is defined in the next section. The values listed on the report of calibration will, of course, be constant for any given mount, until the unit is periodically recalibrated. This uncertainty is based on a Type B evaluation and has a rectangular distribution.

4.3 Mismatch Uncertainty

The net power delivered to a termination by a source is given by

$$P_t = P_0 \frac{1 - |\Gamma_t|^2}{|1 - \Gamma_g \Gamma_t|^2}, \tag{4.7}$$

where P_0 is the power the source would deliver to a nonreflecting termination, Γ_g is the generator reflection coefficient, and Γ_t is the termination reflection coefficient. Ideally, the calibrator should deliver a net power of 1 mW to the power detector being calibrated, but that can be accomplished only if the complex reflection coefficients of the power detector, generator, and calibrating thermistor mount are known, which is generally not the case. Assuming, then, that the calibrator output specification is the power delivered to a nonreflecting load P_0, the measured output is given by

$$P_0 = \frac{P_m}{\eta_m} \frac{|1 - \Gamma_g \Gamma_m|^2}{1 - |\Gamma_m|^2}, \tag{4.8}$$

where P_m is the bolometrically measured power, η_m is the effective efficiency of the thermistor mount, Γ_g is the generator reflection coefficient, and Γ_m is the thermistor mount reflection coefficient. The denominator of eq (4.8) is the mount calibration factor

$$C_f = \eta_m \left(1 - |\Gamma_m|^2\right), \tag{4.9}$$

so eq (4.8) becomes

$$P_0 = \frac{P_m}{C_f} |1 - \Gamma_g \Gamma_m|^2. \tag{4.10}$$

The value of Γ_m has been measured during the NIST calibration, but only an upper limit to the magnitude of Γ_g is known (from the source return loss specification). Only the limits to the term involving the reflection coefficients are known. Thus,

$$(1 - |\Gamma_g||\Gamma_m|)^2 \leq |1 - \Gamma_g \Gamma_m|^2 \leq (1 + |\Gamma_g||\Gamma_m|)^2, \tag{4.11}$$

so P_0 is also only known within the limits

$$\frac{P_m}{C_f}(1 - |\Gamma_g||\Gamma_m|)^2 \leq P_0 \leq \frac{P_m}{C_f}(1 + |\Gamma_g||\Gamma_m|)^2. \tag{4.12}$$

This uncertainty in P_0 is the mismatch uncertainty and its relative value is given to first order by

$$\pm 2\,|\Gamma_g|\,|\Gamma_m|\,. \tag{4.13}$$

The return loss specification on the calibrator output is greater than 25 dB, which results in a value for $|\Gamma_g|$ of $\leq$ 0.056. Since value of $|\Gamma_m|$ is different for each thermistor mount, the mismatch uncertainty is calculated for each. This uncertainty is based on a Type B evaluation and has a U-shaped distribution [3].

4.4 Dual-Element Error

The power detector is a dual-element coaxial thermistor mount. Dual-element bolometer units are nonlinear with power level as a result of a dc-rf substitution error that arises because the two elements are not identical [4]. The magnitude of the error is different for each mount. The error is of concern because the measurement is being made at 1 mW, while the NIST calibration of mount efficiency is done at 10 mW. The only way to determine the error magnitude is by direct measurement, which is difficult at best.

Several methods were tried, but all had one or more deficiencies in giving a completely accurate, self-consistent determination. The problem is the effect is comparable to the noise, especially at 1 mW. However, the different methods did give results in general, if not exact agreement. The results reported here are from measurements on 20 mounts using a six-port reflectometer calibrated at 10 mW. The effective efficiency of each mount was measured at 10 mW and again at 1 mW without disconnecting the mount.

The differences between the effective efficiencies at the two powers for the sample of 20 mounts is used to make inferences about the differences of the entire population (80 mounts). A normal probability plot indicated the data can be considered normal. The two-sided tolerance interval [5] for the differences is [-0.00269, 0.00305]. This interval should include 99 percent of the population with 95 percent confidence. Making the interval symmetric about 0 [-0.003, 0.003] will still include at least 99 percent of the population with 95 percent confidence. This uncertainty is based on a Type B evaluation and is assumed to have a rectangular distribution.

4.5 Random Effects

The measurement is repeated a minimum of six times. The standard deviation of the mean of the measurement set is the uncertainty component. This uncertainty is based on a Type A evaluation and has a normal distribution.

4.6 Expanded Uncertainty

Table 4.1 shows how the contribution of each uncertainty component is converted to a standard uncertainty. Again, definitions for the variables and terms used are found in reference [1]. The numbers in the table come from the sample measurement detailed in section 2. The components used in the worst case total shown in figure 2.10 are the values from the half-width interval column except for the random effects. The value of the random component for the worst case total is three times the standard deviation of the mean.

Table 4.1. Value of uncertainty components in percent					
Uncertainty factor	Evaluation type	Half-width interval (a)	Distribution	Conversion formula	Standard uncertainty
DVM and power meter	B	0.034	Rectangular	$u_j = a/\sqrt{3}$	0.020
Mount calibration	B	0.380	Rectangular	$u_j = a/\sqrt{3}$	0.219
Mismatch	B	0.195	U-shaped	$u_j = a/\sqrt{2}$	0.138
Dual-element	B	0.300	Rectangular	$u_j = a/\sqrt{3}$	0.173
Random effects	B	-	Normal	-	0.008
Combined standard uncertainty (RSS)					0.312
Expanded uncertainty ($k = 2$)					0.626

5. REFERENCES

[1] Taylor, B.N.; Kuyatt, C.E. Guidelines for evaluating and expressing the uncertainty of NIST measurement results. Natl. Inst. Stand. Technol. Tech. Note 1297; 1993 January. 15 p.

[2] Larsen, N.T. A new self-balancing dc-substitution rf power meter. IEEE Trans. Instrum. Meas. IM-25: 343-347; 1976 December.

[3] Harris, I. A.; Warner, F.L. Re-examination of mismatch uncertainty when measuring microwave power and attenuation. IEE Proc. 128, Pt. H, No.1: 35-41; 1981 February.

[4] Engen, G.F. A dc-rf substitution error in dual-element bolometer mounts. IEEE Trans. Instrum. Meas. IM-13: 58-64; 1964 June-September

[5] Hahn, G.S.; Meeker, W.Q. Statistical intervals: a guide for practitioners. New York, NY: John Wiley & Sons; 1991, 58-59.

APPENDIX A. Software Menu Tree

The numbered entries are menu soft-key labels where the numbers correspond to function keys, except for 0 which is function key 10 (F10).

- 1 MOUNT
  - 1 MOUNT ONE
  - 2 MOUNT TWO
  - 3 CUSTOM MOUNT
    - Enter Mount Model/Serial Number
    - Enter Mount Calibration Factor
    - Enter Calibration Uncertainty in Percent
    - Enter Mount Reflection Coefficient
    - Permanently save these changes to BDAT file CALDATA ?
      - (Y)es
      - (N)o
    - Enter 1 to save as mount one, 2 to save as mount two, or 'ESC' to abort.
      - 1 — Enter path and name of file to SAVE. Enter blank line to exit.
      - 2 — Enter path and name of file to SAVE. Enter blank line to exit.
      - ESC
  - 4 LOAD or SAVE
    - (L)oad or (S)ave 'CALDATA'. Press 'ESC' to abort.
      - (L)oad — Enter path and name of file to LOAD. Enter blank line to exit.
      - (S)ave — Enter path and name of file to SAVE. Enter blank line to exit.
      - ESC
  - 0 MAIN MENU
- 2 SERIAL NO. — WAVETEK SERIAL NUMBER ?
- 3 NO. POINTS — NUMBER OF MEASUREMENT POINTS ?
- 4 HELP — 1 MAIN MENU
- 5 MEASURE
  - TURN RF ON/OFF (Measurement loop)
    - 1 DUMP SCREEN
    - 2 PRINT REPORT
    - 3 REPORT TO FILE — Enter path and name of output file.
    - 0 MAIN MENU
  - ESC (To abort measurement)
- 0 EXIT

APPENDIX B. Instrument Specifications

1. Digital voltmeter: 5½ digit resolution; 3 V dc range with 0.007 percent of reading and 0.0007 percent of full scale accuracy; 300 mV dc range with 0.012 percent of reading and 0.001 percent of full scale accuracy; IEEE Std-488 bus; optional integrated reed relay multiplexer.

2. Multiplexer: integrated with the DVM (or separate unit); minimum six single-pole, single-throw contacts; maximum thermal offset of 3 μV; IEEE Std-488 bus.

3. Dual NIST Type IV power meter (or two single units).

4. Coaxial thermistor mount: type N male connector; temperature compensation thermistors; dc bias power $\approx$ 30 mW; maximum $|\Gamma| < 0.025$; NIST calibration at 1 GHz; modified for a 4-wire connection to both the measurement thermistors and the compensation thermistors.

5. Computer controller: programmable in Hewlett Packard Work Station Basic version 5.13 ("Rocky Mountain Basic"), or TransEra "HTBasic" with IEEE Std-488 capability; IEEE Std-488 bus.

APPENDIX C. Software Listing

```
100     ! NIST-PM2    Power Measurement System      Version 2.0
110     File$="PWR_MTR2"                      ! Started:9001111632/FRC
120     Rev$="9312171312" ! NTL/FRC/PGV
130     !
140! RE-STORE "PWR_MTR2"
150     !!!
160     !       US DEPARTMENT OF COMMERCE
170     !       NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
180     !       MICROWAVE METROLOGY GROUP
190     !       325 BROADWAY
200     !       BOULDER, CO 80303-3328
210     !!!
220     ! NOTES:
230     ! 9311151100 - Added Escape key support (setup, update). PGV
240     ! 9311110930 - Added keyboard & knob(mouse) trapping in RF and MEAS sub's
250     ! 9310251015 - Added error trapping for PM & DVM now works under HTB 3.2
260     ! 9310220905 - Load or Save 'CALDATA' file under setup menu
270     ! 9310220825 - Automatic backup of CALDATA file.
280     !            - Loads new CALDATA file (must be bdat).
290     ! 9310211400 - Now fully functional under HTBasic 4.0
300     ! 9310201740 - Added print report to DOS ASCII file (hardcopy)
310     ! 9309301445 - Now supports bdat file CALDATA. This file stores the
320     ! calibration data for the two mesurement mounts used with this system
330     ! (PM2).  This file must be in the current directory during program.
340     ! execution.
350     ! 9308260845 - Cleaned up code and squashed bugs.
360     ! 9308201530 - Print measurement results in text/table format to PRT on
370     !              parallel port (#10).
380     ! 9308170735 - Modified for use with Epson FX-86e/FX-800 compatible
390     ! printer (e. g.,  Panasonic KX-P1180 9-pin printer).  May work with an
400     ! Epson LQ printer [untested]).  Screen resolutions of 640x480 or
410     ! 800x600 are sensed automatically.  PGV
420     ! Written with HTBasic 3.2                    ;PGV
430     !
440     ! This program attempts to load the following data file upon execution:
450     !    CALDATA
460     !
470     ! Errors, Select_v, Dvm_init, Pm_init, Ke_199 defined for use with:
480     !    Keithley 199 DMM/Scanner
490     !    Arbiter 1096A Dual Type IV Power Meter
500     !
510     ! This program measures the 1 mW calibrator output of the Wavetek
520     ! model 8501A peak power meter.
530     !
540     ! This version measures V1 and delta V with the compensation element
550     ! used as a voltage source (RVG) to offset the DVM.  It also calculates
560     ! the measurement uncertainty.
570     !
580     ! Total measurement uncertainty components include:
590     !    Mount calibration factor,
600     !    Calculated mismatch uncertainty for the source (|Gamma|<=0.056)
610     !    and the mount,
620     !    Dual element uncertainty,
630     !    The DVM and Type IV error contributions.
640     !
650     ! INSTRUMENTS CONTROLLED:            ADDRESS
660     !    1.  Keithley 199 DMM/Scanner     722
670     !    2.  Epson FX compatible printer   10 (PRT)
680     !    3.  Arbiter 1096A Type IV PM     713
690     !
700     ! DESCRIPTION OF PRINCIPAL VARIABLES IN LABELED COMMON:
710     !
720     !  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
730     !    The following are in the COMmon labeled "/Dvm/":
740     !
750     ! ** "Dvm_name$" - The DVM identifier (ie, K199)
760     !
770     !  * "P0" - Power level in milliwatts. The measurement results are
780     !           compared with this value.  Default setting is 1 mW.
790     !
800     !  * "R0" - Mount operating resistance in ohms.  It is normally 200
810     !           ohms for a coax mount and may be either 100 or 200 ohms
820     !           for a waveguide mount.  Default setting is 200 ohms.
830     !
840     !  * "A1-A5" - Fraction of reading error, for each DVM range
850     !
860     !  * "B1-B5" - Fraction of full scale error, for each DVM range
870     !
880     !  * "R1-R5" - Full scale DVM ranges available
890     !
900     !  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
910     !    The following are in the COMmon labeled "/Mount/":
920     !
930     ! ++ "Mount$"  -.Bolometer mount identifier for active mount
940     !                (manufacturer, model, and serial number).
950     !
960     ! ++ "Cf" - Mount calibration factor as measured by NIST.  This value
970     !           must be changed after mount replacement or recalibration.
980     !
990     !  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1000    !    The following are in the COMmon labeled "/Errs/":
1010    !
1020    ! ++ "Cfu" - Total quoted uncertainty of the NIST mount calibration
1030    !            factor.
1040    !
1050    !  * "Mmu" - Calculated mismatch uncertainty.
1060    !
1070    !  * "Deu" - Added uncertainty for dual-element error.
1080    !
1090    !  * "Dp"  - Power uncertainty due to DVM.
1100    !
1110    ! ++ "Gm"  - Mount reflection coefficient magnitude.
1120    !
1130    !  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1140    !    The following is in the COMmon labeled "/Wavetek/":
1150    !
```

```
1160   !     "Sn$" - records the serial number of the Wavetek meter
1170   !             being measured.  It can be input before the measure-
1180   !             ment from an item on the initial menu.
1190   !
1200   !  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1210   !
1220   !  CHANGING INITIAL VALUE OF VARIABLES
1230   !
1240   !  * |These variables are initally defined in the subprogram "Set_up".|
1250   !    |To change them, move to the subprogram by executing  "EDIT       |
1260   !    |Set_up".  Change the values as needed and "Re-store" the program|
1270   !    |if the changes are to be permanent.                               |
1280   !
1290   ! ++ |These variables are stored in the bdat file CALDATA and are     |
1300   !    |called from the subprogram "Set_up".  To change them from the   |
1310   !    |main menu, choose option 1 (Select measurement mount).  From    |
1320   !    |the setup menu choose option 3 (Change attributes) and follow   |
1330   !    |the prompts to change and save the data to the file CALDATA.    |
1340   !
1350   ! ** |Dvm_name$ is defined in the subprogram "Ke_199".  If a different|
1360   !    |DVM is used, the subprogram Ke_199 must be replaced by a similar|
1370   !    |module for the new DVM.  Follow the pattern of SUB Ke_199.  The |
1380   !    |corresponding CALL statement must also be changed.  The SUB     |
1390   !    |Dvm_init contains the DVM driver, which must be changed.        
1400   !    |program.  Use the manufacturer's specifications for the new DVM.|
1410   !
1420   ! ------------------------- MAIN  PROGRAM ----------------------------
1430   !
1440 Main:  !
1450    OPTION BASE 1
1460    COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
1470    COM /Dvm/Dvm_name$[40]              ! DVM ID
1480    COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
1490    COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
1500    COM /Mount/Mount$[40],Cf,Defm      ! Mount ID
1510    COM /Wavetek/Sn$[7]                ! Wavetek serial number
1520    COM /Hardcopy/Tdate$[40]           ! Time and date of measurement
1530    COM /Harddata/Pdata(100,7),Pres(7,1)  ! Measurement data and results
1540    COM /Caldata/Mount1$[40],Mount2$[40],Cf1,Cfu1,Gm1,Cf2,Cfu2,Gm2
1550    COM /Init/Pm_avail,Dvm_avail       ! Power Meter/DVM availability
1560    REAL P(100,1)                      ! Power measurement data
1570    Num_meas=6                         ! Default no. of measurements (<=100)
1580    Pm_avail=1                         ! Power meter available if =1, else, 0
1590    Dvm_avail=1                        ! DVM available if =1, else, 0
1600    RESET 7                            ! Reset GPIB
1610    CONTROL 2,1;0                      ! Turn PRT ALL off
1620    KBD CMODE ON                       ! Turn on Nimitz style softkeys
1630    Sys_prty=VAL(SYSTEM$("SYSTEM PRIORITY"))   ! Determine system priority
1640    Lcl_prty=Sys_prty+1                ! Set local priority higher for ON KEY
1650    ON INTR 7,Lcl_prty CALL Pm_init    ! If power meter error (for SRQ)
1660    GINIT
1670    PLOTTER IS CRT,"INTERNAL";COLOR MAP
1680    PRINTER IS CRT                     ! Make CRT output device
1690    Crt_id$=SYSTEM$("CRT ID")          ! Determine the no. of CRT columns
1700    KEY LABELS PEN 5                   ! Cyan
1710    KBD LINE PEN 4                     ! Yellow
1720    CALL Set_up(0)                     ! For mount & measurement parameters
1730    CALL Pm_init                       ! Arbiter 1096A initialization
1740    CALL Ke_199                        ! Get DVM parameters
1750    CALL Dvm_init                      ! Keithly 199 initialization
1760 Top: LOOP                             !
1770      CALL Menu1(Num_meas,Quit,Rev$)   ! First user menu
1780      IF Quit THEN GOTO Quit           ! Terminate
1790      REDIM P(Num_meas,1)              ! Redimension
1800      CALL Hdr                         ! Screen header
1810      CALL Measloop(Num_meas,P(*),Esc)     ! Start Measurement loop
1820      IF Esc=1 THEN Top
1830      CALL Errors                      ! Calculate errors
1840      CALL Stats(P(*))                 ! Calculate the statistics of the run
1850      CALL Menu2(Num_meas,P0)          ! Post print options
1860    END LOOP
1870 Quit: CLEAR SCREEN                    ! Have a nice day! :-)
1880    KEY LABELS ON
1890    END
1900!
1910! -------------------- S U B    P R O G R A M S -----------------------
1920!
1930 Set_up: SUB Set_up(Cp)                ! Initialize mount parameters.
1940                                       ! Cp=0 Load default mount spec's
1950                                       ! Cp=1 User Select mount spec's
1960      OPTION BASE 1
1970      COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
1980      COM /Dvm/Dvm_name$[40]           !DVM ID
1990      COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
2000      COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
2010      COM /Caldata/Mount1$[40],Mount2$[40],Cf1,Cfu1,Gm1,Cf2,Cfu2,Gm2
2020      COM /Mount/Mount$[40],Cf,Defm    ! Mount ID
2030 Execution: IF Cp=0 THEN               !
2040        CALL Mount_data(1,"CALDATA")   ! Read mount data from file CALDATA
2050        IF Defm=0 THEN GOSUB Mount1    ! Make mount one the default mount
2060        IF Defm=1 THEN GOSUB Mount2    ! Make mount two the default mount
2070        Deu=.30                        ! Uncertainty for dual element error
2080        R0=200                         ! Mount operating resistance in ohms
2090        P0=1.0                         ! Comparison power in mW.  Note that
2100                                       ! the following line limits this set-
2110                                       ! ing to a 0.1 mW resolution.
2120        P0=DROUND(P0,2)                ! Limit P0 to 1 place beyond decimal
2130      END IF
2140 User: IF Cp=1 THEN                    ! User enters mount data
2150        Sys_prty=VAL(SYSTEM$("SYSTEM PRIORITY"))! Determine system priority
2160        Lcl_prty=Sys_prty+1            ! Set local priority higher for ON KEY
2170        M_flag=1                       ! To write menu
2180        USER 1 KEYS                    ! 1st set of soft keys
2190        FOR N=0 TO 19                  ! Clear keys
2200          ON KEY N LABEL "" GOTO Top ! Default destination
2210        NEXT N
2220        ON KEY 0 LABEL "  MOUNT ONE   ",Lcl_prty GOSUB Mount1
2230        ON KEY 1 LABEL "  MOUNT TWO   ",Lcl_prty GOSUB Mount2
2240        ON KEY 2 LABEL " CUSTOM MOUNT ",Lcl_prty GOSUB Custom
```

```
2250        ON KEY 3 LABEL " LOAD or SAVE ",Lcl_prty GOSUB Caldata_io
2260        ON KEY 9 LABEL "  MAIN MENU   ",Lcl_prty GOSUB Nochange
2270 Top:   LOOP                          ! Wait for input
2280          IF M_flag=1 THEN GOSUB Menu
2290        END LOOP
2300 Menu:  CLEAR SCREEN
2310        STATUS 1,13;Rows              ! Get CRT height
2320        KEY LABELS ON
2330        PEN 6
2340        IF Rows>31 THEN CLIP 15,85,35,87  ! 800x600 displays
2350        IF Rows<31 THEN CLIP 20,102,22,80 ! 640x480 displays
2360        FRAME
2370        PRINT TABXY(21,8),CHR$(136)&"- - - MOUNT SELECTION MENU - - -"&CHR$(138)
2380        PRINT TABXY(20,10),CHR$(129)&" 1 "&CHR$(128)&" "&Mount1$
2390        PRINT TABXY(20,12),CHR$(129)&" 2 "&CHR$(128)&" "&Mount2$
2400        PRINT TABXY(20,14),CHR$(129)&" 3 "&CHR$(128)&" Custom Mount or Change Attributes"
2410        PRINT TABXY(20,16),CHR$(129)&" 4 "&CHR$(128)&" Load/Save CALDATA File"
2420        PRINT TABXY(20,18),CHR$(129)&" 0 "&CHR$(128)&" Main Menu"
2430        PRINT TABXY(15,20),CHR$(137)&"Current Selection is "&Mount$
2440        PRINT TABXY(15,21),"Calibration Factor = ";Cf
2450        PRINT TABXY(15,22),"Calibration Uncertainty = ";Cfu
2460        PRINT TABXY(15,23),"Reflection Coefficient = ";Gm;CHR$(138)
2470        M_flag=0
2480        RETURN
2490 Mount1: Mount$=Mount1$               ! Mount 1
2500        Cf=Cf1                        ! Mount calibration factor
2510        Cfu=Cfu1                      ! Mount calibration uncertainty in %
2520        Gm=Gm1                        ! Mount reflection coefficient
2530        Mmu=200*.056*Gm               ! Mismatch factor uncertainty in %.
2540                                      ! Generator refl. coeff. <=0.056
2550        Defm=0                        ! Remember mount selection
2560        M_flag=1
2570        RETURN
2580 Mount2: Mount$=Mount2$               ! Mount 2
2590        Cf=Cf2                        ! Mount calibration factor
2600        Cfu=Cfu2                      ! Mount calibration uncertainty in %
2610        Gm=Gm2                        ! Mount reflection coefficient
2620        Mmu=200*.056*Gm               ! Mismatch factor uncertainty in %.
2630                                      ! Generator refl. coeff. <=0.056
2640        Defm=1                        ! Remember mount selection
2650        M_flag=1
2660        RETURN
2670 Custom: KEY LABELS OFF               ! Custom mount data or change value
2680        CLEAR SCREEN
2690        PRINT TABXY(10,10),"CURRENT MOUNT"
2700        PRINT TABXY(10,12),"Model/Serial Number: ";Mount$
2710        PRINT TABXY(10,14),"Calibration Factor = ";Cf
2720        PRINT TABXY(10,16),"Calibration Uncertainty in Percent = ";Cfu
2730        PRINT TABXY(10,18),"Reflection Coefficient = ";Gm
2740        OUTPUT 2;Mount$;CHR$(255)&"H";
2750        LINPUT "Enter Mount Model/Serial Number",Mount$
2760        PRINT TABXY(10,12),"Model/Serial Number: ";Mount$,"                    "
2770        OUTPUT 2 USING "#,Z.DDDD";Cf
2780        INPUT "Enter Mount Calibration Factor",Cf
2790        PRINT TABXY(10,14),"Calibration Factor = ";Cf,CHR$(128)
2800        OUTPUT 2 USING "#,Z.DD";Cfu
2810        INPUT "Enter Calibration Uncertainty in Percent",Cfu
2820        PRINT TABXY(10,16),"Calibration Uncertainty in Percent = ";Cfu,CHR$(128)
2830        OUTPUT 2 USING "#,Z.DDDD";Gm
2840        INPUT "Enter Mount Reflection Coefficient = ",Gm
2850        Mmu=200*.056*Gm               ! Recalculate mismatch factor uncert.
2860        PRINT TABXY(10,18),"Reflection Coefficient = ";Gm,CHR$(128)
2870        BEEP
2880        ON KNOB 1 GOSUB Mouse
2890        ON KBD GOSUB Keytest
2900        DISP CHR$(136)&"Permanently save these changes to BDAT file CALDATA?  ("&CHR$(138)&"Y"&CHR$(136)&")es or
            ("&CHR$(138)&"N"&CHR$(136)&")o"
2910        LOOP
2920          Ans$=KBD$
2930        EXIT IF UPC$(Ans$)="Y"        ! Yes
2940        EXIT IF UPC$(Ans$)="N"        ! No
2950        EXIT IF Ans$=CHR$(27)         ! Escape
2960        END LOOP
2970        OFF KBD
2980        OFF KNOB
2990        IF UPC$(Ans$)="Y" THEN CALL Update(0)
3000        M_flag=1                      ! Reset menu flag
3010        RETURN
3020 Caldata_io: KEY LABELS OFF           ! Load/Save CALDATA file
3030        DISP CHR$(136)&"("&CHR$(138)&"L"&CHR$(136)&")oad or ("&CHR$(138)&"S"&CHR$(136)&")ave 'CALDATA'.  Press
            '"&CHR$(138)&"ESC"&CHR$(136)&"' to abort."! Load or save data
3040        ON KNOB 1 GOSUB Mouse         ! Mouse trap
3050        ON KBD GOSUB Keytest          ! Trap keyboard
3060        LOOP
3070          K$=KBD$                     ! Read KBD$ buffer
3080        EXIT IF UPC$(K$)="L"          ! Load file
3090        EXIT IF UPC$(K$)="S"          ! Save file
3100        EXIT IF K$=CHR$(27)           ! Exit
3110        END LOOP
3120 Action: OFF KBD                      !
3130        OFF KNOB                      !
3140        IF K$=CHR$(27) THEN End_action    ! Exit
3150        IF UPC$(K$[1,1])="L" THEN     ! Load
3160          CALL Update(1)
3170          IF Defm=0 THEN GOSUB Mount1! Make mount one the default mount
3180          IF Defm=1 THEN GOSUB Mount2! Make mount two the default mount
3190        END IF
3200        IF UPC$(K$[1,1])="S" THEN CALL Update(2) ! Save data
3210 End_action: KEY LABELS OFF           ! Return to menu
3220        M_flag=1
3230        RETURN
3240 Mouse: RETURN                        ! Trap mouse   [NO RODENTS]
3250 Keytest: RETURN                      ! Trap unused keys [DEAD KEYS]
3260     END IF
3270 Nochange: SUBEND                     ! Exit back to main menu
3280   !
3290   ! -------------------------------------------------------------------
3300   !
3310 Mount_data: SUB Mount_data(A,F$)    ! Writes or reads mount cal data from
```

```
3320                                    ! file CALDATA or special filename
3330      OPTION BASE 1
3340      COM /Caldata/Mount1$[40],Mount2$[40],Cf1,Cfu1,Gm1,Cf2,Cfu2,Gm2
3350      DIM Cat$(40)[80]
3360      F$=UPC$(F$)                   ! Make string all uppercase
3370      IF A=0 THEN GOSUB Write_data
3380      IF A=1 THEN GOSUB Read_data
3390      SUBEXIT
3400 Write_data:                        !
3410      IF F$="CALDATA" THEN          ! Backup CALDATA only
3420        A=2
3430        ASSIGN @Path_1 TO F$&".BAK";RETURN Uncreated! Open file CALDATA.BAK
3440        ASSIGN @Path_1 TO *         ! Close path
3450        IF NOT Uncreated THEN PURGE F$&".BAK"  ! Purge file if found
3460      END IF
3470      ASSIGN @Path_1 TO F$;RETURN Uncreated    ! Open file CALDATA
3480      ASSIGN @Path_1 TO *           ! Close path
3490      IF A=2 AND NOT Uncreated THEN COPY F$ TO F$&".BAK"     ! Backup CALDATA only
3500      IF NOT Uncreated THEN PURGE F$ ! Purge file if found
3510      IF F$<>"CALDATA" THEN A=3
3520      ON ERROR GOTO Cant_make
3530      CREATE BDAT F$,1              ! Create file CALDATA
3540      OFF ERROR
3550      ASSIGN @Path_1 TO F$          ! Open file CALDATA
3560      OUTPUT @Path_1;Mount1$        ! Mount one S/N
3570      OUTPUT @Path_1;Cf1            ! Mount calibration factor
3580      OUTPUT @Path_1;Gm1            ! Reflection coefficient magnitude
3590      OUTPUT @Path_1;Cfu1           ! Cal factor uncertainty in percentage
3600      OUTPUT @Path_1;Mount2$        ! Mount two serial number
3610      OUTPUT @Path_1;Cf2            ! Mount calibration factor
3620      OUTPUT @Path_1;Gm2            ! Reflection coefficient magnitude
3630      OUTPUT @Path_1;Cfu2           ! Cal factor uncertainty in percentage
3640      ASSIGN @Path_1 TO *           ! Close path
3650      RETURN
3660 Read_data:                         ! Open file & read data
3670      IF F$<>"CALDATA" THEN A=3
3680      ASSIGN @F TO F$;RETURN Uncreated  ! Open file CALDATA or user filename
3690      IF Uncreated THEN GOSUB No_file! If not found warn
3700      ENTER @F;Mount1$              ! Mount one serial number
3710      ENTER @F;Cf1                  ! Mount calibration fatctor
3720      ENTER @F;Gm1                  ! Reflection coefficient magnitude
3730      ENTER @F;Cfu1                 ! Cal factor uncertainty in percentage
3740      ENTER @F;Mount2$              ! Mount two serial number
3750      ENTER @F;Cf2                  ! Mount calibration factor
3760      ENTER @F;Gm2                  ! Reflection coefficient magnitude
3770      ENTER @F;Cfu2                 ! Cal factor uncertainty in percentage
3780      ASSIGN @F TO *                ! Close file
3790      RETURN
3800 No_file:                           ! No file CALDATA found; warn user
3810      IF A=3 THEN Cant_make
3820      CLEAR SCREEN
3830      BEEP                          ! Beep Beep
3840      BEEP
3850      BEEP
3860      PRINT PEN 2
3870      PRINT TABXY(5,10),"Can not find BDAT file "&F$&"."
3880      PRINT PEN 3
3890      PRINT TABXY(5,12),"The file 'CALDATA' is used to store the calibration data"
3900      PRINT TABXY(5,13),"for the measurement mounts and should be located in the same"
3910      PRINT TABXY(5,14),"directory as this program."
3920      ASSIGN @F TO *                ! Close path
3930      LINPUT "Press ENTER to continue.",Fake$
3940      CLEAR SCREEN
3950      SUBEXIT
3960      RETURN
3970 Cant_make:                         ! Can not make file
3980      OFF ERROR
3990      BEEP
4000      LINPUT "ERROR - Filename or Directory not found. Press enter.",Fake$
4010      A=-1
4020      SUBEXIT
4030    SUBEND
4040    !
4050    ! ---------------------------------------------------------------------
4060    !
4070 Update: SUB Update(Pv)             ! Displays and updates bdat file CALDATA
4080      OPTION BASE 1                 ! with new info entered by user
4090      COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
4100      COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
4110      COM /Mount/Mount$[40],Cf,Defm  ! Mount ID
4120      COM /Caldata/Mount1$[40],Mount2$[40],Cf1,Cfu1,Gm1,Cf2,Cfu2,Gm2
4130      STATUS 1,13;Rows              ! Get screen rows
4140      CLEAR SCREEN
4150      IF Pv=0 THEN GOSUB Mount_1
4160      IF Pv=1 OR Pv=2 THEN
4170        A=1
4180        GOSUB Caldata_mem
4190      END IF
4200      SUBEXIT
4210 Mount_1:                           ! Display data for mount one
4220      PRINT PEN 1
4230      IF Jump=0 THEN PRINT TABXY(41,4),"Current data in file CALDATA"
4240      IF Jump=1 THEN PRINT TABXY(41,4)," Current/New data in memory "
4250      PRINT PEN 3
4260      IF A=1 AND Pv=0 THEN PRINT PEN 5
4270      PRINT TABXY(40,6),"MOUNT ONE"        !
4280      PRINT TABXY(40,8),"S/N  ";Mount1$    ! Serial number
4290      PRINT TABXY(40,9),"Cf=  ";Cf1        ! Calibration factor
4300      PRINT TABXY(40,10),"Cfu= ";Cfu1      ! Calibration factor uncertainty in %
4310      PRINT TABXY(40,11),"Gm=  ";Gm1       ! Reflection coefficient
4320      PEN 6
4330      IF Rows>31 THEN CLIP 50,95,69,88     ! For 800x600 screen
4340      IF Rows<31 THEN CLIP 62,118,62,85    ! For 640x480 screen
4350      FRAME
4360 Mount_2:                                  ! Display data for mount two
4370      PRINT PEN 3
4380      IF A=2 AND Pv=0 THEN PRINT PEN 5
4390      PRINT TABXY(40,15),"MOUNT TWO"
4400      PRINT TABXY(40,17),"S/N  ";Mount2$   ! Serial number
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4410      PRINT TABXY(40,18),"Cf=  ";Cf2       ! Calibration factor
4420      PRINT TABXY(40,19),"Cfu= ";Cfu2      ! Calibration factor uncertainty in %
4430      PRINT TABXY(40,20),"Gm=  ";Gm2       ! Reflection coefficient
4440      IF Rows>31 THEN CLIP 50,95,45,64     ! 800x600
4450      IF Rows<31 THEN CLIP 62,118,32,55    ! 640x480
4460      FRAME
4470      PEN 2
4480      IF Rows>31 THEN CLIP 49,96,44,89     ! 800x600
4490      IF Rows<31 THEN CLIP 61,119,31,86    ! 640x480
4500      FRAME
4510      IF Jump=1 THEN RETURN
4520 New_data:                                 ! Display new mount data
4530      PRINT PEN 5
4540      PRINT TABXY(5,10),"NEW DATA"
4550      PRINT TABXY(5,12),"S/N  ";Mount$     ! Serial number
4560      PRINT TABXY(5,13),"Cf=  ";Cf         ! Calibration factor
4570      PRINT TABXY(5,14),"Cfu= ";Cfu        ! Calibration factor uncertainty in %
4580      PRINT TABXY(5,15),"Gm=  ";Gm         ! Refelection coefficient
4590      PRINT PEN 3
4600 Update_caldata:                           ! Update date for mount one or two
4610      ON KNOB 1 GOSUB Mouse_trap
4620      ON KBD GOSUB Keytest
4630      DISP CHR$(136)&"Enter "&CHR$(138)&"1"&CHR$(136)&" to save as mount one, "&CHR$(138)&"2"&CHR$(136)&" to save as mount two,
          or '"&CHR$(138)&"ESC"&CHR$(136)&"' to abort."
4640      LOOP
4650        A$=KBD$
4660      EXIT IF A$="1"
4670      EXIT IF A$="2"
4680      EXIT IF A$=CHR$(27)
4690      END LOOP
4700 Action:!
4710      OFF KNOB
4720      OFF KBD
4730      IF A$=CHR$(27) THEN End_action
4740      A=VAL(A$)
4750      IF A=1 THEN                      ! Update mount ONE data
4760        Mount1$=Mount$                 !     Model/serial number
4770        Cf1=Cf                         !     Calibration factor
4780        Cfu1=Cfu                       !     Calibration factor uncertainty in percent
4790        Gm1=Gm                         !     Reflection coefficient
4800      END IF
4810      IF A=2 THEN                      ! Update mount TWO data
4820        Mount2$=Mount$                 !     Model/serial number
4830        Cf2=Cf                         !     Calibration factor
4840        Cfu2=Cfu                       !     Calibration factor uncertainty in percent
4850        Gm2=Gm                         !     Reflection coefficient
4860      END IF
4870 Caldata_mem:                          ! Display Caldata in memory
4880      IF A=1 OR A=2 THEN               ! Redisplay data with new changes
4890        Jump=1
4900        CLEAR SCREEN
4910        GOSUB Mount_1
4920        PRINT PEN 3
4930        BEEP
4940        ALLOCATE Y$[255]
4950        Y$="C:\NIST_PM2\CALDATA"
4960   .    IF Pv=1 THEN Y$="C:\NIST_PM2\CALDATA.ORG"   ! Default Path
4970 User_input:                           !
4980        IF Pv=1 THEN A=1
4990        IF Pv=0 OR Pv=2 THEN A=0
5000        OUTPUT 2;Y$;CHR$(255)&"H";     ! Output default filename
5010        IF Pv=1 THEN LINPUT "êEnter path and name of file to èLOADê.  Enter a blank line to Exit.",Y$
5020        IF Pv=2 OR Pv=0 THEN LINPUT "êEnter path and name of file to èSAVEê.  Enter a blank line to Exit.",Y$
5030        Y$=TRIM$(Y$)                   ! Remove trailing and leading spaces
5040        IF Y$="" THEN SUBEXIT          ! If string is empty then exit
5050        CALL Mount_data(A,Y$)          ! Save data as bdat file CALDATA or User filename
5060        IF A=-1 THEN GOTO User_input
5070      END IF
5080 End_action: RETURN                    !
5090 Keytest: RETURN                       ! Dead Keys
5100 Mouse_trap: Return                    ! No Rodents
5110   SUBEND
5120   !
5130   ! ------------------------------------------------------------------
5140   !
5150 Pm_init: SUB Pm_init                  ! Initialize Arbiter 1096A Power Meter
5160      OPTION BASE 1
5170      COM /Init/Pm_avail,Dvm_avail
5180      ON TIMEOUT 7,.2 GOTO Pm_e
5190      CLEAR 713
5200      OUTPUT 713;"RA2,RB2,MA2,DB0,E1a"    ! Initialize power meter
5210                                       ! RA2 = Set mount A for 200 ohm
5220                                       ! RB2 = Set mount B for 200 ohm
5230                                       ! MA2 = Activate front panel meter
5240                                       ! DB0 = Turn DVM bus off
5250                                       ! E1a = SRQ interrupt mask byte=11
5260      Stat=SPOLL(713)                  ! Poll for power meter status
5270      IF Stat>0 THEN CALL Pm_error     ! If error warn user
5280      Pm_avail=1                       ! PM ready
5290      OFF TIMEOUT 7
5300      SUBEXIT
5310 Pm_e:                                 ! PM, where are you?
5320      OFF TIMEOUT 7
5330      BEEP
5340      Pm_avail=0                       ! PM not available
5350      OUTPUT 1;""                      ! Warn user
5360      OUTPUT 1;"          Arbiter 1096A dual type IV power meter not found at address 713."
5370      LINPUT "Press 'ENTER' to Continue",Fake$
5380   SUBEND
5390   !
5400   ! ------------------------------------------------------------------
5410   !
5420 Pm_error: SUB Pm_error                ! Service 1096A PM error interrupt
5430      CLEAR SCREEN                     ! Danger! Danger! - Will Robinson!
5440      PRINT TABXY(25,10),CHR$(137)&"HARDWARE ERROR - PROGRAM HALTED"&CHR$(136)
5450      PRINT TABXY(21,12),"Arbiter 1096A Type IV power meter error."&CHR$(138)
5460      PRINT TABXY(19,28),"Check Power Meter and Press RUN To Restart"
5470      DISP " "
5480      KEY LABELS ON
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5490      BEEP 400,.3
5500      STOP
5510   SUBEND
5520   !
5530   ! ----------------------------------------------------------------
5540   !
5550 Ke_199: SUB Ke_199                  ! DVM ranges and uncertainty
5560      OPTION BASE 1                  ! (Keithly 199, 1 yr, 5-1/2 dig)
5570      Dvm_name$="Keithley 199"
5580 !     FOR DVM:        VALUE            QUANTITY
5590      COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
5600      COM /Dvm/Dvm_name$[40]         !DVM ID
5610 Nc: DATA              3.02999E5     ! number of counts, full scale
5620 A1: DATA              1.2E-4        ! fraction-of-rdg error, range R1, 1 yr
5630 A2: DATA              7.0E-5        ! fraction-of-rdg error, range R2, etc.
5640 A3: DATA              9.0E-5        ! fraction-of-rdg error, range R3
5650 A4: DATA              9.0E-5        ! fraction-of-rdg error, range R4
5660 B1: DATA              3.            ! fraction-of-FS error, counts, range R1
5670 B2: DATA              2.            ! fraction-of-FS error, counts, range R2
5680 B3: DATA              2.            ! fraction-of-FS error, counts, range R3
5690 B4: DATA              2.            ! fraction-of-FS error, counts, range R4
5700 R1: DATA              0.302999      ! lowest range (including overrange), volts
5710 R2: DATA              3.02999       ! next range up
5720 R3: DATA             30.2999        ! next range up
5730 R4: DATA            302.999         ! next range up
5740      READ Nc,A1,A2,A3,A4,B1,B2,B3,B4,R1,R2,R3,R4
5750 Convert_fs_errs:! Normalize FS count errors to fractional errors
5760      B1=B1/Nc
5770      B2=B2/Nc
5780      B3=B3/Nc
5790      B4=B4/Nc
5800   SUBEND
5810   !
5820   ! ----------------------------------------------------------------
5830   !
5840 Dvm_init: SUB Dvm_init              ! Initialize Ke199 DVM/Scanner
5850      OPTION BASE 1
5860      COM /Init/Pm_avail,Dvm_avail
5870      ABORT 7                        ! Stop all HP-IB activity (HTB 3.0)
5880      ON TIMEOUT 7,.5 GOTO Dvm_e     !
5890      CLEAR 722                      ! Clear the DVM
5900      OUTPUT 722;"F0R0T4P1S1N1X"     ! Initialize Keithly 199 DVM/Scanner
5910      CALL Dvm(V,T)                  ! Get DVM reading if ready (HTB 3.0)
5920                                     ! F0 = DC Volts
5930                                     ! R0 = Auto Range
5940                                     ! T4 = Trigger Continuous on X
5950                                     ! P1 = Internal Filter Enabled
5960                                     ! S1 = 5 1/2-digit resolution
5970                                     ! N1 = Channel one
5980      Dvm_avail=1                    ! DVM ready to go
5990      OFF TIMEOUT 7
6000      SUBEXIT
6010 Dvm_e:                              ! DVM not found
6020      OFF TIMEOUT 7
6030      BEEP
6040      Dvm_avail=0                    ! No DVM available
6050      OUTPUT 1;""                    ! Warn user
6060      OUTPUT 1;"          Keithly 199 System DMM/Scanner not found at address 722."
6070      LINPUT "Press 'ENTER' to continue",Fake$
6080   SUBEND
6090   !
6100   ! ----------------------------------------------------------------
6110   !
6120 Menu1: SUB Menu1(Num_meas,Quit,Rev$)     ! Premeasurement set up & soft keys
6130      OPTION BASE 1
6140      COM /Wavetek/Sn$[7]            ! For the serial number
6150      COM /Mount/Mount$[40],Cf,Defm  ! Mount ID
6160      COM /Init/Pm_avail,Dvm_avail
6170      STATUS 1,13;Rows               !
6180      Sys_prty=VAL(SYSTEM$("SYSTEM PRIORITY")) !Determine system priority
6190      Lcl_prty=Sys_prty+1            ! Set local priority 1 higher for ON KEY
6200      M_flag=1                       ! To write menu
6210      USER 1 KEYS                    ! 1st set of soft keys
6220      KEY LABELS ON                  ! Turn on soft keys
6230      FOR N=0 TO 19                  ! Clear keys
6240        ON KEY N LABEL "" GOTO Top   ! Default destination
6250      NEXT N
6260      ON KEY 0 LABEL "    MOUNT    ",Lcl_prty GOSUB Change_setup
6270      ON KEY 1 LABEL "  SERIAL NO. ",Lcl_prty GOSUB Sn
6280      ON KEY 2 LABEL "  NO. POINTS ",Lcl_prty GOSUB Change
6290      ON KEY 3 LABEL "     HELP    ",Lcl_prty GOSUB Help
6300      ON KEY 4 LABEL "   MEASURE   ",Lcl_prty GOSUB Exit_to_meas
6310      ON KEY 9 LABEL "     EXIT    ",Lcl_prty GOTO Quit
6320 Top: LOOP                           ! Wait for input
6330        IF M_flag=1 THEN GOSUB Menu
6340        IF Pm_avail=1 THEN Errorloop=1+Errorloop! Check PM every 3000 counts
6350        IF Errorloop=3000 THEN GOSUB Error_pm
6360      END LOOP
6370 Menu: CLEAR SCREEN                  ! Main menu
6380      PEN 6
6390      IF Rows>31 THEN CLIP 15,85,30,87     ! 800x600 display
6400      IF Rows>31 THEN A=0
6410      IF Rows<31 THEN CLIP 23,97,28,88     ! 640x480 display
6420      IF Rows<31 THEN A=3
6430      FRAME
6440      PRINT TABXY(5,4-(A/2)),CHR$(137);" P W R _ M T R   2 . 0 ";CHR$(138)
6450      PRINT TABXY(24,8-A),"- - - MEASUREMENT MENU - - -"
6460      PRINT TABXY(20,11-A),CHR$(129);" 1 ";CHR$(128);"  SELECT MEASUREMENT MOUNT"
6470      PRINT TABXY(25,12-A),CHR$(136)&"(";Mount$;")"&CHR$(138)
6480      PRINT TABXY(20,14-A),CHR$(129);" 2 ";CHR$(128);"  INPUT WAVETEK SERIAL NUMBER"
6490      IF LEN(TRIM$(Sn$))<1 THEN PRINT TABXY(25,15-A),CHR$(137)&"(No S/N in memory)"&CHR$(138)
6500      IF LEN(TRIM$(Sn$))>0 THEN PRINT TABXY(25,15-A),CHR$(136)&"(S/N ";Sn$;" in memory)"&CHR$(138)
6510      PRINT TABXY(20,17-A),CHR$(129);" 3 ";CHR$(128);"  CHANGE # OF MEASUREMENT POINTS"
6520      PRINT TABXY(25,18-A),CHR$(136)&"(Present setting =";Num_meas;")  "&CHR$(138)
6530      PRINT TABXY(20,20-A),CHR$(129);" 4 ";CHR$(128);"  WAVETEK OPERATING INSTRUCTIONS"
6540      PRINT TABXY(20,22-A),CHR$(129);" 5 ";CHR$(128);"  BEGIN MEASUREMENT"
6550      PRINT TABXY(20,24-A),CHR$(129);" 0 ";CHR$(128);"  EXIT PROGRAM"
6560      PRINT TABXY(48-A,28-A),CHR$(139);"rev ";Rev$
6570      M_flag=0
```

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6580     RETURN
6590 Sn:                                   ! Input the WAVETEK serial number
6600     KEY LABELS OFF                    ! Turn off soft keys
6610     OUTPUT 2;Sn$;
6620     LINPUT "WAVETEK SERIAL NUMBER ?",Sn$[1,7]
6630     Sn$=TRIM$(Sn$)
6640     KEY LABELS ON                     ! Turn keys back on
6650     M_flag=1
6660     RETURN
6670 Change:                               ! Change # of meas points
6680     KEY LABELS OFF                    ! Turn off soft keys
6690     INPUT "NUMBER OF MEASUREMENT POINTS ?",Num_meas
6700     Num_meas=MIN(Num_meas,100)
6710     Num_meas=MAX(Num_meas,1)
6720     KEY LABELS ON                     ! Turn keys back on
6730     M_flag=1
6740     RETURN
6750 Help:                                 ! With operation of Wavetek
6760     CALL Help
6770     M_flag=1
6780     RETURN
6790 Change_setup:                         ! Change default mount settings
6800     CALL Set_up(1)
6810     KEY LABELS ON
6820     M_flag=1
6830     RETURN
6840 Error_pm:                             ! Poll power meter for error
6850     ON TIMEOUT 7,.2 GOTO Pm_e
6860     Stat=SPOLL(713)
6870     IF Stat>0 THEN CALL Pm_init
6880     Errorloop=0
6890     OFF TIMEOUT 7
6900     RETURN
6910 Pm_e:                                 ! Power meter error
6920     OFF TIMEOUT 7
6930     Errorloop=0
6940     Pm_avail=0
6950     RETURN
6960 Exit_to_meas:                         ! Exit to begin measurement
6970     IF Pm_avail=0 OR Dvm_avail=0 THEN   ! PM or DVM have not been init.
6980       CALL Pm_init
6990       CALL Dvm_init
7000     END IF
7010     M_flag=1
7020     IF Pm_avail=0 OR Dvm_avail=0 THEN RETURN ! No PM, no DVM, no measure
7030     SUBEXIT
7040 Quit:                                 ! Terminate program
7050     Quit=1                            ! User goes home
7060     KEY LABELS OFF
7070   SUBEND
7080   !
7090   !-------------------------------------------------------------------
7100   !
7110 Help: SUB Help                        ! Wavetek user information
7120     OPTION BASE 1
7130     Sys_prty=VAL(SYSTEM$("SYSTEM PRIORITY")) ! Determine system priority
7140     Lcl_prty=Sys_prty+1               ! Set local priority 1 higher for ON KEY
7150     USER 1 KEYS                       ! 1st set of soft keys
7160     KEY LABELS ON                     ! Turn on soft keys
7170     FOR N=0 TO 19                     ! Clear keys
7180       ON KEY N LABEL "" GOTO Top      ! Default destination
7190     NEXT N
7200     ON KEY 9 LABEL "  MAIN MENU  ",Lcl_prty GOTO Exit
7210     GOSUB Text                        ! Print info
7220 Top: LOOP                             ! Wait for input
7230     END LOOP
7240 Text:                                 ! Here be info
7250     CLEAR SCREEN
7260     PRINT PEN 1
7270     PRINT TABXY(22,2),"CONTROLLING 8502A CALIBRATOR OUTPUT"
7280     PRINT TABXY(12,4),"Press the following 8502A front panel control keys in the"
7290     PRINT TABXY(12,5),"sequence indicated:"
7300     PRINT TABXY(14,7),"(1)-'CW',"
7310     PRINT TABXY(25,7),"(2)-'Menu',"
7320     PRINT TABXY(38,7),"(3)-'F3',"
7330     PRINT TABXY(49,7),"(4)-'F1'."
7340     PRINT TABXY(12,9),"Then, pressing the 8502A key '7' will turn the calibrator"
7350     PRINT TABXY(12,10),"output ON, and pressing the 8502A key 'CLEAR' will turn the"
7360     PRINT TABXY(12,11),"calibrator output OFF."
7370     PRINT TABXY(12,13),"For more detail see 'Calibrator Output Level Test' on page 6-2"
7380     PRINT TABXY(12,14),"of the 8502A manual."
7390     PRINT TABXY(12,17),"CAUTION: Do not press any UNITS key when the mount is"
7400     PRINT TABXY(12,18),"connected to the calibrator.  This will cause the"
7410     PRINT TABXY(12,19),"calibrator to output 100 mW which might damage the mount."
7420     RETURN
7430 Exit:                                 ! Helped
7440   SUBEND
7450   !
7460   ! -----------------------------------------------------------------
7470   !
7480 Hdr: SUB Hdr                          ! Header text for measurement and screen
7490     OPTION BASE 1
7500     COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
7510     COM /Dvm/Dvm_name$[40]            ! DVM ID
7520     COM /Mount/Mount$[40],Cf,Defm     ! Mount ID
7530     COM /Wavetek/Sn$[7]               ! For the serial number
7540     COM /Hardcopy/Tdate$[40]
7550     CLEAR SCREEN
7560     PRINT TABXY(1,2),CHR$(137)&"P W R _ M T R   2 . 0"&CHR$(136)
7570     PRINT TABXY(30,2),CHR$(136);CHR$(129);"  M E A S U R E M E N T   I N   P R O G R E S S  ";CHR$(128)
7580     PRINT TABXY(1,4),CHR$(140);"MOUNT: ";Mount$;CHR$(136)
7590     PRINT TABXY(59,4),CHR$(140);TIME$(TIMEDATE);"  ";DATE$(TIMEDATE);CHR$(136)
7600     Tdate$=TIME$(TIMEDATE)&"  "&DATE$(TIMEDATE) !Sore time and data of measurement
7610     PRINT TABXY(1,5),CHR$(140);"POWER METER: WAVETEK MODEL 8502A, S/N ";Sn$;CHR$(136)
7620     PRINT ""
7630     OUTPUT B$ USING "#,K";P0          ! Format power string
7640     PRINT " No.     Power      Pwr-";B$;" mW              V1       Delta V   V1 Drift   Ref. Offset"
7650     IMAGE "å    Ç",4X,"å  (mW)  Ç",4X,"å   (%)    Ç",7X,"å    (V)  Ç",3X,"å (mV)  Ç",3X,"å (uV/s) Ç",3X,"å     (mV)    Ç"
7660     PRINT USING 7650
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7670   SUBEND ! Hdr
7680   !
7690   ! -----------------------------------------------------------------
7700   !
7710 Measloop: SUB Measloop(Num_meas,P(*),Esc)     ! Measurement loop
7720     KEY LABELS OFF
7730     FOR N=1 TO Num_meas               ! Num_meas= no. of measurements(1-100)
7740       DISP N
7750       Esc=0                           ! Reset bailout flag
7760       CALL Meas(N,P1,Esc)             ! Do the measurement
7770       IF Esc=1 THEN SUBEXIT           ! bailout
7780       P(N,1)=P1                       ! Fill array for statistics
7790 !     WAIT 1                          ! Wait before measuring again
7800     NEXT N
7810     OUTPUT 722;"T4X"                  ! Let DVM continue reading
7820     KEY LABELS ON
7830   SUBEND
7840   !
7850   ! -----------------------------------------------------------------
7860   !
7870 Meas: SUB Meas(N,P1,Esc)              ! Performs measurement, calculates
7880     OPTION BASE 1                     ! and prints results.
7890     COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
7900     COM /Dvm/Dvm_name$[40]            ! DVM ID
7910     COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
7920     COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
7930     COM /Mount/Mount$[40],Cf,Defm   ! Mount ID
7940     COM /Harddata/Pdata(100,7),Pres(7,1)
7950     DIM Esc$[255]
7960     ON KBD GOSUB Bail_out             ! Escape if user hits ESC key
7970     CALL Dvm(V1i,T1i)                 ! V1 before rf turn_on
7980     OUTPUT 722;"N2R1T0X"              ! Connect for delta V/Trig on talk
7990     WAIT .2                           !
8000     CALL Dvm(V1xi,T1xi)               ! Initial delta V1 (V1xi) with rf off
8010     Vt=V1xi+V1i-SQR(V1i^2-9.E-4*R0)! Calculate threshold for Rf sub
8020     CALL Rf(1,Vt,Lcl_prty,Esc)        ! Calls for rf ON and determines when
8030     IF Esc THEN Bail_out
8040     WAIT 1                            ! For source to settle
8050     CALL Dvm(V2x,T2x)                 ! Read delta V2 (V2x) with rf on
8060     CALL Rf(0,Vt,Lcl_prty,Esc)        ! Calls for rf OFF and determines when
8070     IF Esc THEN Bail_out
8080     WAIT 1                            ! Wait again
8090     CALL Dvm(V1xf,T1xf)               ! Final delta V1 (V1xi) with rf off
8100     OUTPUT 722;"N1R2X"                ! Reconnect for V1
8110     WAIT .2
8120     CALL Dvm(V1f,T1f)                 ! Final V1 with rf off
8130     T1fac=(T2x-T1i)/(T1f-T1i)         ! First timing factor
8140     V1c=V1i+T1fac*(V1f-V1i)           ! V1 corrections
8150     T2fac=(T2x-T1xi)/(T1xf-T1xi)      ! Second timing factor
8160     V1x=V1xi+T2fac*(V1xf-V1xi)        ! Delta V corrections
8170     Dv1=(V1f-V1i)*1.E+6               ! Change in V1
8180     Dv1_dt=Dv1/(T1f-T1i)              ! Drift rate of V1 in mV/sec
8190     Dv2=V2x-V1x                       ! Change in V2 - (delta V)
8200     P1=(2*V1c-(Dv2))*(Dv2)*1000/R0 ! Power in mW
8210     P1=P1/Cf                          ! Cal factor correction
8220 Printout:                             ! Realtime
8230     IMAGE 3D,5X,Z.5D,6X,MZ.3D,9X,Z.6D,2X,3D.3D,6X,M2D.D,5X,M2D.3D
8240     PRINT USING 8230;N,P1,100*(P1-P0)/P0,V1c,Dv2*1.E+3,Dv1_dt,V1x*1.E+3
8250 Save_results:                         !
8260     Pdata(N,1)=N                      ! Store data into array for future use
8270     Pdata(N,2)=P1
8280     Pdata(N,3)=100*(P1-P0)/P0
8290     Pdata(N,4)=V1c
8300     Pdata(N,5)=Dv2*1.E+3
8310     Pdata(N,6)=Dv1_dt
8320     Pdata(N,7)=V1x*1.E+3
8330     SUBEXIT                           !
8340 Bail_out:                             ! User interrupt
8350     IF Esc$=CHR$(27) THEN Esc=1       ! If ESC key
8360     IF Esc=1 THEN
8370       OFF KBD                         ! Turn off trapping
8380       OFF KNOB                        !
8390       BEEP                            ! Beep Beep
8400       BEEP
8410       BEEP
8420       PRINT TABXY(30,2),CHR$(128);CHR$(136);"  M E A S U R E M E N T   S T O P P E D         "
8430       LINPUT "ESC Key Pressed; Measurement ABORTED, Press ENTER to Exit.",Fake$
8440       CALL Dvm_init                   ! Reset DVM
8450       SUBEXIT                         ! Leave
8460     END IF
8470     RETURN
8480 Exit:                                 ! Measurement complete
8490   SUBEND ! SUB Meas
8500   !
8510   ! -----------------------------------------------------------------
8520   !
8530 Rf: SUB Rf(On,Vt,Lcl_prty,Esc)        ! Turn rf ON/OFF
8540     DIM Esc$[255]                     ! Long string to handle key bangers
8550     Esc$=""
8560     ON KNOB 1 GOSUB Knob_service      ! Trap mouse
8570     ON KBD GOSUB Bail                 ! Bailout to keyboard
8580     IF On THEN
8590       DISP CHR$(139)&CHR$(129);" TURN RF ON (PRESS 8502A KEY '7') "&CHR$(143)&"   "&CHR$(137)&" Press 'ESC' to ABORT ";
           CHR$(128)&CHR$(138)             !Tell operator
8600       BEEP                            ! Attention
8610       LOOP                            ! Wait for rf to be turned on/off
8620         CALL Dvm(V,T)                 ! Read DVM
8630         WAIT 1                        !
8640       EXIT IF V>Vt                    ! If rf is turned ON
8650       END LOOP
8660     ELSE
8670       DISP CHR$(136)&CHR$(129);" TURN RF OFF (PRESS 8502A KEY '7') "&CHR$(143)&"   "&CHR$(137)&" Press 'ESC' to ABORT ";
             CHR$(128)&CHR$(138)           !Tell operator
8680       BEEP                            ! Attention
8690       WAIT .2
8700       BEEP
8710       LOOP                            ! Wait for rf to be turned on/off
8720         CALL Dvm(V,T)                 ! Read DVM
8730         WAIT 1                        !
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8740       EXIT IF V<Vt                   ! If rf is turned OFF
8750       END LOOP
8760     END IF
8770     DISP ""
8780     SUBEXIT
8790 Knob_service:                        ! Mouse trap
8800     ! NO RODENTS
8810     RETURN
8820 Bail: !
8830     Esc$=KBD$                        ! Trap keyboard
8840     IF Esc$=CHR$(27) THEN            ! If ESC key
8850       Esc=1                          ! Set bail flag
8860       SUBEXIT                        ! Leave
8870     END IF
8880     RETURN                           ! Else continue
8890   SUBEND
8900   !
8910   ! ----------------------------------------------------------------
8920   !
8930 Dvm: SUB Dvm(V,T)                    ! DVM reading
8940     SEND 7;UNL LISTEN 22             ! Get dvm's attention
8950     TRIGGER 7                        ! Trigger to read
8960     ENTER 722;V                      ! Read DVM
8970     T=TIMEDATE                       ! Get the time
8980   SUBEND
8990   !
9000   ! ----------------------------------------------------------------
9010   !
9020 Errors: SUB Errors              ! Calculates uncertainty in power due to DVM
9030     OPTION BASE 1
9040     COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
9050     COM /Dvm/Dvm_name$[40]           ! DVM ID
9060     COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
9070     COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
9080     CALL Select_v(V1i,Aa1i,Bb1i,Ss1i)       ! Aa_ - fract. of reading error
9090     CALL Select_v(V1f,Aa1f,Bb1f,Ss1f)       !
9100     CALL Select_v(V1xi,Aa1xi,Bb1xi,Ss1xi)   !
9110     CALL Select_v(V1xf,Aa1xf,Bb1xf,Ss1xf)   ! Bb_ - fract. of FS error
9120     CALL Select_v(V2x,Aa2x,Bb2x,Ss2x)       ! Ss_ - fullscale reading
9130 With_rvg:                              ! Eq's derived 900111/FRC
9140     Dv1i=Aa1i*V1i+Bb1i*Ss1i             ! Delta-V due to initial V1 measmnt
9150     Dv1f=Aa1f*V1f+Bb1f*Ss1f             ! Delta-V due to final V1 measmnt
9160     Dv1xi=ABS(Aa1xi*V1xi)+Bb1xi*Ss1xi   ! Delta due to initial V1x measmnt
9170     Dv1xf=ABS(Aa1xf*V1xf)+Bb1xf*Ss1xf   ! Delta-V due to final V1x measmnt
9180     Dv2x=ABS(Aa2x*V2x)+Bb2x*Ss2x        ! Delta-V due to V2x measmnt
9190     Dv1c=(1-T1fac)*Dv1i+T1fac*Dv1f      ! Error in corrected V1
9200     Dv1x=(1-T2fac)*Dv1xi+T2fac*Dv1xf    ! Error in delta V correction
9210     Dpv1=ABS((V2x-V1x)*Dv1c)        ! Delta-power due to V1 measmnt errors
9220     Dpv1x=ABS((V1c-V2x+V1x)*Dv1x)   ! Delta-power due to V1x   "       "
9230     Dpv2x=ABS((V1c-V2x+V1x)*Dv2x)   ! Delta-power due to V2x   "       "
9240     Dp=2*(Dpv1+Dpv1x+Dpv2x)/R0      ! Sum (2 & R0 left out above)
9250     Dp=Dp*1.E+3                     ! Dp in mW
9260   SUBEND
9270   !
9280   ! --------------------------------------------------------------------
9290   !
9300 Select_v: SUB Select_v(V,Aa,Bb,Ss) ! Returns range with fraction of full
9310     OPTION BASE 1                   ! scale & fraction of reading error
9320     COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
9330     COM /Dvm/Dvm_name$[40]          ! DVM ID
9340     SELECT ABS(V)                   ! V may be of either polarity
9350     CASE <=R1                       ! Start at lowest range
9360       Aa=A1                         ! Fraction of rdg error for V on range R1
9370       Bb=B1                         ! Fraction of FS error for V on range R1
9380       Ss=R1                         ! Fullscale reading for V, range R1
9390       Range=1                       ! Range_no number for plot
9400     CASE <=R2                       ! Uprange if necessary
9410       Aa=A2
9420       Bb=B2
9430       Ss=R2                         ! Etc. for range R2
9440       Range=2
9450     CASE <=R3                       ! And again
9460       Aa=A3
9470       Bb=B3
9480       Ss=R3
9490       Range=3
9500     CASE <=R4
9510       Aa=A4
9520       Bb=B4
9530       Ss=R4
9540       Range=4
9550     CASE <=R5
9560       Aa=A5
9570       Bb=B5
9580       Ss=R5
9590       Range=5
9600     CASE ELSE
9610       BEEP
9620       PRINT "Voltage Error"
9630     END SELECT
9640   SUBEND
9650   !
9660   ! --------------------------------------------------------------------
9670   !
9680 Stats: SUB Stats(REAL P(*))         ! Calculates standard deviation and
9690                                     ! final uncertainty, prints results to
9700                                     ! screen & stores results for hard copy
9710     OPTION BASE 1
9720     COM /Dvm/P0,R0,A1,A2,A3,A4,A5,B1,B2,B3,B4,B5,R1,R2,R3,R4,R5
9730     COM /Dvm/Dvm_name$[40]          ! DVM ID
9740     COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
9750     COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
9760     COM /Harddata/Pdata(100,7),Pres(7,1)
9770     Sz=SIZE(P,1)
9780     MAT Pres=(0)                    ! Zero out array
9790     ALLOCATE Dum(Sz,1)              ! Use Dum(*) to preserve P(*)
9800 Sd:                                 !
9810     MAT Dum=P
9820     Sum=SUM(Dum)                    ! Sum of the elements in P(*)
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9830      Mean=Sum/Sz                        ! Mean of P(*)
9840      MAT Dum=P-(Mean)                   ! Dum(*) contains deviations from mean
9850      Maxpdv=MAX(Dum(*))                 ! Largest positive deviation
9860      Maxndv=MIN(Dum(*))                 ! Largest negative deviation
9870      Maxdv=MAX(ABS(Maxpdv),ABS(Maxndv))      ! Largest largest deviation
9880      MAT Dum=Dum . Dum                  ! Dum holds squares of deviations
9890      IF Sz>1 THEN Var=SUM(Dum)/(Sz-1)      ! Variance
9900      Sd=SQR(Var)                        ! Standard deviation
9910      Dpu=(Dp/Mean)*100                  ! % uncertainty due to DVM
9920      Sdpu=Dpu/SQR(3)                    ! DVM and Type IV
9930      Sdm=Sd/SQR(Sz)                     ! Standard Deviation of the mean
9940      Sdmu=100*Sdm/Mean                  ! % of standard deviation of the mean
9950      Scfu=Cfu/SQR(3)                    ! Calibration factor std uncertainty
9960                                         ! rectangular distribution
9970      Smmu=Mmu/SQR(2)                    ! Mismatch std. unc U-shaped dist.
9980      Sdeu=Deu/SQR(3)                    ! Dual elemant std. unc. rec. dist.
9990      Wc_unc=(Sdmu*3)+Cfu+Mmu+Deu+Dpu! Worst case sum
10000     Cs_unc=SQR(Scfu^2+Smmu^2+Sdeu^2+Sdpu^2+Sdmu^2) ! Combined standard
10010     Ex_unc=Cs_unc*2                    ! Expanded uncertanty
10020 Prt:                                   !
10030     PRINT "- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -"
10040     PRINT "RESULTS:"
10050     IF Sz=1 THEN
10060       PRINT
10070       OUTPUT Scr$ USING "#,Z.5D";P(1,1)
10080       PRINT "     The single power measurment resulted in a value of "&Scr$&" mW."
10090       PRINT
10100       PRINT "     The table of uncertainties is not displayed for a single measurement."
10110     ELSE
10120       OUTPUT B$ USING "#,K";P0
10130       PRINT "          AVG PWR    AVG-";B$;" mW            MAX DEV       STD DEV    W/C UNC    EXP UNC"
10140       IMAGE 8X,"â  (mw)  Ç",4X,"â    (%)    Ç",7X,"â      (%)       Ç",3X,"â  (%)  Ç",3X,"â  (%)  Ç",3X,"â  (%)  Ç"
10150       PRINT USING 10140
10160       IMAGE 8X,Z.5D,6X,SZ.3D,8X,SZ.3D,K,SZ.3D,5X,Z.3D,5X,Z.3D,5X,Z.3D
10170       PRINT USING 10160;Mean,100*(Mean-P0)/P0,100*Maxpdv/Mean,",",100*Maxndv/Mean,Sdmu,Wc_unc,Ex_unc
10180     END IF
10190     PRINT TABXY(30,2),CHR$(128);CHR$(136);"  M E A S U R E M E N T   C O M P L E T E        "
10200 Save_stats:                            ! Store data into array for future use
10210     Pres(1,1)=Mean                     ! Mean power in mW
10220     Pres(2,1)=100*(Mean-P0)/P0         ! Mean percent offset from P0
10230     Pres(3,1)=100*Maxpdv/Mean          ! Max % dev from the mean(+)
10240     Pres(4,1)=100*Maxndv/Mean          ! Max % dev from the mean(-)
10250     Pres(5,1)=Sdmu                     ! Standard deviation of the mean
10260     DEALLOCATE Dum(*)                  ! Free memory
10270  SUBEND
10280  !
10290  ! ----------------------------------------------------------------------
10300  !
10310 Menu2: SUB Menu2(Num_meas,P0)       ! Post measurement soft keys
10320     OPTION BASE 1
10330     Sys_prty=VAL(SYSTEM$("SYSTEM PRIORITY")) ! Determine system priority
10340     Lcl_prty=Sys_prty+1                ! Set local priority 1 higher for ON KEY
10350     USER 1 KEYS                        ! 1st set of soft keys
10360     KEY LABELS ON                      ! Turn on soft keys
10370     FOR N=0 TO 19                      ! Clear keys
10380       ON KEY N LABEL "" GOTO Top       ! Default destination
10390     NEXT N
10400     ON KEY 0 LABEL " DUMP SCREEN  ",Lcl_prty GOSUB Dump
10410     ON KEY 1 LABEL " PRINT REPORT ",Lcl_prty GOSUB Print
10420     ON KEY 2 LABEL "REPORT TO FILE",Lcl_prty GOSUB Text_file
10430     ON KEY 9 LABEL "  MAIN MENU   ",Lcl_prty GOSUB Exit
10440 Top: LOOP                              ! Wait for input
10450     END LOOP
10460 Dump:                                  ! Alpha dump to printer at 10
10470     CALL Kx_init                       ! Init Panasonic KX-P1180 Printer
10480     KEY LABELS OFF                     ! Turn off soft keys
10490     KBD LINE PEN 0                     ! Line pen black
10500     DUMP ALPHA #10                     ! Alpha dump to printer
10510     KBD LINE PEN 4                     ! Line pen green
10520     KEY LABELS ON                      ! Turn keys back on
10530     PRINTER IS CRT
10540     RETURN
10550 Print:                                 ! Print report to printer
10560     CALL Hardcopy(Num_meas,P0,"H")
10570     RETURN
10580 Text_file:                             ! Print report to text file
10590     CALL Hardcopy(Num_meas,P0,"S")
10600     RETURN
10610 Exit:                                  !
10620     KEY LABELS OFF
10630     ON KNOB 1 GOSUB Mousetrap
10640     ON KBD GOSUB Keytrap
10650     DISP CHR$(136)&"All data will be lost.  EXIT ("&CHR$(138)&"Y"&CHR$(136)&")es or ("&CHR$(138)&"N"&CHR$(136)&")o."
10660     LOOP
10670       M$=KBD$
10680     EXIT IF UPC$(M$)="Y"               ! Exit on YES
10690     EXIT IF UPC$(M$)="N"               ! Exit on NO
10700     END LOOP
10710     M$=TRIM$(M$)                       ! Remove leading and trailing spaces
10720     OFF KNOB
10730     OFF KBD
10740     DISP ""                            ! Clear display line
10750     IF UPC$(M$)="Y" THEN SUBEXIT       ! Lost the data
10760     KEY LABELS ON
10770     RETURN
10780 Mousetrap:                             ! Trap mouse
10790     ! No Rodents
10800     RETURN
10810 Keytrap:                               ! Trap unused keys
10820     ! Dead Keys
10830     RETURN
10840  SUBEND
10850 !
10860 ! ----------------------------------------------------------------------
10870 !
10880 Hardcopy: SUB Hardcopy(Num_meas,P0,O$) ! Hardcopy report
10890     OPTION BASE 1                      ! O$="H" use Printer
10900     COM /Hardcopy/Tdate$[40]           ! O$="S" use DOS ASCII file
10910     COM /Harddata/Pdata(100,7),Pres(7,1)
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10920    COM /Mount/Mount$[40],Cf,Defm
10930    COM /Wavetek/Sn$[7]
10940    DIM Tfile$(80)
10950    IF O$="H" THEN                    ! Output to printer
10960      CALL Kx_init                    ! Init Panasonic KX-P1180 Printer
10970      ASSIGN @P1 TO 10                ! Assign path to printer
10980    ELSE                              ! Output to DOS ASCII file
10990      KEY LABELS OFF
11000      Tfile$="C:\NIST_PM2\"&Sn$&".RPT"      ! Build filename
11010 Enter_name:                          !
11020      OUTPUT 2;Tfile$;                ! Output to CRT
11030      LINPUT "CHR$(136)Enter path and name of output file. ",Tfile$
11040      Tfile$=TRIM$(Tfile$)            ! Remove leading & trailing spaces
11050      IF LEN(Tfile$)<1 THEN SUBEXIT             ! If no path/file then exit
11060      ASSIGN @P1 TO Tfile$;RETURN Uncreated   ! Open file TFile$
11070      ASSIGN @Path_1 TO *                       ! Close path
11080      IF NOT Uncreated THEN                     ! Dupicate file name
11090        BEEP
11100        ON KNOB 1 GOSUB Mousetrap   ! Disable mouse movement
11110        ON KBD GOSUB Keytrap        ! Trap input
11120        DISP "CHR$(138)Duplicate file name found. Delete file? (CHR$(136)YCHR$(138))es or (CHR$(136)NCHR$(138))o."
11130        LOOP
11140          D$=KBD$
11150        EXIT IF UPC$(D$)="Y"        ! Yes
11160        EXIT IF UPC$(D$)="N"        ! No
11170        END LOOP
11180        OFF KNOB
11190        OFF KBD
11200        DISP ""
11210        IF UPC$(D$)="Y" THEN PURGE Tfile$      ! Purge file
11220        IF UPC$(D$)="N" THEN Enter_name        ! Enter new path/file
11230      END IF
11240      ON ERROR GOTO Error_handler               ! On file error
11250      CREATE Tfile$,1                           ! Create file
11260      OFF ERROR                                 ! Turn off error branching
11270      ASSIGN @P1 TO Tfile$;FORMAT ON            ! Open path & format output
11280      KEY LABELS ON
11290    END IF
11300    OUTPUT P$ USING "#,K";P0                    ! Compact field - Power in mW
11310    OUTPUT @P1;"                                  MEASUREMENT DATA"
11320    OUTPUT @P1;""
11330    OUTPUT @P1;"FOR POWER METER: WAVETEK MODEL 8502A, S/N ";Sn$
11340    OUTPUT @P1;""
11350    OUTPUT @P1;"USING MOUNT: ";Mount$;"           ";Tdate$;""
11360    OUTPUT @P1;""
11370    OUTPUT @P1;"         Power    Pwr-";P$;" mW      V1      Delta V   V1 Drift  Ref. Offset"
11380    OUTPUT @P1;"          (mW)        (%)        (V)        (mV)      ("&CHR$(230)&"V/s)        (mV)"
11390    OUTPUT @P1;""
11400    IMAGE 3D,4X,Z.5D,4X,SZ.3D,4X,Z.6D,2X,3D.3D,4X,S2D.D,6X,S2D.3D
11410    FOR N=1 TO Num_meas
11420      OUTPUT @P1 USING 11400;Pdata(N,1),Pdata(N,2),Pdata(N,3),Pdata(N,4),Pdata(N,5),Pdata(N,6),Pdata(N,7)
11430      IF N=48 AND O$="H" THEN OUTPUT @P1;CHR$(12) ! Send form feed (page is 57 lines)
11440      IF N=48 AND O$="H" THEN                   ! Set new line and set page to two
11450        Lines=0
11460        Page=2
11470      END IF
11480      Lines=Lines+1                             ! Line count
11490    NEXT N
11500    OUTPUT @P1;"________________________________________________________________________"
11510                                                ! Make strings for text output
11520    OUTPUT Num_meas$ USING "#,K";Num_meas     ! Number of measurements
11530    OUTPUT M$ USING "#,Z.DDDDD";Pres(1,1)     ! Mean power in mW
11540    OUTPUT Sd$ USING "#,Z.DDD";Pres(5,1)      ! Sdmu - Percent  standard deviation
11550    OUTPUT Md1$ USING "#,SZ.DDD";Pres(3,1)    ! Max % dev from the mean(+)
11560    OUTPUT Md2$ USING "#,SZ.DDD";Pres(4,1)    ! Max % dev from the mean(-)
11570    OUTPUT Av$ USING "#,Z.DDD";ABS(Pres(2,1))! Mean % from P0
11580    IF Page=2 AND O$="H" AND Lines>20 THEN OUTPUT @P1;CHR$(12) ! Send form feed to printer
11590    IF Page=0 AND O$="H" AND Num_meas>12 THEN OUTPUT @P1;CHR$(12) ! Send FF
11600    OUTPUT @P1;""
11610    OUTPUT @P1;"                               MEASUREMENT RESULTS"
11620    OUTPUT @P1;""
11630    IF Num_meas>1 THEN
11640      OUTPUT @P1;"The mean of the ";Num_meas$;" measurements is ";M$;" mW with ";Sd$;" percent standard deviation"
11650      OUTPUT @P1;"of the mean.  The maximum deviation from the mean is ";Md1$;" and ";Md2$;" percent."
11660      IF Pres(2,1)<0 THEN
11670        OUTPUT @P1;"The mean is ";Av$;" percent less than ";P$;" mW."
11680      ELSE
11690        OUTPUT @P1;"The mean is ";Av$;" percent greater than ";P$;" mW."
11700      END IF
11710      OUTPUT @P1;""
11720      OUTPUT @P1;"The table below shows the values of the major uncertainty components.  The total"
11730      OUTPUT @P1;"uncertainty is expressed as both the worst case sum and the expanded uncertainty."
11740      OUTPUT @P1;"For a discussion of standard and expanded uncertainty see NIST Technical Note 1297,"
11750      OUTPUT @P1;CHR$(34);"Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement"
11760      OUTPUT @P1;"Results.";CHR$(34)
11770    ELSE
11780      OUTPUT @P1;"The table of uncertainties is not computed for single measurements."
11790    END IF
11800    OUTPUT @P1;""
11810    IF Num_meas>1 THEN CALL Table(@P1)       ! Print table of results
11820    IF O$="H" THEN OUTPUT @P1;CHR$(12)        ! Send form feed to printer
11830    ASSIGN @P1 TO *                           ! Close path
11840    PRINTER IS 1                              ! CRT
11850    SUBEXIT                                   ! Back to sub Menu2
11860 Error_handler:                               ! Error Branch
11870    BEEP
11880    BEEP
11890    LINPUT "ERROR - Filename or Directory not found. Press enter.",Fake$
11900    Enter_name                                ! Back to enter path/filename
11910    RETURN
11920 Mousetrap:                        !
11930    !NO RODENTS
11940    RETURN
11950 Keytrap:                          !
11960    !DEAD KEYS
11970    RETURN
11980  SUBEND
11990  !
12000  ! ----------------------------------------------------------------
```

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12010  !
12020 Table: SUB Table(@P1)              ! Table of results
12030     OPTION BASE 1
12040     COM /Errs/Dp,V1c,V1i,V1f,V1xi,V1xf,V1x,V2x,T1fac,T2fac,Cfu,Mmu,Deu,Dpu
12050     COM /Errs/Gm,Scfu,Smmu,Sdeu,Sdpu,Wc_unc,Cs_unc,Ex_unc
12060     COM /Harddata/Pdata(100,7),Pres(7,1)
12070                                    ! Make Strings
12080     OUTPUT Cfu$ USING "#,Z.DDD";Cfu           ! Mount calibration factor
12090     OUTPUT Scfu$ USING "#,Z.DDD";Scfu         ! Std mount calibration factor
12100     OUTPUT Mmu$ USING "#,Z.DDD";Mmu           ! Mismatch uncertainty
12110     OUTPUT Smmu$ USING "#,Z.DDD";Smmu         ! Std mismatch uncertainty
12120     OUTPUT Deu$ USING "#,Z.DDD";Deu           ! Dual element uncertianty
12130     OUTPUT Sdeu$ USING "#,Z.DDD";Sdeu         ! Std dual element uncertainty
12140     OUTPUT Dpu$ USING "#,Z.DDD";Dpu           ! DVM uncertainty
12150     OUTPUT Sdpu$ USING "#,Z.DDD";Sdpu         ! Std DVM uncertainty
12160     OUTPUT Sd$ USING "#,Z.DDD";Pres(5,1)      ! Sdmu - Percent of std dev
12170     OUTPUT Sdu$ USING "#,Z.DDD";Pres(5,1)*3   ! Percent of std dev
12180     OUTPUT Wc$ USING "#,Z.DDD";Wc_unc         ! Worst case sum
12190     OUTPUT Cs$ USING "#,Z.DDD";Cs_unc         ! Combined std uncertainty
12200     OUTPUT Ex$ USING "#,Z.DDD";Ex_unc         ! Expanded uncertainty
12210     OUTPUT Gm$ USING "#,Z.DDDD";Gm            ! Mount reflection coefficient
12220                                    ! Print Table
12230     OUTPUT @P1;""
12240     OUTPUT @P1;"╔══════════════════════════════════════════════════════════════════╗"
12250     OUTPUT @P1;"║          Value of uncertainty components in percent at 1 GHz.    ║"
12260     OUTPUT @P1;"╠══════════════════════════════════════════╤═══════════╤═══════════╣"
12270     OUTPUT @P1;"║           Uncertainty factor             │Uncertainty│ Standard  ║"
12280     OUTPUT @P1;"║                                          │  limits   │uncertainty║"
12290     OUTPUT @P1;"╟──────────────────────────────────────────┼───────────┼───────────╢"
12300     OUTPUT @P1;"║ DVM                                      │   ";Dpu$;"   │   ";Sdpu$;"   ║"
12310     OUTPUT @P1;"╟──────────────────────────────────────────┼───────────┼───────────╢"
12320     OUTPUT @P1;"║ Mount calibration factor                 │   ";Cfu$;"   │   ";Scfu$;"   ║"
12330     OUTPUT @P1;"╟──────────────────────────────────────────┼───────────┼───────────╢"
12340     OUTPUT @P1;"║ Mismatch (mount reflection coefficient = ";Gm$;") │   ";Mmu$;"   │   ";Smmu$;"   ║"
12350     OUTPUT @P1;"╟──────────────────────────────────────────┼───────────┼───────────╢"
12360     OUTPUT @P1;"║ Dual element                 .           │   ";Deu$;"   │   ";Sdeu$;"   ║"
12370     OUTPUT @P1;"╟──────────────────────────────────────────┼───────────┼───────────╢"
12380     OUTPUT @P1;"║ Random effects (standard deviation of the mean) │   ";Sdu$;"   │   ";Sd$;"   ║"
12390     OUTPUT @P1;"╟──────────────────────────────────────────┼───────────┼───────────╢"
12400     OUTPUT @P1;"║ Worst case sum                           │   ";Wc$;"   │           ║"
12410     OUTPUT @P1;"╟──────────────────────────────────────────┴───────────┼───────────╢"
12420     OUTPUT @P1;"║ Combined standard uncertainty (RSS)                  │   ";Cs$;"   ║"
12430     OUTPUT @P1;"╟──────────────────────────────────────────────────────┼───────────╢"
12440     OUTPUT @P1;"║ Expanded uncertainty (coverage factor = 2)           │   ";Ex$;"   ║"
12450     OUTPUT @P1;"╚══════════════════════════════════════════════════════╧═══════════╝"
12460  SUBEND
12470  !
12480  ! ------------------------------------------------------------------
12490  !
12500 Kx_init: SUB Kx_init              ! Init Panasonic KX-P1180 Printer
12510                                   ! or any Epson FX-86e/FX-800 compatible.
12520                                   ! Printer must be in PGM mode.
12530                                   ! (Epson LQ untested)
12540     PRINTER IS 10;WIDTH 96        ! Output to printer
12550     PRINT CHR$(27)&"@";           ! Reset printer
12560     PRINT CHR$(27)&"k3";          ! 0=Courier, 1=Sans Serif, 3=Prestige
12570     PRINT CHR$(27)&"x1";          ! NLQ font
12580     PRINT CHR$(27)&"M";           ! P=10 cpi M=12 cpi
12590     PRINT CHR$(27)&"t1";          ! Selects standard graphic character set
12600     PRINT CHR$(27)&"7";           ! Selects IBM mode (character set 1)
12610     PRINT CHR$(27)&"2";           ! 6 lpi
12620     PRINT CHR$(27)&"l"&CHR$(12);  ! Set left Margin to 12 chr's (1")
12630  SUBEND
12640  !
12650  ! ------------------------------------------------------------------
12660  !
```