A USER'S GUIDE FOR AUTOMATIC PHASE NOISE MEASUREMENTS

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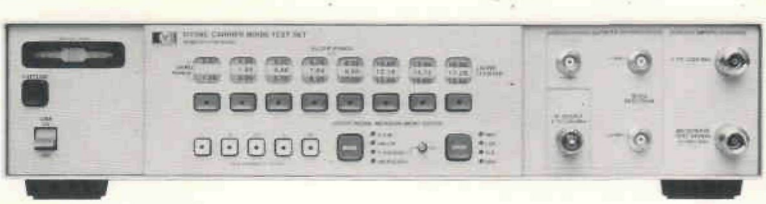

HEWLETT PACKARD

Product Note 11729C-3

A User's Guide For Automatic Phase Noise Measurements

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CHAPTER

I Introduction

The increased focus on the spectral purity of microwave signal sources has created a need for a measurement system that provides the high performance necessary for R&D applications and that can be automated for production environments. The HP 11729C Carrier Noise Test Set is the key element of a system that meets this requirement. With appropriate companion instrumentation, phase noise measurements can be made on a broad range of sources, from 10 MHz to 18 GHz. An inexpensive, easy to use software solution that allows automatic operation of the HP 11729B/C, along with the necessary spectrum analyzers and local oscillator, is the subject of this product note.

This internally modular, user-friendly software, called "**EASY_$\mathscr{L}$**," is designed to make automatic phase noise measurements from 10 MHz to 18 GHz on both free-running and synthesized sources. The software implements both the Phase Detector Method and the Delay Line Discriminator Method, and provides a plot of the phase noise measurement in units of script-L ($\mathscr{L}$). Its drivers can also be user-modified to control instruments other than those supported by the software. However, it does not make 2-port or AM noise measurements, nor does it make the necessary corrections to validate the data obtained inside the phase lock loop bandwidth, offer a choice of units with which to display the phase noise data, or display correct discrete signal levels. **The software is not specified or warranted. This product note is the only documentation available.** It is written in HP BASIC so that enhancements can easily be user added to better match a particular application.

EASY_$\mathscr{L}$ works with:

- **HP 11729 B/C:** Carrier Noise Test Set
- **HP 8662/8663 A:** Synthesized Signal Generator
- **HP 8566/8568 A/B:** Spectrum Analyzer
- **HP 3561A:** Dynamic Signal Analyzer

All instruments are linked together via HP-IB and their functions are controlled by a HP Series 300 or 200 technical computer. The software coordinates the instruments during the measurement, and makes the necessary calibrations to improve the accuracy of the results.

The user is allowed to choose between two methods for making automatic phase noise measurements on sources: the Phase Detector Method, and Frequency Discriminator Method.

Phase Detector Method

This method **requires** the HP 8662A or HP 8663A, acting as a reference source, to be phase-locked to the device under test (DUT). Two configurations are used for phase-locking in this method. The first technique, called Electronic Frequency Control (or EFC), uses the phase-lock circuitry of the Carrier Noise Test Set to directly change the frequency of the HP 8662A/63A Signal Generator's 10 MHz crystal reference oscillator. EFC is used to make accurate measurements on low drift sources such as synthesized sources.

The second technique, called DC-FM, uses the phase-lock circuitry of the Carrier Noise Test Set to control the FM circuitry of the HP 8662A/63A Signal Generator. DC-FM is used for measurements on sources with a greater drift rate. (For more information on the Phase Detector Method refer to Product Note 11729B-1, "Phase Noise Characterization of Microwave Oscillators, Phase Detector Method", HP Literature No. 5952-8286).

Frequency Discriminator Method

This method does not require a reference source to make the measurement. However, a discriminator such as a delay line or a resonator, and a phase shifter are needed. This technique is useful for characterizing sources with large, low rate phase instabilities such as free-running sources. Two configurations for down-converting the test frequency are implemented in the software. The first configuration, uses the HP 8662A/63A for down-conversion, and provides a lower noise floor close to the carrier. The second configuration uses the HP 11729C in stand-alone (self-oscillator) mode to generate the down-conversion frequency. This configuration does not require an HP 8662A/63A Signal Generator for down conversion and provides a lower broadband noise floor. (For more information on the Frequency Discriminator Method, refer to Product Note 11729C-2, "Phase Noise Characterization of Microwave Oscillators, Frequency Discriminator Method", HP Literature No. 5953-6497).

This product note discusses the use of the "**EASY_$\mathscr{L}$**" program for making automatic phase noise measurements. Chapter II describes the instruments controlled by the software. The set-up procedure is shown in Chapter III. Chapter IV shows two techniques for measuring the phase noise of sources; it explains when each technique should be applied and what the software limitations are for each technique. The different software menus and softkeys are covered in Chapter V. Finally, Chapter VI outlines some of the measurement difficulties that the user may encounter. To order your copy of "**EASY_$\mathscr{L}$**", refer to the Ordering Information section at the end of this Product Note.

NOTE: This product note assumes the user has had some previous experience in making phase noise measurements and has read Product Notes HP 11729B-1 and HP 11729C-2. Copies of these product notes may be obtained at no cost from your local Hewlett-Packard Sales and Service Office.

CHAPTER

II System Description

INSTRUMENTS SUPPORTED BY EASY_ℒ

This section describes the instruments controlled by the software. Refer to Figure 1 for a block diagram representation of the system components.

HP 11729B/C Carrier Noise Test Set

This instrument provides the down-conversion of the DUT signal, the phase detection and phase-locking of the resultant IF product with the RF output signal of the HP 8662A/63A as well as baseband signal processing. It can be configured in one of two modes to generate the required IF. When using the HP 11729C in normal mode, a selected harmonic of the fixed 640 MHz signal from the rear panel of the HP 8662A/63A is used as a reference signal to down-convert the frequency of the DUT to an IF. A second mixer in the HP 11729C then down-converts this IF to baseband.

The HP 11729C can also be used in a SAW "oscillator" mode. In this mode, the 640 MHz SAW filter in the HP 11729C is configured into a low-noise internal SAW oscillator capable of generating the necessary reference signal. When used in this mode, the 640 MHz reference signal from the HP 8662A/63A is not required.

HP 8662A/63A Synthesized Signal Generator

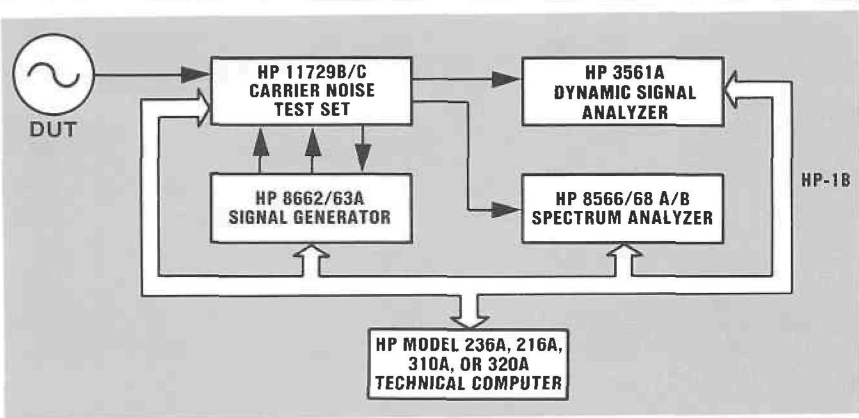
When making phase noise measurements with the Phase Detector Method the HP 8662A/63A serves as the voltage controlled oscillator in the phase-lock-loop and provides the fixed 640 MHz LO signal required by the HP 11729B/C for the down-conversion process. When using the HP 11729C in the SAW oscillator mode, the HP 8662A/63A may be used as the calibration source for the frequency discriminator.

HP 3561A Dynamic Signal Analyzer and HP 8566/68 A/B Spectrum Analyzer

Two baseband spectrum analyzers are used to measure the noise spectrum output from the Carrier Noise Test Set. For offset frequencies from 1 Hz to 100 kHz the HP 3561A Dynamic Signal Analyzer is used. For low offsets, the HP 3561A can rapidly produce results by taking time domain data and performing an FFT to get the necessary frequency domain data.

For higher offset frequencies, the broad range of the HP 8566/68 A/B Spectrum Analyzer is selected. This Spectrum Analyzer is also used to measure the frequency of the DUT and the IF frequency when the **COUNT IF SIG** or the **COUNT UW SIG** softkeys are pressed. The combined capabilities of the two spectrum analyzers (HP 8566/68 A/B and HP 3561A) give the system an offset range of 1 Hz to 10 MHz. The user can select a measurement covering the entire range, or any portion of it. If an HP 3561A is not available to the user, the software will allow the HP 8566/68 A/B to be used for offsets from the carrier ranging from 100 Hz to 10 MHz. In order to make a measurement with the software an HP 8566 or an HP 8568 is required to be present in the system.

Figure 1. Instruments controlled by the software.



HP Technical Computers

The software runs on an HP 9816A (requiring the large keyboard model number 98203B) or an HP 9836A series 200 computer. It will also run on the HP 9000 Series 300 computers Model 310 and 320. The Series 300 computers must be configured with an HP 98546A display compatibility interface. The software, on two 5¼-inch discs or on two single sided 3½-inch discs, requires 450K bytes of memory and needs the system to be configured with BASIC 2.1, 3.0, or 4.0 with extensions. The BASIC software with extensions, occupies 500K bytes of memory, so a total of 1M bytes of memory is needed to run the program. The BASIC 3.0 or 4.0 binaries needed to run the program are listed below.

NAME	DESCRIPTION
GRAPH	Graphics
IO	I/O
MAT	Matrix Statements
KBD	Keyboard Extensions
CLOCK	Clock
TRANS	Transfer Statement
ERR	Error Messages
HPIB	HP-IB Interface Driver
CRTA	ALPHA CRT Driver

Depending on which mass storage device you are using, select the appropriate version of the following BASIC 3.0 binaries:

SRM	Shared Resource Mgm.
DISC	Small Disc Driver
CS80	CS80 Disc Driver

Printer/Plotter

A hardcopy output of the phase noise measurement can be obtained using any printer (with "raster dump" capability) and/or plotter supported by the HP Series 200 (models 216A and 236A) or Series 300 (models 310A and 320A) Technical Computers.

NOTE: The instruments described above are the HP instruments controlled by the software. The only HP instruments required to run the program are the HP 11729C Carrier Noise Test Set and an HP 8566/68 A/B Spectrum Analyzer. (If you are using EASY_$\mathscr{L}$ in the Phase Detector Method, the HP 8662A/63A is required to be connected to the system.) A user supplied RF spectrum analyzer, FFT spectrum analyzer, or signal generator can be integrated into the system provided that the necessary programming changes are made by the user in the appropriate instrument driver. The following line identifiers are used to locate the appropriate instrument driver (via [EDIT] line Identifier):

IDENTIFIER	INSTRUMENT	FILE NAME
Lo_Begin	Signal Generator	EL866XA
Sa_Begin	SA Interface	ELsaSTUBa
Sa856XX_Begin	Spectrum Analyzer	EL856XX
Sa3561a_Begin	FFT Spectrum Analyzer	EL3561A

CHAPTER

III Set Up Procedure

Configuring the System

Before running the program, the user must configure the HP-IB instruments connected to the system and controlled by the software.

After loading BASIC 2.1, 3.0, or 4.0 and all necessary binaries, insert Disc 1 in Drive 0 and Disc 2 in Drive 1. Then type LOAD "ELautost" and press [EXECUTE] to load the greeting file. The start-up message gives detailed address setting instructions for each instrument. The following is a list of the instruments controlled by the software and the addresses they should be set to in order to run the program:

INSTRUMENT	ADDRESS
Hi-Frequency Spectrum Analyzer (HP 8566/68 A/B)	718
Low Frequency Spectrum Analyzer (HP 3561A)	711
Local Oscillator (HP 8662/63A)	719
Carrier Noise Test Set (HP 11729C)	706*
External Plotter (HP 7470A, etc.)	705
External Printer (to dump graphics)	701

NOTE: The last two digits are used to specify the instrument address. The first digit (7) is a select code used to specify the internal HP-IB interface.

*Since computer peripherals usually occupy bus addresses 0 through 7, the software will recognize the HP 11729C Carrier Noise Test Set when this instrument is set to either address 706 (original address with which the instrument is shipped) or an alternate address of 716. To set your instrument address to 716 refer to the HP 11729C Operating and Service Manual.

In some cases, depending on the user's needs, some of the above instruments may be omitted. The printer/plotter provide for the hardcopy output and are not necessary for the operation of the system. The LO may be omitted if another source is used to provide for the calibration sideband in the Frequency Discriminator Method. For users interested only in offset frequencies greater than 100 Hz and up to 10 MHz, the HP 3561A may be omitted and the only spectrum analyzer used will be the HP 8566/68 A/B. For users interested in the entire range of offset frequencies, from 1 Hz to 10 MHz, both spectrum analyzers need to be provided. The software cannot do a Microwave Signal Count if the HP 8566 is not connected to the system. The Carrier Noise Test Set is required to be present in the system at all times, regardless of the offset frequency, method chosen, or calibration procedure used.

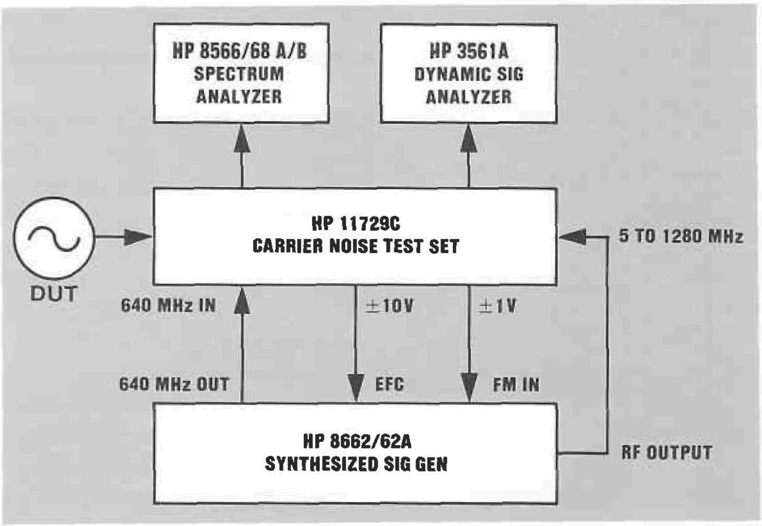
Once the user decides which instruments are needed for his specific measurement, the address setting instructions in the start-up message provide the guidance for configuring the correct adresses.

Cabling the System

The start-up message gives the user instructions to set up the system for the Phase Detector Method. The program assumes this configuration exists when it guides the user through the cabling for the discriminator method. If the Frequency Discriminator Method is chosen at the Main Menu, the user is then instructed to change the connections from the phase detector to the discriminator configuration.

Figure 2 shows the connections that should be made to set up your system for the Phase Detector Method:

Figure 2. System set up for the Phase Detector Method; instruments supported by the software and connections needed.



Cabling the System

1. Connect the DUT to the HP 11729C Microwave Test Signal Input.
2. Connect the RF Output of the HP 8662/63A to the HP 11729C's 5 to 1280 MHz Input.
3. Connect the HP 11729C <1 MHz Output to the HP 3561A Input (if available).
4. Connect the HP 11729C <10 MHz Output to the HP 8566/68 A/B RF Input.
5. Connect the HP 8662/63A front panel FM Input to the HP 11729C rear panel DC-FM Output (±1V).
6. Connect the HP 8662/63A rear panel 640 MHz OUT to the HP 11729C rear panel 640 MHz IN.
7. Connect the HP 8662/63A rear panel EFC IN to the HP 11729C rear panel EFC Output (±10V).

All instruments (except the DUT) must be connected to the technical computer via HP-IB cables. Remember not to exceed the IEEE-488 specifications on total cable length: 2 meters/device up to 20 meters. Avoid long cable lengths.

Driver Loading

Once the start-up message has been loaded press the **LOAD MAIN PGM** softkey. After pressing the **LOAD MAIN PGM** softkey and the program is loaded, the software identifies the instruments that are turned on and connected to the technical computer at the addresses previously specified. The user is then prompted to load the subprogram drivers for those instruments into memory. Press the **LOAD SUBS** softkey (K5) to automatically load the instrument's drivers. Press the **ABORT LOADING** softkey (K4) if you only want to use the PROCESS DATA menu.

If at a later time the user wants the program to stop using one of the instruments, the procedure to follow is: turn off the instrument, press [STOP] on the technical computer and then press [RUN]. The computer search will not find the instrument (respond NONE OF THESE when the controller asks you what instrument is connected at the unused instrument address) and will only use those instruments that remained ON when [RUN] was pressed.

Running the Main Program

The MAIN MENU is used to set up all parameters prior to performing the test or calibrations.

Once the program has been run and all drivers for the connected instruments have been automatically loaded, the user is prompted to set up the specific measurement parameters. To set up the measurement parameters, use the knob on the HP 9836A or HP 9816A Technical Computer keyboard to move the double arrow to the parameter that you wish to modify (you may use the ↑ and ↓ arrow keys if you are using a Series 300 Technical Computer). Then press the **CHANGE PARAMS** softkey and follow the directions to enter the appropriate information. (Refer to Figure 3 for a software flowchart.)

Figure 3. Software Flowchart

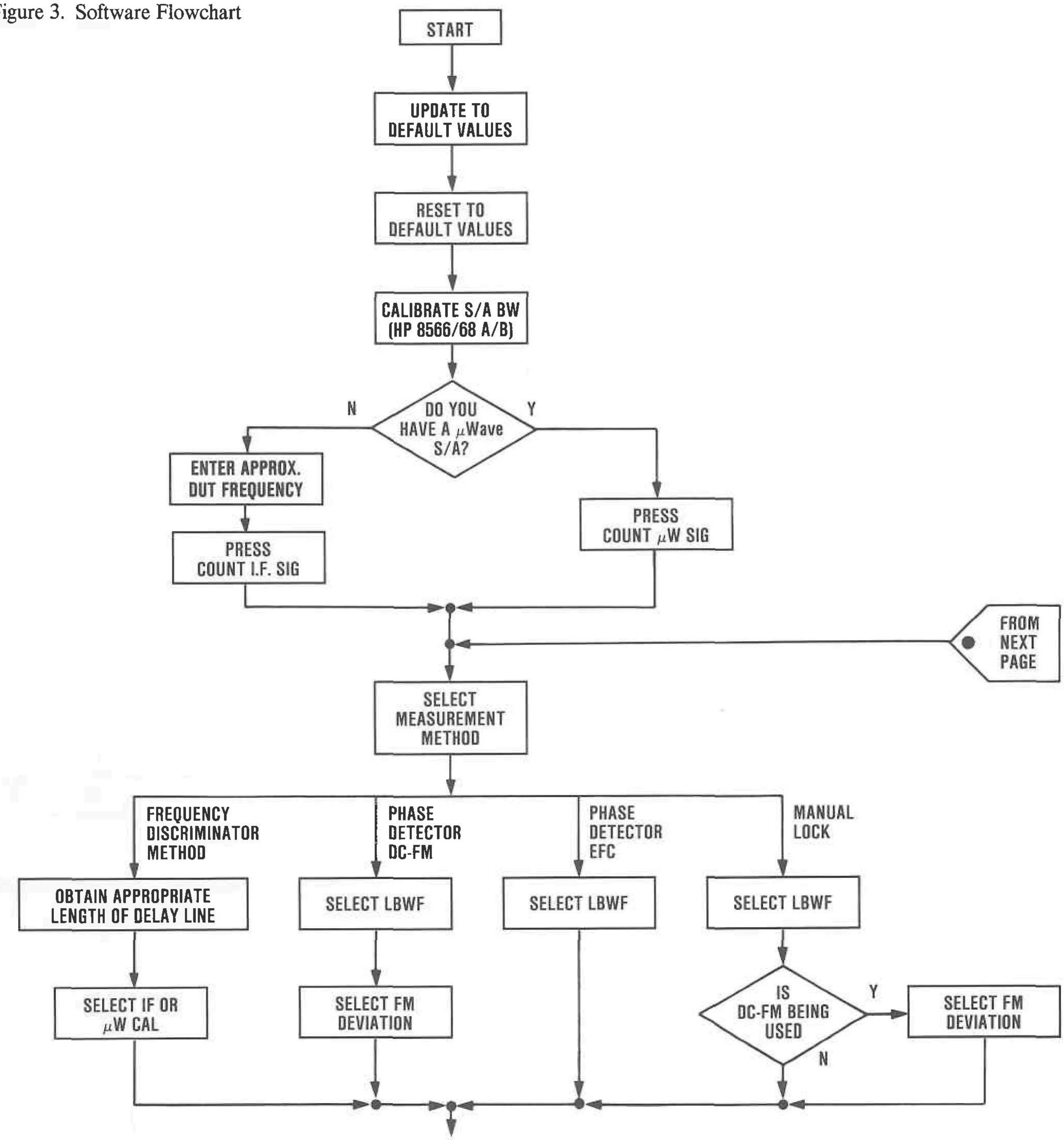
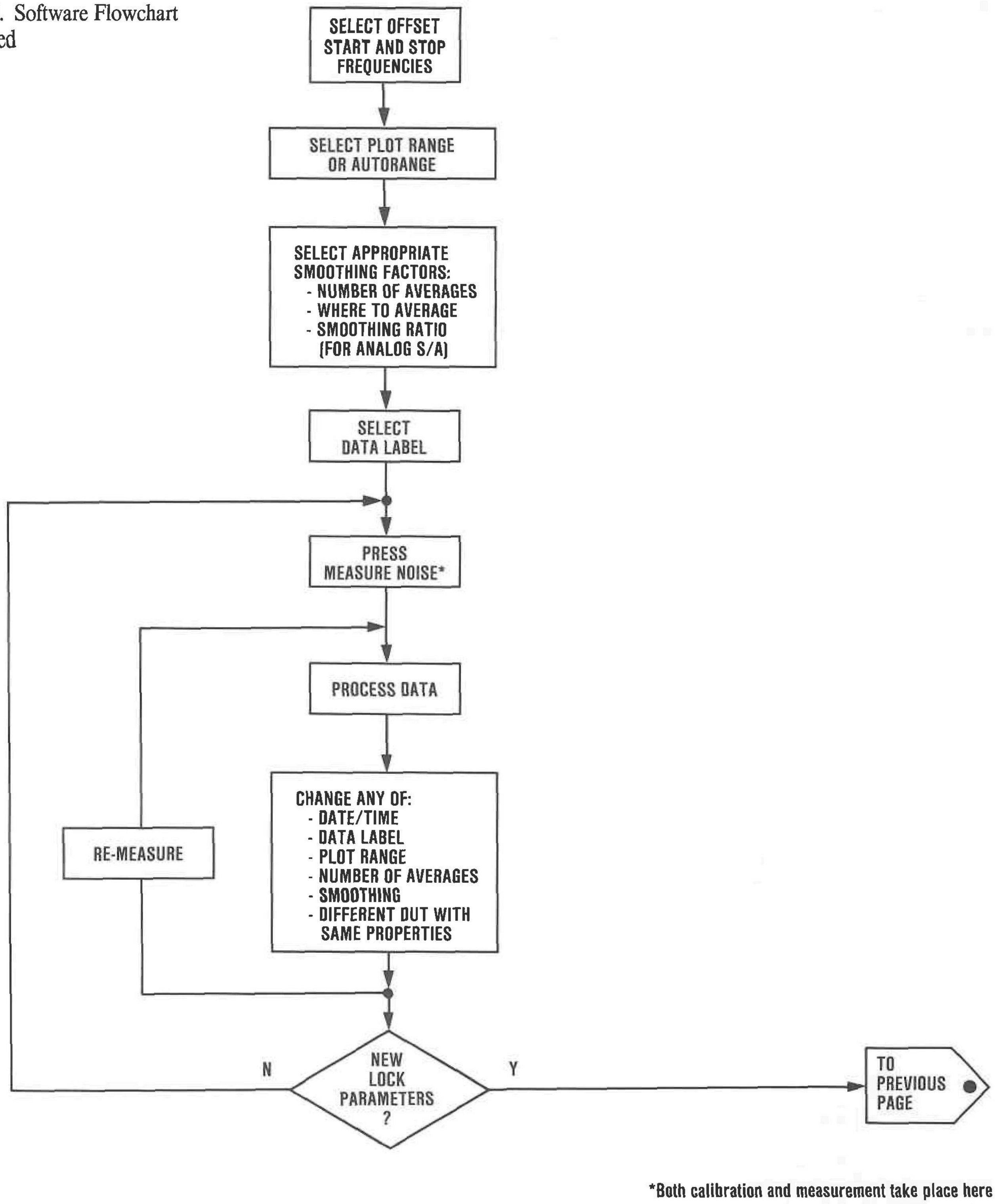


Figure 3. Software Flowchart Continued



CHAPTER

IV Measurement Methods Overview

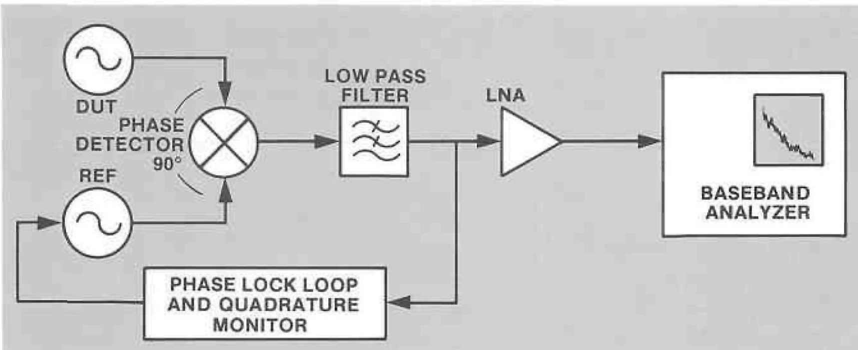
There are basically two methods of making phase noise measurements, each with its own set of advantages and disadvantages. This software allows the user to use either the Phase Detector Method or the Frequency Discriminator Method. The final decision to use one or the other of the two methods depends on the characteristics of the device under test (DUT), the offset frequencies the user is interested in, the availability of the necessary equipment, and the capabilities and limitations of the software and the instruments.

THE PHASE DETECTOR METHOD

The Phase Detector Method is sometimes called the two-source technique. In this method, the DUT and a low noise reference source are connected to a phase detector at the same frequency and 90 degrees out of phase (phase quadrature) as shown in Figure 4. The output of the phase detector is then proportional to the *combined* phase noise of the two input sources, and can be measured on a baseband spectrum analyzer.

Since the output of the phase detector is proportional to the combined noise of the two input sources, it is necessary to use a reference source that has lower noise than the source under test. The combination of the HP 11729C and the HP 8662A/63A represent the lowest noise 5 MHz to 18 GHz reference source available from HP. Because the two input signals must be phase locked, the phase detector method works optimally with fairly stable test sources. See HP Product Note 11729B-1 "Phase Noise Characterization of Microwave Oscillators, Phase Detector Method" for a complete discussion of this measurement technique.

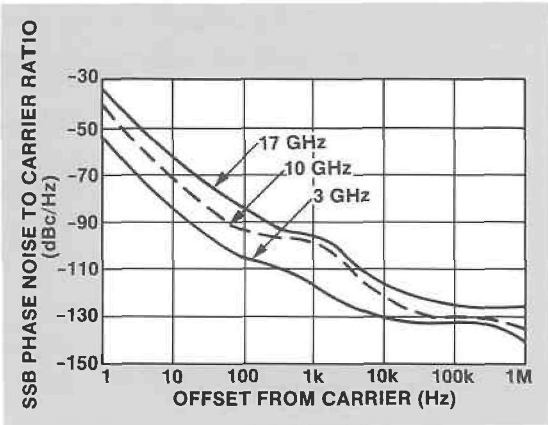
Figure 4. Basic Phase Detector Method implementation, using a double-balance mixer as the phase detector.



Typical System Sensitivity

The overall sensitivity of the Phase Detector Method is shown in Figure 5. The Phase Detector Method provides good sensitivity over the entire offset frequency range; it can be used to measure high quality standards (good close-in noise) or state-of-the-art free-running oscillators (good far-out noise).

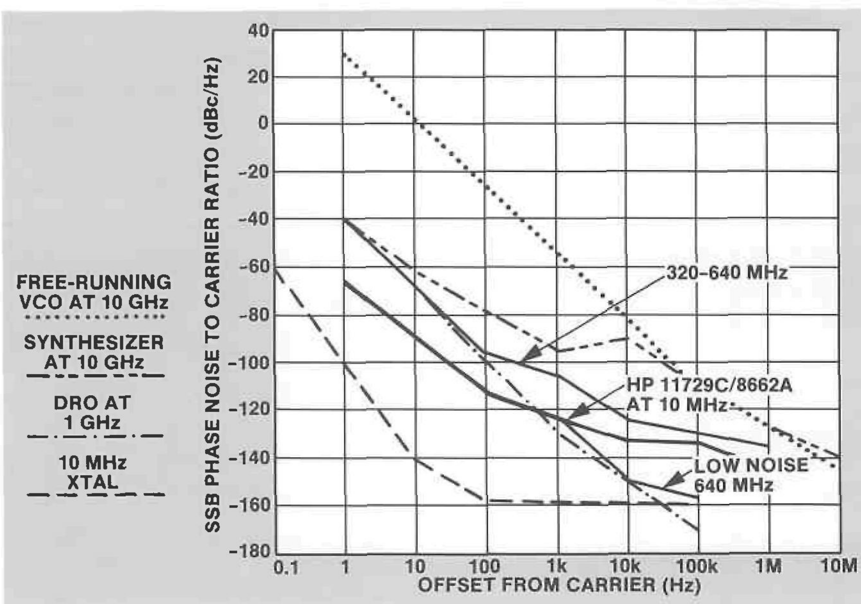
Figure 5. Typical HP 11729C/8662A system noise (Phase Detector Method, locking via EFC).



The most critical component of the Phase Detector Method is the reference source. Since the spectrum analyzer measures the rms sum of the noise of both oscillators, the most important criterion for choosing a reference source is that its phase noise be less than that of the source being measured. At any given frequency offset from the carrier, one of the source's noise will dominate.

Generally, the choice of a reference source depends on the frequency of the DUT, the required noise performance, and whether or not the reference source must operate as the loop VCO. The HP 11729C/8662A/63A provides the lowest noise floor for test signals ranging from 5 MHz to 18 GHz (see Figure 6). It also provides the loop VCO needed for the Phase Detector Method.

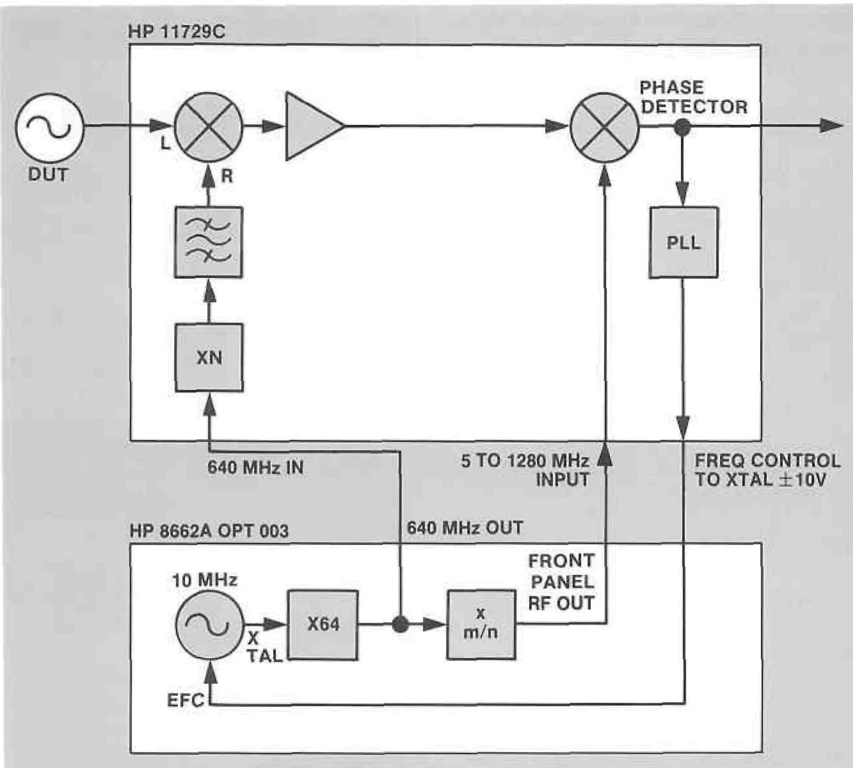
Figure 6. Typical HP 11729C/8662A system sensitivity.



Phase Locking Techniques

Depending on the source under test and how wide a phase-lock-loop bandwidth will be needed to maintain the phase detector in its linear range, there are two techniques supported by the HP 11729C and the software to phase lock. First, for very stable sources, phase lock can be established through the electronic frequency control (EFC) of the HP 8662A/63A internal 10 MHz reference oscillator, using the HP 11729C $\pm$10V phase lock loop control voltage output (Figure 7). This yields a loop holding range of 1 kHz at 10 GHz and a maximum loop bandwidth of about 1 kHz also. The advantage of locking using EFC is lower noise, but with narrow tuning range (1 part in 10^7).

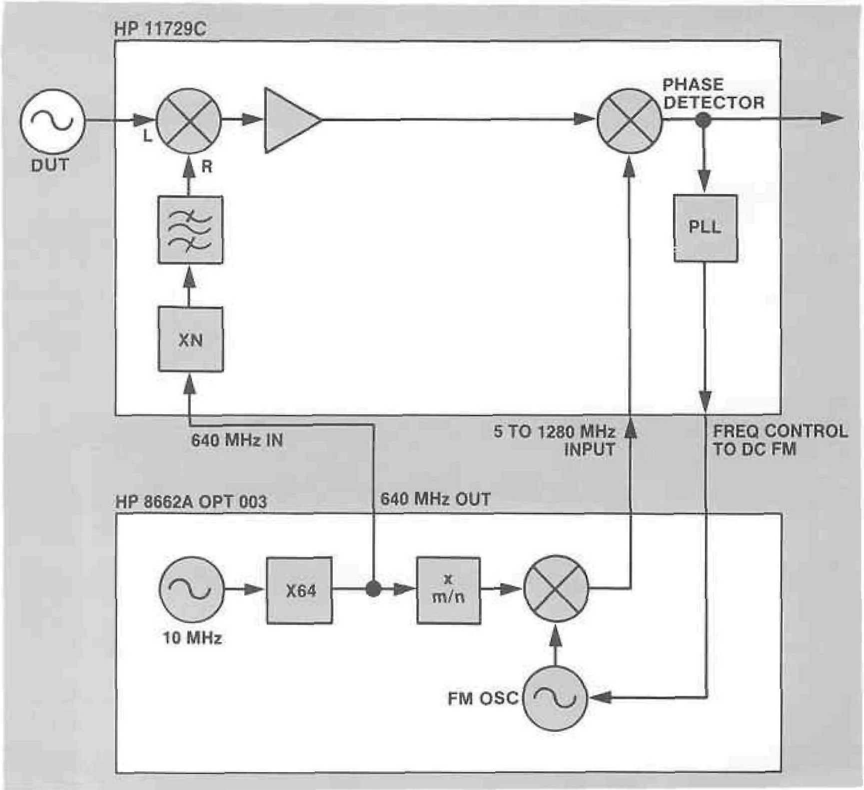
Figure 7. Phase locking with the HP 8662A/63A Reference Oscillator.



For synthesized sources, this loop holding range would probably be sufficient. However, for free-running sources and some stabilized sources, the drift characteristics or the rate of large phase instabilities in the source under test may be such that larger loop holding range and loop bandwidth are required.

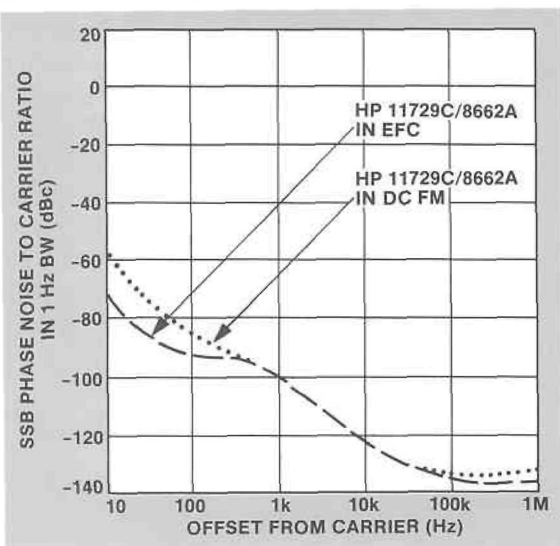
The second phase-lock method for maintaining quadrature at the phase detector permits greater loop holding range and loop bandwidth. By applying the HP 11729C ±1V Frequency Control DC FM signal to the HP 8662A/63A DC-coupled FM input, the HP 8662/63A front panel signal acts as the loop VCO (see Figure 8). The HP 8662A/63A has ±200 kHz maximum DC-FM deviation, and a maximum loop bandwidth of about 50 kHz. Since the maximum obtainable HP 8662A/63A DC FM deviation is a function of output frequency and can drop as low as 25 kHz, the obtainable Loop Holding Range (LHR) and Loop Bandwidth (LBW) is dependent on the frequency of the source under test and the resultant IF frequency. If in a situation where the allowable deviation is only 25 kHz and lock cannot be established, first change the test source frequency if possible to yield a new IF. If this cannot be done, use the Frequency Discriminator Method.

Figure 8. Phase locking with the HP 8662A/63A DC FM input.



In general, choosing a loop VCO with more tuning range increases the system noise. However, since it is usually noisier sources that require more loop bandwidth, the increased system noise typically does not limit the measurement. Figure 9 shows the effect on system noise floor of choosing either of the two phase lock techniques described above.

Figure 9. Typical system noise floor at 10 GHz using the Phase Detector Method.



Choosing between the two locking techniques described above requires the user to have some previous knowledge about the applicabilities and advantages of each technique. As a "rule-of-thumb", EFC is a good choice for measuring noise on very stable sources like frequency synthesizers. However, DC-FM provides the larger LBW needed for maintaining lock on sources with greater drift, like low-drift, free-running sources.

If the user is interested in offset frequencies very close to the carrier and the source under test can be locked by either technique, EFC would probably be the right choice. With the EFC technique the noise floor of the HP 8662A/63A at these close in frequencies is lower than that obtained when locking via DC-FM. This is exactly what is required if the phase noise of the source under test is very low at small offsets from the carrier.

Loop Characterization

In the Phase Detector Method a PLL (phase lock loop) forces the VCO to track the source under test in phase for offsets less than the bandwidth of the PLL. This tracking results in suppression of phase noise within the loop bandwidth at the output of the phase detector. Since no software correction is made for this effect, the measurement data obtained is not valid for those offset frequencies less than the loop bandwidth. A vertical line at the offset frequency corresponding to the phase locked-loop bandwidth is added to the data plot of measurements using the Phase Detector Method. See Figure 10.

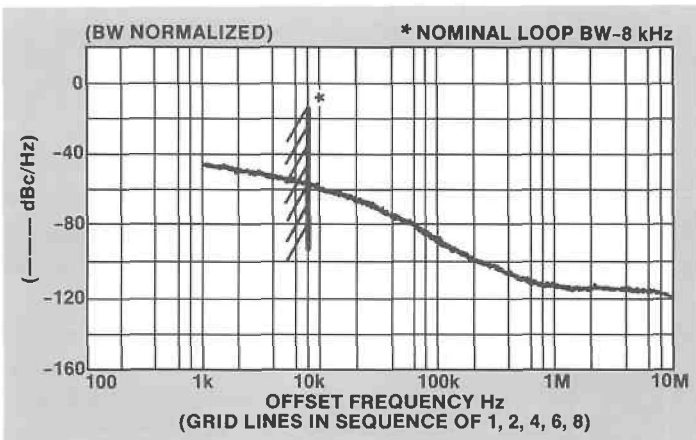


Figure 10. Typical system output of a phase noise measurement using the Phase Detector Method.

The lack of correction inside the loop bandwidth is a very important fact to take into consideration when making phase noise measurements using this software. In general, a wider loop bandwidth is needed when locking via DC-FM since less stable sources need more frequency tracking. The two equations below show how to calculate the nominal loop bandwidth when using either technique. The program computes this value and displays it both on the Main Menu and on the data plot.

$$\text{nominal EFC LBW (Hz)} = \frac{\text{11729C LBF}*f_{DUT}\text{ (Hz)}}{10^{10}}$$

$$\text{nominal DC-FM LBW (Hz)} = \frac{\text{(8662A/63A FM Peak Deviation [Hz])}*\text{11729C LBF}}{10^{3}}$$

Thus, the loop bandwidth can be changed by varying the Lock Bandwidth Factor (LBF) when using EFC or by varying the Lock Bandwidth Factor and varying the peak FM deviation when locking with DC-FM. Note that changing the Lock Bandwidth Factor changes the loop bandwidth in decade steps, while changing the FM deviation can change the loop bandwidth in finer increments.

For those users interested in measuring phase noise at offset frequencies inside the loop bandwidth, HP offers another solution. The HP 11740S Microwave Phase Noise Measurement System is a fully specified, documented and warranted system capable of making automatic phase noise measurements at offset frequencies ranging from 0.02 Hz to 40 MHz. The software that runs the system performs the necessary calculations to make the measurement data valid over the entire range of offset frequencies.

It is also possible for the user to make the software enhancements to **EASY_ℒ** so that the obtained data would be valid inside the loop bandwidth. Contact your local HP Systems Engineer for a quotation on consultation or software enhancements to match your specific measurement application.

USING EASY_ℒ IN THE PHASE DETECTOR MODE

This section covers the procedure for using the software when making a phase noise measurement with the Phase Detector Method. The main steps with a brief explanation are listed below.

Loading the Main Program

In order to run **EASY_ℒ** you must configure the system with BASIC 2.1, 3.0, or 4.0 Turn on the controller and load BASIC 2.1, 3.0, or 4.0 with the necessary binaries. Place Disc 1 in Drive 0 and Disc 2 in Drive 1. Type **LOAD** "ELautost" and press [EXECUTE]. This will load the Start-up Message giving you detailed instructions on how to cable the system. After all the instruments have been properly connected, press the **LOAD MAIN PGM** softkey. Make sure the software identifies all the instruments connected to the computer via HP-IB and press the **LOAD SUBS** softkey to load the drivers corresponding to these instruments. After the driver loading is done, you are ready to start your phase noise measurement.

Cabling the System

The set up procedure for the Phase Detector Method was described earlier in Chapter III. The necessary connections are listed below. Notice that an HP 8662A/63A must be connected to the system in order to use EASY_ℒ in the Phase Detector mode. Refer to Figure 2 for a diagram of the set-up.

1. Connect the DUT to the HP 11729C Microwave Test Signal Input.
2. Connect the RF Output of the HP 8662A/63A to the HP 11729C 5 to 1280 MHz Input.
3. Connect the HP 11729C <1 MHz Output to the HP 3561A Input.
4. Connect the HP 11729C <10 MHz Output to the HP 8566/68 A/B Input.
5. Connect the HP 8662A/63A rear panel 640 MHz OUT to the HP 11729C rear panel 640 MHz IN.
6. Connect the HP 8662A/63A front panel FM Input to the HP 11729C rear panel DC-FM Output (±1V).
7. Connect the HP 8662/63A rear panel EFC Input to the HP 11729C rear panel EFC Output (±10V).

All instruments (except the DUT) must be turned on and connected to the controller via HP-IB.

Specifying the Measurement Parameters for the System

Once all the connected HP-IB instruments are identified by the software and the corresponding drivers have been loaded, the user is prompted to set up the parameters corresponding to his measurement (see Figure 11). The information the user needs to enter before starting the measurement is described below. For the rest of this Product Note, the words enclosed in rectangular boxes represent the text seen on the technical computer display.

Figure 11. EASY_ℒ main menu for the HP Series 200 Technical Computer.

```
2 Oct 1985          09:19:46                                        Rev 1.0
RESET TO DEFAULT VALUES
Data Label:"MEASUREMENT OF HP 8673C AT 10 GHz AND +13 dBm EFC LOCK"
Device frequency = 10 GHz
METHOD: Phase Det. -- EFC.. (Nominal Loop BW: 10 Hz)
         11729C Lock BW Factor = 10
BASEBAND:Offset Start Frequency = 1 Hz
          Offset Stop Frequency = 10 MHz
          Baseband HiPass Filter: ..(NOT IN USE)
          Analog SA Smoothing Ratio (Res BW/Video BW) = 3
          Number of sweeps to average = 4 .. (at Spect. Analyzer)
==> PLOT RANGE: Plot will be scaled as shown:
           Top = —50 dBc
           Bottom = —150 dBc

Use KNOB and/or select a Softkey:

==>CHANGE PARM | COUNT µW SIG | COUNT I.F. SIG | MEASURE NOISE | PAUSE PROGRAM
PROCESS DATA   | CAL NOISE BW |                |               | CRT --> PRINTER
```

To set up or change any of the measurement parameters described below, use the knob on the HP 9836A/9816A Technical Computer keyboard (or the ↑ and ↓ arrow keys on the Series 300 computers) to move the double arrow to the parameter that you wish to modify. Then press the **CHANGE PARAMS** softkey (K0) and follow the directions to enter the appropriate information.

RESET TO DEFAULT VALUES

Resets all the parameters in the main menu to their default values. See figure 11a.

Figure 11a. Default value of the main menu program.

```
20 Sep 1985         00:03:15                                        Rev 1.0
RESET TO DEFAULT VALUES
Data Label:(no label defined)
Device Frequency = 10 GHz
METHOD: Phase Det. -- DC FM .. (Nominal Loop BW: 20 KHz)
          11729C Lock BW Factor = 100
          FM Deviation = 200 KHz
BASEBAND: Offset Start Frequency = 1 KHz
           Offset Stop Frequency = 1 MHz
           Baseband HiPass Filter: .. (NOT IN USE)
           Analog SA Smoothing Ratio (Res BW/Video BW) = 3
           Number of sweeps to average = 1 .. (at Spect. Analyzer)
PLOT RANGE: Plot will be AUTO scaled
```

Data Label

The type of DUT, carrier frequency, serial number, and locking technique are usually specified in the data label, but you can specify any information you desire. The maximum number of characters allowed in the data label is 60. This label will be displayed at the top of the phase noise graph.

Device Frequency

Specify the carrier frequency of the device under test.

METHOD

Choose the Phase Detector Method. The user is now presented with the following choices to phase-lock to his source: EFC, DC-FM, or Manual Lock.

Use EFC for stable synthesized sources (LBW $<$ 1 kHz).

Use DC-FM for stable free-running sources (LBW $>$ 1 kHz).

Use Manual Lock to tell the program to pause after acquisition and allow you manual set-up of phase lock. This is useful when the user is not familiar with the characteristics of his source.

If in doubt as to which lock technique to use, first try to lock via EFC. This results in lower system noise floor performance. If lock cannot be established or maintained, relock using DC-FM.

11729 Lock Factor

Use softkeys to select your lock bandwidth factor. When locking via EFC the LBF determines the value of the loop bandwidth. Choose the LBF that minimizes your loop bandwidth and still allows the sources to remain locked.

FM Deviation

When locking via DC-FM, the user must provide the value of both the FM deviation and the LBF by using the softkeys. The software shows the value of the maximum allowable FM deviation for the currently specified carrier frequency. Note that the product of the LBF and the FM deviation in Hertz divided by 1000 determines the value of the loop bandwidth. Also, changing the LBF changes the loop bandwidth in decade steps, while changing the FM deviation can change the loop bandwidth in smaller increments.

BASEBAND

Offset Start Frequency

Specify the offset frequency closest to the carrier that you are interested in. Use the softkeys to make your choice. The smallest offset start frequency at which the software can measure phase noise is 1 Hz (provided that the HP 3561A is connected to the system). If the HP 3561A is not present, the smallest offset start frequency will be 100 Hz.

Offset Stop Frequency

Use the softkeys to specify the stop frequency of interest. The largest offset stop frequency choice offered by the software is 10 MHz.

Baseband Hi Pass Filter

The HP 3561A autoranges up on the presence of low-frequency spurs. This autoranging causes discontinuities on the phase noise graph. To prevent this from happening, you might choose to insert a high-pass filter at the input of the HP 3561A Dynamic Signal Analyzer. Use this parameter to specify whether or not you would like to insert a high-pass filter, and to select the desired high-pass filter frequency.

Analog SA Smoothing Ratio

Use this softkey to specify the ratio of Resolution BW to Video BW for the HP 8566/68 A/B. The use of smoothing allows the user to resolve spurs. The software gives the user hints on how to choose between the different alternatives for this parameter.

Number of sweeps to average

Some averaging is usually desired because of the random nature of noise. Use softkeys to choose the preferred number of sweeps to be averaged. Averaging can be either at the controller or at the Spectrum Analyzer.

PLOT RANGE

By using the **CHANGE PARAMS** softkey you can modify this parameter to have the graph auto scaled or to specify the maximum and minimum values of the vertical axis on the graph. Note that the maximum value should not be greater than zero since $\mathscr{L}(f)$ is not a valid unit above 0 dBc.

Once all of the above parameters have been chosen and entered into the computer, the user can directly use the Main Menu softkeys:

K0: CHANGE PARAMS

Used to modify any of the measurement parameters as explained above.

K1: COUNT μW SIGNAL

Counts the carrier frequency of the DUT on the microwave spectrum analyzer and updates its value. This step requires the HP 8566 A/B to be connected to the system and the DUT signal to be connected to the Spectrum Analyzer Input. If the HP 8568 A/B is the only available spectrum analyzer, then input an approximate F_{DUT} and do an IF count.

K2: COUNT IF SIGNAL

Updates the carrier frequency of the DUT according to the measured value of the IF signal frequency. The menu entry of the DUT frequency must be close enough to the real value so that the program can select the correct HP 11729C filter band to down-convert. To measure the value of the IF, the IF Output from the HP 11729C must be connected to the HP 8566/68 A/B Spectrum Analyzer when prompted by the program.

K3: MEASURE NOISE

Starts the phase noise measurement using all current parameter settings.

K4: PAUSE PROGRAM

Pauses the phase noise measurement program. Press [CONTINUE] to get back to the MAIN MENU.

K5: PROCESS DATA

Used to save the current data, do re-plots, graph more than one measurement result on the same plot, etc.

K6: CAL NOISE BW

Calibrates the resolution bandwidth of the HP 8566/68 A/B Spectrum Analyzer.

K8: RE-MEAS NOISE

This softkey will re-measure the noise using the previous calibration and specified parameters. Use this softkey when the test set-up has not changed and you wish to re-measure the noise. The **RE-MEASURE** softkey omits the calibration step and therefore makes the re-measuring procedure faster. The **RE-MEASURE** softkey dissappears on **RUN** or when a non-graph parameter is changed via the Main Menu. When between measurements, the following parameters can be modified without suppressing the re-measure option: Date/Time, Data Label, Number of Sweeps to Average and Plot Range.

K9: CRT-->PRINTER

Dumps the CRT display to the printer that is connected to the system.

After pressing any of the above softkeys, a set of instructions will appear on the display to guide the user through any new connections that need to be made and/or softkeys that should be selected.

Establishing Quadrature, Calibrating and Locking

In order for the software to select the proper HP 11729B/C filter band, the system must know the correct value of the microwave carrier frequency. If this value is not known within ±30 MHz, the user must do a COUNT μW SIGNAL or COUNT IF SIGNAL so the software can update the carrier frequency to the new value. To count the Microwave Signal frequency, press the **COUNT μW SIGNAL** softkey (K1), and connect the DUT to the input of the HP 8566 A/B Spectrum Analyzer, when prompted by the software. Then press the softkey labeled **CONNECTED** and the software will use the spectrum analyzer to count the microwave signal. Once the spectrum analyzer is done counting, a message will be displayed on the screen showing the new value of the DUT frequency. To count the IF press the **COUNT IF SIGNAL** (K2) and connect the HP 11729B/C IF Output to the HP 8566/68 A/B RF Input. Then press the softkey labeled **CONNECTED**. The IF value will be measured by the Spectrum Analyzer and the test frequency will be updated based on the value of the IF frequency measured. Press the **ABORT** softkey if you decide to leave the Main Menu device frequency entry unchanged after doing either a μW or an IF signal count. The frequency update will not happen if the **ABORT** softkey is pressed.

Once the DUT frequency value has been updated through an IF or μW signal count (this step is not necessary but it is strongly recommended), press the **MEASURE NOISE** softkey to start the measurement. The steps followed by the software to measure the phase noise of the DUT are described below:

Seeking the Signal

In this step the software automatically tunes the front panel output signal of the HP 8662A/63A to match the unknown IF frequency and in this way is able to obtain phase quadrature. The signal search process can be observed on the HP 8566/68 A/B Spectrum Analyzer.

Calibrating the Phase Detector

To calibrate the phase detector the software sets up a beat note by offsetting the frequency and decreasing the amplitude of the HP 8662/63A output signal. This beat note will be displayed on the HP 8566/68 A/B or the HP 3561A, or both in sequence. The carrier power reference level is established automatically by placing the beat note at the top of the screen and reading the amplitude V_b in dBm. An HP 8566/68 A/B must be part of the system during the calibration procedure.

Locking the DUT

The software checks for the lock condition of the input signals to the mixer. In normal operation it is desired to keep the PLL bandwidth as narrow as possible to have minimum loop noise suppression. However, if too narrow a bandwidth is chosen, it may be very difficult for the PLL to acquire or maintain lock after the calibration procedure. To facilitate locking the DUT, the software enables the Loop CAPTURE feature on the HP 11729B/C. When Loop CAPTURE is activated, a wider first-order PLL enables the two signals to acquire lock (indicated by a green bar on the LED display). Then when CAPTURE is disabled, the normal second order loop is again engaged, the signals will remain in quadrature, and a measurement can be made. If phase lock is achieved the green LED will be illuminated in the center of the quadrature indicator (located on the left side of the front panel of the HP 11729B/C).

Manual Lock

At the start of the measurement, the software makes up to three attempts in each band to re-lock the DUT to the reference source. If after the third attempt the two sources did not remain phase locked, the user will be presented with the choice of either aborting the measurement, doing a manual lock or having the software try again. To lock the two sources manually, when EFC locking is being used, proceed as follows. Press the **MANUAL LOCK** softkey. Hold the CAPTURE button depressed on the HP 11729C while tuning the frequency on the HP 8662A/63A until the center green LED is illuminated on the quadrature indicator. When the green LED is illuminated release CAPTURE. If the green LED does not stay illuminated increase the Lock Bandwidth Factor to re-enable lock. Once lock is achieved, press the **USER LOCKED** softkey to inform the software of the new condition. The software resumes automatic control of the instruments again and starts the phase noise measurement.

If the locking technique chosen was not EFC but DC-FM, use the following procedure for manually locking the two sources. Press the **MANUAL LOCK** softkey. Hold CAPTURE depressed while tuning the frequency of the HP 8662/63A until the green LED of the quadrature indicator is illuminated. If the sources drift out of phase lock after CAPTURE is released, repeat the procedure each time increasing the FM deviation until lock is acquired. If maximum deviation is reached and the two sources still will not stay locked, repeat the above procedure but this time increase the Lock Bandwidth Factor until the two sources are phase locked. Then press the **USER LOCKED** softkey and the software will proceed to make the measurement. If lock cannot be achieved, use the frequency discriminator method to make your measurement.

If at any time during the measurement the sources trip out of lock, the software will automatically try (up to three times) to regain lock. If lock cannot be acquired, repeat the above procedure until the green LED illuminates in the center of the quadrature indicator. The software saves the data measured before the out-of-lock condition appeared and resumes the measurement from the point where this condition was created. Therefore, the user does not have to wait for the software to remeasure the valid data already obtained before the sources tripped out of lock, the measurement is restarted from the point of trouble and not from the beginning. Verify that the sources remain in lock (green LED in the center of the quadrature indicator) for the duration of the measurement.

Graphing the Phase Noise Data

The system measures the phase detector output in frequency segments, beginning with the highest offset to be measured. Data is normalized, corrected and graphed while each segment is being measured by the Spectrum Analyzers. The software first normalizes the noise bandwidth to 1 Hz. It then adds a +2.5 dB correction factor to the final result to compensate for the use of an analog spectrum analyzer (HP 8566/68 A/B), and finally converts from units of $S\phi(f)$ to $\mathcal{L}(f)$. This +2.5 dB correction factor is not applied to those segments measured with an FFT spectrum analyzer (HP 3561A).

Once the measurement has started, the user is presented with a new softkey menu. He can choose the appropriate softkey to display on the CRT the graph that is being generated (press **VIEW GRAPHICS**), the measurement parameters and current computer operation (press **VIEW MENU**), or choose to have the software automatically switch between the alpha display and the graph display (press **VIEW AUTO**) when they are being updated. The user is also given the choice to abort the test any time during the measurement (press **ABORT TEST**). If you chose to install a high-pass filter at the input of the HP 3561A to avoid discontinuities on the graph, the software will prompt you with instructions to connect and to remove the filter when appropriate.

Once the measurement is finished the process data menu is displayed on the screen (refer to the next section for a detailed explanation of this menu). The user can then obtain a hardcopy output from a printer or plotter, save the data, recall data, do re-plots or go back to the main menu to start a new measurement.

THE PROCESS DATA MENU

This section describes methods for obtaining a hardcopy output of the measurement data from the system. It also explains how to save/recall data, replot a new axis, recall data from previous measurements, or change the graph title.

The PLOT menu is displayed on the CRT when you press the **PROCESS DATA** softkey (K5) available to you from the Main Menu (see Figure 12a). The following list describes the softkey options that are available when using the process data menu:

Figure 12a. Softkey menu obtained after pressing the **PROCESS DATA** softkey.

RE PLOT			SAVE DATA	EXTERNAL PLOTS
MAIN MENU			RECALL DATA	CRT --> PRINTER

K0: RE-PLOT

Redraws the last measured data that is currently in memory on the computer CRT, using the current Main Menu parameters (plot scaling, data label, bandwidth, etc.).

K3: SAVE DATA

Used to save the current measurement results to a disc. After pressing this softkey a new softkey menu is displayed (see Figure 12b) offering a choice of files in which to store the data; the user may also specify which disc drive contains the disk on which the data will be stored. The program shows a default disc drive, which may be changed by the user if desired.

Figure 12b. Softkey menu obtained after pressing the **SAVE DATA** softkey.

SAVE DATA TO DISK

Current DFile Disk Drive= : INTERNAL.4.1

Press EXIT Softkey when done...

DFile DISK= ?	DFile CATALOG	REDRAW PLOT		EXIT
INIT. DISK	SAVE-->DFile A	SAVE-->DFile B	SAVE-->DFile C	SAVE-->DFile D

K4: EXTERNAL PLOTS

Allows the user to plot the measurement data on the CRT or to an external plotter. A new softkey menu is displayed on the screen (see Figure 12c) after pressing this softkey. You may then use the softkeys to change the data file to be plotted, the disk drive containing the data file, and the type of plotter to be used.

Figure 12c. Softkey menu obtained after pressing the **EXTERNAL PLOTS** softkey.

EXTERNALLY PLOTTING RECALLED DATA

Current Plot Device = 3."INTERNAL"

Current DFile Disk Drive = : INTERNAL.4.1

Press EXIT Softkey when done...

DFile DISK= ?	DFile CATALOG	PLOT AXIS	PLOTTER= ?	EXIT
PLOT LAST MEAS	PLOT DFile A	PLOT DFile B	PLOT DFile C	PLOT DFile D

K5: MAIN MENU

Returns the program to the Main Menu.

K8: RECALL DATA

Recalls measured data from a disk or from the computer memory to the CRT. A new softkey menu is displayed (see Figure 12d) after pressing this softkey. The new menu is used to specify the data file disc drive, the data file to be recalled, redraw the axis or view the graph/alpha. If you want the recalled data to be plotted on a graticule, you have to press the **PLOT AXIS** softkey (K2) before that data file is recalled from the disk. Otherwise, the data will be plotted on a blank screen and the axis, scale and title will be missing. Also, the vertical line that indicates the value of the Loop Bandwidth in the Phase Detector Method is omitted for clarity when plotting recalled data. However, the value of the loop bandwidth factor, the FM deviation and the method used are recorded by the computer, so you can calculate the loop bandwidth value if needed. These parameters are available to you when pressing the **DFile CATALOG** softkey.

Figure 12d. Softkey menu obtained after pressing the **RECALL DATA** softkey.

```
RECALL DATA FROM DISK

Current DFile Disk Drive = : INTERNAL.4.1

Press EXIT Softkey when done...

DFile DISK= ?    | DFile CATALOG | REDRAW AXIS | SEE GRAPH  | EXIT
DRAW LAST MEAS   | GET DFile A   | GET DFile B | GET DFile C | GET DFile D
```

K9: CRT-->PRINTER

Dumps the CRT display to the external HP-IB graphics printer connected to the system.

The software allows measurement results to be shown on the computer screen, a printer (such as the HP 2673A) or an external Hewlett-Packard Graphics Language Plotter (such as the HP 7475A). Press the **CRT-->PRINTER** softkey (K9) to dump the graphics or alpha to an external printer.

In contrast to using an external printer where the data to be printed is displayed on the computer screen, when using an external plotter the measurement data to be printed is not shown on the computer CRT. In order to observe the data to be plotted prior to plotting, you must choose the computer screen (internal plotter) as your plotter and then choose the external plotter when you are done observing the graph. The default plotting device is the computer screen. To tell the software that you are using an external plotter as your output device press the **PROCFSS DATA** softkey (K5). Then press the **EXTERNAL PLOTS** softkey (K4), this will display a new softkey menu. Choose K3 (**PLOTTER = ?**) softkey to specify the type of plotter being used. You are presented with the following choices to select from:

K0: OTHER

Used to plot the measurement data with a different type of plotter or with a plotter connected at an address different from 705. The software will ask you to enter the type of plotter being used after this key is pressed, consult the BASIC Reference Guide under "Plotter is" for acceptable plotter specifiers.

K5: 705, "HPGL"

Select this softkey if you are using an external Hewlett-Packard Graphics Language plotter connected at address 705. To use a plotter at a different address, use the **K0** softkey and then enter the correct specifier and address.

K6: 3, INTERNAL

Select this softkey if you want the computer screen to act as your plotting device.

The process data menu also allows you to add a plot of previously stored data to your graph. For example, you may want to compare recent measurement results with older stored data from a particular instrument. When you perform this operation, the recalled data will be plotted on top of (overlayed) the data presently in memory. The procedure to follow is described below:

1. If you have not stored the data presently in memory, you might want to do so if you would like to use it in future sessions. To store the data to a disc press the **SAVE DATA** (K3) softkey, and use the softkeys to specify the disc drive and the data file in wich the data is to be saved. After saving your data the program brings you back to the PROCESS DATA menu.

2. To overplot the old data to the new graph, press the **RECALL DATA** softkey (K8) and use the new softkey menu to specify the data file to be recalled. Don't forget to also specify the data file disc drive. After this has been done the computer screen will display both measurement data overlayed on the same graph. If you would like to use the last measured data in future sessions, you must save it to a disc (follow the procedure described in step 1) before a new measurement is started or before the program is stopped.

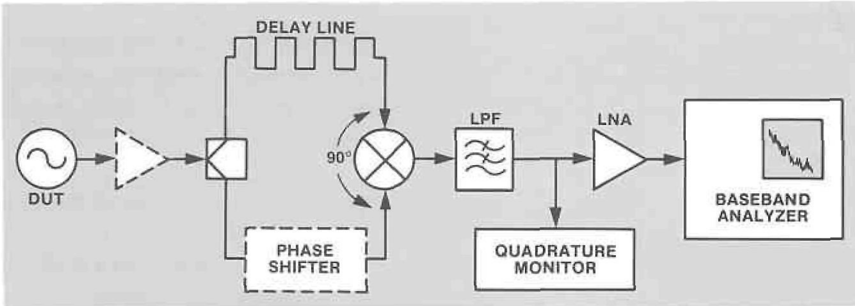
3. To get a print out of the new graph, press the **EXIT** softkey (K4) to get out of the Recall Data menu and get back to the PROCESS DATA menu. At the PROCESS DATA menu press the **CRT-->PRINTER** softkey to obtain your hardcopy output.

The process data menu is also used to redraw the measurement data with new axis scaling. To do this, go back to the MAIN menu, move the double arrow to point to the "Plot will be scaled as shown" parameter, press the **CHANGE PARAMS** softkey and enter the new values. Then, press the **PROCESS DATA** softkey to get to the process data menu. Once the process data menu has been displayed on the CRT, use the **RE-PLOT** softkey to plot your data on the new axis. You can also vary the offset start and stop frequencies and then redraw the data on the new axis following the same procedure.

THE FREQUENCY DISCRIMINATOR METHOD

Unlike the Phase Detector Method, the Frequency Discriminator Method does not require a reference source locked to the source under test (see Figure 13). This makes the Frequency Discriminator Method extremely useful for measuring sources that are difficult to phase-lock, including sources that are microphonic or drifting. It can also be used to measure sources with high-level close-in noise, low far-out noise floor or high close-in spurious sidebands, conditions which can pose serious problems for the Phase Detector Method. A wide band delay line/mixer frequency discriminator is easy to implement using the HP 11729C Carrier Noise Test Set and common coaxial cable. This wide band approach will be discussed in detail. For a detailed explanation of the Frequency Discriminator Method refer to HP product note PN 11729C-2 "Phase Noise Characterization of Microwave Oscillators, Frequency Discriminator Method."

Figure 13. Basic delay line/mixer implementation of the Frequency Discriminator Method.



In the Frequency Discriminator Method the short-term frequency fluctuations of the source under test are translated to baseband voltage fluctuations which are then measured and analyzed with a spectrum analyzer. The HP 11729B/C can be easily configured for Frequency Discriminator Method measurements of free-running sources.

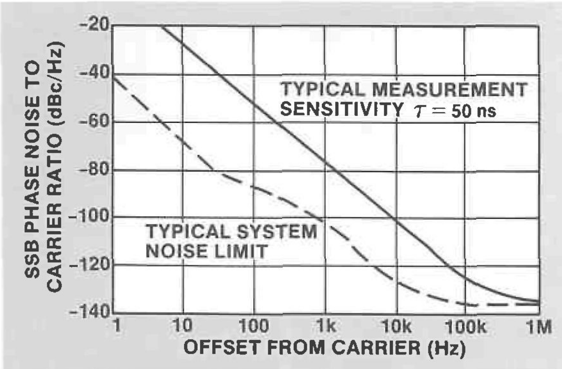
A source signal in the range of 10 MHz to 18 GHz, applied to the HP 11729C Carrier Noise Test Set, is internally down-converted to an IF frequency using a low noise microwave reference signal. The actual discriminator is then implemented at the IF, thus avoiding any requirement for a microwave frequency discriminator. The HP 11729B/C IF signal is internally divided into two paths. One path connects directly to one port of the phase detector. The other path is available at the front panel as the IF OUT signal. This signal is then delayed through a user supplied delay line, and applied to the 5- to 1280-MHz Input (the second port of the phase detector). When the two signals at the inputs of the phase detector are adjusted for phase quadrature, the baseband voltage fluctuations at the output of the phase detector are proportional to the frequency fluctuations of the test source.

The HP 11729B/C Carrier Noise Test Set implements the delay line/mixer frequency discriminator for phase noise measurements on sources from 10 MHz to 18 GHz. This section explains how the HP 11729B/C makes measurements using the delay line/mixer Frequency Discriminator Method and provides sensitivity of better than −140 dBc/Hz at a 1 MHz offset from the carrier. For a more detailed explanation of the Frequency Discriminator Method refer to HP product note PN 11729C-2 "Phase Noise Characterization of Microwave Oscillators, Frequency Discriminator Method."

System Sensitivity and the Delay Line

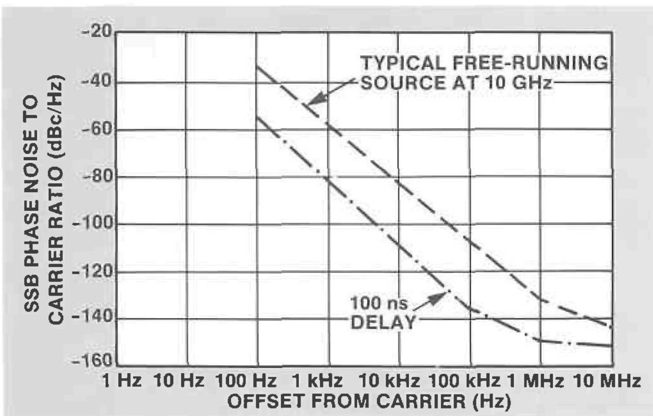
A delay line/mixer used as a discriminator has typical sensitivity as shown in Figure 14; notice that the sensitivity is a function of the delay time. The Frequency Discriminator Method has very good broadband sensitivity; however, because of the inherent relationship between frequency and phase, the sensitivity of the discriminator method degrades as the square of 1/f as the carrier under test is approached. Because this slope follows the phase noise characteristics of free-running sources, and because this technique does not require a reference source, it is very useful for measuring sources with large, low rate phase instabilities. But because of its poor close-in sensitivity, it is not very useful for measuring very stable sources close to the carrier.

Figure 14. Typical noise contribution of HP 11729C/8662A (Frequency Discriminator Method) at X-band and typical system sensitivity using a 50 ns delay line discriminator.



The system sensitivity when using the Frequency Discriminator Method is dependent on both the length and the attenuation of the delay line. Because the HP 11729B/C down-converts the microwave signal to an IF of less than 1.28 GHz, the delay line can be common coaxial or semirigid cable. Because cable attenuation is frequency dependent, system sensitivity can be improved by reducing the resulting IF out of the HP 11729B/C. This technique is only possible by tuning the DUT frequency to be closer to the nearest comb line frequency. The reduction of delay line attenuation translates directly into increased system sensitivity. Figure 15 shows the sensitivity of the HP 11729C implementation of the delay line frequency discriminator using a 100 ns RG 223 delay line. The maximum delay to be used is determined by the highest offset frequency of interest. For example, if measurements are desired to an offset frequency (f_m) of 10 MHz, the delay must be less than $1/2f_m = 1/2(10 \text{ MHz}) = 50$ ns.

Figure 15. The HP 11729C in the stand alone discriminator mode provides the necessary sensitivity for phase noise measurements on free-running sources.



Generating the 640 MHz Reference Signal

The HP 11729C Carrier Noise Test Set uses a selected harmonic of a 640 MHz low noise reference signal to down-convert test signals greater than 1280 MHz to an IF frequency.

There are two ways to obtain this 640 MHz signal. One is to use the auxiliary 640 MHz fixed frequency output of the HP 8662A/63A Synthesized Signal Generator. If an HP 8662A/63A is part of the measurement system, the auxiliary 640 MHz output is an excellent low noise drive signal for the HP 11729C.

However, for a low-cost, stand-alone system, the HP 11729C (not possible with the HP 11729B) can be configured to generate its own 640 MHz signal. A 640 MHz SAW oscillator can be created by connecting the 640 MHz output to the 640 MHz input (on rear panel of the HP 11729C) with the cable-attenuator assembly shipped with the HP 11729C, as indicated in Figure 16.

Figure 16. HP 11729C cable hookup for 640 MHz self generation.

The 640 MHz drive signal determines the HP 11729C noise floor. Figure 17 shows the noise floor of the HP 11729C at 10 GHz when in the SAW oscillator mode and when using the signal from the HP 8662A/63A. Note that the noise floor for the SAW oscillator mode is lower from 70 kHz to 10 MHz, and the floor provided by the HP 8662A/63A is lower close-in.

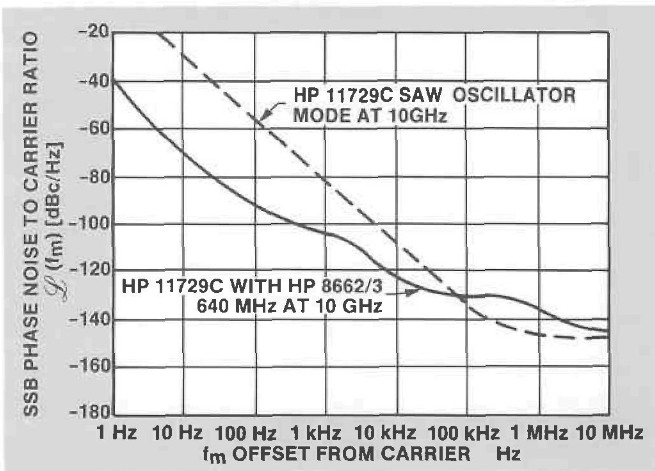


Figure 17. The HP 11729C noise floor when in self oscillator mode or when using the signal from the HP 8662A/63A.

System Calibration

Usually the easiest way (and the one supported by the software) to determine the discriminator constant K_d is to measure the system response to a known FM signal. This can be done by introducing a single FM tone with known sideband/ carrier ratio, known modulation index, or known peak deviation. The response of the system to this known value is used as a reference level.The signal depicted in Figure 18 represents a carrier with a single FM tone. The modulation index β is kept below 0.2 so the power in the higher order sidebands is negligible. Note that the system must remain in quadrature during calibration.

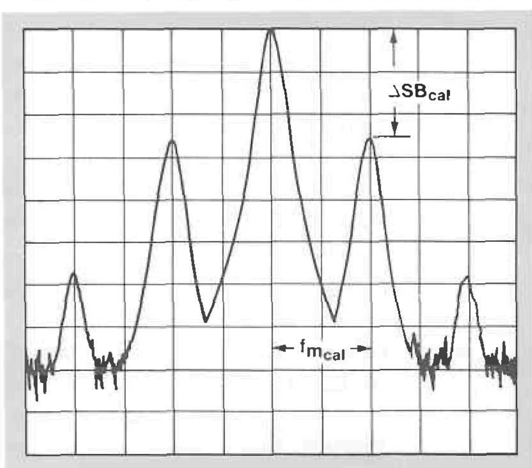


Figure 18. Carrier with a single FM tone used as the calibration signal.

Often the source under test itself can be modulated to produce the calibration signal. If not, an alternate source can be substituted for the test source. The substitution method can be made either with a microwave source at the same level and frequency as the DUT or with an RF source substituted at the IF frequency. **EASY_$\mathscr{L}$** uses the HP 8662A/63A or a manual external source substituted at the IF frequency as the calibration source.

Maintaining Quadrature

The inputs to the phase detector must be maintained in quadrature for the duration of the measurement. Quadrature can be observed on the red and green LED display of the front panel of the HP 11729C. The phase lock loop circuitry is not used when implementing the frequency discriminator because the DUT signal is phase-detected against a delayed version of itself. However, the quadrature indicator is active and is used to ensure that quadrature is maintained.

There are several ways to establish quadrature. First, the frequency of the DUT can be varied slightly, until quadrature is indicated on the LED display. If the DUT frequency cannot be changed, a line stretcher or a phase shifter can be added to the fixed delay path and adjusted until quadrature is established.

USING EASY_$\mathscr{L}$ IN THE DISCRIMINATOR MODE

This section explains the main steps that need to be followed when using **EASY_$\mathscr{L}$** to make an automatic phase noise measurement with the Frequency Discriminator Method.

Loading the Main Program

Before running the Main Program, make sure your system has been configured with BASIC 2.1, 3.0, or 4.0 and that the necessary binaries have been loaded. Then, insert Disc 1 in Drive 0 and Disc 2 in Drive 1. Load the start-up message by typing LOAD "ELautost". Press [RUN] and then follow the instructions to cable the system for the phase detector method and to set up the instrument addresses. After all the instruments have been properly configured, press the **LOAD MAIN PGM** softkey to load the Phase Noise Measurement Program. After the software identifies all of the instruments connected to the computer via HP-IB press the **LOAD SUBS** softkey to load the drivers corresponding to these instruments. After this step has been completed, you are ready to start your phase noise measurement.

Specifying the Measurement Parameters

After loading the drivers corresponding to the connected HP-IB instruments, you are prompted to enter the measurement parameters that characterize your specific measurement.

Use the knob of the HP 9836A/9816A (or the ↑ and ↓ arrow keys on the Series 300 computers) Technical Computer keyboard to move the double arrow to point to the parameter that you wish to modify. Press the **CHANGE PARAMS** softkey (K0) and follow the instructions to enter the appropriate information. Described below is the information that you need to enter before the measurement is started (see Figure 19).

Figure 19. **EASY_$\mathscr{L}$** main menu.

```
Data Label: "MEASUREMENT OF HP 8684 AT GHz USING 50ns DELAY LINE
Device Frequency = 10 GHz
METHOD: Delay Line Discriminator -- (I.f. Calibration)
BASEBAND: Offset Start Frequency = 1 Hz
          Offset Stop Frequency = 10 MHz
          Baseband Hi-Pass Filter: .. (NOT IN USE)
          Analog SA Smoothing Ratio (Res. BW/Video BW) = 3
          Number of sweeps to average = 4 .. (at Spect. Analyzer)
==> PLOT RANGE: Plot will be scaled as shown:
          Top = 0 dBc
          Bottom = -170 dBc

Use KNOB and/or select a SoftKey:
```

==>CHANGE PARM	COUNT μW SIG	COUNT I.F. SIG	MEASURE NOISE	PAUSE PROGRAM
PROCESS DATA	CAL NOISE BW			CRT --> PRINTER

Data Label

The model number of the DUT, carrier frequency, power level, serial number, etc. are information frequently specified in the data level. The software displays this information at the top of the phase noise graph. The maximum number of characters allowed in the data label is 60.

Device Frequency

This parameter specifies the carrier frequency of the device under test and is entered in GHz.

METHOD

Select the delay-line Frequency Discriminator Method. You are faced with two calibration choices when using this method:

DISCR:I.F. CAL

Select this option when the HP 8662A/63A is part of the system or if you are using any other RF source for calibration.

DISCR: μW CAL

Select this option if you are using a microwave source (covering the microwave test frequency) for calibration.

BASEBAND

Offset Start Frequency

Use the softkeys to enter the offset frequency closest to the carrier at which you wish to measure phase noise. The smallest offset start frequency choice offered is 1 Hz if the HP 3561A is connected to the system. If the only spectrum analyzer available is the HP 8566/68 A/B, then the smallest offset frequency at which you can start measuring is 100 Hz.

Offset Stop Frequency

Use the softkeys to specify the offset frequency at which you wish to stop measuring phase noise. The largest offset stop frequency choice offered is 10 MHz.

Baseband HiPass Filter

The HP 3561A autoranges on the presence of low-frequency spurs. This autoranging causes discontinuities on the phase noise graph. When measuring at higher offsets, this problem can be solved by installing a high-pass filter at the input of the HP 3561A. Use this parameter to specify whether or not you would like to insert a high-pass filter and to select the desired high-pass filter frequency.

Analog SA Smoothing Ratio

Smoothing is used to allow the user to average noise and resolve spurious. Use the softkeys to specify the ratio of Res BW/Video BW to be used for the HP 8566/68 A/B. The software gives you hints to choose between the different alternatives for this parameter.

Number of sweeps to average

Use the softkeys to enter your choice of number of sweeps to be averaged. Because of the random nature of noise, some averaging is needed to smooth the plot of the measured data.

PLOT RANGE

By using the **CHANGE PARMS** softkey you can modify this parameter to have the graph auto scaled or to specify the maximum and minimum values of the vertical axis on the graph. Note that the maximum value cannot be greater than zero since $\mathscr{L}$(f) is not a valid unit above 0 dBc.

After entering the above parameters, the user is presented with a choice of softkeys. Refer to the Phase Detector Method, Chapter IV for a description of the softkey options. Make sure you remember to update the above parameters if needed before starting a new measurement. Read the next section before selecting the **MEASURE NOISE** softkey.

Generating the 640 MHz Low Noise Signal

The software assumes the system was initially configured for the Phase Detector Method, which uses the 640 MHz signal from the rear panel of the HP 8662A/63A as the reference signal. If an HP 8662A/63A is part of the measurement system, proceed to "Calibrating and Establishing Quadrature".

If no HP 8662A/63A is available to the user or a lower noise floor is required at offsets >70 kHz, the HP 11729C can be configured to generate its own 640 MHz signal (Notice that this only applies to the HP 11729C and not to the HP 11729B). To use the Carrier Noise Test Set in SAW oscillator mode, choose the Frequency Discriminator Method from the Main Menu, specify all the remaining measurement parameters, press [STOP] on the Technical Computer and then turn off the HP 11729C. Connect the 640 MHz Out to the 640 MHz In on the rear panel of the HP 11729C using the cable/attenuator assembly (PN: 11729-60096) provided with this instrument (see Figure 16). Turn on the Carrier Noise Test Set and press [RUN] on the computer. You have just configured your HP 11729C to generate its own 640 MHz reference signal. If all other Main Menu parameters have been correctly entered, then you are now ready to press the **MEASURE NOISE** softkey (K3).

Calibrating and Establishing Quadrature

After all the measurement parameters have been specified, press the **MEASURE NOISE** softkey (K3) to begin the phase noise measurement. The software will assume the system was initially configured for the Phase Detector Method and will guide the user from that configuration through the new connections. The instructions given by the software to cable the system for the Discriminator Method are explained below:

Step 1. Establish Quadrature

ESTABLISH QUADRATURE

(1) Connect one side of delay line (Call this side A) to the 11729C IF Output.

(2) Connect other side of delay line (=side B) to the HP 11729C's 5-1280 MHz Input.

Set DUT freq. or delay line length for GREEN on the HP 11729C quadrature indicator.

Follow above steps & press GOT QUADrature or ABORT . . .

These connections provide the delayed IF frequency that will enter the R port of the RF mixer to be phase detected against the nondelayed version of itself. Adjust the DUT frequency or the length of the delay line until the green LED of the quadrature indicator is illuminated. Press the **GOT QUAD** softkey once quadrature has been obtained.

Step 2. Count the Down Converted Frequency

```
COUNT DOWNCONVERTED FREQUENCY
(1) Find side B of delay line (It's connected to the HP 11729C's 5-1280 MHz Input).
(2) Connect side B of delay line to HP 8566A/B RF Input.
Press CONNECTED softkey when done, or ABORT softkey. . .
```

The purpose of this step is to make sure that the power level at the output of the delay line is at least −5 dBm and to determine the frequency required for calibration. Note that this step requires an HP 8566/68 A/B to be connected to the system.

Step 3. Calibration and Measurement

There are three calibration techniques supported by the software. The technique used will be determined by the sources and equipment available to you. The three available calibration techniques are:

1. Using the HP 8662A/63A for calibration.
2. Using a manually controlled RF source for calibration.
3. Using a microwave source or the DUT (manually controlled) for calibration.

If an HP 8662A/63A Signal Generator is connected to the system, the software will automatically find and use this instrument (when [RUN] is pressed) to automatically generate an IF calibration signal.

If an HP 8662A/63A is not available, you can use any other RF or microwave source with FM capability for calibration. The RF calibration source must be set at the IF frequency (power level: −10 dBm) while the microwave source must be tuned to the frequency of the DUT (output power level should be the same as the DUT). If the DUT has internal frequency modulation capabilities, it can also be used as the calibration source.

Described below are the three different calibration techniques that are available to you. Choose that technique which best fits your measurement needs and available equipment.

Step 3.1. Using the HP 8662A/63A for Calibration

If the HP 8662A/63A is connected to the computer via HP-IB, the software will use this instrument to generate a signal with a single FM tone to be used as the calibration signal. An FM rate of 1 kHz with a peak deviation of 0.2 kHz is used to generate the calibration signal. This calibration procedure is done automatically at the IF frequency that corresponds to the DUT frequency. The instructions that the computer gives you to set up the HP 8662A/63A as the calibration source are as shown below:

```
SET UP HP 8662A/63A AS CALIBRATOR
(1) Re-connect side B of delay line to HP 11729C's 5-1280 MHz IN.
(2) Connect the HP 8662/63A RF Output to HP 8566/68 A/B RF Input.
Press the CONNECTED softkey when done, or ABORT softkey...
```

In this step the software measures the sideband to carrier ratio of the calibration signal. This number is internally used to calculate the final value of the discriminator constant K_d.

After the **CONNECTED** softkey is pressed, a new set of instructions appears on the computer screen:

> **MEASURE CALIBRATION SIDEBAND THRU DELAY LINE**
>
> (1) Connect HP 8662/63A RF Out to the HP 11729C Microwave Test Signal Input.
>
> (2) Connect the HP 11729C <10 MHz Noise Spectrum Out to the HP 8566/68 A/B RF Input.
>
> Press the CONNECTED softkey when done, or ABORT softkey...

The spectrum analyzer now measures the response of the sysytem to the calibration signal. The demodulated calibration signal will have a sharp response at the baseband frequency corresponding to the FM rate, as shown in Figure 20. The power level of this beat note is measured and recorded by the software to calculate the discriminator constant K_d.

After completion of the calibration routine, the following prompt and instruction will appear on the screen.

> **CONFIGURE FOR DUT NOISE MEASUREMENT**
>
> (1) Re-Connect the DUT output to the HP 11729C Microwave Test Signal In.
>
> (2) Re-adjust the DUT frequency or delay line length for quadrature if needed.
>
> Press the GOT QUADrature softkey when done, or ABORT softkey...

After the above instructions have been executed the software automatically starts the phase noise measurement. If you chose to install a high-pass filter at the input of the HP 3561A, the software will give you instructions on when to install and when to remove the filter. Refer to "Measure and Graph the Phase Noise Data" for an explanation of how to process the phase noise data obtained.

Step 3.2. Using a Manually Controlled RF Source for Calibration

To calibrate the discriminator (delay line/mixer) with an RF source other than the HP 8662A/63A, make sure that your source covers the IF frequency range. When the phase noise program is first run, the software searches for the instruments connected to the controller via HP-IB. If the HP 8662A/63A is turned off or not present in the system, the following message will appear on the CRT:

> Which source (LO) is at HP-IB address 719? (choose softkey)

Press the **MANUAL LO** softkey (K7) when the software asks you which instrument is connected at address 719. This tells the computer that you want to have manual control of your local oscillator (LO). Then press the **MEASURE NOISE** softkey (K3) and follow the directions to cable your system for the frequency discriminator method and to configure your RF source to work as the calibration source. The instructions given by the software on sequential screens are listed below:

Set the LO's FM deviation for 200 Hz & press CONTinue.

Set the LO's FM rate to 1 kHz & press CONTinue.

Set the LO frequency output to the IF (the software will prompt you with a numerical value for this frequency) **& press CONTinue.**

Set the LO's amplitude to —10 dBm and press CONTinue.

After completing the above instructions, the computer will prompt you with the necessary connections to set up your manual RF source as the calibrator.

Set Up LO source as Calibrator

(1) Reconnect side B of Delay Line to HP 11729C's 5-1280 MHz IN.

(2) Connect LO source RF Output to the HP 8566/68 A/B RF Input.

Press CONNECTED softkey when done, or ABORT softkey...

In this step the software measures the sideband to carrier level of the calibration signal. This number is internally used to calculate the value of the discriminator constant K_d.

MEASURE CALIBRATION SIDEBAND THRU DELAY LINE

(1) Connect LO source's RF OUT to the HP 11729C's Microwave Test Signal In.

(2) Re-Connect the HP 11729C <10 MHz Noise Spectrum Out to the HP 8566/68 A/B RF Input.

Press the CONNECTED softkey when done, or ABORT softkey...

The program measures the response of the system to the calibration signal in this step. Before pressing the **CONNECTED** softkey make sure the GREEN LED is lit on the center of the HP 11729C's quadrature indicator.

CONFIGURE FOR DUT NOISE MEASUREMENT

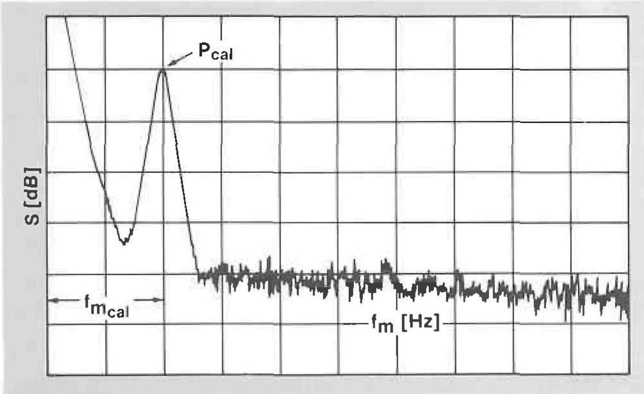
(1) Re-connect DUT Output to the HP 11729C's Microwave Test Signal In.

(2) Re-adjust DUT Frequency or Delay Line Length for quadrature if needed.

Press GOT QUADrature softkey when done, or ABORT softkey...

After all these steps have been completed, the software starts measuring and plotting the phase noise data. If you chose to install a high-pass filter at the input of the HP 3561A the software will give you instructions on when to install and when to remove the filter. The section titled "Measure and Graph the Phase Noise Data" describes how to process and interpret the measurement data obtained.

Figure 20. System response to the calibration signal.



Step 3.3. Using a Substitute Microwave Source (or the Microwave DUT) for Calibration

This is the last calibration option supported by the software. If you are using a microwave source other than the DUT for calibration, tune the source to the microwave test signal and set the power output to the DUT power level. The software will instruct you on when and how to proceed when using a microwave source or the microwave DUT for calibration. The instructions that need to be followed are described below:

> **SET UP uW SOURCE AS CALIBRATOR**
>
> **(1) If not using DUT as calibrator, connect uW cal source to 11729C uW Test In.**
>
> **(2) Set the uW Source's FM to approximately 1 kHz Deviation and 80 kHz Rate.**
>
> **Set uW source's FM (above). Observe cal sideband on SA, & press softkey...**

The purpose of this step is to measure the sideband to carrier ratio of the calibration signal. If the microwave calibration source is not the DUT, tune the calibration source to the same frequency and amplitude as the DUT.

> **MEASURE CALIBRATION SIDEBAND THRU DELAY LINE**
>
> **(1) Connect Delay Line Side B (now at SA input) to the HP 11729C's 5-1280 MHz IN.**
>
> **(2) Reconnect the 11729C's <10 MHz Noise Spectrum Out to the HP 8566/68 A/B RF Input.**
>
> **Do the above, verify QUADrature, & then press the CONNECTED softkey (or ABORT).**

The HP 8566/68 A/B spectrum analyzer measures the response of the system to the calibration signal. Check to see that the system is operating in phase quadrature. Set quadrature by adjusting the frequency of the microwave calibration source or by adjusting the length of the delay line. The system will have a sharp response at the frequency corresponding to the FM rate. The software measures and records the power level of the calibration signal and uses it to calculate the value of the discriminator constant K_d.

> **CONFIGURE FOR DUT NOISE MEASUREMENT**
>
> **(1) Re-connect DUT to 11729C uW-Input if needed, and make sure its FM is OFF.**
>
> **(2) Re-adjust DUT Frequency or Delay Line Length for QUADrature if needed.**
>
> **Press GOT QUADrature softkey when done, or ABORT softkey...**

This is the last calibration step. If you were using a microwave calibration source other than the DUT, disconnect the calibration source and re-connect the DUT to the HP 11729B/C Microwave Test Signal Input. If you were using the DUT as the calibration source, turn off the modulation and make sure the green LED is illuminated indicating that the inputs to the phase detector are in quadrature.

After completing these steps the software starts the phase noise measurement. If you chose to connect a filter at the input of the HP 3561A, the software will give instructions on when to install and when to remove the filter. Refer to the section below for an explanation of how to process the phase noise data obtained.

Measure and Graph the Phase Noise Data

Once the calibration is completed and quadrature is obtained, the phase noise measurement starts. The data that is being measured can be observed as it is graphed, by pressing the **VIEW GRAPHICS** softkey. The **VIEW ALPHA** softkey provides messages indicating the measurement step in process. The **VIEW AUTO** softkey switches automatically to alpha or graphics, whichever is being updated at the moment.

The system measures the phase detector output in frequency segments, beginning with the highest offset to be measured. Both data and spurs are normalized, corrected and graphed while each segment is being swept by the spectrum analyzers. After the phase noise measurement has been completed, the PROCESS DATA menu allows the user to obtain a hardcopy output, do re-plots, save the data obtained, or return to the MAIN MENU to start a new measurement. See the previous PROCESS DATA MENU discussion on page 25 for a full explanation of the softkey options.

CHAPTER

V EASY_ℒ Softkey Listing

ABORT	Terminates the current process and brings the program back to the current menu.
ABORT LOADING	Skips the loading of the missing SUB drivers into memory.
ABORT TEST	Terminates the current measurement and brings the program back to the main menu.
CAL NOISE BW	Calibrates the resolution bandwidth of the HP 8566/68 A/B Spectrum Analyzer.
CHANGE PARM	Used to modify the desired measurement parameter indicated by the cursor ==>.
CONNECTED	Press this softkey when the connection instructed by the software have been made.
COUNT I.F. SIG	Updates the carrier frequency of the DUT according to the measured value of the I.F. signal frequency and the approximate value of the DEVICE FREQUENCY parameter menu entry.
COUNT μW SIG	Directly counts the carrier frequency of the DUT on the Spectrum Analyzer and updates its value.
CRT-->PRINTER	Dumps the CRT graphics and alpha display to the HP-IB graphics printer connected to the system.
DC FM	Select this phase locking technique when measuring stable free-running sources using the Phase Detector Method.
DFILE CATALOG	Gives a catalog of the four possible **EASY_ℒ** data files stored on the currently specified data file disk.
DFILE DISK?	Used to specify the disk drive that contains the disk from which data is to be recalled or to which data is to be stored.
DISCR: I.F. CAL	Select this option if you are making a phase noise measurement using the Frequency Discriminator Method and the HP 8662A/63A is part of the system. Also, select this option if you are using any other RF source to calibrate the delay line/mixer discriminator.
DISCR: μW CAL	Select this option if you are using a microwave source or the microwave DUT to calibrate the delay line/mixer discriminator.
DISCRIMINATOR	The discriminator method is used when measuring phase noise on unstable free-running sources. The software will give the user instructions on how to connect the system for a frequency discriminator measurement.
EFC	Select this phase locking technique when measuring a stable synthesized source using the Phase Detector Method.
EXIT	Leaves the current menu and displays the next higher menu on the screen.
EXTERNAL PLOTS	Allows the user to plot the measurement results on the CRT and/or to an external plotter.

FM SET UP	Press this softkey after you are done setting up your microwave source as the calibration source in the Frequency Discriminator Method.
GOT QUAD	Press this softkey when quadrature is obtained (this softkey is shown when doing a frequency discriminator measurement or locking manually in the Phase Detector Method).
INSTALLED	Press this softkey after installing the high-pass filter at the input of the HP 3561A.
LOAD MAIN PGM	Loads and runs the phase noise measurement program after the start-up message is shown. Press after all instruments are connected and their respective HP-IB addresses have been checked.
LOAD SUBS	Starts loading the missing SUBS corresponding to the connected HP-IB instruments.
MAIN MENU	Returns to the main menu.
MANUAL LO	Press this key when using a local oscillator that will not be automatically controlled. Remember to connect the 640 MHz signal needed to generate the series of comb lines in the Phase Detector Method. Or, if using the Frequency Discriminator Method, use the cable-attenuator assembly provided with the HP 11729C to configure this instrument for stand-alone mode.
MANUAL LOCK	Choose manual lock when you are not familiar with the characteristics of the source under test. Manual lock allows the user to directly observe and iterate the loop bandwidth, and therefore quickly maximizes the range of valid measurement data.
MEASURE NOISE	Starts the phase noise measurement using the currrent Main Menu parameters.
NEXT	Displays on the screen the next page of the start-up message.
NO CHANGE	Leaves unchanged the parameter that the double arrow is pointing at.
NO FILTERING	Press this softkey if you choose not to install a high-pass filter to prevent the HP 3561A from autoranging.
NONE OF THESE	Press this softkey if the instruments connected to the indicated HP-IB address, is not one of the softkey choice model numbers.
PAUSE PROGRAM	Stops the phase noise measurement program. Press [CONTINUE] to get back to the MAIN MENU.
PREVIOUS	Displays (on the screen) the previous page of the start-up message.
PROCESS DATA	Used to save/recall the current data, do re-plots, graph more than one measurement result on the same plot, etc. Allows access to the Process Data menu.
RECALL DATA	recalls measured data from a disk or from the computer memory (last measure data) to the CRT.

RE-COUNT FREQ	Press this softkey if you want the software to re-count the microwave carrier frequency or the IF frequency during the IF or μW signal count.
REDRAW PLOT	Redraws on the CRT the last measured data stored in computer memory.
REDRAW AXIS	Blanks the display and redraws on the CRT the graph axis according to the current parameters.
RE-MEASURE	Re-measures the noise using the last specified parameters and calibration. RE-MEASURE key disappears on RUN, or when a non-graph parameter is changed via the Main Menu.
REMOVED	Press this softkey after you are done removing the high-pass filter from the input of the HP 3561A.
RE-PLOT	Redraws the last measured data that is currently in memory on the screen, using the current graph parameters.
RE-START	Returns the program to the first page of the start-up file.
SAVE DATA	It is used to save the current measurement results to a mass storage.
SEE GRAPH	Shows on the CRT the data stored on the current graphics memory of the controller.
USE THIS COUNT	Press this softkey if you want the software to update and use the value of the microwave frequency to the new measured value.
VIEW AUTO	When this key is pressed **EASY_$\mathscr{L}$** automatically switches between the alpha display and the graph display as each is updated.
VIEW GRAPHICS	Displays on the screen the data that is being measured.
VIEW MENU	Displays on the screen the measurement parameters and current measurement operation.

VI Measurement Difficulties

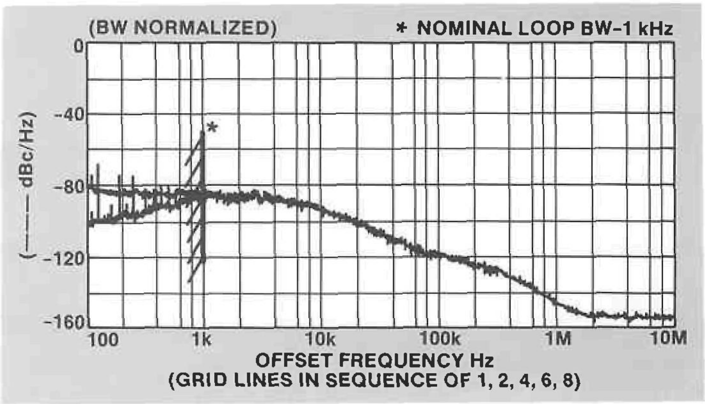
This section explains some of the measurement subtleties that the user may encounter when making a measurement with **EASY_$\mathscr{L}$**. For each measurement difficulty a probable cause and a corresponding corrective action are given to help overcome the problem.

Measured Data Appears in Error at Low Offset Frequencies

Cause: Suppression of phase noise at the output of the phase detector for offset frequencies less than the bandwidth of the PLL. See Figure 21.

Correction: Try to minimize the PLL BW while still maintaining quadrature. Software enhancements are needed to provide for corrected data inside the loop bandwidth.

Figure 21. Phase noise suppression inside the loop bandwidth.



Beat Note Not Found

Cause: Source not connected, not oscillating, or insufficient amplitude.

Correction: Check source connections and characteristics. Also check the parameters list for erroneous frequency entry (specifically, check DUT frequency against actual DUT frequency by doing an IF COUNT or a UW SIGNAL COUNT).

System Cannot Phase Lock to the Signal

Cause: Excessive frequency drift, tuning voltage not effective, or loop bandwidth chosen too small.

Correction: Check that the tuning line is connected and tuning capability of source is activated. Try locking manually. Increase the Loop Bandwidth to accommodate the expected source drift during the measurement. Try to isolate microphonics from DUT and from the system. Isolate line spurs using a line stabilizer.

Out of Lock Indicator Tripped

Cause: Sources have drifted apart more than 20% of the available tuning range.

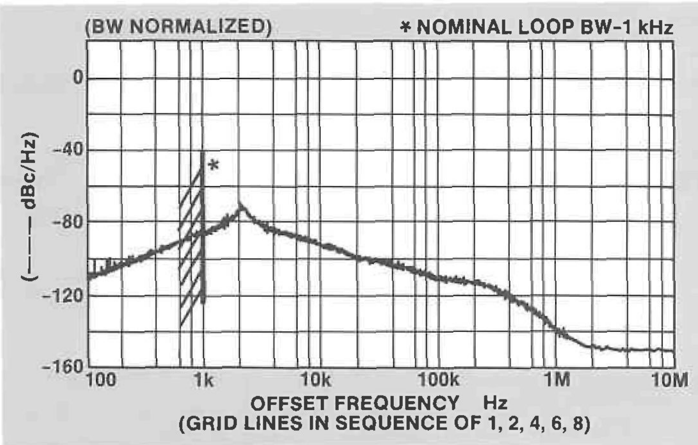
Correction: Increase the phase lock loop bandwidth by increasing the Lock Bandwidth Factor or the Peak Deviation set on the front panel of the HP 8662A/63A (if DC FM locking is employed).

Incorrect Spurious Signal Levels Observed

Cause: The software does not differentiate spurious signals from noise and so applies Bandwidth normalization correction to the discrete signals (spurious). Therefore, the spurs are reduced from the full value by the bandwidth correction. Also, the effective measurement threshold is actually above the displayed noise levels, due to the bandwidth correction. Hence, a spur above the displayed noise floor but below the bandwidth corrected level, will not be shown.

Correction: Software enhancements are necessary to obtain a correct spurious signal level reading.

Figure 22. Effect of noise peaking on the phase noise graph.



Noise Peaking

Cause: The phase lock loop bandwidth selected is close to an effective internal Low Pass Filter cut-off frequency (3 kHz if locking via EFC) which causes the loop to be unstable. See Figure 22. For a test frequency of 10 GHz, the HP 11729 B/C 10k and 100k lock bandwidth factors always yield an unstable loop. In some situations, the 1k lock bandwidth factor might also be unstable, and will always give a loop amplitude response which peaks up several dB before rolling off.

Correction: Select a smaller lock bandwidth factor or choose to lock via DC FM if a smaller factor does not yield a loop bandwidth large enough to lock up the two sources.

Discontinuities in the Graph

Cause: The presence of large spurious signals with levels that exceed the dynamic range of the HP 3561A, cause this spectrum analyzer to autorange. The autoranging of the Dynamic Signal Analyzer attenuates the noise of the DUT below the noise floor of the HP 3561A. The noise that is measured in this case is the noise floor of the spectrum analyzer, not that of the DUT. The discontinuities that appear in the graph are due to this autoranging of the HP 3561A.

Correction: The software will prompt you to connect a high-pass filter at the input of the HP 3561A in order to filter out the line spurious that cause the Dynamic Signal Analyzer to autorange. Remove the filter when measuring noise at offsets less than the filter's loop bandwidth.

HP 11729 B/C Internal Misinterpretation of Quadrature Condition

Cause: An adjustment on the Phase Lock Board in the HP 11729C sets the lock and unlock trip thresholds on the Phase Lock Indicator. If the Phase Lock Indicator does not agree with the status byte sent out over HP-IB, the Phase Lock Board may need adjustment.

Correction: Perform the Phase Lock Indicator adjustment. Follow the standard procedure outlined in Section 5-7 of the HP 11729C Operating and Service Manual.

A Easy_ℒ Main Program Variables Definitions

MAIN PROGRAM ONLY

Abort	* (I)	A flag used to exit lower level subroutines. A non-zero value in those routines which use 'Abort' causes that routine to end without completing it's designed task.
Auto_scale	(I)	=0 if plot limits shouldn't be automatically chosen. =1 if plot is to be automatically scaled based on data. (Default = 1, autoscale.)
Avg_no	(R)	=1, 2, 4, 8, 16, or 32; number of sweeps to be averaged on SA. (Default = 1 sweep)
Avg_way	(R)	Tells where sweep averages are computed during Measure Noise. 0→SA does Avg_no averages and returns one averaged trace to controller; 1→Controller reads back each sweep of SA and averages internally. (Controller averaging is rather slow.)
Baseband_filt	(R)	A high-pass filter can be used to suppress low level spurs while an FFT analyzer measures higher-band noise data. This variable equals the baseband filter frequency in Hertz. Zero means the high-pass filter isn't currently being used. The program actually prompts the user to put the filter in whenever any noise >= 10* Baseband_filt is measured on the FFT analyzer (i.e., HP 3561A).
Bbeat(*)	(R)	One row element per measurement band. When the frequency band corresponding to that element is measured for noise on SA's, the system will be beat-note calibrated (or discrete-spur calibrated for delay line).
Bcor(*)	(R)	Holds band correction factors for the currently selected measurement method. Phase Detector: Col. 1: 2.5 dB plus Resolution BW of SA (in dB) Col. 2: −6 dB for double-sideband→single-sideband Script L Col. 3: −40 dB Calib. atten. step Col. 4: =Calibration power measured in Signal_cal Delay Line Dis: Col. 1: (Same as Col. 1 for PDetect Method) Col. 2, 3: Not used and set to zero. Col. 4: (dBc of cal. spur) − (discr. spur ampl.)
Bfreq(*)	(R)	Each measurement band measured data spans the offset frequency range in Bfreq(*,1) through Bfreq(*,2). This is the data's frequency range, NOT the SA span. SA span is dynamically increased to force the datapoints to agree with Bfreq's range at each band.
Bnav(*)	(R)	Number of SA sweeps taken in each band. Avg_way tells where those sweeps are averaged.
Bno(*)	(R)	Indicates the sequential order which the bands are going to be measured. Bno(1) equals number of total bands; as the row count increases, the Bno(*) decreases by 1 till last band, whose Bno(*) row element is 1. Hence, the bands corresponding to the higher frequency band numbers are measured first.
Bptr(*)	(R)	The pair of numbers at each row entry point to where in the SA measurement array Noise(*) the data is for that band. For example, Bptr(3,1)=300 and Bptr(3,2)=399, then the SA measured data corresponding to the band of row 3 in COM/Btbl/ is between Noise(300) and Noise(399) inclusive.

* (I) = Integer, (R) = Real

Brbw(*)	(R)	Resolution BW that the SA is set to before or during the Measure of noise for each band. Analog SA's get set to this BW, and DFT (i.e., HP 3561A) report back their resolution BW to this array after their spans have been set per Bfreq(*).
Bsa(*)	(R)	Tells which SA is to be used at each band. The value is used as a pointer into the COMmon /Sa_tbl/ structure's row elements.
Bvbw(*)	(R)	The video BW used on an analog SA at each band. For digital DFT SA's, the corresponding row element in Bvbw(*) is −1 and completely unused.
Changed_val	(I)	Used in test parameter change subroutines in MAIN to flag when the variable chosen for modification is actually changed.
Choice	(I)	When calls are made to the Key_sel softkey selection program, this variable is used to return the softkey number chosen by operator.
Clock_mask	(I)	When non-zero, this variable disables the clock updating on row 1 of the CRT. Used during Gbw cal of SA, cataloging of datafile disk, etc.
Cns_tbl(*)	(R)	Holds attributes of the currently used carrier noise test set. Since there's only one CNS in the system, only row one is used. Col 1=CNS's HP-IB address; all other columns equal 0.
Discr_cal_type	(I)	Tells if the delay line discriminator is calibrated with an IF frequency source (=0) or a μW source (=1). The IF calibration source will be the automatically tuned HP 8662A/63A if it has been configured per program's driver loading instructions when the program is first run. A manual source is also possible at IF. The μW cal source must be manually controlled and tuned to the μW DUT's frequency. **Note:** The frequency deviation and rate of the calibration sideband for the delay line method is specified in the Discr_cal subprogram. They are assigned into local variables Fsband and Dsband just after line Discr_cal_mid in the **EASY_**$\mathscr{L}$ file.
Err	(I)	Returns back from Subs with an error number that's dependent on the called program segment.
Fc	(R)	Returns back from Filter_band subprogram call with the comb frequency that corresponds to the F_{dut} frequency that was passed in.
Fcor(*)	(R)	Delay Line method only; used to compute −20*LGT(F_{offset}/F_{dut}) where F_{offset} is determined by each band's frequency in Bfreq(*). This applies a slope correction to the discriminated spectrum which, when added column by column to the corrected Noise(*) elements, yields Script-L.
Fdut	(R)	Equals frequency of device under test (DUT). Initially measured by μW_signal and If_signal routines, and used by Measure Noise to acquire lock. (Default = 10 GHz). Units Hz.
Fif	(R)	Returns from Filter_band call with the IF corresponding to the F_{dut} which had been passed in.
Fm_max	(R)	(100 Hz to 200 KHz) FM sensitivity on 866x generator, as inputted by user. Units Hz. (Default = 200 kHz).
Fstart	(R)	=100, 300, 1k, 3k, . . 3 MHz. Starting offset frequency where noise is to be measured. (Default = 1 kHz) Units Hz.

Fstop (R) 300, 1k, 3k,..,10 MHz. Stopping offset frequency where noise is to be measured. (Default = 1 MHz) Units Hz.

Ft (R) Returns from Filter_band call with the HP 11729C filter number needed to down-convert the F_{dut} freq which was passed into Filter_band.

Gbwf(10) (R) =GAIN-BW factors measured in Cal_bw routine. Indices are for HP 8666/68 SA resolution BW:

1 – 10 Hz	5 – 1 kHz	9 – 100 kHz
2 – 30 Hz	6 – 3 kHz	10 – 300 kHz
3 – 100 Hz	7 – 10 kHz	
4 – 300 Hz	8 – 30 kHz	

Glast (R) Shows the last actually set state of the alpha/graphic display. =1 → GRAPHICS was last on, =0 → ALPHA. This differs from Gmode in that it tracks the actual set mode of the CRT, instead of what the program would set it to if it WASN'T LOCKED. Thus, if Glock=1 and Crt_alpha or Crt_graph were called, Glast would not changed because all CRT display changes are locked out. Gmode would, however. Part of COM /Gmode/.

Glock (R) When =1, the Crt_graph and Crt_alpha CALLs are ignored, and the CRT remains in the graph/alpha mode determined by Gmode. (The Crt_alpha and Crt_graph calls are kept track of within COMmon /Gmode/ , but they aren't used to change the CRT mode.)

Gmode (R) 1→Graphics mode; 0→Text mode for CRT display mode. These modes are changed by calls to Crt_graph and Crt_alpha. If the Glock is set <>0, then Gmode is updated with calls to Crt_graph and Crt_alpha—but no change is made to Glast or the CRT mode.

Hpib_gone (I) Part of COM /Main/, this is set <>0 when the program couldn't find an HP 8566/68 A/B, or an HP 11729A/B. This is done in the Hpib_init subroutine in MAIN program. All main menu choices are blocked out <>0 except for the data post processing key. This checking would have to be changed if the program were modified to work with a different SA.

Lbwf (I) =(1, 2, 3, 4, 5); Lock Bandwidth Factor for HP 11729B Test Set. Corresponds to the HP 11729C front panel legend via 10**(Lbwf→1). Default = 3, corresponding to front panel LBWF of 100.

Lo_tbl(*) (R) Holds local oscillator's (LO) characteristics. Since only one LO is allowed at a time, Lo_tbl(*) has only 1 row. The columns are: 1 - HP-IB Address; 2 - unused; 3 - F_{min} of LO (Hz), 4 - F_{max} of LO (Hz); 5 - Length of fast learn string. These values are looked up by calling Lo_capab_q.

Lost_lock (I) Set by Srq_server subprogram during a noise measurement if it both gets jumped to because of SRQ (during Measure subprogram execution) and the HP 11729 CNS was out of lock.

Max_ptr (I) Returned by Menu_init, equals number of rows displayed in current menu.

Method (I) =(1 or 2) Phase Lock Method to be used with HP 8662A/63A; 1 = Elect. Freq. Ctl; 2 = DC (866x Front Panel) FM. (Default = 2, lock by DC FM). Unitless.

Noise(*)	(R)	Holds uncorrected noise data. To be changed into one array each for frequency, noise, and spur measured.
Noise_hi	(R)	During measure, this keeps track of the largest plotted script-L dBc value. It's used by the autoranging function to determine Y-axis limits automatically.
Noise_lo	(R)	During measure, this keeps track of the LOWEST plotted script-L dBc value. It's used by the autoranging function to determine Y-Axis limits automatically.
Not_there	(I)	Used during Hpib_init subroutine (main program) in calls to the Cns_id, Sa_id, and Lo_id subroutines to see if a physical device is actually connected to the bus.
Pflag	(R)	A "dirty" flag; indicates when a value (other than date and time) in menu has been changed and should be updated to disc the next time a Cal BW, Analyze μW, Analyze IF, or Measure Noise is called. = 1 means diskfile should be updated; =0 → no update needed.
Pointer	(R)	Indicates current position of the screen cursor, and is used to tell which row of menu item is currently being worked on. Pointer also equals the row number on CRT where cursor is, as well as the current Pvector(*) row number.
Pvector(50,2)	(I)	Row 1 = a parameter assignment number. Row 1 breaks down as follows; values found in this row mean the following: 1—F_{dut} 2 - F_{start} 3 - F_{stop} 4 - Video Smoothing 5 - # Sweeps to Average 6 - EFC Method used 7 - Lock BW Factor 8 - Spectrum Analyzer=HP 8566/68? 9 - RESET all parameters to DEFAULT 10 - Date (Pvector(*,2)=0) 11 - Time (Pvector(*,2)=0) 12 - FM Deviation for 866x 13 - Plot scaling 14 - Top plot scale 15 - Bottom plot scale 16 - Optional label for plot
Recal	(I)	Determines whether or not the Measure_noise SUBpgm should do a new discriminator calibration (or beat-note cal) before noise gets measured. 0→do not recal; 1→calibrate normally. If any test parameter EXCEPT FOR Y-Axis scaling or the Data Label gets changed, Recal gets set back to one to indicate a REMEASURE option is not available for the next noise measurement sequence. If Recal is 0, and a previous run has been taken, the main menu show a REMEASURE NOISE option just below the MEASURE NOISE key; that button allows the noise measurement to use the last calibration. If Recal=1, that function is not shown.
Rev	(R)	Containing the current revision code of the program. This revision number gets printed at the upper right corner of the main menu.
Revx	(R)	=Revision number of program which recorded on the last default parameter file from which the program had first loaded. It is updated whenever the main program reads the default parameter file.
Sa_no	(R)	Identifies the currently active SA. This is set by calling Sa_choose, or Sa_select, which assigns the @Sa I/O path to one of the two SA's, and sets Sa_no to point to the row in the COMmon /Sa_tbl/ arrays for that spectrum analyzer.

MAIN PROGRAM STRINGS

Atof$[1]	=CHR$(128); turns CRT attributes off when printed.
Bl$[1]	=CHR$(130); turns on CRT blinking attribute.
Clear$[21]	=CHR$(255) and CHR$(72); simulates CLEAR-SCREEN keystroke when output to the keyboard (SHIFT-CLEAR LINE).
Cns_files$(*)	One-row array whose columns are: 1 - the HP 11729's response to instrument ID (Example: "11729C"); 2 - Filename of where the carrier noise test set is (example: "EL11729X"). This array is set up based on the Cns_id Subprogram.
D$[80]	Used to form and pass DISPlay messages to SUBs.
Date$[18]	The date is placed here in BASIC's TIMEDATE format.
Df_-disk$[160]	The disk's mass storage unit specifier for where the program looks to SAVE and RECALL measured noise data files.
Df_plot$[160]	Plotter specification where external plotting is sent—when so selected via the EXTERNAL PLOTS softkey in the See_data menu.
File$[10]	="ELparams," the diskfile where the parameters are kept.
Fpref$[2]	The two characters the program appends to the beginning of any filename during any file operation. If you don't like the EL at the beginning of all the files, change the assign statement in the Mainvar_init subroutine, and change all the filenames on the disks. (Nearly all calls use Fpref$.)
Gd$[80]	Holds the current alpha DISPlay value in COMmon /Gmode/ block. This is set and cleared via calls to Crt_alpha w/Gd$ passsed in.
Home$[2]	=CHR$(255) and CHR$(84); simulates SHIFT-DOWNARROW when output to the keyboard; it homes the screen vertically.
Ivon$[1]	=CHR$(129); turns on CRT Inverse Video attribute.
Klabel$(10)[16]	A Null-set of key definitions which are passed to Key_sel when the main menu is being shown. The dummy parameter is needed to allow the specification of pointer variables for the cursor.
Label$[60]	=User defined label that goes on top of plot. (Default = "")
Lo-files$(*)	A one row array containing information about the current LO (local oscillator). Column: 1 - Current LO's response to an instrument ID (actually determined by the length of it's fast learn string); column 2 - Filename of driver for current LO. This array is set up in the Lo_id subprogram.
Menu$(15)[80]	The last 'Menu_init'-ed menu. This array is assigned when the Menu_init subprogram is called to reflect the current values of all test parameters.
Sa_files$(*)	Two rows each holding info on the identity of the two configured SA's. The columns are: 1 - SA's response to instrument ID. 2 - The name of the driver file for that SA. (Examples: "8566A" and "EL856XX.")

Sold$[80]		Holds old string values for the date and label test parameter modification subroutines (Set–date and Enter–label).
Subs_disk$[160]		Disk Mass Storage Unit Specifier where the SUBPGMS will be loaded from during configuration. This includes the driver kernel "ELdrKERNAL," as well as instrument drivers. The pgm loads the drivers it needs at run time based on what instruments are on and identifiable.
Time$[18]		=the time in the format required for the SET TIME statement in BASIC.
U1$[18]		=CHR$(132); causes CRT Underlining attribute to be turned on when printed to the CRT.
Sa_tbl(*)	(R)	Holds characteristics for both SA's (two rows in table). The columns are: 1 - HP-IB Address; 2 - #pts/trace; 3 - Low frequency range of SA; 4 - High-end frequency range of SA; 5 – 1 if an analog SA with programmable BW; 0 if a Digital Four. Xform SA like the HP 3561A. This is assigned in the Sa_capab_q SUBprogram.
Sel_code	(I)	Used in the STATUS query to look up the SA's (and assumably the other instrument's) HP-IB select code. This is usually 7.
Spur(*)	(R)	NOT CURRENTLY IMPLEMENTED. We thought about saving peak values of noise in this array, and plot discrete line spectra without the BW correction. One might also write a spur seek routine to look away from the carrier for spurs with the SA resolution BW at its narrowest span. Size of this has been reduced to 1 since it isn't being used.
Sweep_completed	(I)	Used in Measure_noise and Srq_server SUBs, this flag is set Srq_server when an srq is received during a measurement and the resulting SA serial poll indicates the SA has finished with its sweep. Measure_noise clears this flag before the measurement is started and srqs get enabled.
Temp	(R)	Holds test parameters while their values are being shown to the user for change. Used only in MAIN.
Timedate	(R)	Used to save and recall the time and day from the Series 200 internal clock as part of the Set_date and Set_time subroutine, and while reading the time/date in off disc file ELparams.
User_max	(R)	User-specified top of scale on plot. Units are dBc; (Default = −50 dBc).
User_min	(R)	User-specified bottom of scale on plot. Units are dBc. (Default = −150 dBc).
Userioprog_gone	(I)	Used to see if the Default parameter file is located on mass storage unit subaddress 0. If not, it assumes the file is located on subaddress 1. (Subaddresses refer to mass storage units such as dual disc drives.)
Video_bw	(R)	Video bandwidth smoothing factor. This is NOT the actual video BW sent to the SA. (Actual SA video bandwidth is a function of the resolution bandwidth; SA VidBW=ResBW/Video_bw.) (Default = 3). Unitless.
Vold	(R)	Holds the unchanged value of a test parameter while that parameter is being prompted to the user for change.
Vold1	(R)	Same as Vold above. Some subroutines have two variables they could change, and this tracks the second variable.

B Easy_ℒ Phase Noise Measurement Program

Subprogram Locations and Sizes

EASY_ℒ	Name	Bytes
Main Program	MAIN	34264
Tests	Uw_signal	7122
	If_signal	7718
	Measure_noise	25922
	Cal_noise_bw	9734
	Discr_cal	18338
Test Utilities	Srq_server	2424
	Signal_seek	14140
	Signal_lock	12342
	Read_instr_parm	3090
	Signal_beat_cal	3196
	Sig_lost_prompt	2502
	Btbl_create_sub	13016
	FNFreq_stop	1458
	Quad_tone	592
	Quad_check	950
Parameter Handlers	Record_params	1358
	Filter_band	1654
	FNMeasure_done	712
	FNLoop_bw	1402
	FNCap_bw	1488
	Noise_to_ary	2554
	Data_save	3298
	Dfile_save	4098
	Dfile_cat	6012
	FNDfile_name$	884
	Dfile_warn	802
	Dfile_get_head	1080
	Data_recall	6244
	Dfile_recall	2982
	Dfile_plot_sel	3458
	Plotter_is	4648
	F_bdat_open	690
	F_bdat_create	1058
	FNF_error$	1914
	D_init	2078
	D_select	3614
	FNMsu_base_name$	1738
	FNFile_spec$	956
	Subpgm_load	1342
	Pgm_pause	1086

ELuserIO	Name	Bytes
User I/O Subprograms	Menu_init	9382
	FNMenu_insert$	932
	Menu_print	1070
	Clock_update	1228
	Clear_message	1126
	Screen_clear	408
	Screen_home_lft	434
	FNFmt$	2236
	FNLoop_bw$	880
	In	3042
	Key_sel	8630
	Key_init	11644
	Wait	988
CRT Mode Selection	Crt_alpha	2472
	Crt_graph	890
	Crt_update	1092
	Crt_alpha_lk	770
	Crt_graph_lk	750
	Crt_unlock	772
Graph Plotting Package	Graph_init	5994
	Graph_dataplot	1826
	Graph_bandplot	4530
	Graph_lbwlabel	1850
	Graph_usrlabel	1726
	Graph_dfileplot	3284
	Graph_clear	958
	Graph_lbwline	4258
	Log_plot	3024
	FNX_pos	502
	Nice_scale	2042
	Move_for_label	460
	Label_limits	650
	Lin_plot	1268
	Vert_plot	1930
"Hidden" Diagnostics	Btbl_print	2370
	Mat_print	2872

ELdrKERNAL	Name	Bytes
Driver Support Routines	Kernal_there_q	694
	Sa_choose	10630
	Sa_select	828
	Driver_checker	5762
	Driver_loader	5584
HP-IB Device ID Routines	Cns_id	3244
	Lo_id	4320
	Sa_id	3102
	FNHpib_out_ent$	1250
Virtual Frequency Counter	FNFreq_count	5414

EL11729X

11729 (CNS) Driver	Cns_begin	2434
	FNCns_driver_q$	284
	FNCns_filter_q	520
	FNCns_lbwf_q	516
	FNCns_lost_lk_q	340
	FNCns_locked_q	302
	FNCns_id_q$	446
	FNCns_lostlk_q	900
	Cns_capab_q	1164
	Cns_unlock_e	302
	Cns_srq_d	374
	Cns_filter	322
	Cns_lbwf	314
	Cns_capture	664
	Cns_mode	656
	Cns_preset	242
	A11729b_learn_q	350
	Cns_end	284

EL866XA

8662/3 (LO) Driver	Lo_begin	3416
	FNLo_driver_q$	474
	FNLo_freq_q	1888
	FNLo_dcfm_q	2412
	FNLo_resolution_q	720
	Lo_capab_q	1128
	Lo_freq	722
	Lo_dcfm	414
	Lo_fmdev	2570
	Lo_fmint	718
	FNLo_dcfm_cap	990
	Lo_preset	266
	Lo_ampl	512
	Lo_deltaf	540
	Lo_deltaa	442
	A866xa_learn_q	478
	A8662a_range	900
	A8663a_range	432
	Lo_end	282

ELsaSTUBa	Name	Bytes
Generic (SA) Driver	Sa_begin	2020
	FNSa_driver_q$	842
	FNSa_sweep_q	818
	FNSa_fpeak_q	982
	Sa_marker_q	842
	FNSa_rbw_q	804
	FNSa_zoom_q	838
	Sa_trace_q	1236
	Sa_capab_q	1096
	Sa_sweepend_e	794
	Sa_srq_d	770
	Sa_preset	1220
	Sa_span	834
	Sa_rbw	786
	Sa_vbw	790
	Sa_local	804
	Sa_remote	802
	Sa_ref_lev	838
	Sa_take_sweep	990
	Sa_sweep_start	982
	Sa_mrk_to_ref	822
	Sa_mrk_to_fr	836
	Sa_end	282

EL856XX

8566/68 A/B (SA) Driver	Sa856xx_begin	4316
	FNSa856xx_driv_q$	440
	FNSa856xx_sweep_q	760
	FNSa856xx_fpeak_q	788
	Sa856xx_mrk_q	426
	FNSa856xx_rbw_q	544
	FNSa856xx_zoom_q	714
	Sa856xx_trace_q	360
	Sa856xx_capab_q	1304
	Sa856xx_eos_e	286
	Sa856xx_srq_d	422
	Sa856xx_preset	1260
	Sa856xx_span	298
	Sa856xx_rbw	258
	Sa856xx_vbw	266
	Sa856xx_local	336
	Sa856xx_remote	460
	Sa856xx_ref_lev	380
	Sa856xx_tk_swp	1106
	Sa856xx_swp_st	774
	Sa856xx_mk_t_rf	286
	Sa856xx_mk_t_fr	316
	Sa856xx_end	198

EL3561A	Name	Bytes
3561A (SA) Driver	Sa3561a_begin	5064
	FNSa3561a_driv_q$	446
	FNSa3561a_sweep_q	876
	FNSa3561a_fpeak_q	842
	Sa3561a_mrk_q	442
	FNSa3561a_rbw_q	660
	FNSa3561a_zoom_q	816
	Sa3561a_trace_q	1876
	Sa3561a_capab_q	1134
	Sa3561a_eos_e	406
	Sa3561a_srq_d	376
	Sa3561a_preset	534
	Sa3561a_span	408
	Sa3561a_rbw	476
	Sa3561a_vbw	652
	Sa3561a_local	340
	Sa3561a_remote	364
	Sa3561a_ref_lev	390
	Sa3561a_tk_swp	1096
	Sa3561a_swp_st	1172
	Sa3561a_mk_t_rf	904
	Sa3561a_mk_t_fr	314
	Sa3561a_ascii_q	758
	FNSa3561a_rf_lv_q	604
	FNSa3561a_fstop_q	786
	FNSa3561a_fr_dec	804
	Sa3561a_end	198

ELLOsource	Name	Bytes
	Lo_begin	3186
	FNLo_driver_q$	388
	FNLo_freq_q	364
	FNLo_dcfm_q	912
	FNLo_resolution_q	478
	Lo_capab_q	1108
	Lo_freq	542
	Lo_dcfm	466
	Lo_fmdev	936
	Lo_fmint	854
	FNLo_dcfm_cap	546
	Lo_preset	568
	Lo_ampl	458
	Lo_deltaf	542
	Lo_deltaa	582
	Lo_end	186

ELkeys300	Key_init	11818

ELautost	MAIN	3184
	Message_load	2094
	FNMsu_base_name$	1858
	FNFile_spec$	1026

Easy_ℒ Ordering Information

Part Number 11729-60126	EASY_ℒ software. (5¼″ media) HP 11729C-3 Product Note, "A User's Guide to Automatic Phase Noise Measurements"
Part Number 11729-60127	EASY_ℒ software. (3½″ media) HP 11729C-3 Product Note, "A User's Guide to Automatic Phase Noise Measurements"

Note: Additional copies of this product note will be available at no cost. Order HP literature number: 5954-6385.

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