

3048MS
**HP 3048A Option 301
Phase Noise
Measurement System**

Operating Manual



Operating Manual HP Part 03048-90042

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Software Versions

This manual applies directly to software version number:

HP 3048A Option 301 Software Version: REV: A.00.02

Printing History

First Edition: 11/90 - Printed in U.S.A.

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- Installation

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1

Getting Started

Designed to Meet Your Needs

The HP 3048A Option 301 Phase Noise Measurement System is a high performance tool that enables you to fully evaluate the noise characteristics of your electronic instruments and components with unprecedented speed and ease. The HP 3048A system provides you with the flexibility needed to meet today's broad range of noise measurement requirements.

In order to use the HP 3048A effectively, it is important that you have a good understanding of the noise measurement you are making. This manual is designed to help you gain that understanding and quickly progress from a beginning user of the phase noise measurement system to a proficient user of the system's basic measurement capabilities.

Note

If you have just received your System, or need help with connecting the hardware or loading software, refer to Appendix A now. Once you have completed the installation procedures presented in Appendix A, return to the following page to begin learning how to make noise measurements with the System.

As You Begin

The *HP 3048A Option 301 Operation; A Guided Tour* contains a step-by-step procedure for completing a phase noise measurement. This measurement demonstration introduces system operating fundamentals for whatever type of device you plan to measure.

Once you are familiar with the information in Chapter 1, you will be ready to refer to chapters 2 and 3 for specific information about *measuring your signal sources* or chapters 4 and 5 for information about *measuring two-port devices*. After you have completed your noise measurement, you will want to refer to Chapter 6 for help in *analyzing and verifying* your test results.

As You Progress

As you become familiar with the operation of the HP 3048A you will need to refer to this guide less often. There may, however, be times when you encounter problems while running your measurements. *Problem solving* suggestions have been provided at the back of chapter 3 to help you deal with conditions that can prevent the system from completing its measurement.

As An Advanced User

The HP 3048A offers many advanced operating functions that allow you to further tailor its operation to fit the special needs of your application. These advanced functions will be fully documented in your HP 3048A Option 301 Reference Manual. Refer to the reference manual after you are familiar with the basic operating capabilities presented in this manual.

HP 3048A Option 301 Operation; A Guided Tour

This measurement demonstration will introduce you to the System's operation by guiding you through an actual phase noise measurement.

You will be measuring the phase noise of the HP 11848A's two internal 10 MHz sources. (The measurement made in this demonstration is the same measurement that is made in Appendix A to verify the system's operation.)

As you step through the measurement procedures, you will soon discover that the HP 3048A Option 301 offers enormous flexibility for measuring the noise characteristics of your signal sources and two-port devices.

Required Equipment

The equipment shipped with this system is all that is required to complete this demonstration. (Refer to appendix A if you need information about setting up the HP 3048A Option 301 hardware or installing the software.)

How to Begin

Follow the set up procedures beginning on the next page. The HP 3048A will display a setup diagram that shows you the correct front panel cable connections to make for this measurement.

Note

The connections shown on the computer display do not show the required rear panel noise source connections between the HP 3561A and the HP 11848A. These connections must be made prior to this measurement. (See appendix A for these connections.) Also, the Spectrum Analyzer output of the HP 11848A must be terminated into 50 Ω if an appropriate analyzer is not connected.

Setting Up the Measurement

The Main Menu provides access to each of the system's main functions. The system always displays the Main Menu first.

Selecting Items in the Main Menu

Most menu items are selected using one of two methods:

- Type the first letter of the item to automatically select it, or
- Use the Δ ∇ keys to highlight the desired item and press **Enter**.

You can select a Main Menu item from a different menu to reduce keystrokes. To do this, simultaneously press the **Alt** key and the first letter of the Main Menu item you want to access. For instance, if you are in the Instrument Control menu and you want to jump directly to the System Configuration menu, hold down the **Alt** key and press the **S** key.

To return to the Main Menu from any other screen, press the **Esc** key until only the Main Menu is shown.

Making a Measurement

1. From the Main Menu, select **File System**.
2. Select **Directory**.
3. Type *.PRM and press **ENTER**.
4. Using the Δ ∇ keys, select **DEFAULT.PRM** and press **ENTER**.
5. Select **Load File**.
6. Press **ENTER** to load the file.
7. Press **ESC** to return to the Main Menu.
8. Select **New Measurement**.

9. Confirm that you do want to perform a new measurement by pressing the Y key. The system presets the instruments listed in the System Configuration menu and displays a connect diagram.

The System will inform you if it does not receive a response at the HP-IB address specified for a particular instrument. (For information on removing an instrument from the System Configuration table or verifying an HP-IB address, refer to *Setting Up the HP-IB Address* in Appendix A.)

10. Connect the instruments as shown on the computer's display.

Checking the Beatnote

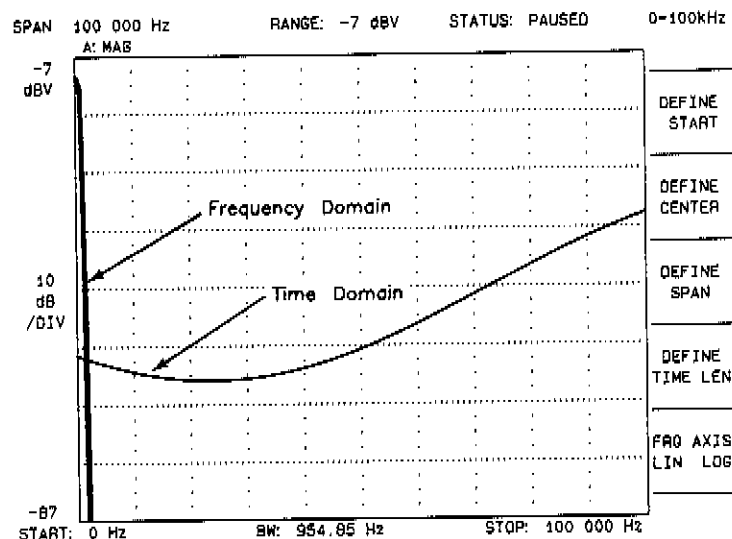


Figure 1-1. HP 3561A Display Showing Low Frequency Beatnote in Frequency and Time Domains

Look at the HP 3561A Dynamic Signal Analyzer and observe the beatnote signal being displayed. You should see the HP 3561A simultaneously display the beatnote in the frequency domain and the time domain, as shown in figure 1-1.

The beatnote signal is produced by mixing the signals from the two low-noise 10 MHz sources in the HP 11848A's Phase Detector, as shown in figure 1-2. The frequency of the beatnote signal represents the difference in frequency between the two 10 MHz sources.

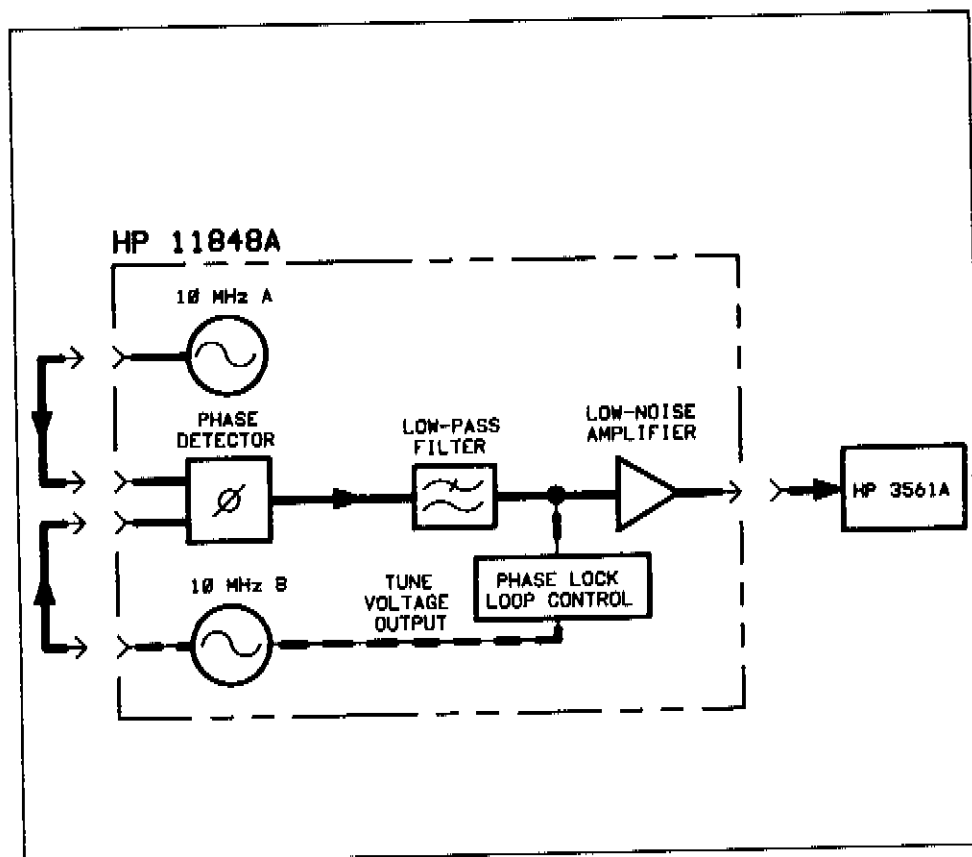


Figure 1-2. Simplified Block Diagram of Measurement Setup

Making the Measurement

1. Press **F1** to start making the necessary system operating constants measurements. Because you selected **New Measurement** to begin this measurement, the System starts by running the routines required to calibrate the current measurement setup. (No additional user inputs are needed until after the "PLL Suppression Factors" screen is displayed.)

The following messages will appear on the display as the System performs the calibration routines. (You will have ample time to read through these message descriptions while the System completes the routines.)

Determining Presence of Beat Note...: An initial check is made to verify that a beatnote is present within the system's detection range of 0.1 Hz to 100 kHz. If an RF analyzer is present and entered in the system-configuration Instrument Address Table, the detection range is extended to 40 MHz.

Verifying zero-beat...: The frequency of the beatnote is measured to see if it is within 5% of the estimated Peak Tuning Range of the system. The system's Peak Tuning Range is the portion of the voltage-controlled-oscillator (VCO) source's tuning range being used for the measurement.

When the System measures the phase noise of a signal source using the Phase Lock Loop technique (the technique being used in this example) it requires that one of the two sources used in the setup is a VCO. For this measurement, the 10 MHz B source is acting as the VCO source. As you will see later in this demonstration, you will be required to estimate the tuning range of the VCO source you are using when you set up your own Phase Lock Loop measurements.

Zero beating sources...: The center frequencies of the sources are now adjusted, if necessary, to

position the beatnote within the 5% range. The adjustment is made with the tune voltage applied to the VCO source set at its nominal or center position.

Measuring the VCO Tuning Constant...: The tuning sensitivity (Hz/V) of the VCO source is now precisely determined by measuring the beatnote frequency at four tune voltage settings across the tuning range of the VCO source. Linearity across the tuning range is also verified. (If you watch the HP 3561A's display, you can observe this process. When the measurement of the VCO Tuning Constant is complete, the System will display the measured value at the top of the screen.)

Measuring the Phase Detector Constant...: The transfer characteristics (V/rad) of the HP 11848A's Phase Detector are now determined for the specific center frequency and power level of the sources being measured. You will see the measured Tuning and Phase Detector Constants appear at the top of the HP 3561A's display along with an approximation of the system's noise floor level derived using the measured Phase Detector Constant value.

Measuring PLL suppression...: The required correction data is created to compensate for the phase noise suppression which occurs within the bandwidth of the phase lock loop created for this measurement.

2. The computer displays the PLL suppression curve and associated measurement values. Press **F1** to continue making the noise measurement. The measurement can be stopped by pressing **Ctrl** and **Break** simultaneously.

Sweep-Segments

When the System begins measuring noise, it places the noise graph on its display. As you watch the graph, you will see the System plot its measurement results in frequency segments.

The System measures the noise level across its frequency offset range by averaging the noise within smaller frequency segments. This technique enables the System to optimize measurement speed while providing you with the measurement resolution needed for most test applications.

Out of Lock Detection

Before and after the System measures each frequency segment, the System verifies that its Out of Lock Detector has not been set. If the detector has been set, the System will alert you by stopping the measurement and placing an error message in its display. (The *Problem Solving* sections included in the Measurement Applications chapters of this manual will help you interpret the error messages and will provide you with recommended actions for correcting the problem and continuing your measurement.)

Evaluating the Results

When the System completes the noise measurement, a short beep will sound and the message *Measurement Complete* will be displayed for approximately 5 seconds. By pressing the **M** key, you can access additional graph features that help you analyze the results. (Further details and demonstrations of these capabilities are provided in Chapter 6 of this manual.)

When you look at the measurement results, notice that the System has measured and plotted both the random noise and deterministic (spurious) signals for the 10 MHz sources. The System differentiates the random noise (which

has been normalized to a 1 Hz bandwidth) from the spurs (which are not normalized) by using a different color for the spurs on the graph.

Press **Esc** to return to the Main Menu.

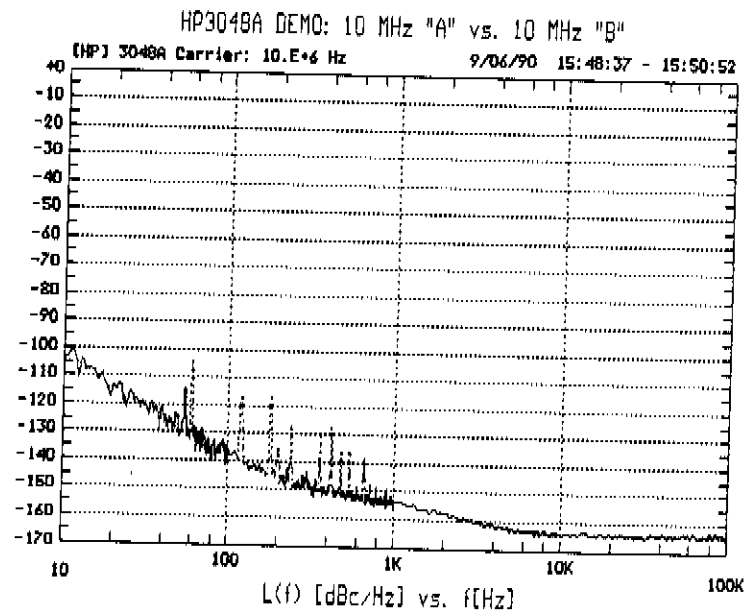


Figure 1-3. Typical Noise Curve for a 10 MHz A versus 10 MHz B Measurement

Congratulations

You have completed a phase noise measurement. You will find that this measurement of the internal 10 MHz sources provides a convenient way to verify that the System hardware and software are properly configured for making noise measurements.

To Learn More

Now continue with this demonstration to learn about setting up and running your own phase noise measurements.

Repeat Measurement versus New Measurement

Notice that two functions are available for beginning a measurement, **Repeat Measurement** and **New Measurement**. When you begin your measurement by selecting **New Measurement**, as you did for this demonstration, you cause the System to perform the routines necessary for calibrating the system before it begins its noise measurement. If you select **Repeat Measurement**, the System will use the same calibration data it used for the previous measurement.

Note

You should always select **New Measurement** for beginning your measurement if the frequency, amplitude, or tuning parameters of the sources you are using change.

Designing Your Own Measurement

To set up your own noise measurements, you will need to determine and enter the required parameter data for your measurement. This process is called "Defining a Measurement".

Defining a Measurement

Measurement definitions are accessed from different functions in the Main Menu.

The Measurement Type and Frequency Range

1. Select the **Type/Range of Measurement** function.

This menu allows you to specify which one of the System's six noise *measurement types* you wish to make. This menu also allows you to specify the *frequency offset range* over which you wish to measure the noise of your device, and how many measurements you want the System to make for *averaging* the noise level.

The different applications chapters in this manual contain "test definition" examples that

will help you setup your own measurements. These examples provide the recommended measurement type and operating parameter entries for many of your devices.

2. Use the **Tab**, **Enter**, or Δ ∇ keys to move to the desired frequency settings.
3. Press the F1 key. You will see the measurement type selection change each time you press this key.
4. Return the measurement selection to "Phase Noise using a Phase Lock Loop".

Note

The Phase Lock Loop measurement is the technique most commonly used for measuring the phase noise of signal sources. Chapter 2 of this manual provides a brief overview of the fundamentals of the Phase Lock Loop technique. You should become familiar with these fundamentals before you begin to set up phase noise measurements for your own signal sources.

-
5. Press **Esc**.

Signal Source Operation

1. Select the **Parameters** function.

When you set up your own signal source measurements, you will need to enter the *center (carrier) frequency* of your source-under-test. You will also need to enter the *tuning characteristics* of the VCO source that you are using. (You will find that Chapter 3 provides the tuning characteristics for many Hewlett-Packard sources commonly used for this measurement.)

2. Press **Esc**.

The Calibration Methods

1. Select the **Calibration Technique** function.

This menu allows you to choose the calibration method most suitable for your measurement situation. When you are setting up a new measurement, you will typically select the *measure method* for determining the calibration constants and have the System *verify* PLL suppression. (The criteria for selecting the other calibrating methods will be covered in your HP 3048A Option 301 Reference Manual.)

2. Press **Esc**.

The Measurement Setup

1. Select the **Instrument Control** function.

When you set up your own measurements, you must configure a block diagram of the measurement setup you plan to use. The purpose of this diagram is to tell the System:

- What hardware you will be using.
- Which instruments will be under HP-IB system control.
- What the interconnecting signal paths will be.

To change the device names and connections, press the first letter of the name of each block until the desired configuration is set. For instance, to change the UUT type, press the **U** key. To change the CTRL VOLTAGE connections, press the **C** key.

2. Press **Esc**.

The Results Graph

1. Select the **Define Graph** function.

This menu allows you to define the noise graph for displaying the results of your measurement, and set specification lines.

The System also allows you to redefine the graph parameters after the measurement is complete. This will enable you to optimize the presentation of your measurement results after you've had a chance to see them.

2. Press **Esc**.

The Test Files

1. Select the **File System** function.
2. Select the **Load File** function.

The **Load File** menu can be used to load a specific test result or parameter file that has been saved, or to display a list of available files.

Parameter files use the file extension **PRM**, and contain the information from the following menus:

- Type/Range of Measurement
- Parameters
- Calibration Technique
- Instrument Control
- Define Graph
- Manipulate Results
- Advanced Functions

Test result files use the file extension **RES**.

3. Use the MS-DOS wildcard "*" to list all of the stored parameter or result files. Example [*.PRM].

Note the test file labeled "Default". This file contains all the measurement parameters required to perform this measurement example.

The Measurement Application chapters (3 and 5) in this manual contain the procedures for measuring your own instruments using these example test files.

4. Press **Esc**.

You can also create your own test files by selecting the **Store File** function. To store a file, enter the drive, the path, the desired file name and the file extension, and press **Enter**. If no

drive or path is designated, the file will be stored to the current working directory.

For example, to store the results of a measurement to the **A** drive, type
A:\EXAMPLE.RES.

5. Press **Esc**.

To make a noise measurement using a device of your own, refer to the remaining chapters in this manual.

You will find that Chapters 2 through 6 provide detailed procedures and recommendations for measuring your signal source and two-port devices.

Specifications

Reliable Accuracy

The HP 3048A minimizes measurement uncertainty by assuring you of accurate and repeatable measurement results.

Frequency Offset Range	Accuracy
0.01 MHz to 1 MHz	± 2 dB
1 MHz to 40 MHz	± 4 dB

Measurement Qualifications

In order for the HP 3048A to meet its accuracy specifications, the following qualifications must be met by the signal sources you are using.

Source Return Loss: > 9.5 dB ($< 2:1$ SWR)

Source Harmonic Distortion < -20 dB (or a square wave)

If either of these conditions are not met, system measurement accuracy may be reduced.

Tuning

The tuning range of the voltage-controlled-oscillator (VCO) source must be commensurate with the frequency stability of the sources being used. If the tuning range is too narrow, the system will not properly phase lock, resulting in an aborted measurement. If the tuning range of the VCO source is too large, noise on the control line may increase the effective noise of the VCO source.

Specifications

System Phase Noise and Spurious Responses

The internal noise of the HP 3048A was designed for the measurement of even very low-noise reference sources. The following graph shows the phase noise and spurious response levels specified for the system.

The specified response does not include the phase noise or spurious signal contributions of a reference source.

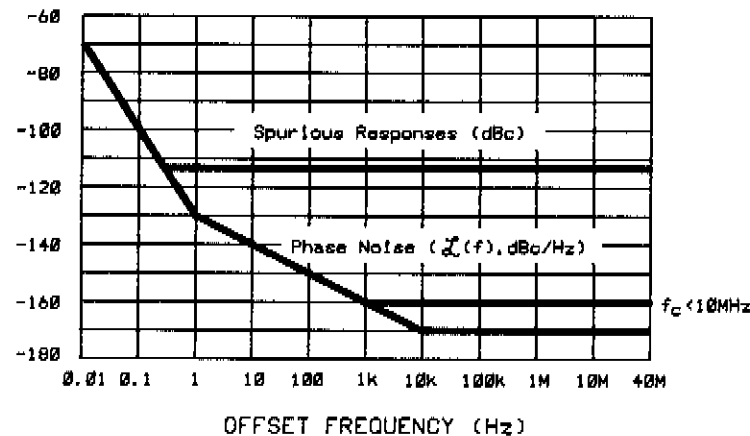


Figure 1-4. Graph of System Phase Noise and Spurious Responses

Specifications

Figure 1-5 shows the increase in system noise and spurious response levels as the signal level at the R input port of the HP 11848A Phase Detector is decreased below +15 dBm.

To determine the system noise and spurious response level for a given R input port level, determine the resulting dB degradation using the Figure 1-5 and then adjust the phase noise and spurious response levels shown in Figure 1-4 by the degradation value.

For example, if the R input signal level is +5 dBm, the resulting degradation is +10 dB. Applying the +10 dB degradation to Figure 1-4 increases the system's maximum noise level at > 10 kHz offset frequencies from -170 to -160 dBc/Hz. The specified maximum spurious signal level also increases from -112 to -102 dBc at all offset frequencies.

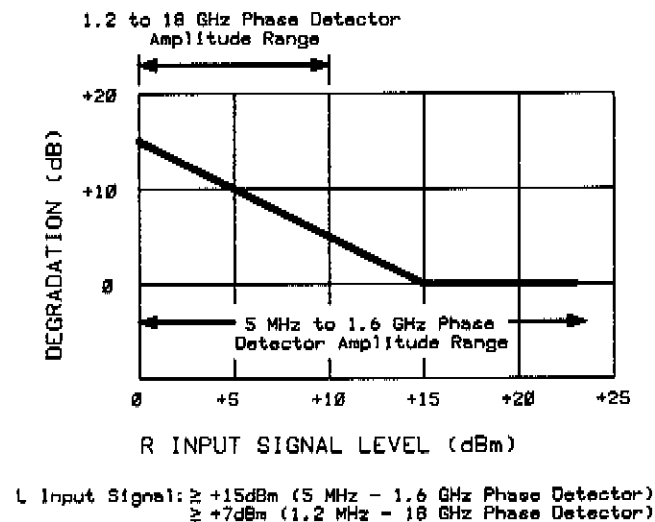


Figure 1-5. Increase in System Noise and Spurious Response Due to Decreased Input Level

Specifications

Phase Detector Input Ports

The wide frequency and amplitude ranges provided by the HP 3048A will enable you to make noise measurements for a wide variety of application requirements. The following tables indicate the frequency and amplitude ranges for the Phase Detector input ports on the HP 11848A.

Frequency Ranges

Carrier Frequency	Frequency Offset
5 MHz to 1.6 GHz ¹	0.01 Hz to 100 kHz ²
¹ Option 201 extends the carrier frequency range to 18 GHz	
² Range extends to 40 MHz using a supported RF Analyzer	

Amplitude Ranges

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz ¹	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm
¹ Option 201 adds 1.2 to 18 GHz High Frequency Phase Detector.			

Specifications

Source Output Ports

Four signal sources are built into the HP 11848A that can be used as low-noise reference sources for your measurements. The typical amplitude level and tuning range for each of the HP 11848A's internal sources are shown below.

Typical Amplitude and Tuning Ranges

Source Outputs	Amplitude	Tuning
10 MHz A	+15 dBm	± 100 Hz
10 MHz B	+6 dBm	± 1 kHz
350–500 MHz	+17 dBm	± 20 MHz
400 MHz	–5 dBm	Fixed Frequency

HP 3048A Phase Noise Measurement System

Operating Manual



**HEWLETT
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Boxed Manual Set HP Part 03048-61004
(Operating Manual 03048-90001 not available separately)

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Software Versions

This manual applies directly to software version numbers:

HP 3048A Software Version: REV: A.02.00 and Above

Printing History

First Edition: 1/87 - Printed in U.S.A.
Second Edition: 3/88 - Printed in U.S.A.
Third Edition: 2/89 - Printed in U.S.A.
Fourth Edition: 8/89 - Printed in U.S.A.
Fifth Edition: 4/92 - Printed in U.S.A.

rev.24JAN92

Specifications

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Frequency Offset Range	Accuracy
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1 MHz to 40 MHz	± 4 dB

Measurement Qualifications

In order for the HP 3048A to meet its accuracy specifications, the following qualifications must be met by the signal sources you are using.

Source Return Loss: > 9.5 dB ($< 2:1$ SWR)

Source Harmonic Distortion < -20 dB (or a square wave)

If either of these conditions are not met, system measurement accuracy will be reduced.

Tuning

The tuning range of the voltage-controlled-oscillator (VCO) source must be commensurate with the frequency stability of the sources being used. If the tuning range is too narrow, the system will not properly phase lock, resulting in an aborted measurement. If the tuning range of the VCO source is too large, noise on the control line may increase the effective noise of the VCO source.

Specifications

System Phase Noise and Spurious Responses

The internal noise of the HP 3048A was designed for the measurement of even very low-noise reference sources. The following graph shows the phase noise and spurious response levels specified for the system.

The specified response does not include the phase noise or spurious signal contributions of a reference source.

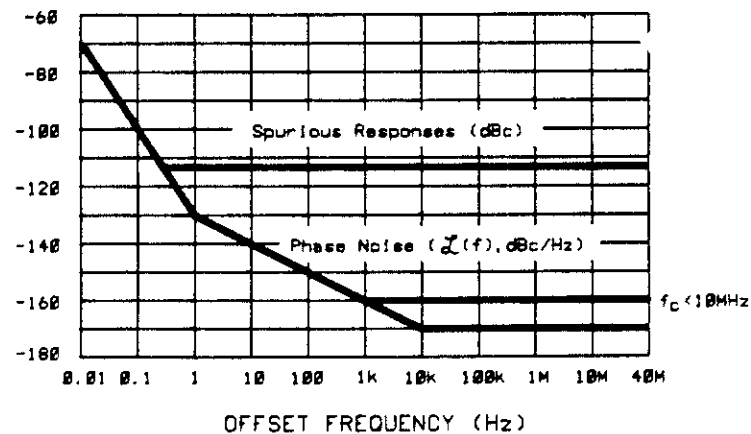


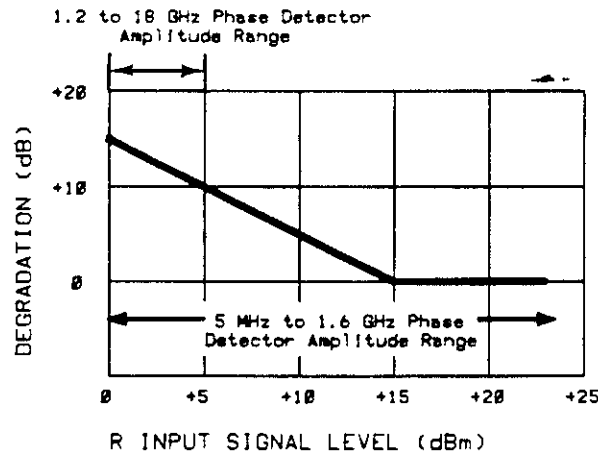
Figure 1-5. Graph of System Phase Noise and Spurious Responses

Specifications

Figure 1-6 shows the increase in system noise and spurious response levels as the signal level at the R input port of the HP 11848A Phase Detector is decreased below +15 dBm.

To determine the system noise and spurious response level for a given R input port level, determine the resulting dB degradation using Figure 1-6 and then adjust the phase noise and spurious response levels shown in Figure 1-5 by the degradation value.

For example, if the R input signal level is +5 dBm, the resulting degradation is +10 dB. Applying the +10 dB degradation to Figure 1-5 increases the system's maximum noise level at > 10 kHz offset frequencies from -170 to -160 dBc/Hz. The specified maximum spurious signal level also increases from -112 to -102 dBc at all offset frequencies.



L Input Signal: $\geq +15$ dBm (5 MHz - 1.6 GHz Phase Detector)
 $\geq +7$ dBm (1.2 MHz - 18 GHz Phase Detector)

Figure 1-6. Increase in System Noise and Spurious Response Due to Decreased Input Level

Specifications

Phase Detector Input Ports

The wide frequency and amplitude ranges provided by the HP 3048A will enable you to make noise measurements for a wide variety of application requirements. The following tables indicate the frequency and amplitude ranges for the Phase Detector input ports on the HP 11848A.

Frequency Ranges

Carrier Frequency	Frequency Offset
5 MHz to 1.6 GHz ¹	0.01 Hz to 100 kHz ²
¹ Option 201 extends the carrier frequency range to 18 GHz	
² When using a supported RF Analyzer).	

Amplitude Ranges

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz ¹	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +10 dBm
¹ Option 201 adds 1.2 to 18 GHz High Frequency Phase Detector.			

2

Signal Source Fundamentals

In This Chapter

This chapter contains information about making absolute phase noise measurements of signal sources. This information is fundamental to using the HP 3048A Option 301 Phase Noise Measurement System. It is important that you understand the concepts contained in this chapter in order to use the system effectively.

The topics covered in this chapter include:

- The noise measurement techniques
- The Phase Lock Loop measurement technique
- The Discriminator Technique
- AM Noise Measurements
- The system noise floor
- The measurement process

The Three Measurement Techniques

The HP 3048A offers three measurement types for measuring the noise of your signal source devices. Two for measuring phase noise and one for measuring AM noise. (Measurement examples for each of the three measurement types are provided in Chapter 3.)

The two phase noise measurement types are:

- The Phase Lock Loop technique and;
- The Discriminator technique.

The Phase Lock Loop Technique

The Phase Lock Loop technique requires two signal sources; the source-under-test and a reference source. This measurement type requires that one of the two sources is a voltage-controlled-oscillator (VCO).

You will most likely use the Phase Lock Loop technique since it is the measurement type most commonly used for measuring signal source devices. This manual focuses on this measurement type for signal source measurements.

The Discriminator Technique

The second measurement choice you have for measuring the phase noise of your signal source devices is the Discriminator method. This method does not require a second signal source. Instead, a discriminator is used to demodulate the frequency fluctuations of the signal source. The discriminator requirements for your measurement will depend on the frequency offset range you wish to measure. You can find a measurement example of the Discriminator Method in Chapter 3. Refer to the HP 3048A Option 301 Reference Manual for detailed information on the Calibration Process for the Discriminator Measurement Method.

AM Noise Measurements

You can also characterize the AM noise level of a signal source using the HP 3048A system. AM noise measurement is becoming more important as phase noise levels are reduced. AM noise represents sideband energy which can affect radar and communication systems, and AM noise is converted to phase modulation in almost all signal processing devices. (Refer to Chapter 3 if you are interested in further information about making an AM noise measurement.)

What You Should Understand About the Phase Lock Loop Technique

This measurement technique requires two signal sources set up in a phase locked loop (PLL) configuration. One of the sources is the unit-under-test (UUT). The second source serves as the reference against which the UUT is measured. (One of the two sources must be a VCO source capable of being frequency tuned by the System.) Figure 2-1 shows a simplified diagram of the PLL configuration used for the measurement.

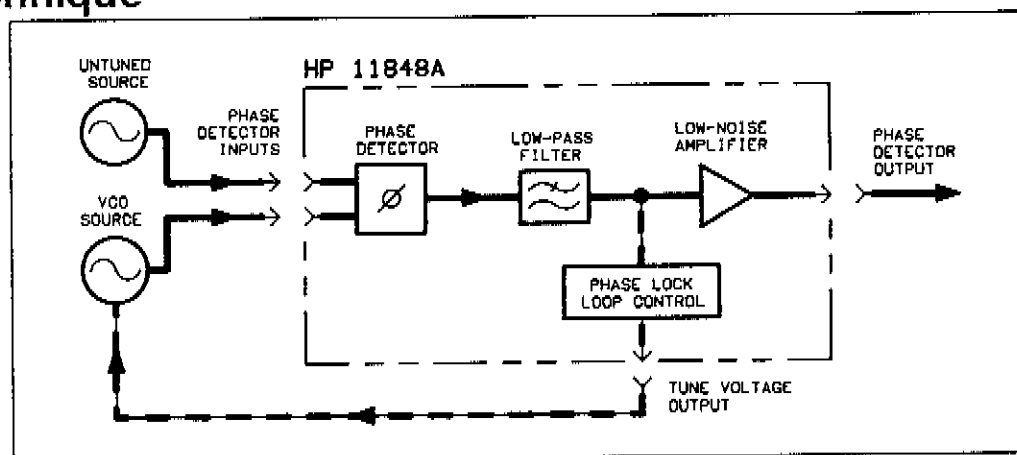


Figure 2-1. Simplified Block Diagram of the Phase Lock Loop Configuration

The Phase Lock Loop Circuit

The Capture and Drift Tracking Ranges

Like other PLL circuits, the phase lock loop created for the HP 3048A measurement has a *Capture Range* and a *Drift Tracking Range*. The *Capture Range* is equal to 10% of the system's Peak Tuning Range, and the *Drift Tracking Range* is equal to 20% of the system's Peak Tuning Range.

The system's Peak Tuning Range is derived from the tuning characteristics of the VCO source you are using for the measurement. Figure 2-2 illustrates the relationship that typically exists between the VCO's peak-to-peak tuning range and the tuning range of the system.

The system's Drift Tracking Range is limited to a small portion of the Peak Tuning Range to minimize the possibility of measurement accuracy degradation caused by non-linearity across the VCO's tuning range.

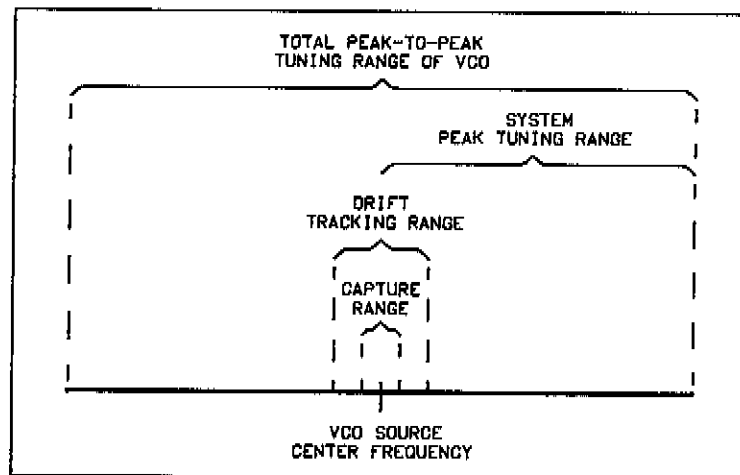


Figure 2-2. Typical Relationship of Capture Range and Drift Tracking Range to Tuning Range of VCO Source

As an Example:

A Peak Tuning Range of 1000 Hz will provide the following ranges:

$$\text{Capture Range} = 0.10 \times 1000 \text{ Hz} = 100 \text{ Hz}$$

$$\text{Drift Tracking Range} = 0.20 \times 1000 \text{ Hz} = 200 \text{ Hz}$$

Tuning Requirements

The Peak Tuning Range required for your measurement will depend on the frequency stability of the two sources you are using. The signals from the two sources are mixed in the HP 11848A's Phase Detector to create a beatnote. In order for the loop to acquire lock, the center frequencies of the sources must be close enough together to create a beatnote that is within the system's *Capture Range*. Once the loop is locked, the frequency of the beatnote must remain within the *Drift Tracking Range* for the duration of the measurement. In Figure 2-3, the ranges calculated in the previous example are marked to show their relationship to the beatnote frequency.

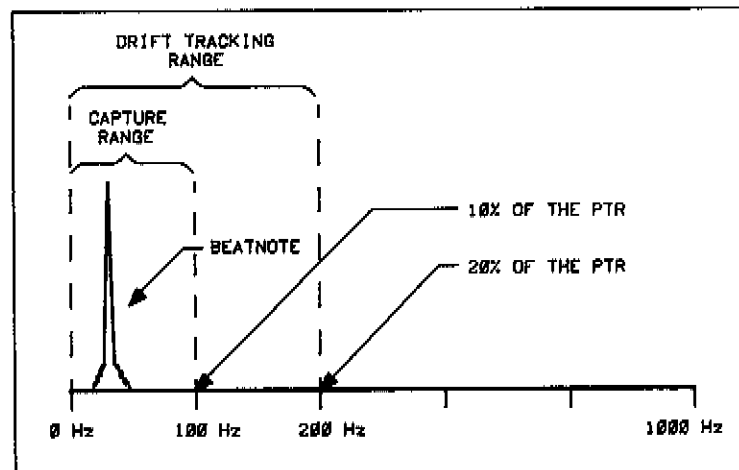


Figure 2-3. Relationship of Capture and Drift Tracking Ranges to Beatnote Frequency

If the beatnote does not remain within the *Drift Tracking Range* during the measurement, the out of lock detector will be set and the System will stop the measurement. If this happens, you will need to increase the system's *Drift Tracking Range* by increasing the system's *Peak Tuning Range* (if possible) or by selecting a VCO source with a greater tuning range.

Selecting the VCO Source

Although you must select a VCO source that will provide a sufficient tuning range to permit the system to track the beatnote, keep in mind that a wide tuning range typically means a higher noise level on the VCO source signal. When the VCO source for your measurement is also the reference source, this trade-off can make reference source selection the most critical aspect of your measurement setup.

Specifying Your VCO Source

When you set up your PLL measurement, you will need to know four things about the tuning characteristics of the VCO source you are using. The System will determine the VCO source's *Peak Tuning Range* from these four parameters.

- **Tuning Constant**, estimated tuning sensitivity (Hz/V)
- **Center Voltage of Tuning Range**, (V)
- **Tune Range of VCO**, ($\pm V$)
- **Input Resistance of Tuning Port**, (ohms)

The measurement examples in Chapter 3 that recommend a specific VCO source will provide you with the tuning parameters for the specified source. The *Designing a Measurement* example in Chapter 3 will help you set up a measurement using an unspecified VCO source.

10 MHz Frequency Standard

This measurement example will help you measure the phase noise of a stable 10 MHz oscillator with frequency drift of <0.1 Hz over a period of thirty minutes.

Required Equipment

The following equipment is required for this example *in addition to the HP 3048A system and your unit-under-test (UUT).*

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

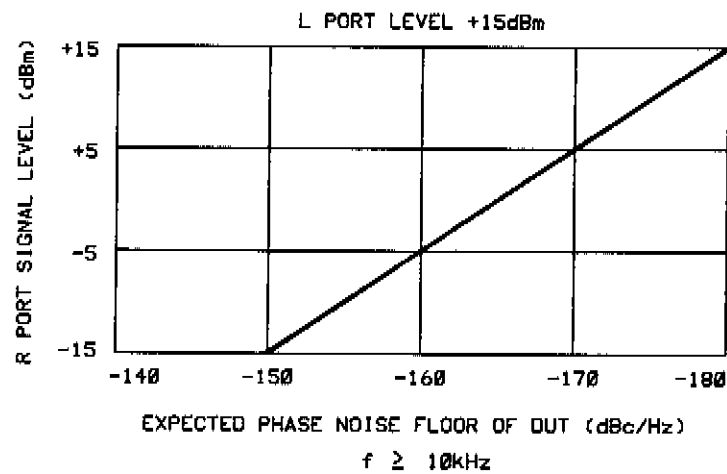
Equipment	Qty.	Comments
HP 8662/3A	1	Must have EFC Input Port.
Coax Cables	4	And adequate adapters to connect to UUT.

Defining the Measurement

1. Select the **File System** function from the Main Menu.
2. Select the **Load File** function. Enter ***.PRM** for the path information.
3. Select the file titled 10 MHZ FREQ STANDARD VS HP 8662/3A 10 MHZ REF OUT and press **Enter**.
The appropriate measurement parameters for this example have been prestored in this file. (Table 3-1 lists the parameter data that has been entered for this measurement example.)
4. Press the **Esc** key to return to the Main Menu.

If the L port signal is within the amplitude range shown in the preceding table, the signal level at the R input port sets the noise floor for the system.

The following graph shows the relationship between the R input level and the system noise floor.



The Noise Level of the Reference Source

Unless it is below the system's noise floor, the noise level of the source you are using as the reference source will set the noise floor for the measurement. When you set up your measurement, you will want to use a reference source with a noise level that is at or below the level of the source you are going to measure.

The following graph demonstrates that as the noise level of the reference source approaches the noise level of the UUT, the level measured by the System (which is the sum of all noise sources affecting the system) is increased above the actual noise level of the UUT.

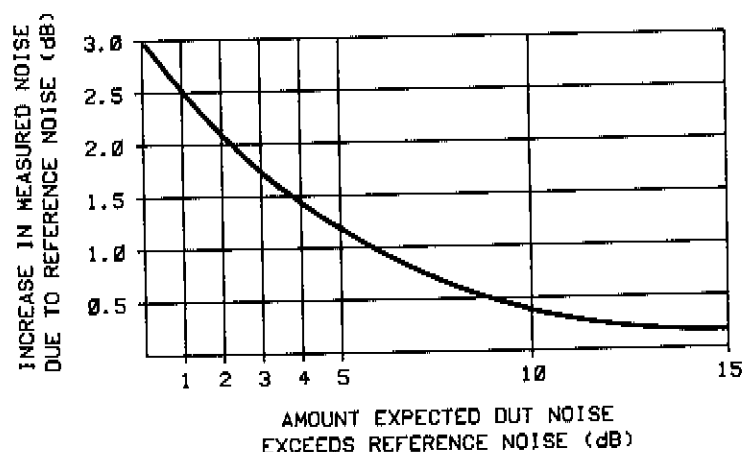


Figure 2-4. Increase in Measured Noise as Reference Source Noise Approaches UUT Noise

Note

To help you select the appropriate reference source for your measurement, the noise plots for the various Hewlett-Packard signal source options are included in the *HP 3048A Option 301 Reference Manual*.

The Measurement Process

The following outline will give you an overview of the steps you will go through when you measure the phase noise of a signal source using the Phase Lock Loop technique for the first time. (Subsequent measurements of the same or a similar source typically will not require that you repeat steps A through C.)

A. Determine Equipment Required.

1. Determine reference source requirement.
 - Estimate noise level of source-under-test.
 - Select a reference source with an adequate noise level.

Note

If your source-under-test is not a VCO source, then the reference source must be a VCO source.

2. Determine VCO source requirement.

- Estimate drift characteristics of source-under-test and reference source.
- Select a VCO source that will provide sufficient drift tracking.

B. Define Measurement Parameters.

1. Determine the tuning parameters for the VCO source you are using.
2. Complete the five steps listed on the HP 3048A's Measurement Definition Menu.

C. Set Up Hardware.

1. Connect the source you wish to test and the reference source to the HP 11848A. (One of the sources must be a VCO.)

D. Run Measurement.

1. Adjust center frequency of sources if necessary to position beatnote within Capture Range.

E. Evaluate Measurement Results

1. Look for any questionable or problem areas on the noise graph.
2. Compare graph against known or expected data.
3. If necessary, use HP 3048A to gather additional data about the noise characteristics of your source.

The process described in the above outline is covered in much greater detail in Chapter 3. The examples provided in Chapter 3 will step you through the setup and measurement procedures.

When you wish to measure the *phase* or *AM* noise of your own source, turn to Chapter 3 and select the example provided for measuring your device type.

3

Signal Source Applications

Measurement Examples

This chapter contains measurement examples to help you measure the phase or AM noise of your signal sources. A list of the measurement examples is provided on the next page.

Turn the page and look through the list of measurement examples in the Directory table. Once you have identified the appropriate example for measuring your source, turn to the page indicated in the Directory table and follow the procedures for setting up and running your measurement.

This chapter also contains a Problem Solving section. A list of the topics covered in the Problem Solving section is provided on the first page of that section.

File Names and Titles

Each file that is stored has a *name* and a corresponding *title*.

- File *names* are used to store, load, or delete files. File names are limited to eight (8) characters and the appropriate file extension. Use the file extension **.PRM** for Parameter files, and **.RES** for Result files. (Example, **DEFAULT.PRM**, **DEFAULT.RES**)
- *Titles* allow you to provide a better description of what the file contains. The title is entered in the *Define Graph* menu, and appears at the top of the Graph of Results display. Titles may contain a maximum of 55 characters. (Example, **HP3048A DEMO: 10 MHz "A" vs. 10 MHz "B"**)

The title is appended to the file name when it is saved, and is displayed to the right of the file name and date when viewing the available files. Example,

DEFAULT.RES | 11/01/90 | HP3048A DEMO: 10 MHz "A" vs. 10 MHz "B"

Note When you are prompted to load various files during the operations in this chapter, the files will be referred to by their *title* only.

Source Drift

You will find that the Phase Lock Loop measurement examples presented on the next page are differentiated by the drift characteristics of the source being measured. (The drift estimates shown for each example are for a period of approximately 30 minutes.)

For further information in determining source drift, refer to "Determining the PTR Required for Drift Tracking" in the Parameters section of Chapter 2 Measurement Definitions of the HP 3048A Option 301 Reference Manual.

Phase Lock Loop Measurements

Note To configure a phase noise measurement effectively, you should have a fundamental understanding of the measurement technique you are using. Insight into the Phase Lock Loop measurement technique is provided in Chapter 2.

When you need to know how to measure:

Refer to:

Phase Lock Loop Measurements

- *A very stable 10 MHz oscillator (drift < 0.1 Hz) such as a frequency standard.* **10 MHz Frequency Standard (pg. 3-4)**
- *A stable RF oscillator (drift < 20 ppm) such as a VHF crystal, RF crystal, SAW, or DRO.* **Stable RF Oscillator (pg. 3-15)**
- *A free-running RF oscillator (drift > 20 ppm) such as an LC or cavity tuned oscillator or a SAW delay line oscillator.* **Free-Running RF Oscillator (pg. 3-28)**
- *An RF synthesizer using the HP 8662A or HP 8663A.* **RF Synthesizer (pg. 3-42)**
- *A microwave source (2.5 to 18 GHz) such as a synthesizer, multiplier chain, or phase-locked cavity tuned oscillator.* **Microwave Source (pg. 3-60)**
- *An RF source using a different reference source than is specified in the examples* **Designing a Measurement (pg. 3-72)**

Discriminator Measurement

- *An RF source using the Discriminator measurement technique.* **Discriminator Measurement (pg. 3-97)**

AM Noise Measurements

- *The AM noise of an RF source using an HP 11792C (Option 130) Carrier Noise Test Set.* **AM Noise Using an HP 11729C (pg. 3-106)**
- *The AM noise of an RF source using an HP 33330C Detector.* **AM Noise Using an HP 33330C (pg. 3-113)**

10 MHz Frequency Standard

This measurement example will help you measure the phase noise of a stable 10 MHz oscillator with frequency drift of <0.1 Hz over a period of thirty minutes.

Required Equipment

The following equipment is required for this example *in addition to the HP 3048A system and your unit-under-test (UUT)*.

Note

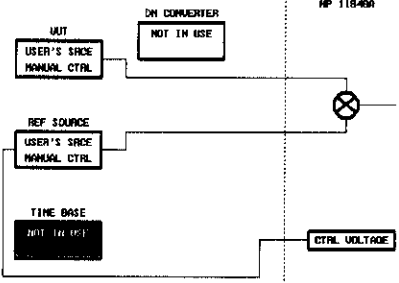
To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

Equipment	Qty.	Comments
HP 8662/3A	1	Must have EFC Input Port.
Coax Cables	4	And adequate adapters to connect to UUT.

Defining the Measurement

1. Select the **File System** function from the Main Menu.
2. Select the **Load File** function. Enter ***.PRM** for the path information.
3. Select the file titled 10 MHZ FREQ STANDARD VS HP 8662/3A 10 MHZ REF OUT and press **Enter**.
The appropriate measurement parameters for this example have been prestored in this file. (Table 3-1 lists the parameter data that has been entered for this measurement example.)
4. Press the **Esc** key to return to the Main Menu.

Table 3-1. Parameter Data for the 10 MHz Frequency Standard Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	10 E + 6 Hz 10 E + 6 Hz 50 E - 3 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	10 MHz FREQ STANDARD VS HP 8662/3A 10 MHz REF OUT 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select the **New Measurement** function, and press the **Y** key to proceed.
2. The System now addresses each of the instruments listed in its System Configuration table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about adding or changing an instrument in the System Configuration - Instrument Address table.)
3. When the Connect Diagram appears on the computer's display, connect the signal paths as shown in Figure 3-1. (Figure 3-1 differs from the Connect Diagram shown on the display.) Table 3-2 provides setup considerations that will help you ensure that your measurement results will be valid.

Note

Although not shown in the setup diagram, the rear-panel cable connection described in Appendix A (SOURCE OUT to NOISE INPUT) is required. Also, the 50 Ω load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

The setup configuration used for this measurement example takes advantage of a 10 dB amplifier available within the HP 11848A. (This low noise amplifier has been designed for use with signal sources whose output level is below the +15 to +23 dBm range required at the L input port on the HP 11848A. The low noise amplifier should only be used for signals below 200 MHz.) Figure 3-2 shows a simplified diagram of the amplifier connections.

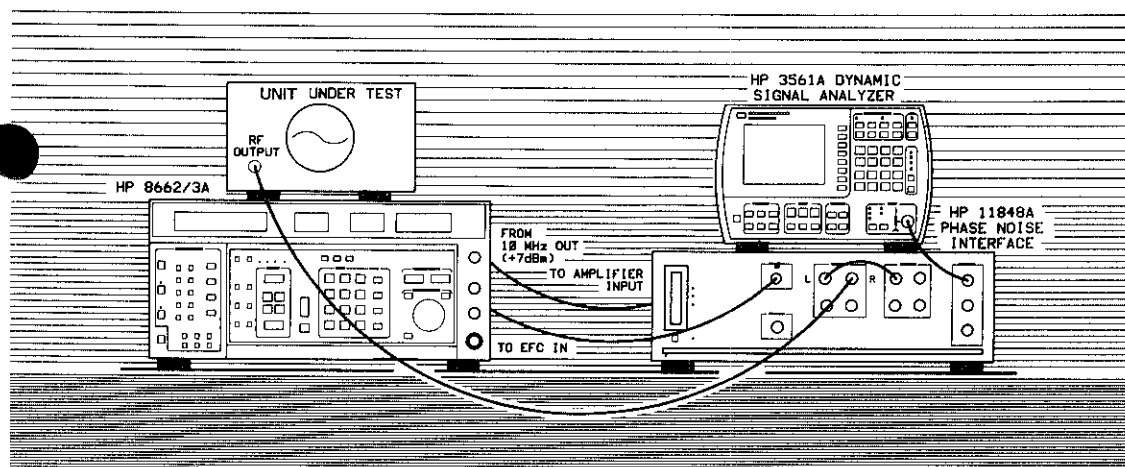


Figure 3-1. Setup Diagram for the 10 MHz Frequency Standard Measurement Example.

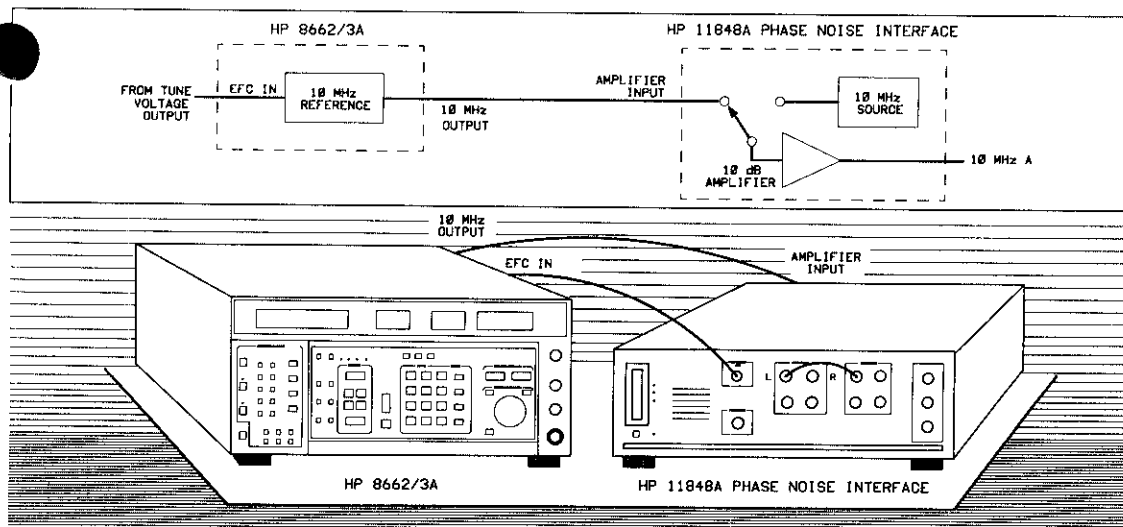


Figure 3-2. Simplified Diagram of the HP 8662/3A's Reference Oscillator and HP 11848A's Internal Amplifier Setup.

Table 3-2. Setup Considerations for the 10 MHz Frequency
Standard Measurement Example (1 of 2).

Setup Considerations	Comments										
Measurement Noise Floor	The signal amplitude at the R input port on the HP 11848A sets the measurement noise floor level. Use the following graph to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your UUT will provide.) L PORT LEVEL +15dBm <table border="1"> <caption>Data points from the graph</caption> <thead> <tr> <th>Expected Phase Noise Floor of DUT (dBc/Hz)</th> <th>R Port Signal Level (dBm)</th> </tr> </thead> <tbody> <tr> <td>-150</td> <td>-15</td> </tr> <tr> <td>-160</td> <td>-5</td> </tr> <tr> <td>-170</td> <td>+5</td> </tr> <tr> <td>-180</td> <td>+15</td> </tr> </tbody> </table> If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the HP 11848A input. (Refer to <i>Inserting a Device</i> in the <i>Problem Solving</i> section of this chapter for details on determining the effect that the amplifier's noise will have on the measured noise floor.)	Expected Phase Noise Floor of DUT (dBc/Hz)	R Port Signal Level (dBm)	-150	-15	-160	-5	-170	+5	-180	+15
Expected Phase Noise Floor of DUT (dBc/Hz)	R Port Signal Level (dBm)										
-150	-15										
-160	-5										
-170	+5										
-180	+15										

**Table 3-2. Setup Considerations for the 10 MHz Frequency
Standard Measurement Example (2 of 2).**

Setup Considerations	Comments
HP 8662A or HP 8663A VCO Reference	This setup uses the HP 8662/3A's internal reference oscillator as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the UUT, the noise level of the reference source should be below the expected noise level of the UUT. If you have an idea of the expected level of your device, you may want to compare it to the noise characteristics graph shown for the HP 8662/3A's reference oscillator in the <i>HP 3048A Option 301 Reference Manual</i>.
Measurement Environment	The low noise floors typical of these devices may require that special attention be given to the measurement environment. The following precautions will help ensure reliable test results: 1. Filtering on power supply lines 2. Protection from microphonics 3. Short coax cable connections 4. Shielding from air currents may even be necessary.

Checking the Beatnote

While the hardware Connect Diagram is being displayed, we recommend that you check the beatnote being created between the HP 8662/3A's 10 MHz reference and your source-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system.

For this measurement setup, the phase lock loop (PLL) Capture Range is 10% of the 0.5 Hz Peak Tuning Range, or 0.05 Hz. (Refer to *Chapter 2* if you are not familiar with the relationship between the PLL Capture Range and the Peak Tuning Range of the VCO.)

Note

If the center frequencies of the sources are not close enough to create a beatnote within the Capture Range, the System will not be able to complete its measurement.

If the beatnote frequency is below 100 kHz, it should appear on the HP 3561A. The HP 3561A is configured to display the beatnote signal in both the frequency domain and the time domain. If the beatnote does not appear on the HP 3561A, then the beatnote is either greater than 100 kHz or it does not exist.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz. You may have to look carefully at the HP 3561A's display to see a beatnote close to 0 Hz.

1. As you observe the beatnote, adjust the beatnote frequency, if necessary, so the time domain display is showing less than 1 full cycle across the screen on each span of the HP 3561A. A tuning screw labeled Fine Frequency Adjust is provided on the rear panel of the HP 8662/3A for adjusting the center frequency of the 10 MHz reference.

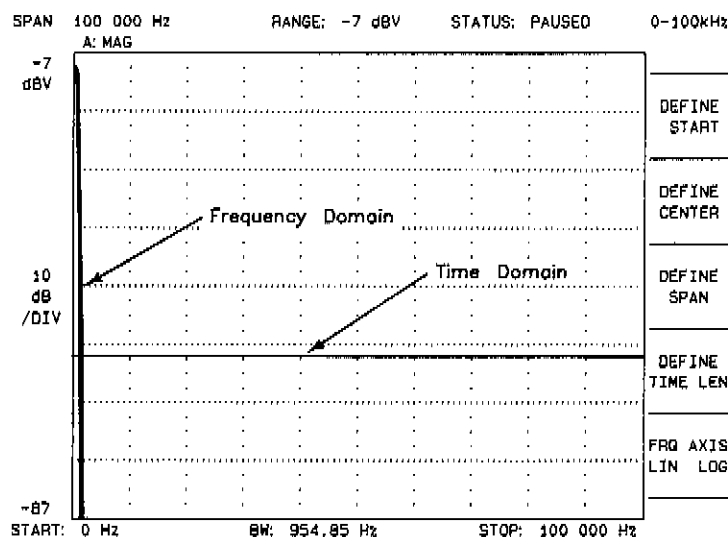


Figure 3-3. HP 3561A Display of a Beatnote Close to 0 Hz

Note

If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to *Minimizing Injection Locking* in the *Problem Solving* section of this chapter for recommended actions.

2. Decrement the HP 3561A's span width when the time domain display on the HP 3561A is showing less than one full cycle. The span width is changed using the computer's Δ ∇ keys. If an RF Analyzer is used, its span width is adjusted using the $\triangleleft$ $\triangleright$ keys.
3. Reduce the beatnote so that the time domain display shows less than one cycle across the screen.
4. Continue decrementing the HP 3561A's span and reducing the beatnote frequency until the span width setting is 10 Hz.
5. Reduce the beatnote frequency to within the 0.05 Hz (10%) Capture Range (less than two cycles on the display with the span set to 10 Hz).

Note

If you are not able to tune the beatnote to within the Capture Range due to frequency drift, refer to *Tracking Frequency Drift* in the *Problem Solving* section of this chapter for information about measuring drifting signals.

6. As you observe the beatnote, compare its level to the following chart to determine the approximate measurement noise floor for the measurement. If the beatnote level will not provide an adequate measurement noise floor to measure your device, increase the signal level at the R input port of the HP 11848A.

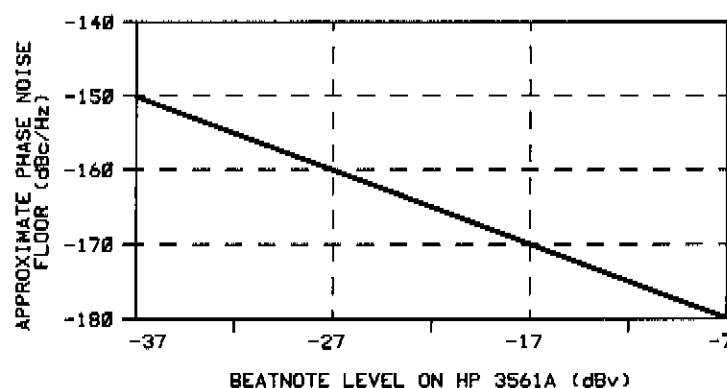


Figure 3-4. The Measurement Noise Floor Can Be Estimated From the Level of the Beatnote.

Making the Measurement

1. Press the F1 key after you have completed the beatnote check and are ready to make the measurement.

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results.

If the System has problems completing the measurement, it will inform you by placing a message on its display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.

Figure 3-5 shows a typical phase noise curve for a 10 MHz Frequency Standard.

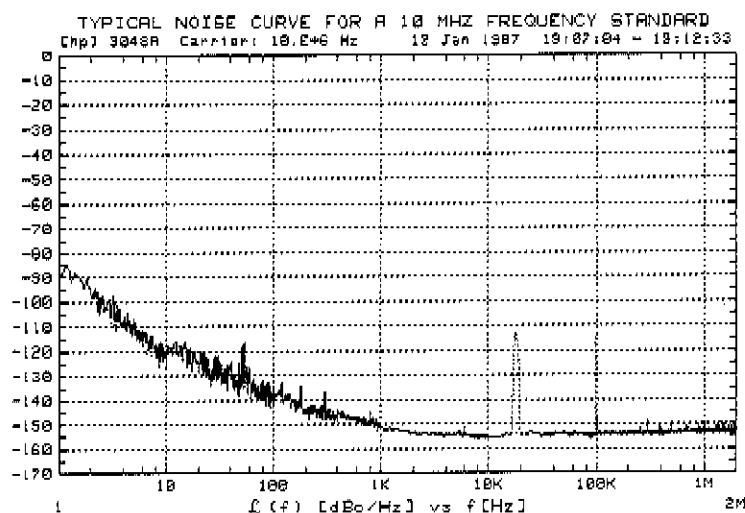


Figure 3-5. Typical Phase Noise Curve for a 10 MHz Frequency Standard.

Stable RF Oscillator

This measurement example will help you measure the phase noise of a stable RF oscillator with frequency drift of < 20 ppm over a period of thirty minutes.

Required Equipment

The following equipment is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

Equipment	Qty.	Comments
VCO Reference Source	1	Refer to <i>Selecting a Reference</i> in the <i>Problem Solving</i> section of this chapter for information about reference source requirements.
Coax Cables	3	And adequate adapters to connect UUT and reference source to HP 11848A.

Defining the Measurement

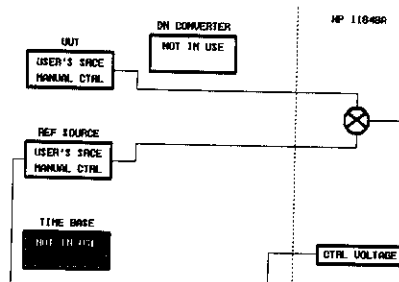
1. Select the **File System** from the Main Menu.
2. Select the **Load File** function and enter ***.PRM** for the path information to list all of the stored parameter files.
3. Select the file titled STABLE RF OSCILLATOR VS SIMILAR REFERENCE SOURCE and press **Enter**. The appropriate measurement definition parameters for this example have been pre-stored in this file. (Table 3-3 lists the parameter data that has been entered for this measurement example.)
4. Note that the source parameters entered for step 2 on the table may not be appropriate for the sources you are using. To change these values, press the **Alt** and **P** keys simultaneously to select the **Parameters** function from the Main Menu.
 - a. Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 GHz). Enter the same frequency for the Detector Input Frequency.
 - b. Enter the estimated Tuning Constant (tuning sensitivity in Hz/V), Tuning Curve Center Voltage and Range, and Tune-Port Input Resistance for the VCO source you are using.

Note

If you do not know the exact Tuning Constant for your VCO source, an estimate that is within a factor of 2 is close enough as long as you have the System measure the exact value for you before it makes its noise measurement. If you estimate the Tuning Constant, enter the input resistance as $1\text{ E} + 6$. If you do know the exact Tuning Constant, enter it and enter the actual input resistance of your VCO.

5. When you have completed these operations, press the **Esc** key to return to the Main Menu.

Table 3-3. Parameter Data for the Stable RF Oscillator Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	 125 E + 6 Hz 125 E + 6 Hz 250 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms 5 MHz to 1600 MHz
3	Calibration Type Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	HP 11948A
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	STABLE RF OSCILLATOR VS SIMILAR REFERENCE SOURCE. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select the **New Measurement** function and press the **Y** key to proceed.
2. The System addresses each of the instruments listed in its System Configuration table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about adding or changing an instrument in the System Configuration - Instrument Address table.)
3. When the Connect Diagram appears on the computer's display, connect the signal paths as shown in Figure 3-6. (Figure 3-6 differs from the Connect Diagram shown on the display.) Table 3-4 provides setup considerations that will help you ensure that your measurement results will be valid.

Note

Although not shown in the setup diagram, the rear-panel cable connection described in Appendix A (SOURCE OUT to NOISE INPUT) is required. Also, the 50 Ω load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

The setup configuration used for this measurement example takes advantage of a 10 dB amplifier available within the HP 11848A. (This low noise amplifier has been designed for use with signal sources whose output level is below the +15 to +23 dBm range required at the L input port on the HP 11848A. The low noise amplifier should only be used for signals below 200 MHz.) Figure 3-7 shows a simplified diagram of the amplifier connections.

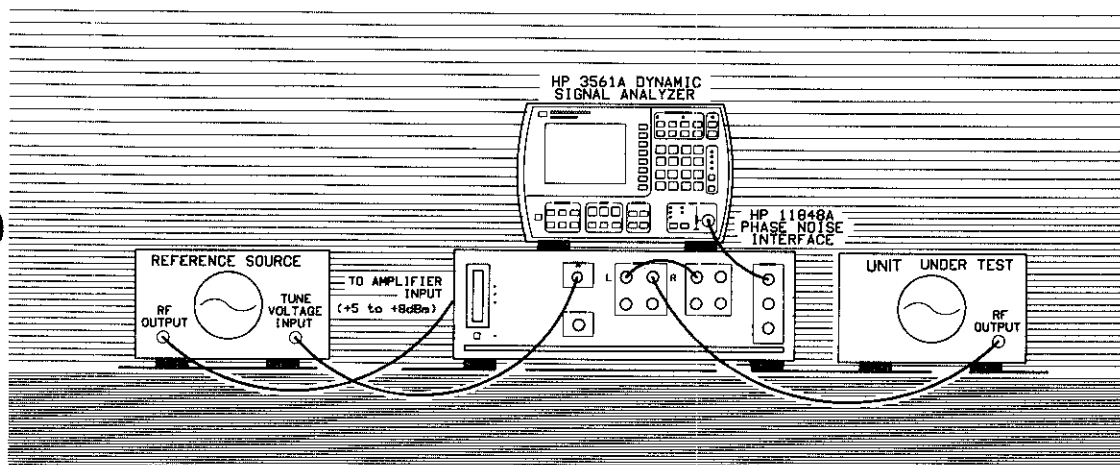


Figure 3-6. Setup Diagram for the Stable RF Oscillator Measurement Example.

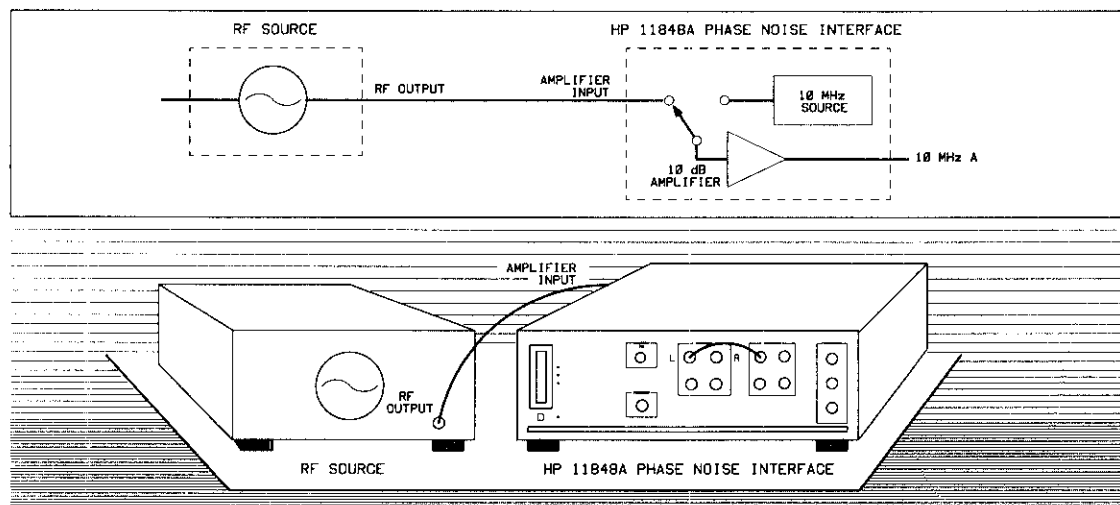


Figure 3-7. Simplified Diagram of the Reference Source and HP 11848A's Internal Amplifier Setup.

Table 3-4. Setup Considerations for the Stable RF Oscillator Measurement Example.

Setup Considerations	Comments
Measurement Noise Floor	The signal amplitude at the R input port on the HP 11848A sets the measurement noise floor level. Use the following graph to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your UUT will provide.) L PORT LEVEL +15dBm R PORT SIGNAL LEVEL (dBm) EXPECTED PHASE NOISE FLOOR OF DUT (dBc/Hz) $f \geq 10\text{kHz}$ If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the HP 11848A input. (Refer to <i>Inserting a Device in the Problem Solving</i> section of this chapter for details on determining the effect that the amplifiers noise will have on the measured noise floor.)
VCO Reference Source	This setup calls for a second signal source that is a similar type to that of the UUT. The second source is used as the reference source. In order for the noise measurement results to accurately represent the noise of the UUT, the noise level of the reference source should be below the expected noise level of the UUT. (For additional help in selecting an appropriate reference source, refer to <i>Selecting a Reference in the Problem Solving</i> section of this chapter.)

Checking the Beatnote

We recommend that you check the beatnote being created between the reference source and your device-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system.

The phase lock loop (PLL) Capture Range is 10% of the Peak Tuning Range of the VCO source you are using. (The Peak Tuning Range for your VCO can be estimated by multiplying the VCO Tuning Constant by the Tune Range of VCO. Refer to *Chapter 2* if you are not familiar with the relationship between the PLL Capture Range and the Peak Tuning Range of the VCO.)

Note

If the center frequencies of the sources are not close enough to create a beatnote within the Capture Range, the System will not be able to complete its measurement.

If the beatnote frequency is below 100 kHz it should now appear on the HP 3561A. The HP 3561A can be configured to display the beatnote signal in both the frequency domain and the time domain. If the beatnote does not appear on the HP 3561A, then the beatnote is either greater than 100 kHz or it does not exist.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz. You may have to look carefully at the HP 3561A's display to see a beatnote close to 0 Hz.

On the other hand, less accurate sources may create a beatnote greater than 100 kHz. Searching for the beatnote will require that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the HP 3561A's display (beatnote < 100 kHz).

If incrementing the frequency of one of the sources does not produce a beatnote within 100 kHz, you will need to verify the presence of an output signal from each source before proceeding.

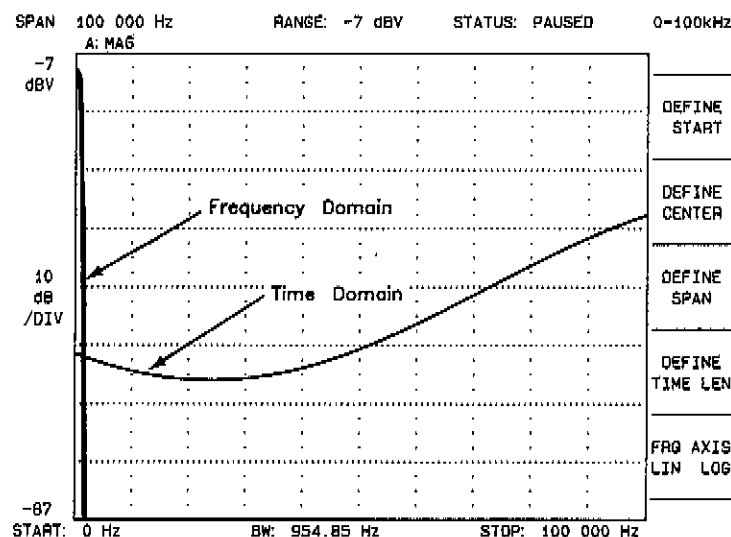


Figure 3-8. The Beatnote is Displayed in Both the Frequency and Time Domain by the HP 3561A

1. Estimate the system's Capture Range (using the VCO source parameters entered for this measurement). The estimated VCO Tuning Constant must be accurate within a factor of 2. A procedure for *Estimating the Tuning Constant* is located in the *Problem Solving* section of this chapter.

$$\text{Capture Range (Hz)} = \frac{\text{VCO Tuning Constant (Hz/V)} \times \text{VCO Tuning Range (V)}}{10}$$

$$\text{Capture Range (Hz)} = \frac{\text{ (Hz/V)} \times \text{ (V)}}{10} = \text{ Hz}$$

Note

If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to *Minimizing Injection Locking* in the *Problem Solving* section of this chapter for recommended actions.

-
2. As you observe the beatnote on the HP 3561A in the frequency domain, reduce the beatnote until it is to the left of the first major graticule on the screen.

Adjust the beatnote by adjusting the center frequency of one of the signal sources if possible. If this is not possible, use the Center Voltage adjustment that is available while the setup diagram is displayed. This adjusts the *Tune Voltage Output* of the HP 11848A that connects to the VCO source. Pressing **F8** or **SHIFT/F8** increases or decreases the tune voltage. (Note: Shifting the center voltage of the tuning range may reduce the available tuning range needed for drift tracking during the measurement.)

3. Continue reducing the beatnote frequency until the time domain display shows less than one full wave cycle across the screen.
4. Decrement the HP 3561A's span width when the time domain display on the HP 3561A is showing less than one full cycle. The span width is changed using the computer's Δ ∇ keys. If an RF Analyzer is used, its span width is adjusted using the $\triangleleft$ $\triangleright$ keys.
5. Reduce the beatnote frequency again until the time domain display is showing less than one full cycle across the new span width.
6. Continue decrementing the HP 3561A's span and reducing the beatnote frequency until the beatnote is within the Capture Range determined in step 1 of this procedure. The following chart will help you select the best span width for adjusting the beatnote to within the Capture Range.

Note

If you are not able to tune the beatnote to within the Capture Range due to frequency drift, refer to *Tracking Frequency Drift* in the *Problem Solving* section of this chapter for information about measuring drifting signals.

Span Width Setting	Frequency of Each Cycle	HP 3561A Time Record
100 kHz	250 Hz	4 msec
10 kHz	25 Hz	40 msec
1 kHz	2.5 Hz	400 msec
100 Hz	.25 Hz	4 sec
10 Hz	0.025 Hz	40 sec
4 Hz	0.01 Hz	100 sec

Span Width Setting

When viewing the frequency domain display, keep in mind that the first major graticule on the HP 3561A's screen represents 10% of the span width.

Frequency of Each Cycle

When viewing the time domain display, you can determine the frequency of the beatnote by multiplying the number of cycles appearing across the HP 3561A's screen by the appropriate Frequency of Each Cycle value from the chart.

For example, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

$$\text{Number of Cycles} \times \text{Frequency of Each Cycle} = \text{Beatnote Frequency}$$

$$2 \text{ cycles} \times 2.5 \text{ Hz} = 5 \text{ Hz}$$

HP 3561A Time Record

Note that the higher the span width setting that you are using, the faster the HP 3561A will respond to the beatnote frequency changes you make.

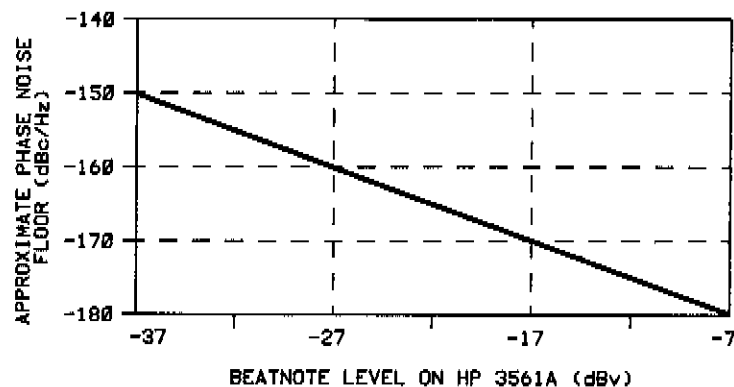


Figure 3-9. The Measurement Noise Floor Can Be Estimated From the Level of the Beatnote.

7. As you observe the beatnote, compare its level to the above chart to determine the approximate measurement noise floor for the measurement. If the beatnote level will not provide an adequate measurement noise floor to measure your device, increase the signal level at the R input port of the HP 11848A.

Making the Measurement

1. Press the **F1** key when you have completed the beatnote check and are ready to make the measurement.

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by placing a message on its display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.)

Figure 3-10 shows a typical phase noise curve for a Stable RF Oscillator.

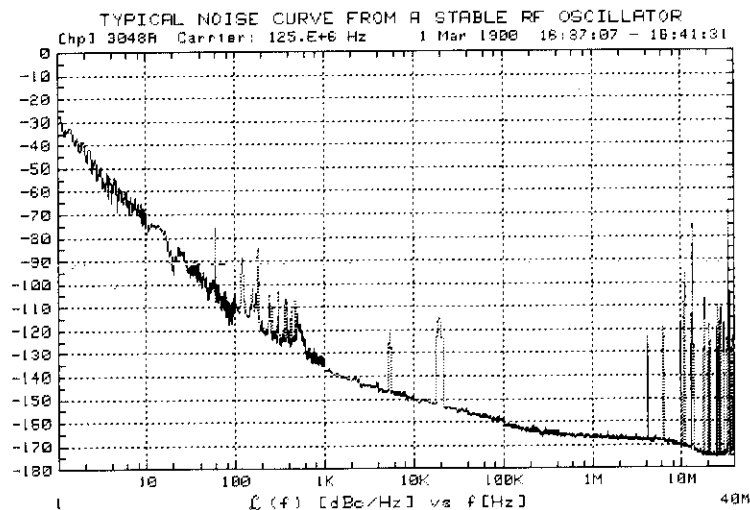


Figure 3-10. Typical Phase Noise Curve for a Stable RF Oscillator.

Free-Running RF Oscillator

This measurement example will help you measure the phase noise of a free-running RF oscillator with frequency drift > 20 ppm over a period of thirty minutes.

Required Equipment

The following equipment is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

Equipment	Qty.	Comments
HP 8640B	1	An HP 8642A/B can be used in place of the HP 8640B.
Coax Cables	3	And adequate adapters to connect UUT to HP 11848A.
RF Analyzer	1	An RF analyzer is necessary when the Peak Tuning Range is > 500 kHz as in this example. Must be entered in Instrument Addresses table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for the procedure).

Defining the Measurement

1. Select the **File System** function from the Main Menu.
2. Select the **Load File** function and enter ***.PRM** for the path information.
3. Select the file labeled **FREE-RUNNING RF OSCILLATOR VS HP 8640B**. The appropriate measurement definition parameters for this example have been prestored in this file. (Table 3-5 lists the parameter data that has been entered for this measurement example.)
4. Note that the Carrier Frequency and VCO Tuning Constant entered for step 2 on the table may not be appropriate for measuring your device. To change these values, press the **Alt** and **P** keys simultaneously to access the **Parameters** menu.
 - a. Enter the carrier (center) frequency of your UUT (5 MHz to 1.6 GHz). Enter the same frequency for the Detector Input Frequency.
 - b. Enter the appropriate VCO Tuning Constant for the HP 8640B. The tuning constant value is the DC FM Peak Deviation setting on the HP 8640B. The following table will help you select the appropriate Peak Deviation setting for your instrument. (The correct center frequency setting for the HP 8640B is the UUT frequency.)

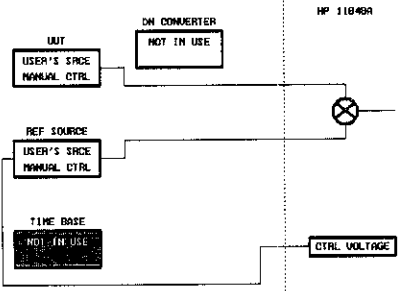
Center Frequency Range (MHz)	Maximum Peak Deviation (kHz)
0.5 - 1	5
1 - 2	10
2 - 4	20
4 - 8	40
8 - 16	80
16 - 32	160
32 - 64	320
64 - 128	640
128 - 256	1280
256 - 512	2560
(Option 002) 512 - 1024	5120

Note

We recommend that you begin by setting DC FM to the maximum Peak Deviation for the center frequency setting. This is not the best setting in terms of the system noise level, but it will provide you with the best tuning range. After you have completed the first measurement, run subsequent measurements and reduce the Peak Deviation setting until there is no further reduction in the measured noise level or until the System indicates that it cannot maintain phase lock during the measurement. Remember, if you do change the Peak Deviation setting for subsequent measurements, you will need to change the VCO Tuning Constant to match the new setting.

- When you have completed this operation, press the **Esc** key to return to the Main Menu. The remaining parameter values are correct for this measurement example.

Table 3-5. Parameter Data for the Free-Running RF Oscillator Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	640 E + 6 Hz 640 E + 6 Hz 5.12 E + 6 Hz/V 0 Volts ±10 Volts 600 ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Computed from expected Tuning Constant Will be verified
4	Instrument Control	 Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	FREE-RUNNING RF OSCILLATOR VS HP 8640B. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select the **New Measurement** function from the Main Menu, and press the **Y** key to proceed.
2. The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about adding or changing an instrument in the System Configuration - Instrument Addresses table.)

Note

Although not shown in the Connect Diagram, the rear-panel cable connection described in Appendix A (SOURCE OUT to NOISE INPUT) is required. Also, the 50 Ω load must be connected to the SPECTRUM ANALYZER OUTPUT whenever an RF spectrum analyzer is not being used.

3. When the Connect Diagram appears, connect the signal paths as shown on the display. (Figure 3-11 also shows the cable connections for this measurement.) Table 3-6 provides additional setup considerations that will help you ensure that your measurement results will be valid.

The HP 8640B should be adjusted to the appropriate center frequency and DC FM Peak Deviation setting for the measurement. Set the HP 8640B's amplitude to +18 dBm (+13 dBm if the center frequency is above 550 MHz).

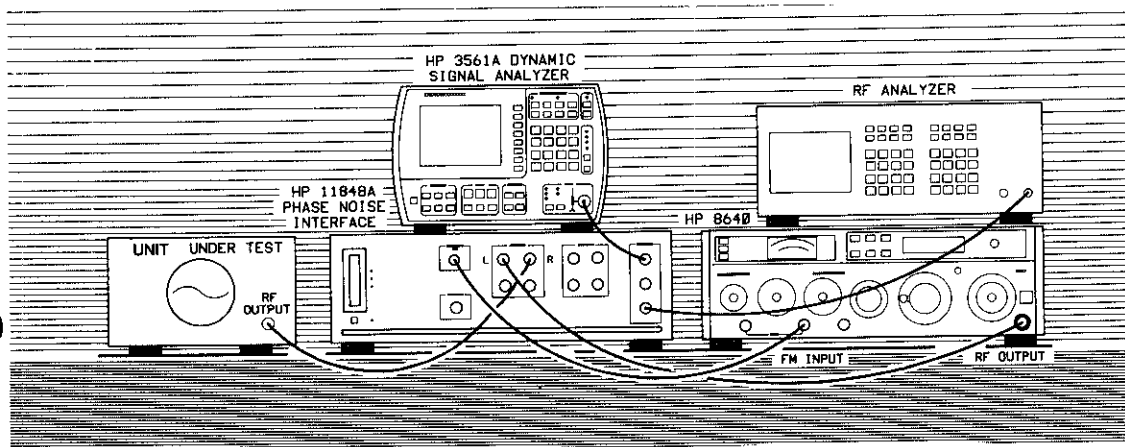


Figure 3-11. Setup Diagram for the Free-Running RF Oscillator Measurement Example.

Table 3-6. Setup Considerations for the Free-Running RF Oscillator Measurement Example.

Setup Considerations	Comments										
Measurement Noise Floor	The signal amplitude at the R input port on the HP 11848A sets the measurement noise floor level. Use the following graph to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your UUT will provide.) L PORT LEVEL +15dBm <table border="1"> <caption>Data points from the graph</caption> <thead> <tr> <th>Expected Phase Noise Floor of UUT (dBc/Hz)</th> <th>R Port Signal Level (dBm)</th> </tr> </thead> <tbody> <tr> <td>-150</td> <td>-15</td> </tr> <tr> <td>-160</td> <td>-5</td> </tr> <tr> <td>-170</td> <td>+5</td> </tr> <tr> <td>-180</td> <td>+15</td> </tr> </tbody> </table> f ≥ 10kHz If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the HP 11848A input. (Refer to <i>Inserting a Device</i> in the <i>Problem Solving</i> section of this chapter for details on determining the effect that the amplifier's noise will have on the measured noise floor.)	Expected Phase Noise Floor of UUT (dBc/Hz)	R Port Signal Level (dBm)	-150	-15	-160	-5	-170	+5	-180	+15
Expected Phase Noise Floor of UUT (dBc/Hz)	R Port Signal Level (dBm)										
-150	-15										
-160	-5										
-170	+5										
-180	+15										
HP 8640B VCO Reference	This uses the HP 8640B as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the UUT, the noise level of the reference source should be below the expected noise level of your UUT. If you have an idea of the expected noise level of your device, you may want to compare it to the noise characteristics graph shown for the HP 8640B in the <i>HP 3048A Option 301 Reference Manual</i>.										

Checking the Beatnote

While the hardware Connect Diagram is displayed, we recommend that you check the beatnote being created between the HP 8640B and your device-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system. For this measurement setup, the phase lock loop (PLL) Capture Range is equal to the DC FM Peak Deviation setting of the HP 8640B. (The Capture Range provided by the HP 8640B can be estimated by multiplying its VCO Tuning Constant (Peak Deviation Setting) by its Tune Range of VCO (10V) and dividing by 10. Refer to *Chapter 2* if you are not familiar with the relationship between the PLL Capture Range and the Peak Tuning Range of the VCO.)

Note

If the center frequencies of the sources are not close enough to create a beatnote within the Capture Range, the System will not be able to complete its measurement.

If the beatnote frequency is below 100 kHz it should now appear on the HP 3561A. The HP 3561A is configured to display the beatnote signal in both the frequency domain and the time domain.

If you are using an RF analyzer, and the beatnote is > 100 kHz but < 40 MHz, the beatnote should appear on the RF analyzer's display. If the beatnote does not appear on either analyzer, then the beatnote is either greater than 40 MHz or it does not exist.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz. You may have to look carefully at the HP 3561A's display to see a beatnote close to 0 Hz.

On the other hand, less accurate sources may create a beatnote greater than 100 kHz. Searching for the beatnote will require that you adjust the center frequency of the HP 8640B above and below the frequency of the UUT until the beatnote appears on the analyzer's display. If the beatnote signal does not appear, you will need to verify the presence of an output signal from each source before proceeding.

Once you have identified the beatnote, tune the HP 8640B until the beatnote frequency is < 100 kHz.

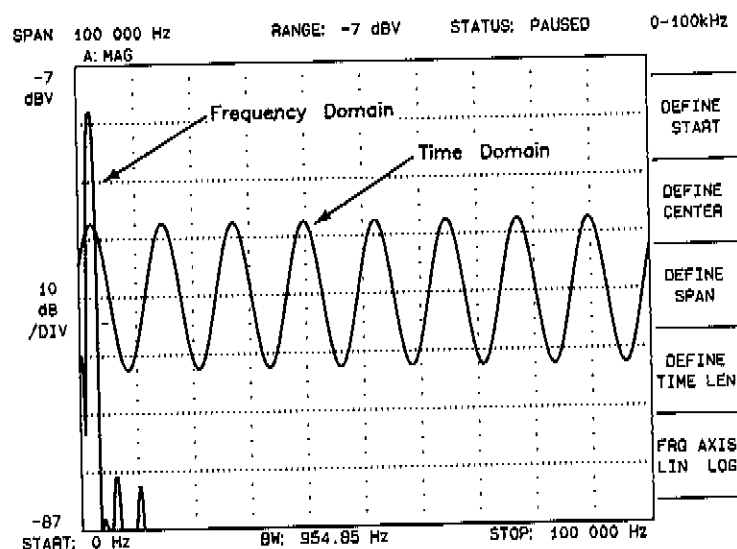


Figure 3-12. The Beatnote is Displayed in Both the Frequency and Time Domain by the HP 3561A.

1. Estimate the system's Capture Range (using the VCO source parameter values entered for this measurement):

$$\text{Capture Range (Hz)} = \frac{\text{VCO Tuning Constant (Hz/V)} \times \text{VCO Tuning Range (V)}}{10}$$

$$\text{Capture Range (Hz)} = \frac{\text{ } (\text{Hz/V}) \times \text{ } (\text{V})}{10} = \text{ } \text{Hz}$$

2. As you observe the beatnote on the HP 3561A in the frequency domain, reduce the beatnote until it is to the left of the first major graticule on the screen. Adjust the beatnote by adjusting the center frequency of the HP 8640B.

Note

If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to *Minimizing Injection Locking* in the *Problem Solving* section of this chapter for recommended actions.

3. Continue reducing the beatnote frequency until the time domain display shows less than one full cycle across the screen.
4. Decrement the HP 3561A's span width when the time domain display on the HP 3561A is showing less than one full cycle. The span width is changed using the computer's Δ ∇ keys. If an RF Analyzer is used, its span width is adjusted using the $\triangleleft$ $\triangleright$ keys.
5. Reduce the beatnote frequency again until the time domain display is showing less than one full cycle across the new span width.
6. Continue decrementing the HP 3561A's span and reducing the beatnote frequency until the beatnote is within the Capture Range determined in step 1 of this procedure. The following chart will help you select the best span width for adjusting the beatnote to within the Capture Range.

Span Width Setting	Frequency of Each Cycle	HP 3561A Time Record
100 kHz	250 Hz	4 msec
10 kHz	25 Hz	40 msec
1 kHz	2.5 Hz	400 msec
100 Hz	.25 Hz	4 sec
10 Hz	0.025 Hz	40 sec
4 Hz	0.01 Hz	100 sec

Note

If you are not able to tune the beatnote to within the Capture Range due to frequency drift, refer to *Tracking Frequency Drift* in the *Problem Solving* section of this chapter for information about measuring drifting signals.

Span Width Setting

When viewing the frequency domain display, keep in mind that the first major graticule on the HP 3561A's screen represents 10% of the span width.

Frequency of Each Cycle

When viewing the time domain display, you can determine the frequency of the beatnote by multiplying the number of cycles appearing across the HP 3561A's screen by the appropriate Frequency of Each Cycle value from the chart.

For example, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

$$\text{Number of Cycles} \times \text{Frequency of Each Cycle} = \text{Beatnote Frequency}$$

$$2 \text{ cycles} \times 2.5 \text{ Hz} = 5 \text{ Hz}$$

HP 3561A Time Record

Note that the higher the span width setting that you are using, the faster the HP 3561A will respond to the beatnote frequency changes you make.

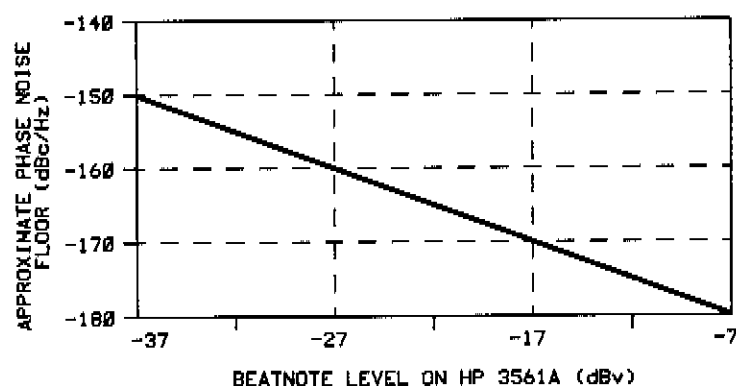


Figure 3-13. The Measurement Noise Floor Can Be Estimated from the Level of the Beatnote.

7. As you observe the beatnote, compare its level to the above chart to determine the approximate measurement noise floor for the measurement. If the beatnote level will not provide an adequate measurement noise floor to measure your device, increase the signal level at the R input port of the HP 11848A.

Making the Measurement

1. Press the **F1** key to proceed after you have completed the beatnote check and are ready to run the measurement.

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by placing a message on the display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.)

Figure 3-14 shows a typical phase noise curve for a free-running RF oscillator.

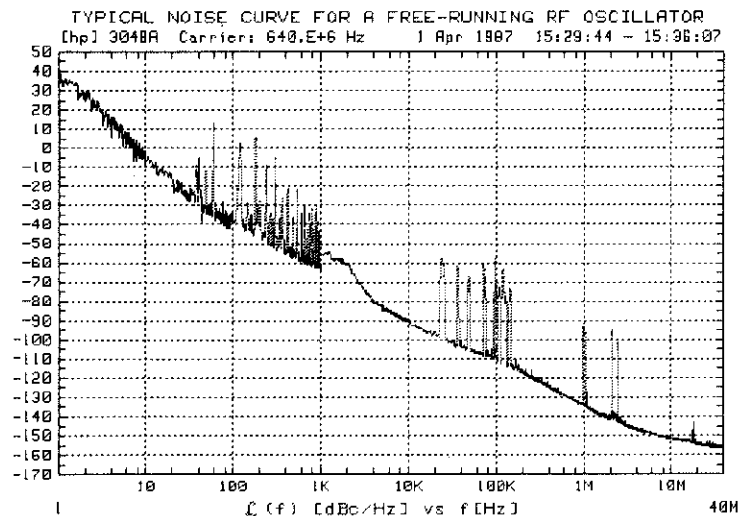


Figure 3-14. Typical Phase Noise Curve
for a Free-Running RF Oscillator.

RF Synthesizer

This measurement example will help you measure the absolute phase noise of an RF synthesizer.

Required Equipment

The following equipment is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Equipment	Qty.	Comments
HP 8662/3A	1	Must have an EFC Input Port. Must be entered in Instrument Addresses table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for procedure).
Coax Cables	3	And adequate adapters to connect UUT to HP 11848A.

Defining the Measurement

1. Select the **File System** function from the Main Menu.
2. Select the **Load File** function and enter ***.PRM** for the path information.

3. Note that four measurement examples are listed with the title RF SYNTHESIZER VS -. Each example provides for an alternative method of tuning the HP 8662/3. The following chart will help you select the appropriate example for your measurement based on the drift characteristics of the source you are measuring.

If Source Drift is ³ :	Then Select:
$< 10 \text{ E} - 9 \times v_0$ ¹	8662/3 USING EFC
$< 1 \text{ E} - 6 \times v_0$	8662/3 AND 10 MHZ A
$< 5 \text{ E} - 6 \times v_0$	8662/3 AND 10 MHZ B ²
$> 5 \text{ E} - 6 \times v_0$	8662/3 USING DCFM
¹ v_0 = center frequency of source-under-test (Hz). ² Use for measuring carrier frequencies ≤ 500 MHz. ³ Source Drift is determined over the time period required to make the measurement. The measurement time is determined by the measured offset range and the number of averages per measurement span.	

4. Select the file that matches your drift characteristics and press **Enter**. The required measurement definition parameters for this example have been prestored in this file.
5. Press the **Esc** key to return to the Main Menu. (Tables 3-7, 3-8, 3-9, and 3-10, list the parameter data that is entered for each RF Synthesizer example.) Note that the source parameter values entered for step 2 on the tables may not be appropriate for the measurement you wish to make.

6. To change the source parameter values, select the **Parameters** function from the Main Menu.
- Enter the carrier (center) frequency at which you wish to measure your synthesizer (5 MHz to 1.6 GHz). Enter the same frequency for the Detector Input Frequency.
 - Enter the VCO Tuning Constant.
 - If you are going to use DC FM tuning, enter an FM deviation setting that will provide the System with an adequate Drift Tracking Range for the measurement.
 - If you are going to use either of the 10 MHz sources to tune the HP 8662/3, or if you are going to use EFC tuning, use the following equation to calculate the appropriate VCO Tuning Constant to enter for the measurement.

$$VCO \text{ Tuning Constant} = T \times \text{Carrier Frequency}$$

Where T =

5 E - 9 for EFC

1 E - 6 for 10 MHz A

10 E - 6 for 10 MHz B

For example, to calculate the Tuning Constant value to enter for EFC tuning when the center frequency is 300 MHz:

$$(5E - 9) \times (300E + 6) = (1500E - 3) = 1.5$$

- e. Enter the Tune Range of VCO. (If you are going to use DC FM or EFC tuning, the appropriate voltage Tuning Range was entered from the example test file. Proceed to step 10.)
- f. If you are going to use either of the 10 MHz sources to tune the HP 8662/3, use the following equation to calculate the appropriate Voltage Tuning Range to enter for the measurement.

$$\text{VCO Tune Range} = V \div \text{Carrier Frequency}$$

Where V =

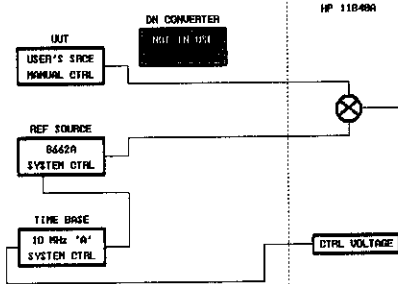
10 E + 9 for 10 MHz A

1 E + 9 * for 10 MHz B

* 2.5V is the maximum Tune Range of VCO value that should be entered for 10 MHz B. Refer to the HP 3048A Option 301 Reference Manual for BW limitations when tuning the HP 8662A/63A 10 MHz External Reference.

- 7. When you have completed these operations, press **Esc** to return to the Main Menu.

**Table 3-7. Parameter Data for the RF Synthesizer
(HP 8662/3 And 10 MHz A) Measurement Example**

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	500 E + 6 Hz 500 E + 6 Hz 500 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	RF SYNTHESIZER VS HP 8662/3A AND 10 MHZ A. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

**Table 3-8. Parameter Data for the RF Synthesizer
(HP 8662/3 And 10 MHz B) Measurement Example**

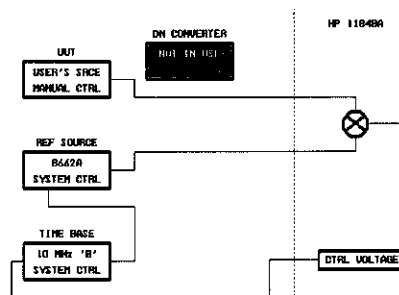
Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	500 E + 6 Hz 500 E + 6 Hz 5 E + 3 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	RF SYNTHESIZER VS HP 8662/3A AND 10 MHz B. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Table 3-9. Parameter Data for the RF Synthesizer (HP 8662/3 DC FM) Measurement Example

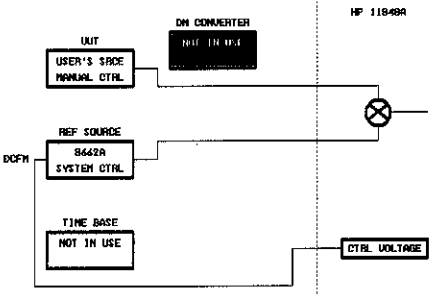
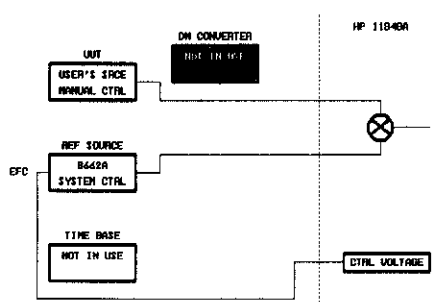
Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	500 E + 6 Hz 500 E + 6 Hz 25 E + 3 Hz/V 0 Volts ±10 Volts 600 ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Use the computed VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	RF SYNTHESIZER VS HP 8662/3A USING DC FM. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Table 3-10. Parameter Data for the RF Synthesizer (HP 8662/3 EFC) Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	500 E + 6 Hz 500 E + 6 Hz 2.5 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	RF SYNTHESIZER VS HP 8662/3A USING EFC. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select **New Measurement** from the Main Menu, and press **Y** to proceed.

The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about adding or changing an instrument in the System Configuration - Instrument Addresses table.)

2. When the Connect Diagram is displayed, connect the signal paths as shown. (Figure 3-15 shows the rear-panel External Timebase Input for connecting a 10 MHz source.) Table 3-11 provides setup considerations that will help you ensure that your measurement results will be valid.

Note

Although not shown in the connect diagram, the rear-panel cable connection described in Appendix A (SOURCE OUT to NOISE INPUT) is required. Also, the 50 Ω load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

Note

If you are using the 10 MHz A Source to tune the HP 8662/3, use the rear-panel 10 MHz A OUTPUT port on the HP 11848A rather than the front-panel connection shown in the Connect Diagram. (The output level of the front-panel port exceeds the input requirements of the External Timebase Input on the HP 8662/3.)

If you are using EFC tuning on the rear-panel of the HP 8662/3, note that the TUNE VOLTAGE OUTPUT is also available on the rear-panel of the HP 11848A.

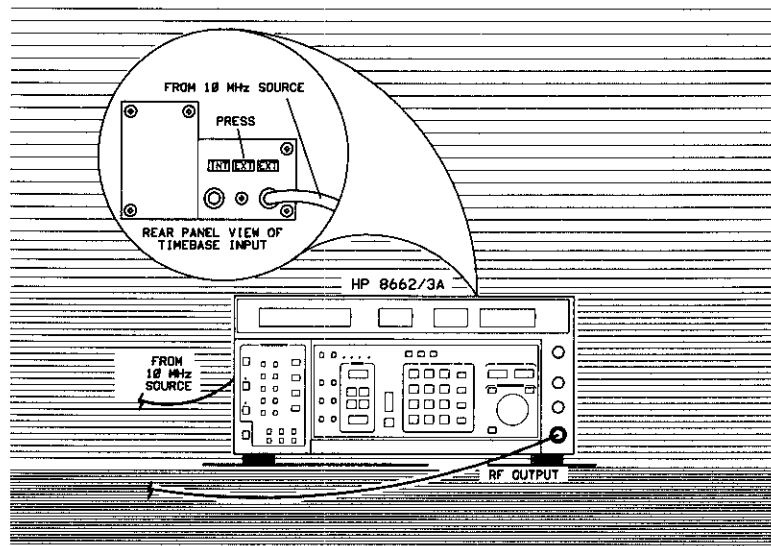


Figure 3-15. 10 MHz External Timebase Input on HP 8662/3.

Table 3-11. Setup Considerations for the RF Synthesizer Measurement Example.

Setup Considerations	Comments
Measurement Noise Floor	The signal amplitude at the R input port on the HP 11848A sets the measurement noise floor level. Use the following graph to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your UUT will provide.) L PORT LEVEL +15dBm R PORT SIGNAL LEVEL (dBm) EXPECTED PHASE NOISE FLOOR OF DUT (dBc/Hz) $f \geq 10\text{kHz}$ If the output amplitude of your UUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the UUT and the HP 11848A input. (Refer to <i>Inserting a Device</i> in the <i>Problem Solving</i> section of this chapter for details on determining the effect that the amplifier's noise will have on the measured noise floor.)
HP 8662A or HP 8663A VCO Reference	This setup uses the HP 8662/3A as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the UUT, the noise level of the reference source should be below the expected noise level of your UUT. If you have an idea of the expected level of your device, you may want to compare it to the noise characteristics graph shown for the HP 8662/3A in the <i>HP 3048A Option 301 Reference Manual</i>.

Checking the Beatnote

While the hardware Connect Diagram is being displayed, we recommend that you check the beatnote being created between the HP 8662/3A and your unit-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system. For this measurement setup, the phase lock loop (PLL) Capture Range is 10% of the Peak Tuning Range. (The Peak Tuning Range for this measurement can be estimated by multiplying the VCO Tuning Constant entered by the Tune Range of VCO (10V). Refer to *Chapter 2* if you are not familiar with the relationship between the PLL Capture Range and the Peak Tuning Range of the VCO.)

Note

If the center frequencies of the sources are not close enough to create a beatnote within the Capture Range, the System will not be able to complete its measurement.

If the beatnote frequency is below 100 kHz, it should now appear on the HP 3561A. The HP 3561A is configured to display the beatnote signal in both the frequency domain and the time domain. If the beatnote does not appear on the HP 3561A, then the beatnote is either greater than 100 kHz or it does not exist.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz. You may have to look carefully at the HP 3561A's display to see a beatnote close to 0 Hz.

On the other hand, less accurate sources may create a beatnote greater than 100 kHz. Searching for the beatnote will require that you adjust the center frequency of the HP 8662/3A above and below the frequency of the UUT until the beatnote appears on the HP 3561A's display (beatnote < 100 kHz).

If incrementing the frequency of the HP 8662/3A does not produce a beatnote within 100 kHz, you will need to verify the presence of an output signal from each source before proceeding.

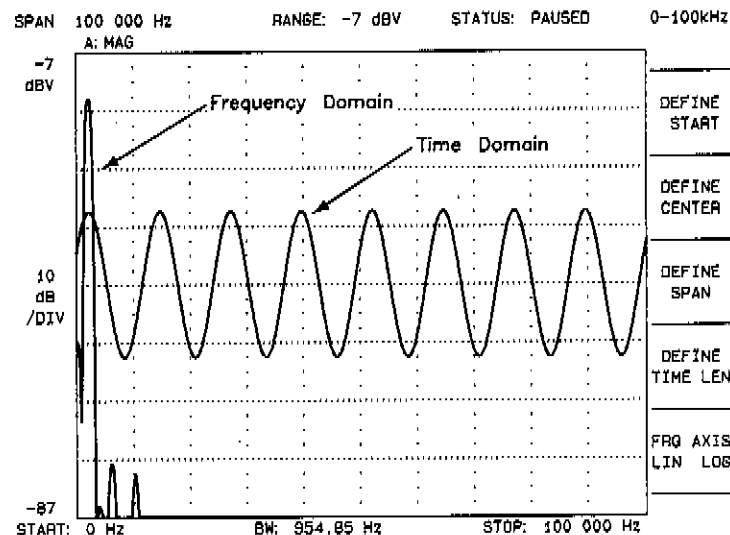


Figure 3-16. The Beatnote is Displayed in Both the Frequency and Time Domain by the HP 3561A

1. Estimate the system's Capture Range (using the VCO source parameter values entered for this measurement):

$$\text{Capture Range (Hz)} = \frac{\text{VCO Tuning Constant (Hz/V)} \times \text{VCO Tuning Range (V)}}{10}$$

$$\text{Capture Range (Hz)} = \frac{\text{ (Hz/V)} \times \text{ (V)}}{10} = \text{ } \text{ Hz}$$

2. As you observe the beatnote on the HP 3561A in the frequency domain, reduce the beatnote until it is to the left of the first major graticule on the screen. Adjust the beatnote by incrementing the center frequency of the HP 8662/3A in 10 kHz steps or less.
3. Continue reducing the beatnote frequency until the time domain display shows less than one full cycle across the screen.

4. Decrement the HP 3561A's span width when the time domain display on the HP 3561A is showing less than one full cycle. The span width is changed using the computer's Δ ∇ keys. If an RF Analyzer is used, its span width is adjusted using the $\triangleleft$ $\triangleright$ keys.
5. Reduce the beatnote frequency again until the time domain display is showing less than one full cycle across the new span width.
6. Continue decrementing the HP 3561A's span and reducing the beatnote frequency until the beatnote is within the Capture Range determined in step 1 of this procedure. The following chart will help you select the best span width for viewing the beatnote within the Capture Range.

Note

If you are not able to tune the beatnote to within the Capture Range due to frequency drift, refer to *Increasing a Synthesizer's PTR* in the *Problem Solving* section of this chapter for information about measuring drifting signals.

Span Width Setting	Frequency of Each Cycle	HP 3561A Time Record
100 kHz	250 Hz	4 msec
10 kHz	25 Hz	40 msec
1 kHz	2.5 Hz	400 msec
100 Hz	.25 Hz	4 sec
10 Hz	0.025 Hz	40 sec
4 Hz	0.01 Hz	100 sec

Span Width Setting

When viewing the frequency domain display, keep in mind that the first major graticule on the HP 3561A's screen represents 10% of the span width.

Frequency of Each Cycle

When viewing the time domain display, you can determine the frequency of the beatnote by multiplying the number of cycles appearing across the HP 3561A's screen by the appropriate Frequency of Each Cycle value from the chart.

For example, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

$$\text{Number of Cycles} \times \text{Frequency of Each Cycle} = \text{Beatnote Frequency}$$

$$2 \text{ cycles} \times 2.5 \text{ Hz} = 5 \text{ Hz}$$

HP 3561A Time Record

Note that the higher the span width setting that you are using, the faster the HP 3561A will respond to the beatnote frequency changes you make.

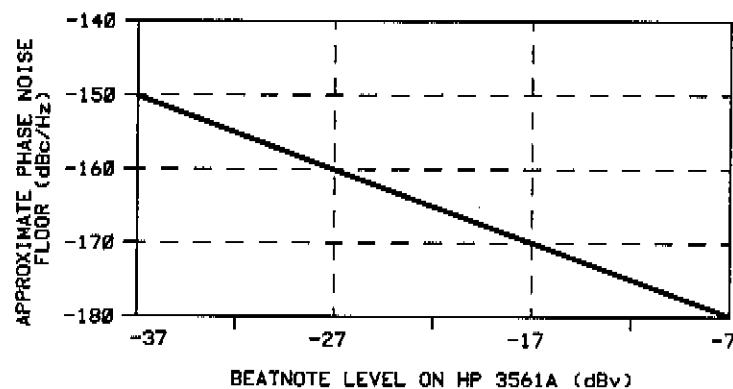


Figure 3-17. The Measurement Noise Floor Can Be Estimated From the Level of the Beatnote.

7. As you observe the beatnote, compare its level to the above chart to determine the approximate measurement noise floor for the measurement. If the beatnote level will not provide an adequate measurement noise floor to measure your device, increase the signal level at the R input port of the HP 11848A.

Making the Measurement

1. Press **F1** to proceed when you have completed the beatnote check and are ready to make the measurement.

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by placing a message on its display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.)

Figure 3-18 shows a typical phase noise curve for an RF Synthesizer.

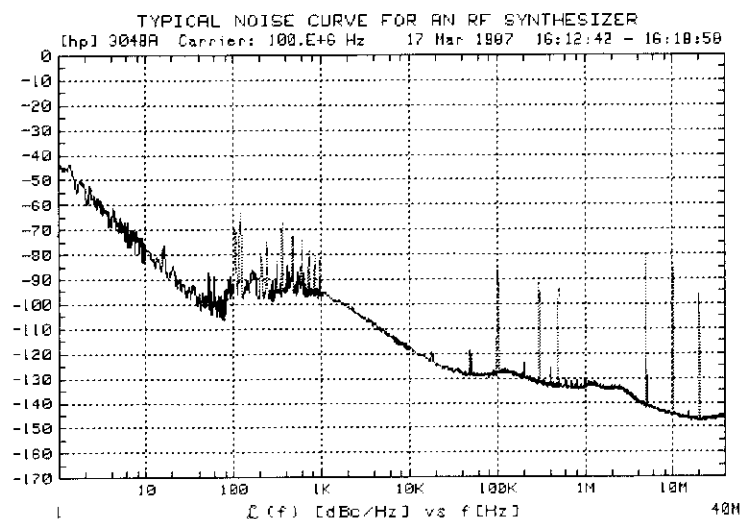


Figure 3-18. Typical Phase Noise Curve for an RF Synthesizer.

Microwave Source

This measurement example will help you measure the absolute phase noise of a microwave source (2.5 to 18 GHz) with frequency drift of $\leq 10\text{E} - 9 \times \text{Carrier Frequency}$ over a period of thirty minutes.

Required Equipment

The following equipment is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

Equipment	Qty.	Comments
HP 8662/3A	1	Must have an EFC Input Port. Must be entered in Instrument Addresses table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for procedure.
HP 11729C	1	Must be entered in System Configuration Table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for procedure.
Coax Cables	1	And adequate adapters to connect UUT to HP 11729C.

Defining the Measurement

1. Before you define the measurement parameters for your microwave measurement, you need to add the HP 11729C and HP 8662/3A to the System Configuration - Instrument Addresses table. (Refer to Appendix A for details on adding instruments to the table.) After you add the HP 11729C to the table, access the System Configuration - 11729C Filter Specs table to verify that the list of harmonic filters that appears on the display matches the filters in the HP 11729C that you are using.
2. After the HP 11729C and HP 8662/3A have been added to the Instrument Address table, select the **File System** function from the Main Menu.
3. Select the **Load File** function and enter *.PRM for the path information. Select the file titled MICROWAVE SOURCE VS HP 8662A AND HP 11729C and press **Enter**. The appropriate measurement definition parameters for this example have been prestored in this file. (Table 3-12 lists the parameter data that has been entered for this measurement example.) Note that the source parameters entered for step 2 on the table may not be the appropriate values for measuring your device.
4. After the system has completed the file loading sequence, press the **Esc** key to return to the Main Menu.

5. To change the source parameter values, select the **Parameters** function from the Main Menu.
 - a. Enter the carrier (center) frequency of your UUT. The System will calculate the correct Detector/Disc. Input Frequency for the measurement.
 - b. Enter the VCO Tuning Constant. Use the following formula to determine the appropriate value to enter for the HP 8662/3A.

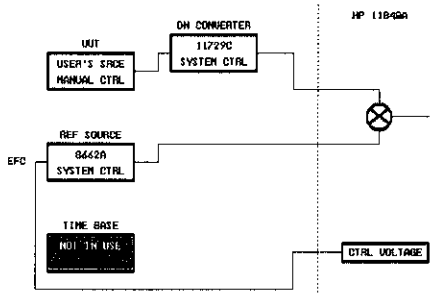
$$VCO \text{ Tuning Constant} = 5E - 9 \times \text{Carrier Frequency}$$

For example, to calculate the VCO Tuning Range for 18 GHz:

$$(5E - 9) \times (18E + 9) = 90$$

6. When you have completed these operations, press **Esc** to return to the Main Menu.

Table 3-12. Parameter Data for the Microwave Source Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance Internal Phase Detector	12 E + 9 Hz 160 E + 6 Hz 60 Hz/V 0 Volts ± 10 Volts 1M ohms 5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control  Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	MICROWAVE SOURCE VS HP 8662A AND HP 11729C. 1 Hz 100 kHz -170 0 Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select **New Measurement** from the Main Menu, and press **Y** to proceed.

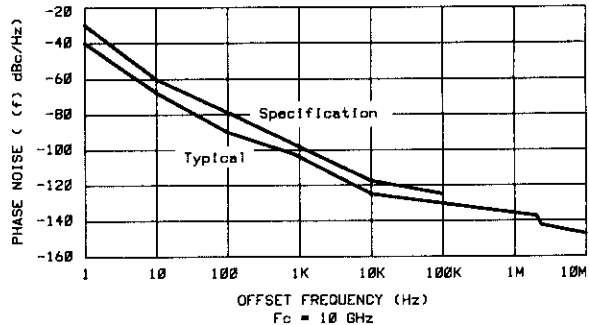
The System now addresses each of the instruments listed in the Instrument Address table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about changing or verifying an HP-IB address in the System Configuration - Instrument Address table.)

2. When the Connect Diagram appears on the display, connect the signal paths as shown. (Figure 3-19 also shows the cable connections for this measurement.) Table 3-13 provides setup considerations that will help you ensure that your measurement results are valid.

Note

Although not shown in the Connect Diagram, the rear-panel cable connection described in Appendix A (SOURCE OUT to NOISE INPUT) is required. Also, the 50 Ω load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

Table 3-13. Setup Considerations for the Microwave Source Measurement Example.

Setup Considerations	Comments
Measurement Noise Floor	The following noise characteristics graph shows a typical noise level for the HP 11729C when used with the HP 8662/3A. Use it to help you estimate if the measurement noise floor that it provides is below the expected noise level of your UUT. 
HP 11729C	The following performance characteristics of the HP 11729C should be considered when setting up your measurement. RF Frequency: • Unable to measure carrier frequencies within 5 MHz of comb lines. Noise: • Has an inherent noise rise near 40 MHz. • IF amplifier limits noise floor below 1280 MHz. Spurs: • Produces down conversion spurs (center frequency of band mixing with carrier frequency). • May have spurs at 10, 20, 30, and 40 MHz offsets when used with HP 8662/3A. • A harmonic of 640 MHz may mix with the carrier frequency to produce spurs on either side of the band center frequency.

Checking the Beatnote

While the hardware Connect Diagram is being displayed, we recommend that you check the beatnote being created between the HP 8662/3A and the down converted signal from your unit-under-test. The objective is to ensure that the center frequencies of the two input signals are close enough in frequency to create a beatnote that is within the capture range of the system. For this measurement setup, the phase lock loop (PLL) Capture Range is 10% of the Peak Tuning Range set for this measurement. (The Peak Tuning Range for this measurement can be estimated by multiplying the VCO Tuning Constant entered by the Tune Range of VCO (10V). Refer to *Chapter 2* if you are not familiar with the relationship between the Capture Range and the Peak Tuning Range of the VCO.)

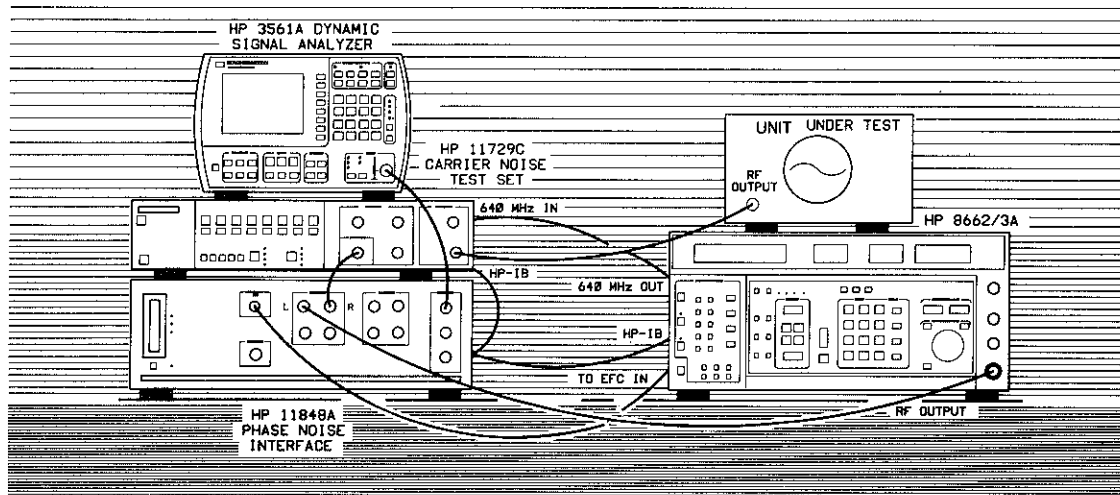


Figure 3-19. Setup Diagram for Microwave Source Measurement Example.

Note

If the input frequencies are not close enough to create a beatnote within the Capture Range, the System will not be able to complete its measurement.

If the beatnote frequency is below 100 kHz it should now appear on the HP 3561A. The HP 3561A is configured to display the beatnote signal in both the frequency domain and the time domain. If the beatnote does not appear on the HP 3561A, then the beatnote is either greater than 100 kHz or it does not exist.

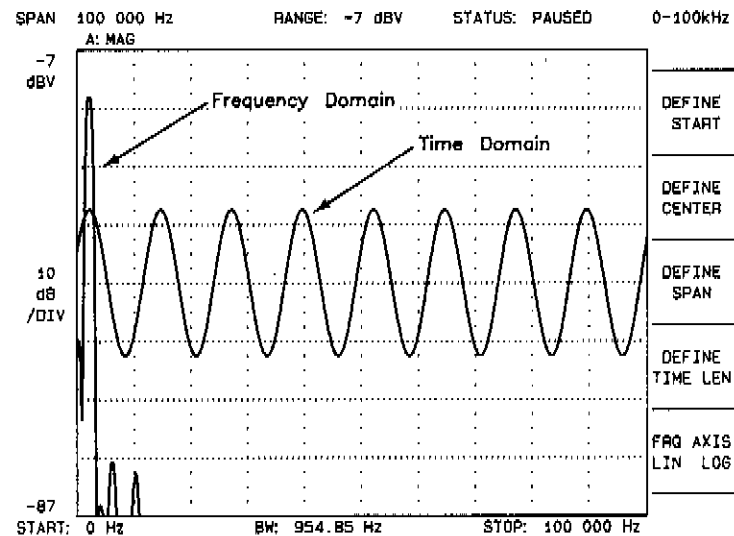


Figure 3-20. The Beatnote is Displayed in Both the Frequency and Time Domain by the HP 3561A

The beatnote frequency is set by the relative frequency difference between the two input signals. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz. You may have to look carefully at the HP 3561A's display to see a beatnote close to 0 Hz.

On the other hand, less accurate sources may create a beatnote greater than 100 kHz. Searching for the beatnote will require that you adjust the center frequency of the HP 8662/3A above and below the frequency of the IF signal from the HP 11729C until the beatnote appears on the HP 3561A's display (beatnote < 100 kHz).

If incrementing the HP 8662/3A frequency does not produce a beatnote within 100 kHz, you will need to verify the presence of an output signal from each source before proceeding.

1. Estimate the system's Capture Range (using the VCO source parameter values entered for this measurement):

$$\text{Capture Range (Hz)} = \frac{\text{VCO Tuning Constant (Hz/V)} \times \text{VCO Tuning Range (V)}}{10}$$

$$\text{Capture Range (Hz)} = \frac{\text{ (Hz/V)} \times \text{ (V)}}{10} = \text{ Hz}$$

Table 3-26. Reference Messages (4 of 7)

9 (cont'd)	Action: Press P to cause the test system to attempt to relock the loop and re-measure the frequency segment. If the software is unable to relock the loop, Error 4 will be displayed, refer to Error 4 for recommended actions. (Note that this error is most typically caused by frequency drift of one of the sources. If this condition persists, it may be necessary to increase the Peak Tuning Range for the measurement.)
10	The LNA of the HP 11848A is currently IN/OUT. This message only appears if the Carrier Type "Pulsed" has been selected. The HP 3048A evaluates the total noise from the Phase Detector to determine whether the Low-Noise-Amplifier (LNA) should be switched IN or OUT. The LNA is normally switched in to provide the maximum measurement sensitivity for the test system. If the HP 3048A determines that the noise level from the Phase Detector will overload the LNA, the LNA is switched out. When the LNA is switched out, the test system's measurement sensitivity is degraded by 20 to 30 dB depending on the offset frequency. If you are measuring a device that has a very low noise level (near the test system's noise floor) this degradation may affect the measurement results. Action: Under most condition it is recommended that you proceed with the decision made by the HP 3048A. Toggling the LNA IN when the HP 3048A has determined it should be switched OUT can cause the noise from the Phase Detector to be compressed and the measurement results to be inaccurate. There are certain conditions when you may want to toggle the LNA OUT, however. 1. When Pulse Mode is enabled. If the Phase Detector dc offset is > 5 mVdc, the test system may not detect that the noise level is high enough to overload the LNA. 2. To duplicate the exact conditions that existed for a previous measurement where the LNA was switched out. 3. When you are performing the System Noise Floor Test and you want to evaluate the test system's noise floor without the LNA in the measurement path. If the HP 3048A has decided to switch OUT the LNA and you are concerned about measurement sensitivity, you may want to further evaluate the decision. Connect an oscilloscope to the AUX Monitor Port on the HP 11848A. Observe the LNA output and toggle the LNA IN. If the peak output level exceeds $-0.5V$ or $+1V$, the noise may be clipped or compressed so the measurements must be made with the LNA OUT. If the noise is not significantly clipped, the measurement may be made with the LNA IN.

Span Width Setting	Frequency of Each Cycle	HP 3561A Time Record
100 kHz	250 Hz	4 msec
10 kHz	25 Hz	40 msec
1 kHz	2.5 Hz	400 msec
100 Hz	.25 Hz	4 sec
10 Hz	0.025 Hz	40 sec
4 Hz	0.01 Hz	100 sec

Span Width Setting

When viewing the frequency domain display, keep in mind that the first major graticule on the HP 3561A's screen represents 10% of the span width.

Frequency of Each Cycle

When viewing the time domain display, you can determine the frequency of the beatnote by multiplying the number of cycles appearing across the HP 3561A's screen by the appropriate Frequency of Each Cycle value from the chart.

For example, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

$$\text{Number of Cycles} \times \text{Frequency of Each Cycle} = \text{Beatnote Frequency}$$

$$2 \text{ cycles} \times 2.5 \text{ Hz} = 5 \text{ Hz}$$

HP 3561A Time Record

Note that the higher the span width setting that you are using, the faster the HP 3561A will respond to the beatnote frequency changes you make.

Making the Measurement

1. Press **F1** to proceed with the measurement when you have completed the beatnote check.

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by placing a message in its display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.)

Figure 3-21 shows a typical phase noise curve for a Microwave Source.

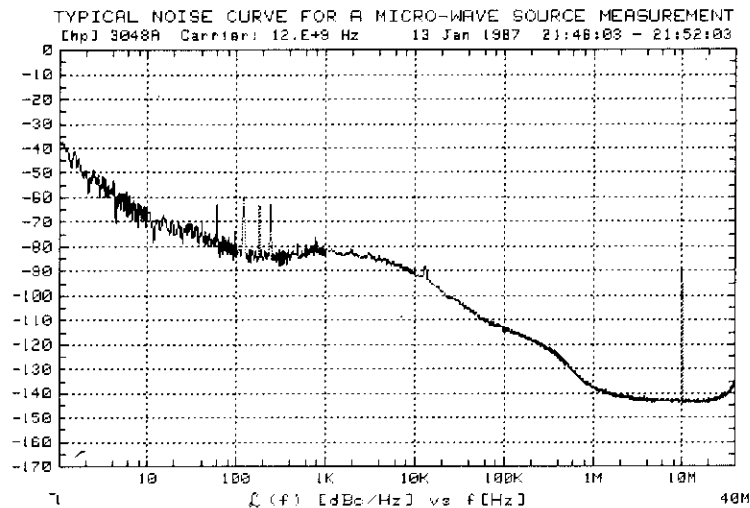


Figure 3-21. Typical Phase Noise Curve for a Microwave Source.

Designing a Measurement

Setting up a Phase Noise Measurement using the Phase Lock Loop technique requires completion of the following steps:

- A. Determine the Equipment Requirements
- B. Define the Measurement Parameters
- C. Set up the Hardware
- D. Evaluate the Beatnote
- E. Run the Measurement

Note

To configure a phase noise measurement effectively, you should have a fundamental understanding of the measurement technique and signal sources you are using. Insight into the Phase Lock Loop measurement technique used in this example is provided in Chapter 2.

Required Equipment

The following equipment is required for this example in addition to the HP 3048A system and your unit-under-test.

- ♦ Reference Source with better phase noise performance than the UUT.
- ♦ Various cables

Table 3-14. describes the operating requirements for the required equipment.

Table 3-14. Equipment Requirement for the Phase Lock Loop Measurement (1 of 3)

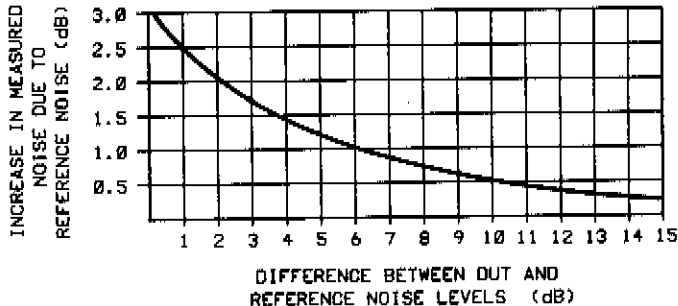
Equipment	Qty	Comments
Reference Source	1	In order for your noise measurement results to accurately represent the noise of your UUT, the noise level of the reference source should be below the expected noise level of the UUT. The following graph shows how the measured noise level is increased as the reference source noise level approaches the noise level of the UUT.  (If you need further information about selecting a reference source, refer to <i>Selecting a Reference</i> in the <i>Problem Solving</i> section of this chapter.) If you are using one of the Hewlett-Packard signal generators that is supported by the HP 3048A and you want it to be under system control, the signal generator's HP-IB address must be entered in the Instrument Addresses table. (Refer to <i>Setting Up the HP-IB Addresses</i> in Appendix A for the procedure.)

Table 3-14. Equipment Requirement for the Phase Lock Loop Measurement (2 of 3)

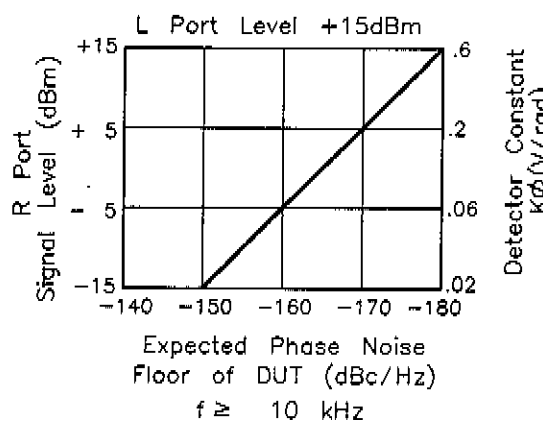
Equipment	Qty	Comments
HP 11848A Interface	1	The measurement noise floor level is set by the signal amplitude at the R input port on the HP 11848A. Use the following graph to determine the amplitude required to provide a noise floor level that is below the expected noise floor of your UUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the actual measurement noise floor that the source you have connected to the R input port will provide.)  L Port Level +15dBm Expected Phase Noise Floor of DUT (dBc/Hz) $f \geq 10 \text{ kHz}$ If the output of your source is not sufficient to provide an adequate measurement noise floor, it may be necessary to insert a low noise amplifier between the source and the HP 11848A input. (For details on determining the effect that the amplifier's noise will have on the measured noise floor, refer to <i>Inserting a Device</i> in the <i>Problem Solving</i> section of this chapter.)
RF Coax Cables	3	And adequate adapters to connect to sources.
HP-IB Cable	1	If the unit-under-test has HP-IB capability, and you wish for the HP 3048A to set its frequency and amplitude for the measurement, you will need to connect an HP-IB cable between the computer's GPIB card and the UUT.

Table 3-14. Equipment Requirement for the Phase Lock Loop Measurement (3 of 3)

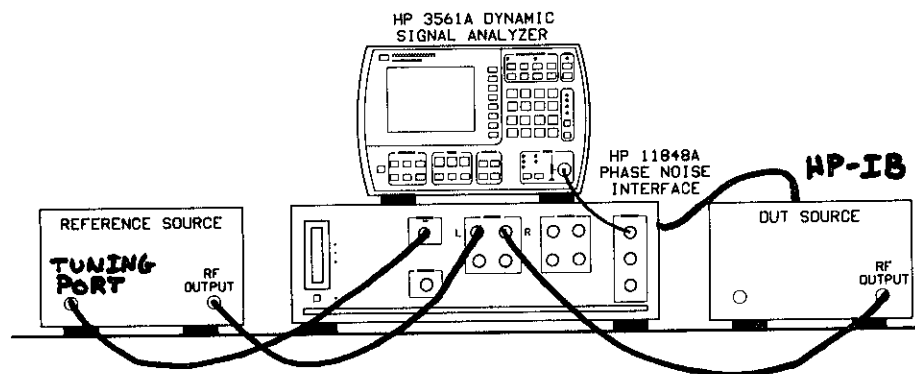
Equipment	Qty	Comments
Voltage-Controlled-Oscillator (VCO) Source	1	The VCO source can be either the unit-under-test or the reference source. To configure this phase noise measurement, you will need to know the following information about the VCO source you are using: • Tuning Constant (Hz/V) (within a factor of 2) • Tuning Voltage Range (V) • Center Voltage of Tuning Range (V) • Input Resistance of Tuning Port (ohms) The primary consideration when evaluating a potential VCO source for your measurement is whether it will provide the system with sufficient Capture and Drift Tracking Ranges to maintain lock throughout the measurement. To make this determination, you must <i>estimate</i> what the drift range of the sources you are using will be over the measurement period (thirty minutes maximum). (Details on the relationship between the Capture and Drift Tracking Ranges and the tuning range of the VCO source are provided in <i>Chapter 2</i>. This information will help you evaluate your VCO source based on the estimated drift of your sources.)

Defining the Measurement

Before you begin entering the measurement parameters into the System, it is a good idea to design your measurement setup on paper first. Drawing a setup diagram will help you identify the equipment and accessories you will need. It is also helpful to list the tuning parameters for the VCO source you will be using. (Table 3-15 in this example lists the tuning parameters for several VCO source options.)

The following *worksheet* shows an example of the design parameters required for a possible Phase Lock Loop measurement. (Additional, blank *worksheets* are provided at the end of this example for you to use for planning your measurement.)

Example Worksheet



Diagram

1. Draw lines to show cable connections.
2. If you wish to have the System control your unit-under-test, list the required command codes below for addressing your UUT and for setting its frequency and amplitude. (See appendix A, *Instrument Addresses Table* for more information.)

UUT Setup Information: **SIGNAL SRCE1, USERS, 719, FR16Z; AP16DM**

VCO Source

1. Enter the tuning characteristics for the VCO you are using in the spaces below. (Table 3-15 provides the tuning characteristics for several VCO source options.)

Tuning Constant (sensitivity)	<u>100</u>	Hz/V
Center Voltage of Tuning Range	<u>0</u>	V
VCO Tuning Voltage Range	$\pm$ <u>10</u>	V
Input Resistance of Tuning Port	<u>1E+6</u>	Ohms

Reference Source

1. Obtain a plot of phase noise and spur characteristics if available.

Table 3-15. Tuning Characteristics of Various VCO Source Options

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range ($\pm V$)	Input Resistance (ohms)	Tuning Calibration Method
HP 8662/3A EFC DCFM	v_o	$5 E - 9 \times v_o$ FM Deviation	0 0	10 10	$1 E + 6$ 1k (8662) 600 (8663)	Measure Compute Compute
HP 8642A/B		FM Deviation	0	10	600	Compute
HP 8640B		FM Deviation	0	10	600	Compute
HP 8656B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for $\pm 1V$		FM Deviation	0	10	R_{in}	Compute
10 MHz Source A Direct Multiplied As a Timebase: To HP 8662/3A To other VCO (PTR known)	v_o v_o v_o v_o	10 $1 E - 6 \times v_o$ $1 E - 6 \times v_o$ $1 E - 6 \times v_o$	0 0 0 0	10 10 $10 E + 9 \div v_o$ $1 E + 6 \times PTR \div v_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
10 MHz Source B Direct Multiplied As a Timebase: To HP 8662/3A To other VCO (PTR known)	v_o v_o v_o v_o	100 $10 E - 6 \times v_o$ $10 E - 6 \times v_o$ $10 E - 6 \times v_o$	0 0 0 0	10 10 $1 E + 9 \div v_o$, (up to 2.5V max.) $100 E + 3 \times PTR \div v_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
350-500 MHz Source		$12 E + 6$	0	2	$1 E + 6$	Measure
Other User VCO Source		Estimated within a factor of 2	-10 to +10	See Figure 3-23	$1 E + 6$	Measure

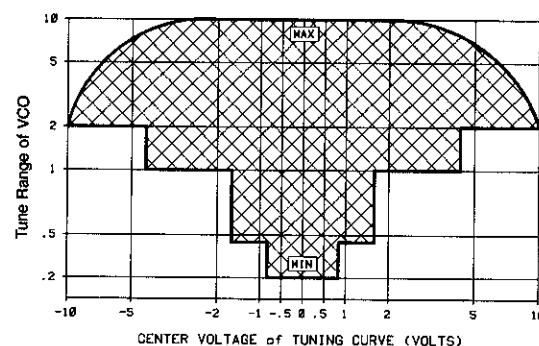


Figure 3-23. HP 3048A Voltage Tuning Range Limits Relative to Center Voltage of the VCO Tuning Curve.

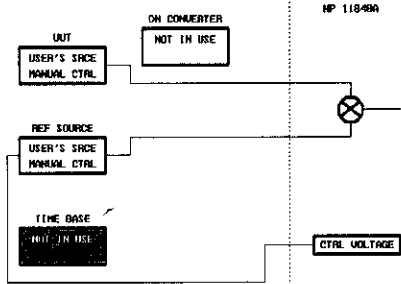
1. After you have completed your worksheet, select the **File System** function from the Main Menu.
2. Select the **Load File** function, and enter *.PRM for the path information.
3. Select the file titled SOURCE-UNDER-TEST VS REFERENCE SOURCE and press **Enter** . Many of the measurement definition parameters required for this measurement technique have been prestored in this file.
4. After the system has completed the file loading sequence, press the **Esc** key to return to the Main Menu. Table 3-16 lists the parameter data that has been loaded from the file.

Note

The Source Parameters Calibration Methods, and Source Control Diagram loaded from the example file may not be appropriate for your measurement setup. The following steps will help you enter the appropriate parameters for your measurements.

5. Select the **Parameters** function from the Main Menu.
 - a. Enter the Carrier (center) Frequency of your UUT (5 MHz to 1.6 GHz).
 - b. Enter the same frequency for the Detector Input Frequency.

Table 3-16. Parameter Data for the Designing a Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Tune Range of VCO VCO Tune-Port Input Resistance	500 E + 6 Hz 500 E + 6 Hz 100 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms
	Internal Phase Detector	5 MHz to 1600 MHz
3	Calibration Technique Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	Instrument Control	 Note: This example uses manual UUT control. For system UUT control, you must enter the necessary setup information in the <i>Instrument Addresses Table</i>. Refer to appendix A for more information regarding this procedure.
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	SOURCE-UNDER-TEST VS REFERENCE SOURCE. 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

6. Enter the tuning characteristics for the VCO source you are using. Table 3-15 lists the tuning parameters for several VCO source options.

Note

If you do not know the exact Tuning Constant for your VCO source, an estimate that is within a factor of 2 is close enough as long as you have the System measure the exact value for you before it makes its measurement. If you estimate the Tuning Constant, enter the VCO Input Resistance as $1 \text{ E} + 6$. If you do know the exact Tuning Constant, enter it and enter the actual input resistance of your VCO.

7. Press **Esc** when you have completed these operations.
8. In Table 3-15, note the column labeled "Tuning Calibration Method". If "Compute" appears in this column for the VCO source you are using, select the **Calibration Technique** function from the Main Menu, and change the calibration method for determining the VCO Tuning Constant to "Calculate from Expected Tune Constant." Press **Esc** when you have completed this operation.
9. Select the **Instrument Control** function from the Main Menu to define your instrument setup.

10. Use the first letter in the title of each functional block to configure the diagram to match the test setup you have planned for your measurement. (For example, to alter the UUT type, press the **U** key). The purpose of this block diagram is to tell the System:

- What hardware you will be using.
- Which instruments will be under HP-IB system control.
- What the interconnecting signal paths will be.

11. Press **Esc** when you have completed this operation.

12. To change the graph title, select the **Define Graph** function from the Main Menu and enter the new title.

13. When you have completed the changes, press **Esc**.

Note

If you plan to use this same measurement setup again in the future, you may want to store these parameters in a Parameter file. To do this, select the **File System** function from the Main Menu and select **Store File**. Then enter a name for your new file (≤ 8 characters) and add the file extension **.PRM**. Press **Enter** to store the new file.

14. Press **Esc** to return to the Main Menu.

Beginning the Measurement

1. Select **New Measurement** from the Main Menu, and press **Y** to proceed. The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about adding or changing an HP-IB address in the System Configuration - Instrument Addresses table.)
2. When the Connect Diagram appears, connect the signal paths as shown on the display.

Note

Although not shown in the connect diagram, the rear-panel cable connection described in Appendix A (SOURCE OUT to NOISE INPUT) is required. Also, the 50 Ω load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

The System generates the Connect Diagram based on the Source Control diagram entered for this measurement. If your measurement setup requires additional equipment or connections not shown on the Connect Diagram (such as an amplifier or attenuator between the UUT and HP 11848A), you should also make these connections now even though they do not appear on the diagram.

Checking the Beatnote

While the hardware Connect Diagram is displayed, we recommend that you check the beatnote being created between the reference source and your unit-under-test. The objective of checking the beatnote is to ensure that the center frequencies of the two sources are close enough in frequency to create a beatnote that is within the Capture Range of the system.

For this measurement setup, the phase lock loop (PLL) Capture Range is 10% of the Peak Tuning Range of the VCO source you are using. (The Peak Tuning Range for your VCO can be estimated by multiplying its Tuning Constant by its Tune Range of VCO. Refer to *Chapter 2* if you are not familiar with the relationship between the PLL Capture Range and the Peak Tuning Range of the VCO.)

Note

If the center frequencies of the sources are not close enough to create a beatnote within the Capture Range, the System will not be able to complete its measurement.

If the beatnote frequency is below 100 kHz it should now appear on the HP 3561A. The HP 3561A is configured to display the beatnote signal in both the frequency domain and the time domain. If the beatnote does not appear on the HP 3561A, then the beatnote is either greater than 100 kHz or it does not exist.

The beatnote frequency is set by the relative frequency difference between the two sources. If you have two very accurate sources set at the same frequency, the resulting beatnote will be very close to 0 Hz. You may have to look carefully at the HP 3561A's display to see a beatnote close to 0 Hz.

On the other hand, less accurate sources may create a beatnote greater than 100 kHz. Searching for the beatnote will require that you adjust the center frequency of one of the sources above and below the frequency of the other source until the beatnote appears on the HP 3561A's display (beatnote < 100 kHz).

If incrementing the frequency of one of the sources does not produce a beatnote within 100 kHz, you will need to verify the presence of an output signal from each source before proceeding.

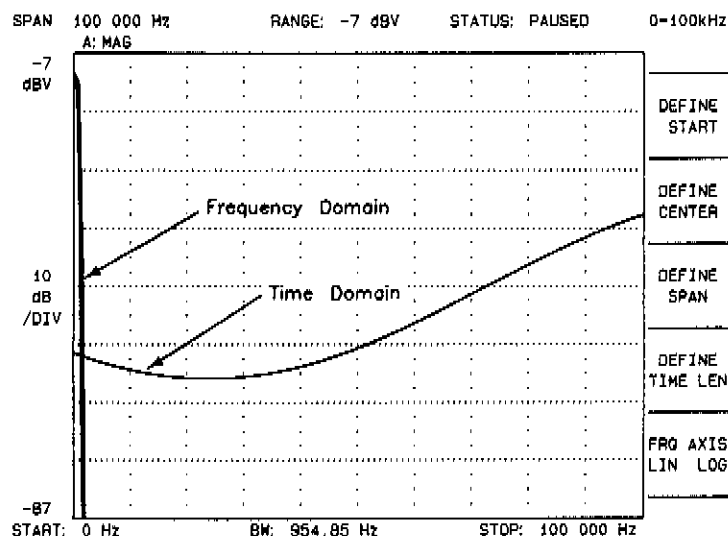


Figure 3-24. The Beatnote is Displayed in Both the Frequency and Time Domain by the HP 3561A

Note

If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to *Minimizing Injection Locking* in the *Problem Solving* section of this chapter for recommended actions.

3. Continue reducing the beatnote frequency until the time domain display shows less than one full cycle across the screen.
4. Decrement the HP 3561A's span width when the time domain display on the HP 3561A is showing less than one full cycle. The span width is changed using the computer's Δ ∇ keys. If an RF Analyzer is used, its span width is adjusted using the $\triangleleft$ $\triangleright$ keys.
5. Reduce the beatnote frequency again until the time domain display is showing less than one full cycle across the new span width.
6. Continue decrementing the HP 3561A's span and reducing the beatnote until the beatnote frequency is within the Capture Range determined in step 1 of this procedure. The following chart will help you select the best span width for viewing the beatnote within the Capture Range.

Note

If you are not able to tune the beatnote to within the PLL Capture Range due to beatnote frequency drift, refer to *Tracking Frequency Drift* in the *Problem Solving* section of this chapter for information about measuring drifting signals.

Span Width Setting	Frequency of Each Cycle	HP 3561A Time Record
0 to 100 kHz	250 Hz	4 msec
0 to 10 kHz	25 Hz	40 msec
0 to 1 kHz	2.5 Hz	400 msec
0 to 100 Hz	0.25 Hz	4 sec
0 to 10 Hz	0.025 Hz	40 sec
0 to 4 Hz	0.01 Hz	100 sec

Span Width Setting

When viewing the frequency domain display, keep in mind that the first major graticule on the HP 3561A's screen represents 10% of the span width.

Frequency of Each Cycle

When viewing the time domain display, you can determine the frequency of the beatnote by multiplying the number of cycles appearing across the HP 3561A's screen by the appropriate Frequency of Each Cycle value from the chart.

For example, to tune the beatnote to within 5 Hz, you can use the 0 to 1 kHz span by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

$$\text{Number of Cycles} \times \text{Frequency of Each Cycle} = \text{Beatnote Frequency}$$

$$2 \text{ cycles} \times 2.5 \text{ Hz} = 5 \text{ Hz}$$

HP 3561A Time Record

Note that the higher the span width setting that you are using, the faster the HP 3561A will respond to the beatnote frequency changes you make.

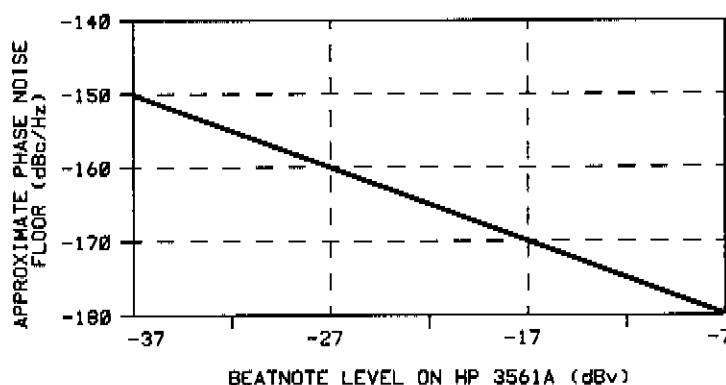


Figure 3-25. The Measurement Noise Floor Can Be Estimated From the Level of the Beatnote.

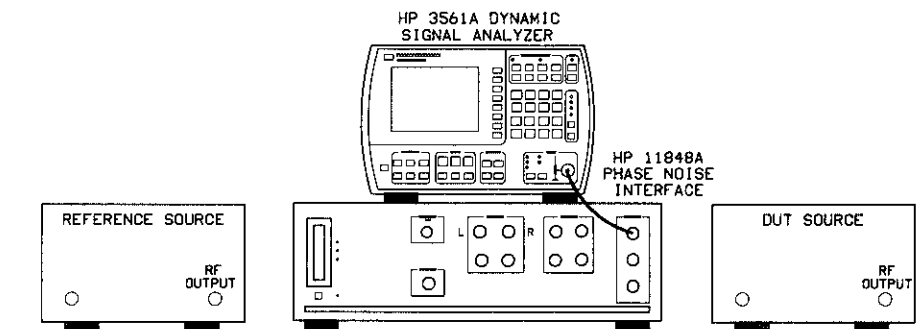
7. As you observe the beatnote, compare its level to the above chart to determine the approximate measurement noise floor for the measurement. If the beatnote level will not provide an adequate measurement noise floor to measure your device, increase the signal level at the R input port of the HP 11848A.

Making the Measurement

1. Press F1 when you have completed the beatnote check and are ready to run the measurement.

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by placing a message in its display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.)

Worksheet



Diagram

1. Draw lines to show cable connections.
2. If you wish to have the System control your unit-under-test, list the required command codes below for addressing your UUT and for setting its frequency and amplitude. (See appendix A, *Instrument Addresses Table* for more information.)

UUT Setup Information: _____

VCO Source

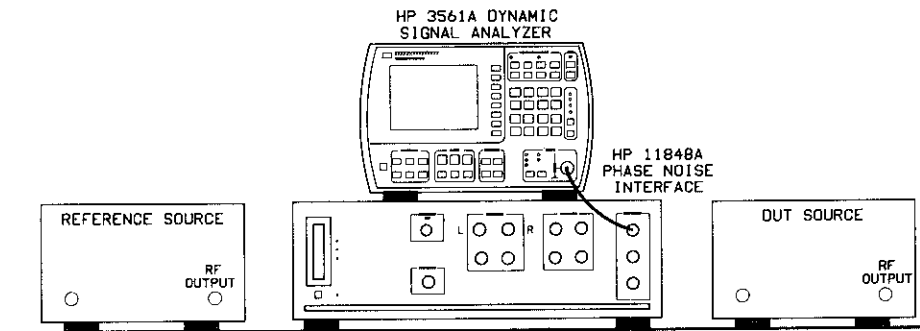
1. Enter the tuning characteristics for the VCO you are using in the spaces below. (Table 3-15 provides the tuning characteristics for several VCO source options.)

Tuning Constant (sensitivity)	_____	Hz/V
Center Voltage of Tuning Range	_____	V
VCO Tuning Voltage Range	$\pm$ _____	V
Input Resistance of Tuning Port	_____	Ohms

Reference Source

1. Obtain a plot of phase noise and spur characteristics if available.

Worksheet



Diagram

1. Draw lines to show cable connections.
2. If you wish to have the System control your unit-under-test, list the required command codes below for addressing your UUT and for setting its frequency and amplitude. (See appendix A, *Instrument Addresses Table* for more information.)

UUT Setup Information: _____

VCO Source

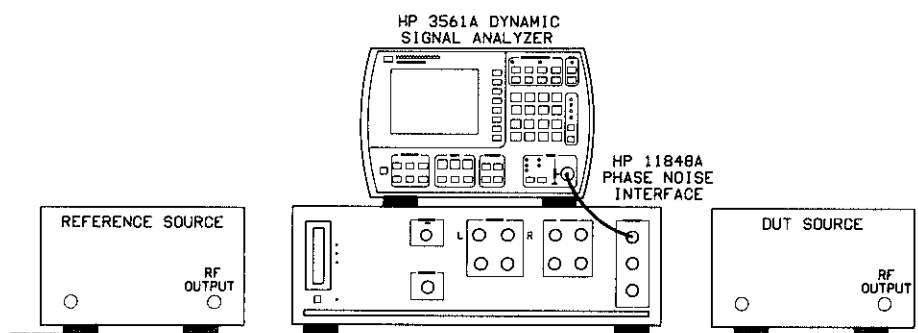
1. Enter the tuning characteristics for the VCO you are using in the spaces below. (Table 3-15 provides the tuning characteristics for several VCO source options.)

Tuning Constant (sensitivity)	_____	Hz/V
Center Voltage of Tuning Range	_____	V
VCO Tuning Voltage Range	± _____	V
Input Resistance of Tuning Port	_____	Ohms

Reference Source

1. Obtain a plot of phase noise and spur characteristics if available.

Worksheet



Diagram

1. Draw lines to show cable connections.
2. If you wish to have the System control your unit-under-test, list the required command codes below for addressing your UUT and for setting its frequency and amplitude. (See appendix A, *Instrument Addresses Table* for more information.)

UUT Setup Information: _____

VCO Source

1. Enter the tuning characteristics for the VCO you are using in the spaces below. (Table 3-15 provides the tuning characteristics for several VCO source options.)

Tuning Constant (sensitivity)	_____	Hz/V
Center Voltage of Tuning Range	_____	V
VCO Tuning Voltage Range	$\pm$ _____	V
Input Resistance of Tuning Port	_____	Ohms

Reference Source

1. Obtain a plot of phase noise and spur characteristics if available.

Discriminator Measurement

This example demonstrates the Discriminator measurement technique for measuring the phase noise of a signal source. This measurement technique works well for measuring free-running oscillators that drift over a range that exceeds the tuning range limits of the phase-locked-loop measurement technique. The Discriminator measurement is also useful for measuring sources when a VCO reference source is not available or is not able to provide adequate drift tracking. In this example, the phase noise of the HP 11848A's internal 350-500 MHz oscillator is measured.

The setup for a Discriminator measurement looks very similar to the setup used for a residual or two-port phase noise measurement. The primary difference is that the unit-under-test is a source with a single output port rather than a device with an input and output port.

In the Discriminator measurement, the source is placed ahead of the power splitter. One output of the splitter feeds a delay line with enough delay to decorrelate the source noise. The delay line generates a phase shift proportional to the frequency. The phase shift is measured in the Phase Detector by comparing the delayed output with the other output of the splitter. The output of the Phase Detector is a voltage proportional to the frequency fluctuations of the source.

Required Equipment

The equipment listed in Table 3-17 is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Table 3-17. Additional Equipment Required to Perform Measurement Example

Equipment	Qty.	Comments
Signal Generator	1	+19 dBm output level at 400 MHz, Calibrated FM at a 1 kHz rate with 10 kHz Peak Deviation.
Power Splitter	1	Use Noise Floor Test Fixture provided with system.
Delay Line	1	Delay (or length) adequate to decorrelate source noise (two 4-foot BNC cables are required for this example).

Determining the Discriminator (Delay Line) Length

Perform the following steps to determine the minimum delay line length (τ) possible to provide an adequate noise floor to measure the source.

1. Determine the delay necessary to provide a discriminator noise floor that is below the expected noise level of the UUT. Figure 3-26 shows the noise floor of the Discriminator for given delay times (τ). (The noise floor provided by 10 ns of delay is adequate for measuring the internal 350-500 MHz oscillator.)

2. Determine the length of coax required to provide the necessary delay (τ). (Eight feet of BNC cable will provide 12 ns of delay for this example.)
3. Determine the loss in the delay line. Verify that the signal source will be able to provide a power level at the output of the delay line of between +5 to +17 dBm. Be sure to take into account an additional 4 to 6 dB of loss in the power splitter. (The loss across the 8 feet of BNC cable specified for this example is negligible.)

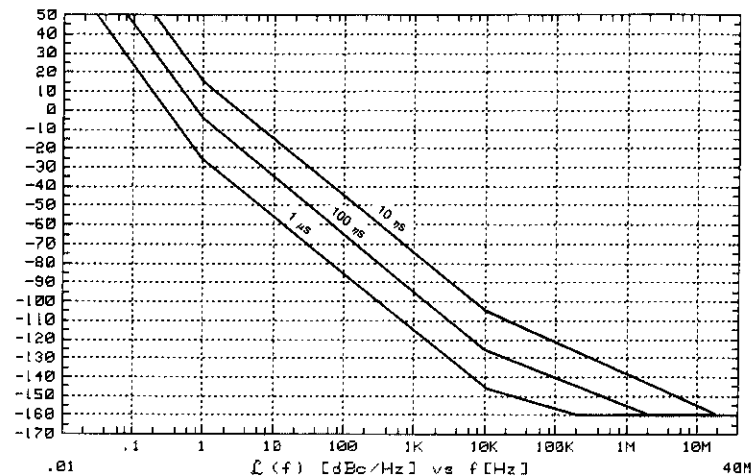


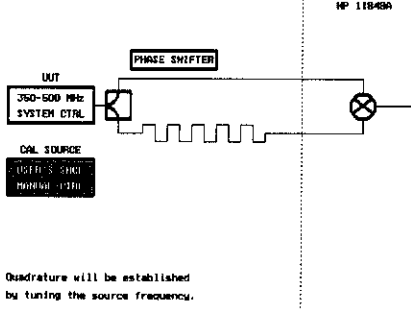
Figure 3-26. Discriminator Noise Floor as a Function of Delay Time.

Defining the Measurement

4. Select the **File System** function from the Main Menu.
5. Select **Load File** and enter **".PRM** for the path information.
6. Select the file titled **350-500 MHz VCO USING 12 NSEC DELAY LINE DISCRIMINATOR** and press **Enter**.
The appropriate measurement parameters for this example have been pre-stored in this file. (Table 3-18 lists the parameter data that has been entered for this measurement example.)
7. Press **Esc** to return to the Main Menu.

Note The stop frequency specified for this measurement example is 100 kHz so that the measurement will run on a standard HP 3048A system. If you have an RF spectrum analyzer configured in your system, you may want to change the Stop frequency to 40 MHz in the Type/Range of Measurement menu. This will allow you to measure over the entire offset range of the System.

Table 3-18. Parameter Data for the Discriminator Noise Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	Phase Noise Using an FM Discriminator 1 Hz 100 E + 3 Hz 4
2	Parameters Carrier Frequency Detector/Discr. Input Frequency Internal Phase Detector	400 E + 6 Hz 400 E + 6 Hz 5 MHz to 1600 MHz
3	Calibration Technique FM Deviation FM Rate	Derive from FM Rate and Deviation 10 E + 3 Hz 1 E + 3 Hz
4	Instrument Control  Quadrature will be established by tuning the source frequency.	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y Graph Type	350-500 MHz VCO USING 12 NSEC DELAY LINE DISCRIM 1 Hz 100 E + 3 Hz -170 0 Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select **New Measurement** from the Main Menu and press the **Y** key to proceed. The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning (the measurement cannot be continued until the problem is corrected). (Refer to Appendix A if you need information about adding or changing an instrument in the Instrument Addresses table.)
2. When the Connect Diagram appears, connect the signal paths as shown. After the connections have been made and checked, press **F1** to proceed.

The following table of setup considerations will help you ensure that your measurement results are valid.

Setup Considerations	Comments
Cable Connections	The best results will be obtained if semi-rigid coaxial cables are used to connect the components used in the measurement; however, BNC cables have been specified because they are more widely available. Using BNC cables will degrade the close-in phase noise results and, while adequate for this example, should not be used for an actual measurement on an unknown device unless absolutely necessary.

Calibrating the Measurement

In this example, you are measuring a source (the HP 11848A source) that does not have internal frequency modulation capabilities. To perform the calibration, you can substitute another RF source for the UUT source (the HP 11848A source) as long as the output power of the substitute source is the same as the output power of the HP 11848A source.

A power meter or spectrum analyzer should be used to measure the output power from the UUT source. It is essential that the substituted calibration source apply the same power to the power splitter as the UUT.

If a substitute signal generator with calibrated frequency modulation capability is not available, you can still complete this measurement using a different calibration method. Abort this measurement and access the Calibration Technique menu. Select the Use the Current Discriminator Constant method and enter the value, $40\text{E}-9$ Hz/V. Then reinitiate a New Measurement.

The system will use the entered Discriminator Constant and you will not be required to perform the following steps. (Note that the accuracy of the measurement is dependent on the accuracy of the entered calibration constant value when this method is used.)

1. When the system prompts you, connect the calibration source. Adjust the source frequency until the Quadrature Meter on the HP 11848A reads center scale (± 1 division). Turn on its FM modulation and set the deviation for 10 kHz and the modulation rate to 1 kHz.
2. Press **F1** to proceed. The system will locate the calibration spur and determine the Discriminator Constant.
3. When the system prompts you, remove the calibration source and reconnect the UUT.

If the UUT source you were measuring was not under system control, the System would also prompt you to re-establish quadrature. This is done by adjusting the source frequency until the HP 11848A meter reads center scale (± 1 division).

The system is now ready to make the measurement. The measurement results will be updated on the computer screen after each frequency segment has been measured.

When the Measurement is Complete

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by placing a message on its display. For recommended recovery actions, refer to *Interpreting Display Messages* in the *Problem Solving* section of this chapter.)

Figure 3-27 shows a typical phase noise curve for the internal HP 11848A 350-500 MHz Source.

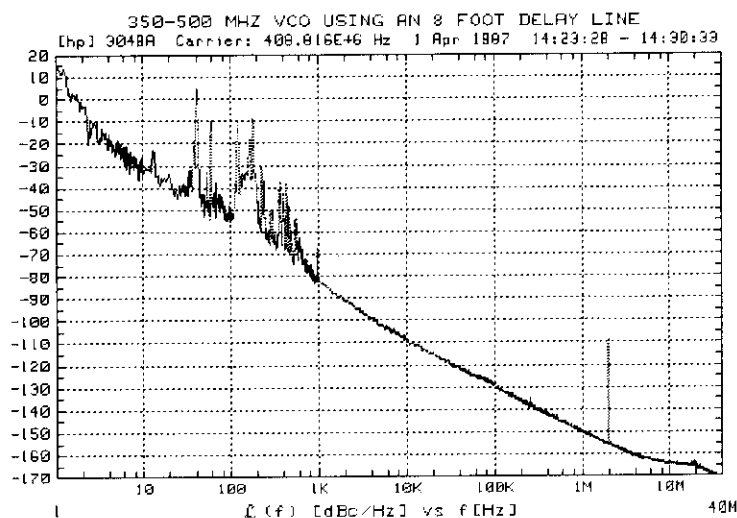


Figure 3-27. Typical Phase Noise Curve for the HP 11848A 350-500 MHz Source.

AM Noise Using an HP 11729C

This example demonstrates the AM noise measurement of an HP 8662A Signal Generator using the AM detector in the HP 11729C Carrier Noise Test Set.

Required Equipment

The following equipment is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

Table 3-19. Additional Equipment Required to
Perform this Measurement Example

Equipment	Qty.	Comments
HP 8662/3A	1	Must be entered in System Configuration Table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for procedure.
HP 11729C	1	Option 130
Attenuator	2	Two 10 dB attenuators or one 20 dB attenuator to prevent overdriving the input to the HP 11848A.
Coax Cables	2	2-foot BNC coaxial cables and adequate adapters to connect to the UUT.

Note

This measurement requires that the HP 11729C Carrier Noise Test Set be included in the Instrument Addresses table if the system is to control the HP 11729C automatically. The HP 11729C should be entered in the row labeled "DOWN CONVERTER".

The HP 11729C can also be controlled manually, if desired, by selecting "AM-CW" mode.

Defining the Measurement

1. Select the **File System** function from the Main Menu.
2. Select **Load File** and enter ***.PRM** for the path information.
3. Select the file titled **HP 8662A AM NOISE USING AN HP11729C DETECTOR** and press **Enter**. The appropriate measurement parameters for this example have been pre-stored in this file. (Table 3-20 lists the parameter data that has been entered for this measurement example.)

↓
is peak detector

Table 3-20. Parameter Data for the AM Noise Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	AM Noise 1 Hz 100 E + 3 Hz 4
2	Instrument Parameters Carrier Frequency Detector/Discr. Input Frequency External Phase/AM Detector	500 E + 6 Hz 500 E + 6 Hz <i>None</i>
3	Calibration Technique Phase Detector Constant Amplitude Frequency	Derive From Double Sided Spur -46 dBc 1 E + 3 Hz
4	Source Control	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y	HP 8662A AM NOISE USING AN HP 11729C DETECTOR 1 Hz 100 E + 3 Hz -170 0

Note

The stop frequency for the stored measurement is 100 kHz so the example will run on a standard HP 3048A system. If you have an RF analyzer configured in your system, you may want to change the stop frequency to 40 MHz in the Type/Range of Measurement menu.

The amplitude of a source under system control, for an AM noise measurement, will automatically be set to +10 dBm. If any other amplitude is desired, the source should be placed under manual control in the Instrument Control menu. All other measurements set the source to +16 dBm automatically.

-
4. Press **Esc** to return to the Main Menu.

Beginning the Measurement

1. Select **New Measurement** from the Main Menu, and press **Y** to proceed. The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you via a displayed warning (the measurement cannot be continued until the problem is corrected). (Refer to Appendix A if you need information about adding or changing an instrument in the System's Instrument Addresses table.
2. When the Connect Diagram appears, connect the signal paths as shown in Figure 3-28.

Table 3-21 contains setup considerations that will help ensure that your measurement results are valid.

Calibrating the Measurement

3. After the connections have been made and checked, press **F1** to proceed.

The HP 8662/3A will be set to the proper AM calibration parameters set in the Calibration Technique menu if you selected the calibration source to be under system control as shown in the source control diagram in Table 3-20. If the source is under manual control the calibration source (actually the UUT in this example) should be set manually to 1% AM at a 1 kHz rate, and press **F1** to proceed.

The detector constant will be measured and the measurement will proceed automatically. The measurement data will be displayed on the computer screen as each segment of data is taken.

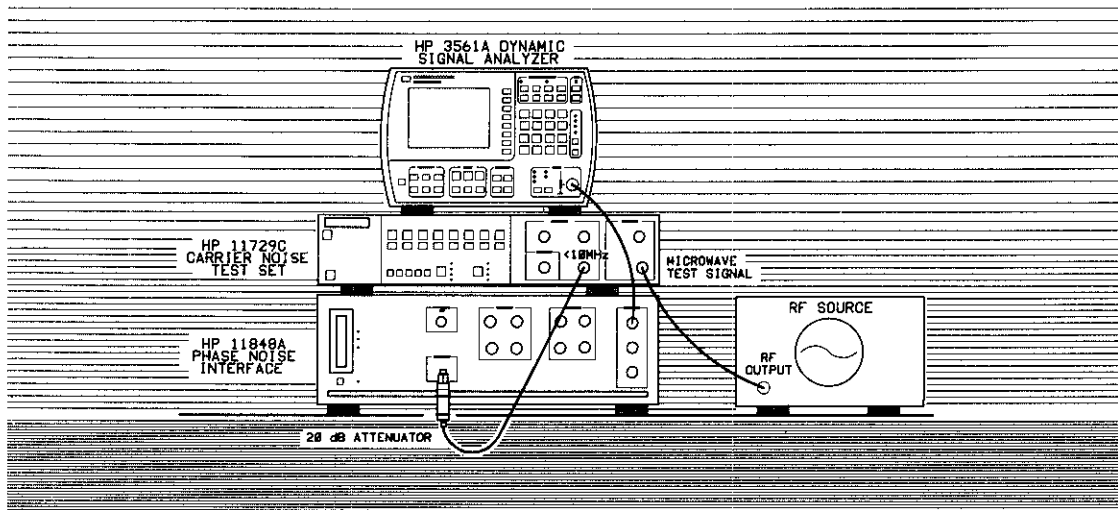


Figure 3-28. Setup diagram for AM Noise Measurement Example.

(REVISED)

Table 3-21. Setup Considerations for AM Noise Measurement Example.

Setup Considerations	Comments
Cable Connections	A special coax cable is supplied with the HP 11729C for making AM noise measurements. It connects the Noise Spectrum <10 MHz output of the HP 11729C to the Noise Input of the interface. This cable uses ferrite beads to suppress spurs generated by the CRTs (cathode ray tubes) used in the computer and spectrum analyzer displays. Use this special cable whenever you make AM noise measurements with the HP 11729C.
Ground Loops	Ground loops can be a problem in this type measurement. Ground loops can be minimized by adding DC Blocks in the signal path to isolate the DUT from the test equipment. The recommended DC Block is the Narda 562 (Type-N connectors) or the Narda 4563 (SMA connectors). DC Blocks may also be referred to as Audio Interference Suppressors or Noise Suppressors. A ground loop can be suspected if the 60 Hz spurs have an amplitude greater than -80 dBc.

Note

The noise will appear to roll-off below 10 Hz and above 10 MHz due to the amplifier and filters in the HP 11729C. However, the measurement results between 10 Hz and 10 MHz are still valid.

Since the measurement calibration was performed at 1 kHz, the 1 kHz data point is guaranteed accurate. Accuracy at all other offsets depends on the flatness of the filters and amplifier in the HP 11729C. Typically HP 11729C unflatness is ± 1 dB. This should be added to the HP 3048A accuracy specification at all offsets other than the calibration offset (1 kHz in this case)

When the Measurement is Complete

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the HP 3048A has problems completing the measurement, it will inform you by placing a message in its display.

Figure 3-29 shows a typical AM noise curve for an HP 8662A Signal Generator. This plot was generated by the HP 3048A using the measurement setup described in this example.

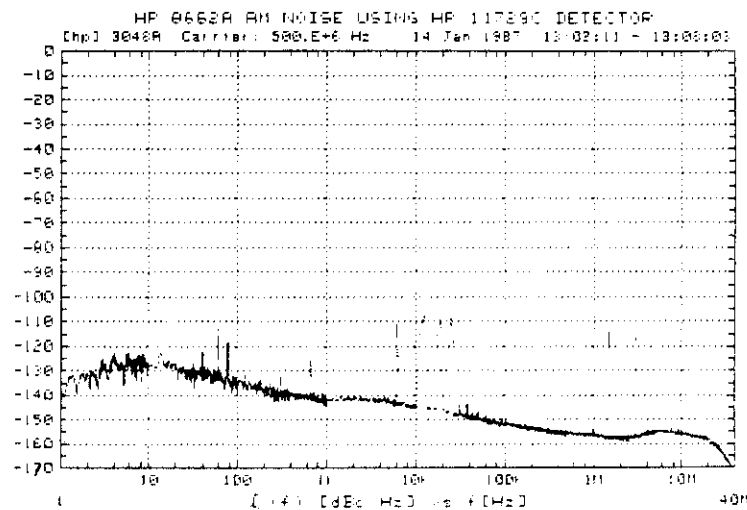


Figure 3-29. Typical AM Noise Curve for an HP 8662A Signal Generator using an HP 11729C Detector.

Table 3-21. Setup Considerations for AM Noise Measurement Example.

Setup Considerations	Comments
Cable Connections	A special coax cable is supplied with the HP 11729C for making AM noise measurements. It connects the Noise Spectrum <10 MHz output of the HP 11729C to the Noise Input of the interface. This cable uses ferrite beads to suppress spurs generated by the CRTs (cathode ray tubes) used in the computer and spectrum analyzer displays. Use this special cable whenever you make AM noise measurements with the HP 11729C.

Note The noise will appear to roll-off below 10 Hz and above 10 MHz due to the amplifier and filters in the HP 11729C. However, the measurement results between 10 Hz and 10 MHz are still valid.

Since the measurement calibration was performed at 1 kHz, the 1 kHz data point is guaranteed accurate. Accuracy at all other offsets depends on the flatness of the filters and amplifier in the HP 11729C. Typically HP 11729C unflatness is ± 1 dB. This should be added to the HP 3048A accuracy specification at all offsets other than the calibration offset (1 kHz in this case)

When the Measurement is Complete

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by displaying a message. For recommended recovery actions, refer to *Interpreting Display Messages in the Problem Solving* section of this chapter.)

Figure 3-29 shows a typical AM noise curve for an HP 8662A Signal Generator.

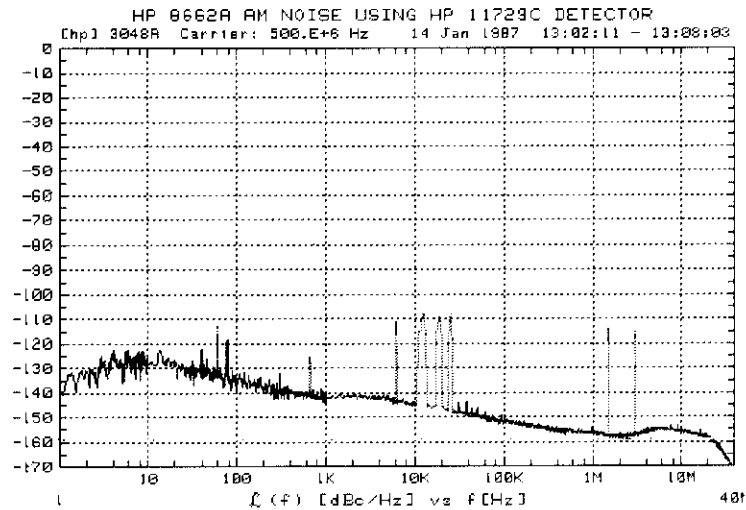


Figure 3-29. Typical AM Noise Curve for an HP 8662A Signal Generator using an HP 11729C Detector.

AM Noise Using an HP 33330C

This example demonstrates the AM noise measurement of an HP 8662A Signal Generator using an HP 33330C Detector and a user-supplied filter network.

Required Equipment

The following equipment is required for this example *in addition to* the HP 3048A system and your unit-under-test (UUT).

Note

To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Table 3-22. Additional Equipment Required to
Perform this Measurement Example

Equipment	Qty.	Comments
HP 8662/3A	1	Enter in System Configuration Table. (Refer to Appendix A.)
HP 33330C	1	
DC Block	1	Recommended type is Narda 562 (Type-N connectors) or Narda 4563 (SMA connectors). The DC Block is optional but should be used to prevent ground loops from affecting the measurement results.
Coax Cables	1	2-foot BNC coaxial cables and adequate adapters to connect UUT.
HP 3048A - Option K21	1	This is the preferred filter network for this measurement. If this instrument is not immediately available, a substitute filter can be constructed by the user. The schematic for the filter is shown in Figure 3-31. The filter should be built in a small metal box and have connectors to connect directly to the HP 11848A Phase Noise Interface front-panel "NOISE INPUT" connector. The HP 33330C Detector should also connect directly to the filter network as shown in the Equipment Setup Diagram, Figure 3-30.

Defining the Measurement

1. Select the **File System** function from the Main Menu.
2. Select **Load File** and enter ***.PRM** for the path information.
3. Select the file titled **HP 8662A AM NOISE USING AN HP 33330C DETECTOR** and press **Enter**. The appropriate measurement parameters for this example have been pre-stored in this file. (Table 3-23 lists the parameter data that has been entered for this measurement example.)

Note The stop frequency for the stored measurement is 100 kHz so the example will run on a standard HP 3048A system. If you have an RF analyzer configured in your system, you may want to change the stop frequency to 40 MHz in the Type/Range of Measurement menu. This will allow you to measure over the entire offset range of the HP 3048A.

The amplitude of a source under system control, for an AM noise measurement, will automatically be set to +10 dBm. If any other amplitude is desired, the source should be placed under manual control in the Instrument Control menu. All other measurements set the source to +16 dBm automatically.

4. Press **Esc** to return to the Main Menu.

Table 3-23. Parameter Data for the AM Noise Measurement Example

Step	Parameters	Data
1	Measurement Type Frequency Range Start Freq. Stop Freq. Averages	AM Noise 1 Hz 100 E + 3 Hz 4
2	Instrument Parameters Carrier Frequency Detector/Discr. Input Frequency External Phase/AM Detector	500 E + 6 Hz 500 E + 6 Hz External Phase/AM Detector
3	Calibration Technique Phase Detector Constant Amplitude Frequency	Derive From Double Sided Spur -46 dBc 1 E + 3 Hz
4	Source Control 	
5	Define Graph Title Minimum X Maximum X Minimum Y Maximum Y	HP 8662A AM NOISE USING AN HP 33330C DETECTOR 1 Hz 100 E + 3 Hz -170 0

Beginning the Measurement

1. Select **New Measurement** from the Main Menu and press **Y** to proceed. The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning (the measurement cannot be continued until the problem is corrected). (Refer to Appendix A if you need information about adding or changing an instrument in the System's Instrument Addresses table.)
2. When the Connect Diagram appears, connect the signal paths as shown in Figure 3-30. Table 3-24 contains setup considerations that will help ensure that your measurement results are valid.

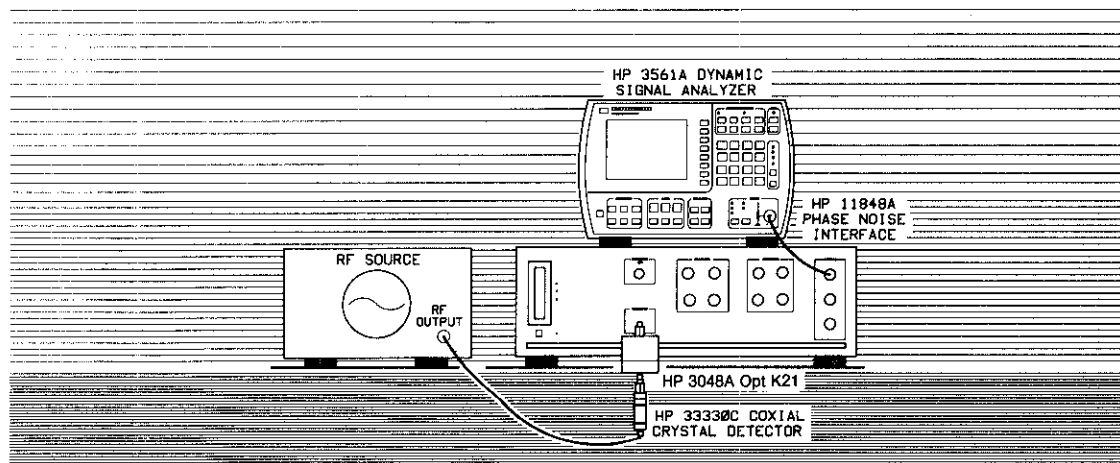


Figure 3-30. Setup Diagram for AM Noise Measurement Example.

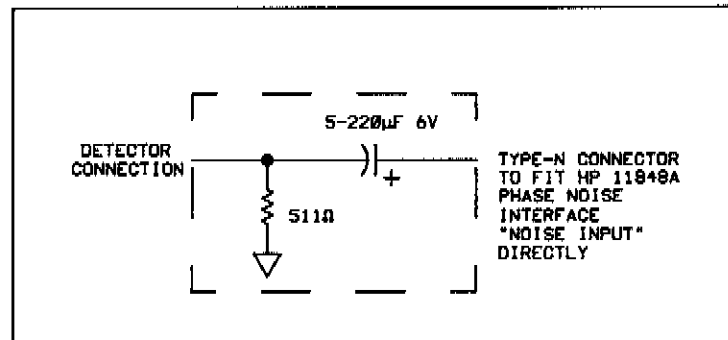


Figure 3-31. Schematic for Required Filter Network.

Table 3-24. Setup Considerations for AM Noise Measurement Example.

Setup Considerations	Comments
Cable Connections	The best results will be obtained if semi-rigid coaxial cables are used to connect the components used in the measurement; however, BNC cables have been specified because they are more widely available. Using BNC cables will degrade the close-in phase noise results and, while adequate for this example, should not be used for an actual measurement on an unknown device unless absolutely necessary.
Ground Loops	Ground loops can be a problem in this type measurement. Ground loops can be minimized by adding DC Blocks in the signal path to isolate the UUT from the test equipment. The recommended DC Block is the Narda 562 (Type-N connectors) or the Narda 4563 (SMA connectors). DC Blocks may also be referred to as Audio Interference Suppressors or Noise Suppressors. A ground loop can be suspected if the 60 Hz spurs have an amplitude greater than -80 dBc.

Calibrating the Measurement

3. After the connections have been made and checked, press **F1** to proceed.

The HP 8662/3A will be set to the AM calibration parameters specified in the Calibration Technique menu. The calibration source is automatically set when it is under system control as shown in the source control diagram in Table 3-23. If the source is under manual or user control, the System will prompt you to set the calibration source (actually the UUT) to 1% AM at a 1 kHz rate.

4. When the calibration source has been set, press **F1** to proceed.

The detector constant will be measured, and the measurement will proceed automatically. The measurement data will be displayed on the computer screen as each segment of data is taken.

Note

The filter network, if built as specified, will provide accurate results down to an offset of 1 Hz.

When the Measurement is Complete

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the System has problems completing the measurement, it will inform you by displaying a message. For recommended recovery actions, refer to *Interpreting Display Messages in the Problem Solving* section of this chapter.)

Figure 3-32 shows a typical AM noise curve for an HP 8662A Signal Generator.

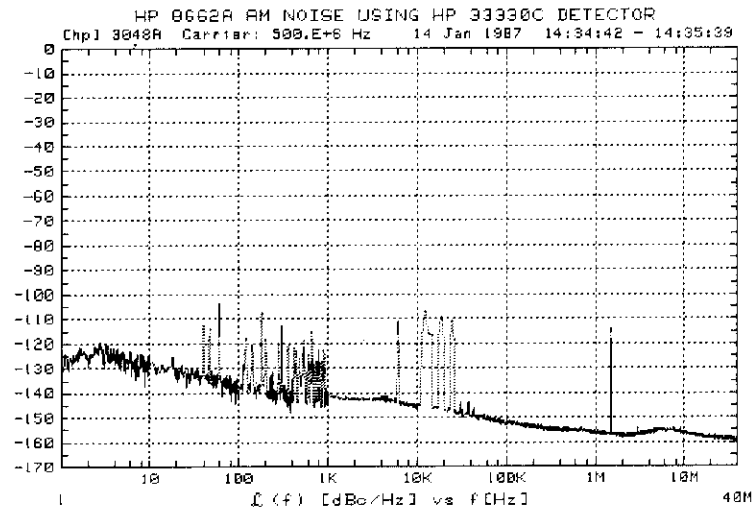


Figure 3-32. Typical AM Noise Curve for an HP 8662A Signal Generator using an HP 33330C Detector.

If you need to know:

Refer to:

- | | |
|--|--|
| • <i>How to interpret a display message</i> | <i>Interpreting Display Messages (pg. 3-122)</i> |
| • <i>What to consider when selecting a reference source.</i> | <i>Selecting a Reference (pg. 3-150)</i> |
| • <i>How to determine the tuning sensitivity of your VCO source</i> | <i>Estimating the Tuning Constant (pg. 3-154)</i> |
| • <i>What the drift tracking capabilities of the system are.....</i> | <i>Tracking Frequency Drift (pg. 3-156)</i> |
| • <i>How to increase or decrease the Peak Tuning Range (PTR) for your VCO source</i> | <i>Changing the PTR (pg. 3-158)</i> |
| • <i>How to Minimize Injection Locking</i> | <i>Minimizing Injection Locking (pg. 3-161)</i> |
| • <i>What to consider when inserting an attenuator or an amplifier between the source output and the HP 11848A .</i> | <i>Inserting a Device (pg. 3-163)</i> |
| • <i>How to determine whether noise near the small angle line exceeds the limits of the system</i> | <i>Evaluating Noise Above the Small Angle Line (pg. 3-166)</i> |

Interpreting Display Messages

The following are lists of the HP 3048A Option 301's Error messages and Reference messages. Each message is provided with a brief description of the conditions which can cause it to be displayed, and the recommended actions to take.

Error Messages

The first message list contains the Error messages. When an Error message is displayed, the number of the Error message appears ahead of the message.

Reference Messages

The reference message list begins after the Error message list. Reference messages are displayed with the reference number at the end of the message.

Additional Messages and Information

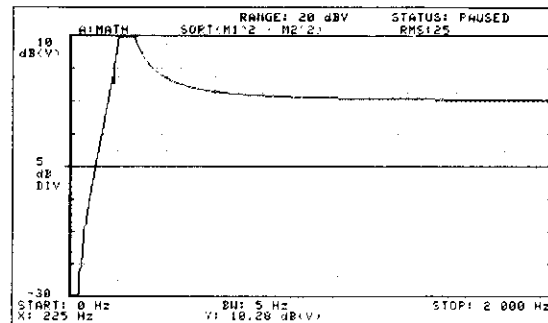
Not all possible display messages are listed in this manual. A complete listing of all messages, warning, and, prompts can be found in the Messages section of the HP 3048A Option 301 Reference Manual.

Table 3-25. Numbered Error Messages (1 of 17)

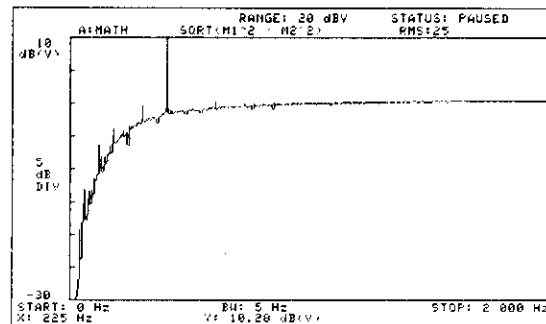
1	Signal level entering the Noise Input port of the 11848A exceeds 1 Volt peak.
	Action: Press R to retry. If the overload condition was transient, the HP 3048A proceeds with the measurement. If Error 1 occurs again, reduce the signal level at the NOISE INPUT port on the HP 11848A. If an HP 11729C is being used to make an AM measurement, insert a 20 dB (50 Ω) pad in the NOISE INPUT signal path. The pad should be connected directly to the HP 11848A.
2	Loop suppression peak exceeds 10 dB. To proceed without verifying the loop suppression press P. Excessive peaking can be caused by various conditions. Continuing with the measurement without verifying loop suppression may result in measurement accuracy degradation at offset frequencies within a decade of the PLL bandwidth. NOTE <i>The SOURCE OUT port on the rear-panel of the HP 3561A must be connected to the NOISE INPUT port on the rear panel of the HP 11848A.</i> Excessive loop suppression peaking is generally caused by one of three conditions. Each condition produces a somewhat different response of the loop suppression curve. The loop suppression curve is displayed on the HP 3561A after the test system has completed the loop suppression characterization. Figure 3-33 illustrates the typical curve response for each of the three conditions. Action: If the loop suppression peak for your measurement exceeds 10 dB (Error 2), observe the loop suppression curve displayed on your HP 3561A. Then refer to the following condition described for the curve in figure 3-33 that most closely resembles the curve displayed on your HP 3561A.

Table 3-25. Numbered Error Messages (2 of 17)

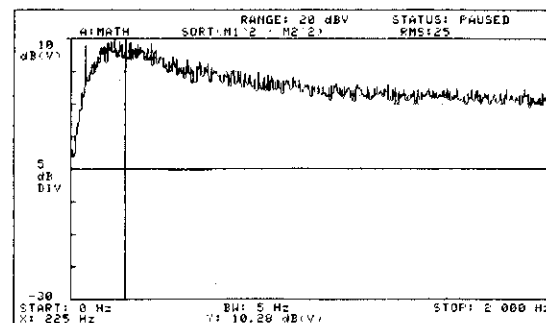
2
(cont'd)



1. Narrow Modulation Bandwidth



2. Large Spur on Input Signal.



3. High Noise on Input Signal

Figure 3-33. HP 3561A Display of Loop Suppression Curves.

Table 3-25. Numbered Error Messages (3 of 17)

2

(cont'd)

1. Narrow Modulation Bandwidth

A broad peak on a relatively clean loop suppression curve occurs when the modulation bandwidth of the VCO's tune port is not wide enough to provide adequate phase margin for the test system's phase lock loop (PLL). The VCO's modulation bandwidth (the upper frequency limit of the VCO's tuning port) should be greater than approximately ten times the PLL bandwidth set for the measurement. PLL bandwidth is shown as a function of the Peak Tuning Range (PTR) in figure 3-34. (The PTR for the measurement is determined by multiplying the VCO's Tune Constant by its Tune Range of VCO.)

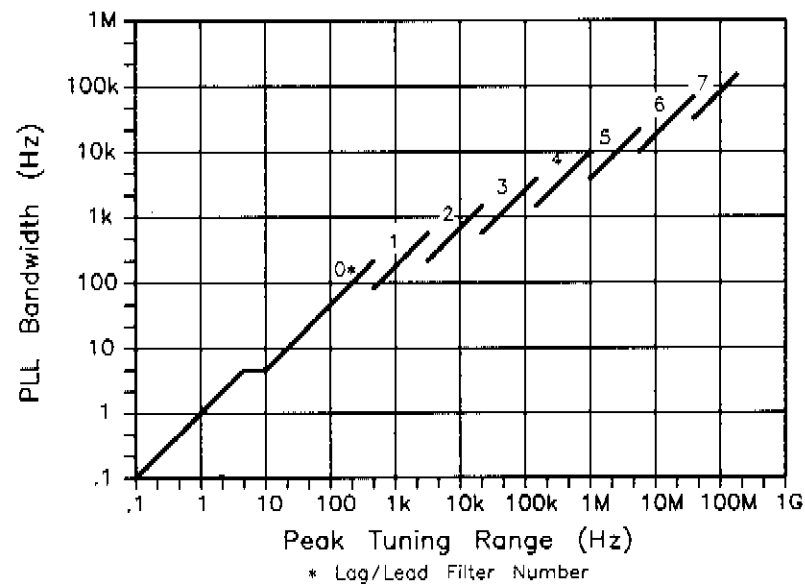


Figure 3-34. Phase Lock Loop Bandwidth as a Function of the Peak Tuning Range of the Measurement.

Table 3-25. Numbered Error Messages (4 of 17)

2 (cont'd)	If the modulation bandwidth of the VCO source you are using is not at least 10 times greater than the PLL bandwidth for the measurement, there are generally three possible actions you can take. • Increase the modulation bandwidth of the VCO source. If the VCO source is a bread-board or prototype oscillator, it may be possible to make the component changes necessary to provide sufficient modulation bandwidth. • Use a different VCO source with greater modulation bandwidth. • Decrease the PLL bandwidth to 1/10 the VCO's modulation bandwidth by decreasing the Peak Tuning Range (PTR) for the measurement. Use figure 3-34 to determine the PTR required. The PTR can be reduced by decreasing the Tune Range of VCO value entered. Divide the required PTR by the VCO's Tune Constant to determine the appropriate Tune Range of VCO to enter. (Keep in mind that reducing the PTR limits the test system's Frequency Drift Tracking Range for the measurement. For further information about changing the PTR, refer to <i>Changing the PTR</i> in chapter 3 of the <i>Operating Manual</i>.) If you do not know the modulation bandwidth for your VCO source, you can determine it by locating the 3 dB roll-off frequency of the VCO tune port. The following steps describe a procedure for determining the modulation bandwidth. a. Connect a tracking generator output (such as the HP 3585A/B) to the tuning input port on your VCO. b. Set the tracking generator output to sweep the audio spectrum. c. Connect the RF output from your VCO to a modulation analyzer (such as an HP 8901A). d. Set the modulation analyzer to measure FM. e. Connect an audio spectrum analyzer to the MODULATION OUTPUT on the HP 8901A. f. Increase the frequency spectrum of the tracking generator, if necessary, until the 3 dB roll-off frequency can be seen on the audio analyzer's display. The 3 dB frequency should be $\geq$ ten times the PLL bandwidth for the measurement. The modulation bandwidth of a VCO can also be determined using the Bessel Null technique. Apply a series of audio frequencies to the tune port of the VCO. Observe the VCO's output signal on an RF spectrum analyzer and adjust the audio modulation level for the first carrier null. Calculate the VCO's modulation sensitivity at each modulation frequency using the level and frequency of the audio signal at the null setting. Plot the modulation sensitivity versus the audio frequency to determine the modulation bandwidth.
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Table 3-25. Numbered Error Messages (5 of 17)

2 (cont'd)	2. Large Spur on Input Signal A sharp peak on an otherwise correct loop suppression curve is evidence of a large spur (typically > -40 dBc) near the phase lock loop (PLL) bandwidth of the measurement (within a factor of two). Press P to continue with the measurement. The measurement results may not be totally accurate but the noise graph will provide you with the offset frequency and approximate level of the spur. (Chapter 6, <i>Evaluating Measurement Results</i> in the <i>Operating Manual</i> provides information that helps you isolate the spur source). If you are not able to reduce the spur level to < -40 dBc, it may be possible to make an accurate noise measurement by changing the PLL bandwidth. Measurement accuracy is only affected by spurs > -40 dBc that are within a factor of 2 of the PLL bandwidth. The PLL bandwidth is shown as a function of Peak Tuning Range (PTR) in figure 3-34. (The PTR for the measurement is determined by multiplying the VCO's Tune Constant by the Tune Range of VCO entered for the measurement. For further information about changing the PTR, refer to chapter 3, <i>Changing the PTR</i> in the <i>Operating Manual</i>). 3. High Noise on Input Signal NOTE <i>Be sure that SOURCE OUT on the rear panel of the HP 3561A is connected to NOISE INPUT on the rear panel of the HP 11848A.</i> A noisy loop suppression curve is caused when one or both of the input signals has noise near the small angle line at offsets near the phase lock loop (PLL) bandwidth. For information about verifying the noise level and recommended actions for compensating for a high noise level, refer to chapter 3, <i>Evaluating Noise Above the Small Angle Line</i> in the <i>Operating Manual</i>.
3	Unable to detect the presence of a beatnote. Action: 1. Check to be sure that the correct Phase Detector is selected in the Parameters window. 2. Check sources to verify the frequency of each output signal. 3. Check for a beatnote. (A procedure for tuning the beatnote to within the Capture Range for the measurement is provided in the <i>Checking the Beatnote</i> section of each Phase Lock Loop measurement example in chapter 3 of the <i>Operating Manual</i>. An oscilloscope connected to the HP 11848A AUX MONITOR port can be helpful for monitoring and zeroing the beatnote.)

Table 3-25. Numbered Error Messages (6 of 17)

4	Unable to close the Phase Lock Loop. Action: There are several possible conditions that can prevent the test system from being able to close the phase lock loop. These conditions and the actions recommended for verifying them are listed below in the order of probable cause. 1. The test system is not able to tune the beatnote to within the capture range set for the measurement. This possibility is minimized by carefully following the <i>Checking the Beatnote</i> procedure in each measurement example in chapter 3 of the <i>Operating Manual</i>. If an oscilloscope is available, you will find that connecting the scope to the AUX MONITOR port on the HP 11848A allows you to continuously monitor the beatnote throughout the measurement. By aborting this measurement and reinitiating a New Measurement, you can observe the beatnote as the HP 3048A attempts to close the phase lock loop (a message will appear on the display to let you know when this is happening). The beatnote frequency, as seen on the scope, should decrease and then go to zero (dc). Watching the beatnote's response as the test system attempts to adjust it to 0 Hz can provide clues about tuning problems that may exist. 2. The beatnote drifted beyond the HP 3048A's capture range before the test system was able to acquire lock. For further information on verifying the frequency stability of the beatnote, refer to chapter 3, <i>Tracking Frequency Drift</i> in the <i>Operating Manual</i>. 3. The VCO Tune Constant entered for the measurement was not within a factor of 2 of the actual VCO Tune Constant, and the HP 3048A was not configured to <i>measure</i> the tune constant for verification. For details on verifying the VCO Tune Constant, refer to chapter 3, <i>Estimating the Tuning Constant</i> in the <i>Operating Manual</i>. 4. The Peak Tuning Range set for the measurement is > 10 MHz and is causing the loop dynamics to be non-linear. When this condition exists, the non-linear response of the beatnote as the test system attempts to close the phase lock loop can often be seen on an oscilloscope connected to the AUX MONITOR port on the HP 11848A. 5. One of the sources is being injection locked as the HP 3048A is tuning the beatnote to 0 Hz. (Refer to chapter 3, <i>Minimizing Injection Locking</i> in the <i>Operating Manual</i> for recommended actions.) 6. The modulation bandwidth of the VCO source's tuning port is not wide enough to provide adequate phase margin for the test system's phase lock loop (PLL). The VCO's modulation bandwidth (the upper frequency limit of the VCO's tuning port) should be greater than approximately ten times the PLL bandwidth set for the measurement. PLL bandwidth is shown as a function of the Peak Tuning Range (PTR) in figure 3-35. (The PTR for the measurement is determined by multiplying the VCO's Tune Constant by its Tune Range of VCO.)
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Table 3-25. Numbered Error Messages (7 of 17)

4
(cont'd)

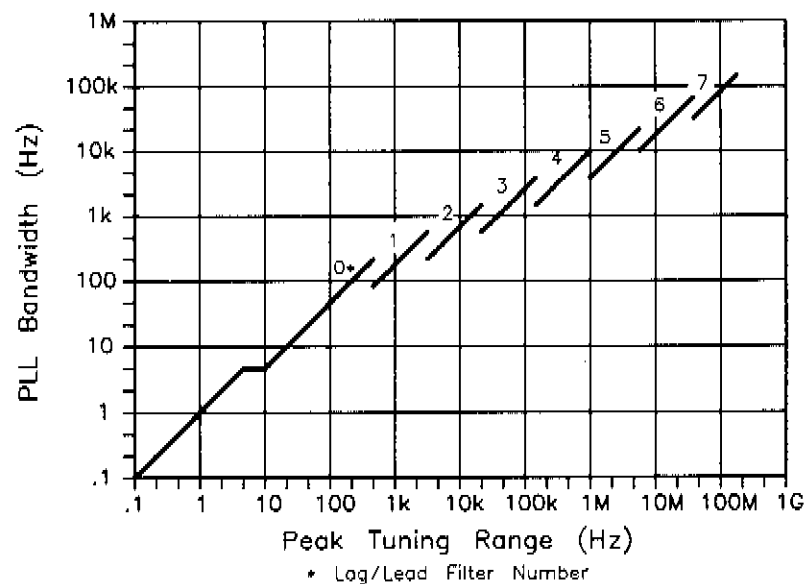


Figure 3-35. Phase Lock Loop Bandwidth as a Function of the Peak Tuning Range of the Measurement.

If the modulation bandwidth of the VCO source you are using is not at least 10 times greater than the PLL bandwidth for the measurement, there are generally three possible actions you can take.

- Increase the modulation bandwidth of the VCO source. If the VCO source is a bread-board or prototype oscillator, it may be possible to make the component changes necessary to provide sufficient modulation bandwidth.
- Use a different VCO source with greater modulation bandwidth.
- Decrease the PLL bandwidth to 1/10 the VCO's modulation bandwidth by decreasing the Peak Tuning Range (PTR) for the measurement. Use figure 3-35 to determine the PTR required. The PTR can be reduced by decreasing the Tune Range of VCO value entered. Divide the required PTR by the VCO's Tune Constant to determine the appropriate Voltage Tuning Range to enter. (Keep in mind that reducing the PTR limits the test system's Frequency Drift Tracking Range for the measurement. For further information about changing the PTR, refer to chapter 3, *Changing the PTR* in the *Operating Manual*.)

Table 3-25. Numbered Error Messages (8 of 17)

4 (cont'd)	If you do not know the modulation bandwidth for your VCO source, you can determine it by locating the 3 dB roll-off frequency of the VCO tune port. The following steps describe a procedure for determining the modulation bandwidth. - Connect a tracking generator output (such as the HP 3585A/B) to the tuning input port on your VCO. - Set the tracking generator output to sweep the audio spectrum. - Connect the RF output from your VCO to a modulation analyzer (such as an HP 8901A). - Set the modulation analyzer to measure FM. - Connect an audio spectrum analyzer to the MODULATION OUTPUT on the HP 8901A. - Increase the frequency spectrum of the tracking generator, if necessary, until the 3 dB roll-off frequency can be seen on the audio analyzer's display. The 3 dB frequency should be $\geq$ ten times the PLL bandwidth for the measurement. The modulation bandwidth of a VCO can also be determined using the Bessel Null technique. Apply a series of audio frequencies to the tune port of the VCO. Observe on an RF spectrum analyzer and adjust the audio modulation level for the first carrier null. Calculate the VCO's modulation sensitivity at each audio frequency using the level and frequency of the audio signal at the null setting. 7. The noise on one or both sources exceeds the small angle limit. For information about verifying the noise level and recommended action, refer to chapter 3, <i>Evaluating Noise Above the Small Angle Line</i> in the <i>Operating Manual</i>. For information about measuring sources with high close-in noise, refer to the <i>Ignore Out of Lock</i> section of chapter 5, <i>Measurement Mode</i> in the HP 3048A Option 301 <i>Reference Manual</i>.
5	Measured VCO peak tuning range exceeds 500 kHz/200 MHz. The Peak Tuning Range limit for the test system is 500 kHz (or 200 MHz if an RF analyzer is configured in the test system). The Peak Tuning Range is the product of the VCO Tune Constant multiplied by the Tune Range of VCO. (If the test system <i>measures</i> the VCO's Tune Constant, it will use the measured value to compute the Peak Tuning Range for the measurement.) Action: Reduce the VCO Tune Range entered for the VCO source you are using, or select a VCO source with a lower Tune Constant.
6	Unable to establish quadrature. Occurs when source is under System Control and the test system is unable to acquire quadrature. The test system attempts to acquire quadrature at the beginning of the measurement and after it has completed a measurement segment if quadrature was lost at any time while the segment was being measured. Action: Manually adjust for quadrature by adjusting the source frequency (or the Phase Shifter if one is being used). Adjust for center scale on the HP 11848A Quadrature Meter.

Table 3-25. Numbered Error Messages (9 of 17)

7	Measured beatnotes depict non-linear VCO tune constant. (Error 7 only occurs when the software has been configured to <i>Measure the Tune Constant</i>.) The values shown on the display represent the measured beatnote frequencies for four Control Voltage settings. The Control Voltage settings are each derived as a percentage of the entered Tune Range of VCO (–45%, –15%, +15%, +45%) relative to the entered Center Voltage of VCO Tune Curve. For Example: Tune Range of VCO = $\pm 10\text{V}$ Center Voltage of VCO Tune Curve = 0V Control Voltage Settings = –4.5V, –1.5V, +1.5V, +4.5V. Refer to chapter 2, <i>Parameters</i> in the <i>Reference Manual</i> for test system VCO linearity requirements. Note that between the four measured frequency values shown on the display, three frequency range intervals are created. (For example, the measured values 95 Hz, 98.2 Hz, 101.2 Hz, 105 Hz produce the following intervals: Interval 1 = 3.2 Hz, Interval 2 = 3 Hz and Interval 3 = 3.8 Hz.) Action: 1. This error occurs if a Tune Range of VCO ± 10 volts has been defined for a source with calibrated DC FM, and the software is configured to <i>Measure the VCO Tune Constant</i> rather than to <i>Calculate</i> it. Refer to chapter 2, <i>Parameters</i> in the <i>Reference Manual</i> for details on extending the Tune Range of VCO for calibrated DC FM. 2. If Interval 2 (described above) $\gg 1$, and Interval 2 $\gg 3$, then: Reduce the value entered for the Tune Range of VCO and then start a New Measurement. 3. If there appears to be too little or no change between the measured frequency values (Intervals 1, 2, and 3 ≈ 0) then : • Check the Control Voltage cable connections. • Verify that the VCO's tuning is enabled. • Perform the <i>Estimating the Tuning Constant</i> procedure provided in chapter 3 of the <i>Operating Manual</i> to verify the tuning response of the VCO and check that the entered VCO Tune Constant is within a factor of 2 of the actual value. • Refer to chapter 2, <i>Parameters</i> in the <i>Reference Manual</i> for Tune Constant linearity requirements. • Verify that the beatnote is tuned to within the Capture Range for the measurement.
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Table 3-25. Numbered Error Messages (10 of 17)

7 (cont'd)	4. If the Frequency Intervals vary greatly and are considerably larger than expected for the tuning range of the the VCO, then: • Check for erratic frequency drift of the beatnote. (Beatnote stability is directly related to the frequency stability of each signal source used in the measurement.) 5. If all four measured frequencies are 0 Hz, then: • Check for injection locking. Refer to <i>Minimizing Injection Locking</i> in chapter 3, of the <i>Operating Manual</i> for further information.
8	Unable to find a beatnote. System was not able to detect a beatnote above -24 dBm (20 mVpk) between 0.1 Hz and 40 MHz. Action: Verify the presence of the beatnote signal. (Refer to the <i>Checking the Beatnote</i> procedure provided in each Phase Lock Loop measurement example in chapter 3 of the <i>Operating Manual</i>.) If you are making a Phase lock loop measurement, be sure the VCO Tune Constant value entered for the measurement is within a factor of 2 of the actual value. Refer to <i>Calibration Process</i> in chapter 2 of the <i>Reference Manual</i> for information about the beatnote calibration technique.
9	The calibration spur could not be found. The HP 3048A was unable to detect a spur within a factor of 2 of the entered spur frequency. Action: 1. Check that the correct spur frequency was entered. 2. Verify the output signal from the spur source. 3. Increase the spur level up to but not exceeding a maximum of -20 dBc. NOTE <i>If a single sided spur is being used and the source frequency is adjusted to maintain quadrature, the frequency of the spur source will also have to be adjusted to maintain the desired spur offset.</i>
10	Waveform departs too drastically from sinusoidal to be used in calculation of the Phase Detector Constant. The test system measures the slope of the waveform at both the positive and the negative zero crossings. If the true slopes differ in magnitude by more than 10%, Error 10 is generated. Action: Check the harmonic content of the two input signals to the Phase Detector. All even harmonics must be below -20 dBc to guarantee good symmetry of the beatnote waveform. If possible, increase the PTR to >10 kHz so that the beatnote is >1 kHz. The HP 3048A then measures the fundamental and its harmonics. (<1 kHz beatnote system measures slope of sinusoid.)

Table 3-25. Numbered Error Messages (11 of 17)

11

DC offset too large. Waveform does not cross 0 volts. This error occurs when the test system is measuring the phase Detector Constant and one of the following conditions exist:

1. The dc offset is greater than the peak beatnote voltage due to a large dc offset or a low beatnote level.
2. The beatnote frequency is much lower than expected and only the top or bottom portion of a sine wave peak is actually measured.

Action:

1. Observe the beatnote on the time record of the HP 3561A or on an oscilloscope connected to the AUX MONITOR port of the HP 11848A. Verify that the beatnote amplitude is correct for the signal level at the R input port on the HP 11848A. Figure 3-36 shows the relationship between the beatnote level and the level at the R input port.

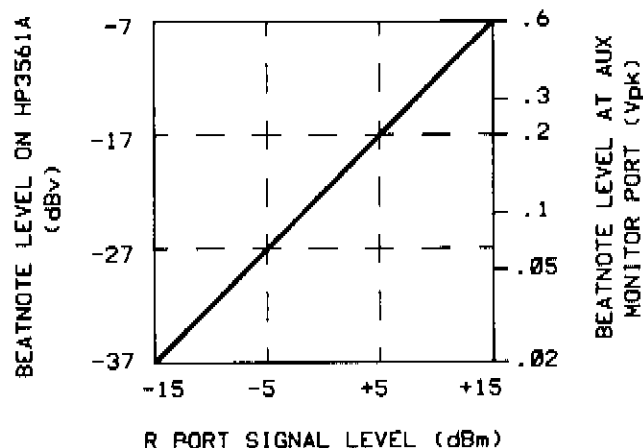


Figure 3-36. Beatnote Level Relative to the Signal Level at the R Port.

2. Verify that the phase detector DC offset is < 50 mV.
3. If the software was not configured to measure the VCO Tune Constant, verify that the entered value is within a factor of 2 of the VCO's actual Tune Constant. A procedure for verifying the VCO's Tune Constant is contained in *Estimating the Tuning Constant* in chapter 3 of the *Operating Manual*.
4. When the test system measures the Phase Detector Constant, the beatnote frequency should be set to approximately 10% of the Peak Tuning Range (PTR) set for the measurement. If it is not, verify the VCO Tuning Constant and Voltage Tuning Range entered for the measurement.

Table 3-25. Numbered Error Messages (12 of 17)

12	Insufficient span. Less than one waveform found. A minimum of four zero crossings is necessary across the HP 3561A's display. This error occurs when the test system is measuring the phase Detector Constant and the expected beatnote is < 1 kHz. Action: When the test system measures the phase Detector Constant, the beatnote frequency should be set to approximately 10% of the Peak Tuning Range (PTR) set for the measurement. If it is not, verify the VCO Tune Constant and Tune Range of VCO entered for the measurement. A procedure for evaluating the tuning sensitivity of the VCO is provided in <i>Estimating the Tuning Constant</i> in chapter 3 of the <i>Operating Manual</i>.										
14	DC offset from mixer $> 1/2$ peak voltage. The dc offset of the Phase Detector is determined and then used to adjust the phase Detector Constant for true slope at the zero voltage point. Action: Observe the beatnote on the HP 3561A display or with an oscilloscope connected to the AUX MONITOR port on the HP 11848A. 1. Verify that the beatnote amplitude is correct for the signal level at the R input port on the HP 11848A. Figure 3-37 shows the relationship between the beatnote level and the level at the R port. The graph shows a linear relationship between the R Port Signal Level (dBm) on the x-axis and the Beatnote Level at AUX Monitor Port (Vpk) on the y-axis. The x-axis ranges from -15 to +15 dBm with major ticks every 10 dB. The y-axis ranges from 0.02 to 0.6 Vpk on a logarithmic scale with major ticks at 0.02, 0.05, 0.1, 0.2, 0.3, and 0.6. A straight line passes through the points (-15, 0.02), (-5, 0.05), (+5, 0.2), and (+15, 0.6). <table border="1"> <thead> <tr> <th>R Port Signal Level (dBm)</th> <th>Beatnote Level at AUX Monitor Port (Vpk)</th> </tr> </thead> <tbody> <tr> <td>-15</td> <td>0.02</td> </tr> <tr> <td>-5</td> <td>0.05</td> </tr> <tr> <td>+5</td> <td>0.2</td> </tr> <tr> <td>+15</td> <td>0.6</td> </tr> </tbody> </table> Figure 3-37. Beatnote Level Relative to the Signal Level at the R Port.	R Port Signal Level (dBm)	Beatnote Level at AUX Monitor Port (Vpk)	-15	0.02	-5	0.05	+5	0.2	+15	0.6
R Port Signal Level (dBm)	Beatnote Level at AUX Monitor Port (Vpk)										
-15	0.02										
-5	0.05										
+5	0.2										
+15	0.6										

Table 3-25. Numbered Error Messages (13 of 17)

14 (cont'd)	2. Verify that the Phase Detector DC offset is < 50 mV. If the dc offset is within this limit and the beatnote level is < -23 dBV (< 0.1 Vpk at AUX MONITOR port), increase the beatnote level, if possible, by increasing the signal level at the R port. If the beatnote level cannot be increased sufficiently it may be necessary to decrease the dc offset by changing the carrier frequency.															
15	Detector Constant < 0.02 V/Rad. The measured phase Detector Constant was below the test system's 20 mV limit. Action: Observe the beatnote on the HP 3561A display or with an oscilloscope connected to the AUX MONITOR port on the HP 11848A. Verify that the beatnote amplitude is correct for the signal level at the R input port on the HP 11848A. Figure 3-38 shows the relationship between the beatnote level and the level at the R port. If necessary, increase the signal level at the R port and verify that the signal level at the L port is $\geq +15$ dBm ($\geq +7$ dBm for the 1.2 GHz to 18 GHz Phase Detector). <table><thead><tr><th>R PORT SIGNAL LEVEL (dBm)</th><th>BEATNOTE LEVEL ON HP3561A (dBV)</th><th>BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)</th></tr></thead><tbody><tr><td>-15</td><td>-37</td><td>0.02</td></tr><tr><td>-5</td><td>-27</td><td>0.05</td></tr><tr><td>+5</td><td>-17</td><td>0.2</td></tr><tr><td>+15</td><td>-7</td><td>0.6</td></tr></tbody></table> Figure 3-38. Beatnote Level Relative to the Signal Level at the R Port.	R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL ON HP3561A (dBV)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)	-15	-37	0.02	-5	-27	0.05	+5	-17	0.2	+15	-7	0.6
R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL ON HP3561A (dBV)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)														
-15	-37	0.02														
-5	-27	0.05														
+5	-17	0.2														
+15	-7	0.6														

Table 3-25. Numbered Error Messages (14 of 17)

16	Detector Constant > 10 V/Rad. The measured phase Detector Constant exceeded the test system's 10 V limit. Action: An internal phase detector cannot produce a beatnote large enough to result in a > 10 V/rad detector constant. Therefore, this message should only occur with an external detector with gain. To reduce the detector constant, insert a 10 or 20 dB pad between the external detector and the noise input. <table><thead><tr><th>R Port Signal Level (dBm)</th><th>Beatnote Level on HP3561A (dBV)</th><th>Beatnote Level at AUX MONITOR PORT (Vpk)</th></tr></thead><tbody><tr><td>-15</td><td>-37</td><td>0.02</td></tr><tr><td>-5</td><td>-27</td><td>0.05</td></tr><tr><td>+5</td><td>-17</td><td>0.2</td></tr><tr><td>+15</td><td>-7</td><td>0.6</td></tr></tbody></table> Figure 3-39. Beatnote Level Relative to the Signal Level at the R Port.	R Port Signal Level (dBm)	Beatnote Level on HP3561A (dBV)	Beatnote Level at AUX MONITOR PORT (Vpk)	-15	-37	0.02	-5	-27	0.05	+5	-17	0.2	+15	-7	0.6
R Port Signal Level (dBm)	Beatnote Level on HP3561A (dBV)	Beatnote Level at AUX MONITOR PORT (Vpk)														
-15	-37	0.02														
-5	-27	0.05														
+5	-17	0.2														
+15	-7	0.6														
17	Measured tune range of the VCO is less than 0.2 Hz. The test system was probably unable to cause a beatnote. The Tune Range of VCO is measured in this case as: $2 \times \text{entered Tune Range of VCO} \times \text{measured VCO Tune Constant}$ Action: If the <i>expected</i> tune range of the VCO source is much larger than 0.2 Hz: 1. Check the Control Voltage cable connection. 2. Verify that the VCO source's tuning capability is enabled. 3. Verify the VCO's tuning response by performing the procedure provided in <i>Estimating the Tuning Constant</i> in chapter 3 of the <i>Operating Manual</i>. 4. Perform the procedure for adjusting the beatnote frequency to within 10% of the Peak Tuning Range (PTR) set for the measurement. (The procedure for adjusting the beatnote is provided in the <i>Checking the Beatnote</i> portion of each measurement example in chapter 3 of the <i>Operating Manual</i>. If the <i>expected</i> tuning range of the VCO source is near 0.2 Hz: 1. Increase the tuning range, if possible, by increasing the Tune Range of VCO value entered for the measurement.															

Table 3-25. Numbered Error Messages (15 of 17)

18	The system perceives that the signals from the two sources differ by more than 15% of the total tuning range. The sources may be re-tuned to reduce the beatnote frequency. Or the VCO Tune Range may be adjusted. Once the test system has measured the VCO Tune Constant, it is able to predict the Control Voltage necessary to phase lock the loop. If the tuning range required for lock is > 15% of the Peak Tuning Range (PTR), The test system may not be able to pull the sources into lock, and will have very little tuning range (< 5% of PTR) left for drift tracking.
	Action: 1. Tune the center frequency of one or both sources to adjust the beatnote to within the Capture Range set for the measurement. As you adjust the beatnote frequency toward 0 Hz, you may find it helpful to manually decrement the analyzer's span setting. (A complete procedure for adjusting the beatnote is provided in the <i>Checking the Beatnote</i> portion of each Phase Lock Loop measurement example in chapter 3 of the <i>Operating Manual</i>.) 2. If necessary, change the Center Voltage value entered for the VCO to reduce the initial beatnote frequency, or increase the entered Tune Range of VCO to provide a larger Peak Tuning Range (PTR). (Details on adjusting the PTR are provided in <i>Changing the PTR</i> in chapter 3 of the <i>Operating Manual</i>.)
20	Unable to detect presence of HP 3561A noise source. Check cabling and HP 3516A Noise Source Function.
	Action: Verify that the HP 3561A rear-panel "Source Out" port is connected to the HP 11848A rear-panel "Noise Input" port.

Table 3-25. Numbered Error Messages (16 of 17)

23	The currently defined measurement has not been properly calibrated. Run 'New Measurement' to calibrate.
	Action: Select New Measurement to allow the HP 3048A to calibrate the measurement.
26	System attempted to set (instrument) to (–) MHz. Test will be aborted.
	Action: Verify that the <i>Parameters</i> defined for the measurement are correct and that the source's frequency range is adequate.
27	Entered carrier frequency cannot be tested. Press Abort.
	Action: Verify the carrier frequency. If the frequency is correct, verify the HP 11729C filter table in the Instrument Addresses table.

Table 3-25. Numbered Error Messages (17 of 17)

31	Random noise obscures waveform. The test system is unable to measure the Detector Constant due to an erratic waveform. This error occurs during the phase Detector Constant calibration.
	Action: Observe spectrum of beatnote and evaluate with respect to small angle criterion for expected PLL BW.
32	Beatnote not expected at frequency.
	Action: Observe the beatnote at the connect diagram. Verify that it is less than 5% of the Peak Tune Range. Verify that the VCO is properly tuned by the voltage output of the HP 11848A. Verify that the VCO Tune parameters are correct in the Parameter menu.

Table 3-25a. Unnumbered Error Messages (1 of 3)

Cannot use the specified Tune Constant. The VCO Tune Constant was set to zero because the last New Measurement was aborted. Action: Define a method for determining the VCO Tune Constant other than use the current Tune Constant. Then select New Measurement
External Timebase not allowed with Internal Source. Action: Redefine the timebase in the <i>Instrument Control</i> menu.
Files not created using identical segments. The 2 Oscillator Comparison or the 3 Oscillator Comparison can only be performed using data acquired from identical segments and measurement spans. Action: Remeasure the devices. Do not change any segment table entries or measurement definitions between measurements.
Insufficient data files for 3 Oscillator Comparison. Less than three Result files were found. Action: Store a Result file for each of the three measurements to be compared.
Insufficient data files for 2 Oscillator Comparison. Less than two Result Files were found. Action: Store a Result file for each of the two measurements to be compared. (Note that these files cannot be identical, they must be distinct measurements).
Internal sources may not be used to drive the high frequency detector. The HP 11848A internal oscillators can not be used as the input for the 1.2 to 1.8 GHz phase detector. Action: Define a different source or phase detector.
No test-instruments defined. Measurement initiated with an empty Configuration file. Action: Define the equipment being used in the Instrument Addresses table.

Table 3-25a. Unnumbered Error Messages (2 of 3)

'10 MHz A' and internal '400 MHz Osc./VCO' are mutually exclusive. 10 MHz A cannot operate while one of the 400 MHz Oscillators is on. Action: Redefine the source selections in the <i>Instrument Control</i> diagram.
3561A Noise Source not functioning or not connected to 11848A. The HP 11848A can not detect the required noise source for this setup. Action: Verify that the HP 11848A's rear-panel noise input is connected to the HP 3561A's SOURCE OUT and attempt to re-run the test.
Peak tuning range exceeds Hz. The maximum Peak Tuning Range is 500 kHz (or 200 MHz when using a configured RF analyzer). Action: Reduce the Peak Tuning Range by reducing the Control Voltage or Tune Constant of VCO value defined for the VCO source in the <i>Parameters</i> window.
Plot range is not within span range. A Plotted Range has been defined that is not within the Measurement Range specified in the segment tables. Action: Define each of the Plotted Ranges in the segment table so they are each within the Measurement Ranges defined in the table.
Range limits must be in ascending order. A segment has been defined with a lower limit greater than the upper limit. Action: Redefine the segment range so that the upper limit is greater than the lower limit.
Source specification is invalid and must be corrected. The HP 3048A has detected an error in the <i>Instrument Control</i> diagram. Action: Check the <i>Instrument Control</i> diagram for accuracy and compatibility with other parameters defined for the measurement.
The currently defined measurement has not been properly calibrated. Select New Measurement to calibrate. The phase Detector Constant or Tune Constant of VCO has not been calibrated. Action: Check that the appropriate calibration method has been defined in the <i>Calibration Technique</i> window. Select New Measurement to initiate calibration.
The frequency of the Internal 400 MHz Osc. cannot be tuned. The test system cannot obtain quadrature since the HP 11848A internal 400 MHz oscillator cannot be tuned. Action: Use a tunable source or manually adjust quadrature using a phase shifter or line stretcher.

Table 3-25a. Unnumbered Error Messages (3 of 3)

Unable to calculate. The HP 3048A was unable to perform the selected calculation.

Action: Check the parameter entry data to make sure it is compatible with the selected calculation. For further information, refer to the HP 3048A Option 301 Reference Manual, chapter 4, *Manipulate Results*.

Table 3-26. Reference Messages (1 of 7)

1	Establish quadrature manually.
	Action: Manually adjust the source frequency or the phase shifter to attain quadrature (within ± 1 division of center scale on the HP 11848A's Quadrature Meter). If the meter is pegged, connect an oscilloscope or voltmeter to the AUX MONITOR port on the HP 11848A and then adjust the source frequency or the phase shifter to decrease voltage level until the level can be observed on the quadrature meter.
2	WARNING: FM Deviation of (instrument) changed from ___ to ___ Hz. In order to zero the beatnote, the HP 3048A had to change the center frequency of the source. As a result, FM deviation must be adjusted to within the limits of the source at the new frequency. Note that a reduced Tune Constant (deviation) will result in a narrower Peak Tuning Range (PTR) for the measurement. Action: If the narrower PTR is adequate for the measurement, proceed. If the resulting PTR will not provide sufficient Capture and Drift Tracking Ranges for the stability of the signal sources, you may need to select a different VCO source with a greater tuning range. If your VCO source is an HP 8642A/B and the carrier frequency for the measurement is < 123 MHz, the following steps will enable you to increase the tuning range of the HP 8642A/B. 1. Configure the <i>Instrument Control</i> diagram for manual control of the HP 8642A/B. 2. Select the HP 8642A/B HET Band for 1.5 MHz maximum deviation. Note that the increase in deviation causes an increase in the HP 8642A/B's noise level as well.

Table 3-26. Reference Messages (2 of 7)

3	Cause FIRST/SECOND calibration PEAK voltage. Action: Adjust the frequency of the source, or adjust the phase shifter to get either a positive or negative peak voltage reading using the Marker function on the HP 3561A. To ensure that you have adjusted to the maximum peak setting, adjust to slightly beyond the maximum peak and then back to it. (The peak voltage setting can also be determined using a voltmeter or oscilloscope connected to the AUX MONITOR port on the HP 11848A.) When the peak setting has been attained, press P. When you are prompted to cause the second calibration peak, adjust to a maximum peak of the opposite polarity using the same technique. NOTE <i>For this calibration technique to be most accurate, the two signal paths to the HP 11848A Phase Detector should be well matched (>10 dB return loss) and the R port level should be at least 5 dB below the L port level. If you are not able to attain a true peak setting, you will have to use a different calibration technique.</i>
4	Apply modulation to carrier. Either a double-sided spur or modulation of the same type as is being measured. Action: Apply the modulation type required for your measurement. Apply angle modulation for a Phase Noise without PLL or FM discriminator measurement, or apply amplitude modulation for an AM measurement. Ensure that the modulation is applied at a level that will enable the HP 3048A to readily detect it above the noise of the device-under-test. The following maximum limits should also be observed. • Double-sided spur < -20 dB • AM < 10% (-26 dB) The offset frequency of the spur should be between 1 Hz and 50 kHz (or between 1 Hz and 20 MHz if an RF analyzer is configured in the test system).
5	Apply calibration spur to carrier. A single-sided spur is expected. Action: The spur is typically generated by combining a signal near the frequency of the device-under-test (UUT) with the UUT output. This can be done using a power splitter or a directional coupler. Turn on the spur signal source and note the amplitude of the spur signal relative to the amplitude of the UUT. The spur level should be high enough to be readily observable above the noise of the UUT on a spectrum analyzer. The spur level should not exceed -20 dBc relative to the UUT amplitude.

Table 3-26. Reference Messages (3 of 7)

6	Remove the calibration spur. If the spur signal is not removed, it will appear in the measurement and could affect the measurement results.
	Action: Disconnect or turn off the spur source without disturbing the frequency or amplitude settings of the source. NOTE <i>If you want to determine the frequency and amplitude of you spur source, leave the source connected and turned on during the measurement. The spur signal should appear in your measurement results. Note, however, that a large spur signal can prevent the test system from having the full dynamic range necessary to make a valid noise measurement.</i>
7	Offset the source and reference signals by at least 1 Hz and not more than 50 kHz/1 MHz/20 MHz. The test system requires that two different signals be applied to the input ports of the HP 11848A's Phase Detector. The frequencies of the two sources must differ as follows: • With RF Spectrum Analyzer in System, phase detector input frequency <95 MHz, Offset Range: 1 Hz to 1 MHz • With RF Spectrum Analyzer in System, phase detector input frequency >95 MHz, Offset Range: 1 Hz to 20 MHz • Without RF Spectrum Analyzer in System, Offset Range: 1 Hz to 50 kHz Action: Adjust the frequency of the unit-under-test (UUT) to offset it from the reference source frequency. If the UUT cannot be adjusted to create a frequency offset that is within the offset range specified above, substitute a different source for the UUT. Adjust the substitute source for the same power level as the UUT source it is replacing. Terminate any ports in 50Ω that are not connected during the substitution. Reconnect the UUT source after the calibration is completed.
8	Remove the beatnote and connect the test system for noise measurement. Action: Readjust the unit-under-test (UUT) to the frequency of the reference source or reconnect UUT.
9	Phase lock has been lost. Select Proceed to attempt to re-lock the loop. This message can be caused by any one of the following conditions. 1. Frequency drift > 25% of the Peak Tuning Range. 2. A phase transient > 0.25 radians. 3. Out-of-Lock detector set by search oscillator.

Table 3-26. Reference Messages (4 of 7)

9 (cont'd)	Action: Press P to cause the test system to attempt to relock the loop and re-measure the frequency segment. If the software is unable to relock the loop, Error 4 will be displayed, refer to Error 4 for recommended actions. (Note that this error is most typically caused by frequency drift of one of the sources. If this condition persists, it may be necessary to increase the Peak Tuning Range for the measurement.)
10	The LNA of the HP 11848A is currently IN/OUT. This message only appears if the Carrier Type "Pulsed" has been selected. The HP 3048A evaluates the total noise from the Phase Detector to determine whether the Low-Noise-Amplifier (LNA) should be switched IN or OUT. The LNA is normally switched in to provide the maximum measurement sensitivity for the test system. If the HP 3048A determines that the noise level from the Phase Detector will overload the LNA, the LNA is switched out. When the LNA is switched out, the test system's measurement sensitivity is degraded by 20 to 30 dB depending on the offset frequency. If you are measuring a device that has a very low noise level (near the test system's noise floor) this degradation may affect the measurement results. Action: Under most condition it is recommended that you proceed with the decision made by the HP 3048A. Toggling the LNA IN when the HP 3048A has determined it should be switched OUT can cause the noise from the Phase Detector to be compressed and the measurement results to be inaccurate. There are certain conditions when you may want to toggle the LNA OUT, however. 1. When Pulse Mode is enabled. If the Phase Detector dc offset is > 5 mVdc, the test system may not detect that the noise level is high enough to overload the LNA. 2. To duplicate the exact conditions that existed for a previous measurement where the LNA was switched out. 3. When you are performing the System Noise Floor Test and you want to evaluate the test system's noise floor without the LNA in the measurement path. If the HP 3048A has decided to switch OUT the LNA and you are concerned about measurement sensitivity, you may want to further evaluate the decision. Connect an oscilloscope to the AUX Monitor Port on the HP 11848A. Observe the LNA output and toggle the LNA IN. If the peak output level exceeds $-0.5V$ or $+1V$, the noise may be clipped or compressed so the measurements must be made with the LNA OUT. If the noise is not significantly clipped, the measurement may be made with the LNA IN.

Table 3-26. Reference Messages (5 of 7)

11	The LNA of the HP 11848A has been bypassed. This will result in a degradation of the test system noise floor. The HP 3048A evaluates the total noise from the Phase Detector to determine whether the Low-Noise-Amplifier (LNA) should be switched IN or OUT. The LNA is normally switched in to provide the maximum measurement sensitivity for the test system. If the HP 3048A determines that the noise level from the Phase Detector will overload the LNA, the LNA is switched out. When the LNA is switched out, the test system's measurement sensitivity is degraded by 20 to 30 dB depending on the offset frequency. If you are measuring a device that has a very low noise level (near the test system's noise floor) this degradation may affect the measurement results.
	Action: Proceed with the measurement. When the measurement is complete, evaluate the results to determine the possible causes of the high noise level at the Phase Detector output. A few possible causes are: 1. A large spur (> -40 dBc) on one of the input signals. 2. A high noise pedestal on one of the sources. 3. Spurs at the output of the Phase Detector. To determine whether bypassing the LNA has affected your noise measurement results, compare your results to the noise floor provided by the HP 3048A when the LNA is OUT. Use the phase Detector Constant value measured by the HP 3048A to determine the test system's noise floor with the LNA OUT from the Approximate HP 3048A Phase Noise Floor vs R Port Signal Level (refer to chapter 7, graph 1) graph. If it appears that your measurement may have been limited by the test system's noise floor with the LNA bypassed, it may be necessary to take one of the following actions to prevent the LNA from being switched out. 1. Reduce the phase Detector Constant by reducing the signal level into the R port of the Phase Detector. Then restart a New Measurement. 2. Suppress the noise and spurs at the Phase Detector output by increasing the Phase Lock Loop (PLL) bandwidth. The PLL bandwidth is increased by increasing the Peak Tuning Range (PTR) for the measurement. Details on increasing the PTR are provided in <i>Changing the PTR</i> in chapter 3 of the <i>Operating Manual</i>. If you want to further evaluate the LNA decision, abort the measurement and access the <i>Advanced Functions</i> window. Select the Carrier Type "Pulsed" and then start a Repeat Measurement. When the LNA decision is displayed again, connect an oscilloscope to the AUX Monitor port or the HP 11848A. Observe the LNA output and toggle the LNA IN. If the peak output level exceeds $-0.5V$ or $+1V$, the noise may be clipped or compressed so the measurements must be made with the LNA OUT. If the noise is not significantly clipped, the measurement may be made with the LNA IN.
12	A comparison of theoretical and actual PLL suppression indicates a degradation of the accuracy specified for the HP 11848A. The Phase Lock Loop (PLL) Suppression is verified by measuring the actual loop suppression at frequencies near the predicted PLL bandwidth. This message is displayed when the measured loop suppression differs from the theoretical by > 1 dB.

Table 3-26. Reference Messages (6 of 7)

12 (cont'd)	Action: 1. The key factor for having a good match between the measured loop suppression and the theoretical is the accuracy of the phase Detector Constant and the VCO Tune Constant. Abort the measurement and verify that these calibration constants are accurate. a. Verify that the VCO Tune Constant entered for the measurement is within a factor of 2 of the VCO's actual tuning constant. (A procedure for evaluating the sensitivity of your VCO is provided in <i>Estimating the Tuning Constant</i> in chapter 3 of the <i>Operating Manual</i>.) b. Verify the phase Detector Constant by connecting an oscilloscope to the AUX MONITOR port on the HP 11848A. The peak voltage at the AUX MONITOR port should equal the phase Detector Constant measured by the test system. 2. If the calibration constants are accurate, begin a New Measurement and proceed to the hardware Connect Diagram. Observe the beatnote signal on the HP 3561A using the <i>Checking the Beatnote</i> procedure provided in each PLL measurement example in chapter 3 of the <i>Operating Manual</i>. a. Verify that the beatnote signal is sinusoidal (or triangular if the input signals are square waves or if the levels of both input signals are $> +15$ dBm). b. Verify that all even harmonics are ≤ -30 dBc on the beatnote and ≤ -20 dBc on the input signals. c. Check for injection locking. d. Check for noise that exceeds the small angle line. (Refer to <i>Evaluating Noise Above the Small Angle Line</i> in chapter 3 of the <i>Operating Manual</i> for a procedure.) 3. If the beatnote signal meets the preceding tests, proceed with a New Measurement. a. If the measured curve does not match the theoretical because it is noisy, press F8 to proceed with the measurement using the theoretical PLL suppression data. The accuracy of the measurement results will be unverified but the results may help you to identify the source of the problem. b. If the measured curve does not match the theoretical because it has high peaks and the Accuracy Degradation is ≤ 2 dB, press F1 to proceed with the measurement using an adjusted PLL suppression. The accuracy of the results will be degraded by 2 dB within a decade of the PLL bandwidth for the measurement. Figure 3-40 shows PLL bandwidth relative to the Peak Tuning Range (PTR) set by the VCO source. (Refer to chapter 2 in the <i>Reference Manual</i> for further information about the PTR.)
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Table 3-26. Reference Messages (7 of 7)

12
(cont'd)

- c. If the Accuracy Degradation is >2 dB, perform steps 1. and 2. again very carefully, pay close attention to the accuracy of the calibration constants and injection locking. If the Accuracy Degradation is still >2 dB, ** press F1 to proceed with the adjustment to get an approximate noise measurement for use in further troubleshooting the problem.

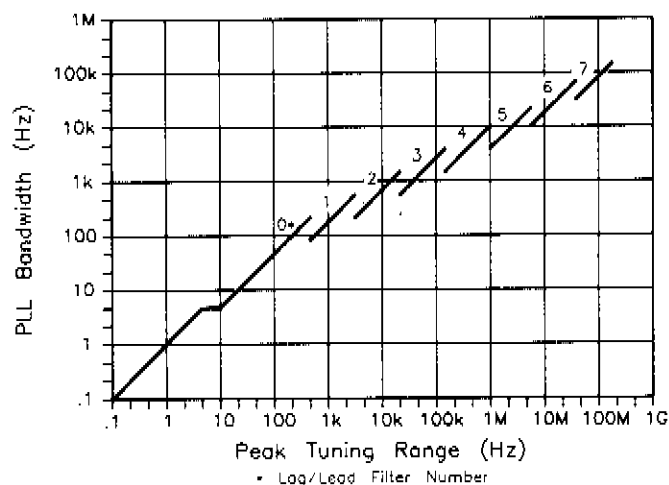


Figure 3-40. Phase Lock Loop Bandwidth Relative to the Peak Tuning Range.

13

Establish a beatnote less than or equal to () Hz. System perceives that sources are not within 5% of the defined Peak Tuning Range. Since the Reference Source is under manual control, the user is required to establish zero beat.

Action: Manually adjust the Reference Source to acquire a beatnote on the analyzer (on oscilloscope if corrected to the HP 11848A any monitor port) of less than or equal to the specified frequency.

Selecting a Reference

Selecting an appropriate reference source is critical when you are making a phase noise measurement using the Phase Lock Loop technique. The key to selecting a reference source is to compare the noise level of the reference with the expected noise level of the unit-under-test (UUT). In general, the lower the reference source's noise level is below the expected noise level of the UUT the better. (Keep in mind that you only need to be concerned about the reference source's noise level within the frequency offset range over which you plan to measure the UUT.)

As shown by the graph in Figure 3-41, the further the reference source's noise level is below the noise level of the UUT, the less the reference source's noise will contribute to the measurement results.

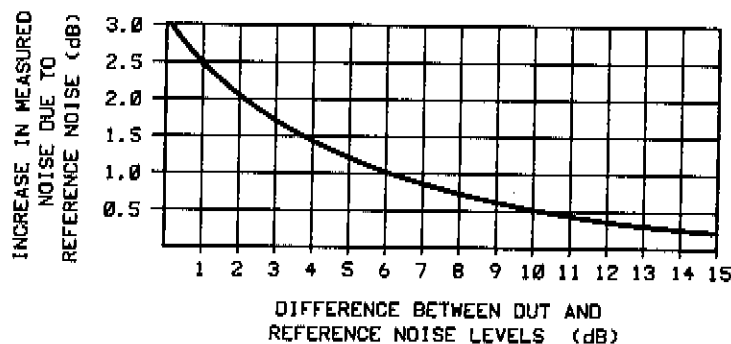


Figure 3-41. Increase in Measured Noise As UUT Noise Approaches Reference Noise

Using a Similar Device

The test system performs best when you are able to use a device similar to the UUT as the reference source for your PLL measurement. Of course one of the devices must be capable of being voltage tuned by the system to do this.

To select a similar device for use as the reference source, you must establish that the noise level of the reference source device is adequate to measure your UUT. The *Three Source Comparison* technique enables you to establish the actual noise levels of three comparable devices when two devices are available in addition to the UUT. (Refer to your HP 3048A Option 301 Reference Manual for details on performing the *Three Source Comparison* procedure.)

If only one device is available in addition to the UUT, you can perform the Phase Noise Using a Phase Locked Loop Measurement using these two devices and know that the noise level of each of the devices is at least as good as the measured results. (The measured results will represent the sum of the noise of both devices.)

Using a Signal Generator

When using a signal generator as a reference source, it is important that the generator's noise characteristics are adequate for measuring your device. The specified and typical noise characteristics of the various HP signal source options are provided in the *HP 3048A Option 301 Reference Manual*.

Tuning Requirements

Often the reference source you select will also serve as the VCO source for the PLL measurement. (The VCO source can be either the unit-under-test (UUT) or the reference source.) To configure a PLL measurement, you will need to know the following tuning information about the VCO source you are using:

- Tuning Constant (Hz/V) (within a factor of 2)
- Tuning Voltage Range (V)
- Center Voltage of Tuning Range (V)
- Input Resistance of Tuning Port (ohms)

The primary consideration when evaluating a potential VCO source for your measurement is whether it will provide the test system with sufficient Capture and Drift Tracking Ranges to maintain lock throughout the measurement. To make this determination, you must *estimate* what the drift range of the sources you are using will be over the measurement period (thirty minutes maximum). (Details on the relationship between the Capture and Drift Tracking Ranges and the tuning range of the VCO source are provided in *Chapter 2*. This information will help you evaluate your VCO source based on the estimated drift of your sources.)

Table 3-27 lists the tuning parameters for several VCO options.

Table 3-27. Tuning Characteristics of Various VCO Source Options

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range ($\pm V$)	Input Resistance (ohms)	Tuning Calibration Method
HP 8662/3A EFC DCFM	v_o	$5 E - 9 \times v_o$ FM Deviation	0 0	10 10	$1 E + 6$ 1k (8662) 600 (8663)	Measure Compute Compute
HP 8642A/B		FM Deviation	0	10	600	Compute
HP 8640B		FM Deviation	0	10	600	Compute
HP 8656B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for $\pm 1V$		FM Deviation	0	10	R_{in}	Compute
10 MHz Source A Direct Multiplied As a Timebase: To HP 8662/3A To other VCO (PTR known)	v_o v_o v_o v_o	10 $1 E - 6 \times v_o$ $1 E - 6 \times v_o$ $1 E - 6 \times v_o$	0 0 0 0	10 10 $10 E + 9 \div v_o$ $1 E + 6 \times PTR \div v_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
10 MHz Source B Direct Multiplied As a Timebase: To HP 8662/3A To other VCO (PTR known)	v_o v_o v_o v_o	100 $10 E - 6 \times v_o$ $10 E - 6 \times v_o$ $10 E - 6 \times v_o$	0 0 0 0	10 10 $1 E + 9 \div v_o$, (up to 2.5V max.) $100 E + 3 \times PTR \div v_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
350-500 MHz Source		$12 E + 6$	0	2	$1 E + 6$	Measure
Other User VCO Source		Estimated within a factor of 2	-10 to +10	See Figure 3-23	$1 E + 6$	Measure

Estimating the Tuning Constant

The VCO Tuning Constant is the tuning sensitivity of the VCO source in Hz/V. The required accuracy of the entered Tuning Constant value depends on the VCO Tuning Constant calibration method specified for the measurement. The calibration method is selected in the Calibr Process menu. The following chart lists the calibration method choices and the Tuning Constant accuracy required for each.

VCO Tuning Constant Calibration Method (selected in calibration screen)	Required Tuning Constant Accuracy (entered in parameter screen)
Use the current Tuning Constant (must be accurate from a previous measurement of the same source).	Within a factor of 2 of actual value. (Enter 1 E + 6 for Input Resistance.)
Measure the VCO Tuning Constant	Within a factor of 2 of actual value. (Enter 1 E + 6 for Input Resistance.)
Compute from expected T. Constant	Exact, within 5% of actual. (Also requires that entered Input Resistance value is accurate.)

If you do not know the tuning sensitivity of the VCO source you are using, perform the following procedure to get a close approximation of the VCO Tuning Constant.

Procedure

If the hardware Connect Diagram is displayed, you are ready to begin this procedure. (If it is not, begin a New Measurement and proceed until the hardware Connect Diagram appears on the display.)

Table 3-27. Tuning Characteristics of Various VCO Source Options

VCO Source	Carrier Freq.	Tuning Constant (Hz/V)	Center Voltage (V)	Voltage Tuning Range ($\pm V$)	Input Resistance (ohms)	Tuning Calibration Method
HP 8662/3A EFC DCFM	v_o	$5 E - 9 \times v_o$ FM Deviation	0 0	10 10	$1 E + 6$ 1k (8662) 600 (8663)	Measure Compute Compute
HP 8642A/B		FM Deviation	0	10	600	Compute
HP 8640B		FM Deviation	0	10	600	Compute
HP 8656B		FM Deviation	0	10	600	Compute
Other Signal Generator DCFM Calibrated for $\pm 1V$		FM Deviation	0	10	R_{in}	Compute
10 MHz Source A Direct Multiplied As a Timebase: To HP 8662/3A To other VCO (PTR known)	v_o v_o v_o v_o	10 $1 E - 6 \times v_o$ $1 E - 6 \times v_o$ $1 E - 6 \times v_o$	0 0 0 0	10 10 $10 E + 9 \div v_o$ $1 E + 6 \times PTR \div v_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
10 MHz Source B Direct Multiplied As a Timebase: To HP 8662/3A To other VCO (PTR known)	v_o v_o v_o v_o	100 $10 E - 6 \times v_o$ $10 E - 6 \times v_o$ $10 E - 6 \times v_o$	0 0 0 0	10 10 $1 E + 9 \div v_o$, (up to 2.5V max.) $100 E + 3 \times PTR \div v_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
350-500 MHz Source		$12 E + 6$	0	2	$1 E + 6$	Measure
Other User VCO Source		Estimated within a factor of 2	-10 to +10	See Figure 3-23	$1 E + 6$	Measure

Estimating the Tuning Constant

The VCO Tuning Constant is the tuning sensitivity of the VCO source in Hz/V. The required accuracy of the entered Tuning Constant value depends on the VCO Tuning Constant calibration method specified for the measurement. The calibration method is selected in the Calibr Process menu. The following chart lists the calibration method choices and the Tuning Constant accuracy required for each.

VCO Tuning Constant Calibration Method (selected in calibration screen)	Required Tuning Constant Accuracy (entered in parameter screen)
Use the current Tuning Constant (must be accurate from a previous measurement of the same source).	Within a factor of 2 of actual value. (Enter 1 E + 6 for Input Resistance.)
Measure the VCO Tuning Constant	Within a factor of 2 of actual value. (Enter 1 E + 6 for Input Resistance.)
Compute from expected T. Constant	Exact, within 5% of actual. (Also requires that entered Input Resistance value is accurate.)

If you do not know the tuning sensitivity of the VCO source you are using, perform the following procedure to get a close approximation of the VCO Tuning Constant.

Procedure

If the hardware Connect Diagram is displayed, you are ready to begin this procedure. (If it is not, begin a New Measurement and proceed until the hardware Connect Diagram appears on the display.)

1. Connect the hardware as shown for your measurement. The beatnote signal should appear on the HP 3561A (or on the RF spectrum analyzer if one is connected to the test system).
2. Note the frequency of the beatnote signal. If the beatnote frequency is too low to resolve, manually decrease the span setting on the HP 3561A. To do this, press **LCL**, **FREQ**, **DEFINE SPAN** on the HP 3561A and enter the desired span, or use the Δ ∇ keys. Continue decreasing the span setting until the beatnote frequency can be easily read.
3. Notice the *Center Voltage* label shown in the corner of the display. The value displayed is the Center Voltage of the VCO Tuning Curve specified in the Parameters menu. This is the voltage level that the HP 11848A TUNE VOLTAGE OUTPUT is currently set to.
4. Press **F8** or **SHIFT/F8**. Notice that the center voltage value is changed by 2% of the entered Tune Range of VCO each time one of these keys is pressed.
5. Increment the center voltage value until you have increased it by 10% (five steps).
6. Observe the beatnote frequency change on the HP 3561A resulting from the change in tune voltage, making sure that the beatnote does not pass through 0 Hz. The frequency change divided by the total voltage change is the Tuning Constant in Hz/V of the VCO source being tuned.

Tracking Frequency Drift

The system's frequency drift tracking capability for the Phase Lock Loop measurement is directly related to the tuning range of the VCO source being used. The system's Drift Tracking Range is approximately 20% of the Peak Tuning Range (PTR) of the VCO.

$$\text{PTR} = \text{VCO Tuning Constant} \times \text{Voltage Tuning Range}$$

This is the frequency range within which the beatnote signal created by the HP 11848A Phase Detector must remain throughout the measurement period. In addition, the beatnote signal must remain within the system's Capture Range (10% of the PTR) during the time it takes the system to calibrate and lock the phase lock loop. (Further understanding of the Capture and Drift Tracking Ranges is provided in Chapter 2.)

The stability of the beatnote is a function of the combined frequency stability of the sources being used for the measurement. If beatnote drift prevents the beatnote from remaining within the Capture Range long enough for the system to attain phase lock, the computer will inform you by displaying a message. If the beatnote drifts beyond the Drift Tracking Range during the measurement, the computer will stop the measurement and inform you that the system has lost lock.

Evaluating Beatnote Drift

The *Checking the Beatnote* section included in each Phase Lock Loop measurement example in this chapter provides a procedure for adjusting the beatnote to within the Capture Range set for the measurement. If you have not done so already, verify that the beatnote signal can be tuned to within the Capture Range and that it will remain within the range.

Continue to observe the beatnote and verify that it will not drift beyond the Drift Tracking Range (20% of the PTR) during the measurement period. The length of the measurement period is primarily a function of the frequency offset range specified for the measurement (Start to Stop Frequency). The following chart shows the approximate measurement periods for measuring various frequency offset segments. To estimate the total period for your measurement from the chart, add the measurement periods for the segments you plan to measure.

Frequency Segment	Approximate Measurement Period (Minutes)
0.01 to 1 Hz	17
1 to 10 Hz	2
10 Hz to 100 kHz	3
10 Hz to 2 MHz	4.5
10 Hz to 40 MHz	6

Action

If beatnote drift exceeds the limits of the Capture or Drift Tracking Ranges set for your measurement, the system will not be able to complete the measurement. You have two possible alternatives.

1. Minimize beatnote drift.

- By Allowing sources to warm-up sufficiently.
- By Selecting a different reference source with less drift.

2. Increase the Capture and Drift Tracking Ranges.

- By Selecting a measurement example in this chapter that specifies a drift rate compatible with the beatnote drift rate you have observed.
- By Increasing the Peak Tuning Range for the measurement. (Further information about increasing the PTR is provided in *Changing the PTR.*)

Changing the PTR

The Peak Tuning Range (PTR) for the Phase Lock Loop measurement is set by the Tune Range entered for the VCO and the VCO's Tuning Constant. (If the Calibration Technique is set to *measure* the VCO Tuning Constant, the measured value will be used to determine the system's PTR.)

$$\text{PTR} = \text{VCO Tuning Constant} \times \text{Voltage Tuning Range}$$

From the PTR, the HP 3048A derives the Capture and Drift Tracking Ranges for the measurement. These ranges set the frequency stability requirements for the sources being used. (Further understanding of the relationship between the PTR and the Capture and Drift Tracking Ranges is provided in Chapter 2.)

The PTR also determines the Phase Lock Loop (PLL) bandwidth for the measurement. An important attribute of the PLL bandwidth is that it suppresses the close-in noise which would otherwise prevent the system from locking the loop.

The Tuning Qualifications

Changing the PTR is accomplished by changing the Tune Range of VCO value or the VCO Tuning Constant value or both. There are several ways this can be done. However, when considering these or any other options for changing the PTR, it is important to remember that the VCO source must *always* meet the following tuning qualifications.

- The tuning response of the VCO source must always remain monotonic.
- The VCO source's output level must remain constant across its tuning range.

As long as these qualifications are met, and the HP 3048A does not indicate any difficulty in establishing its calibration criteria, an increase in PTR will not degrade the system's measurement accuracy.

The following methods may be considered for increasing or decreasing the PTR.

Voltage-Controlled-Oscillators

1. Select a different VCO source that has the tuning capabilities needed for the measurement.
2. Increase the Tune Range of the VCO source.

Caution

Be careful not to exceed the input voltage limitations of the Tune Port on the VCO source.

Note

Increasing the Tune Range of the VCO is only valid as long as the VCO source is able to continuously meet the previously mentioned tuning qualifications.

Signal Generators

1. If you are using a signal generator with a calibrated 1 Vpk DC FM Input (such as the HP 8640B, HP 8642A/B, HP 8656B, or HP 8662/3), the Voltage tuning Range can be increased to 10 V as long as you select "Computed from the expected T. Constant" in the Calibration Process display. These signal generators continue to meet all of the previously mentioned tuning qualifications across a 10V tuning range.
2. Increase the signal generator's frequency deviation setting and set the HP 3048A Option 301 to measure the new Tuning Constant or enter the increased deviation if it is known. (Note that increasing the deviation setting often increases the source's noise level as well. Refer to your HP 3048A Option 301 Reference Manual for information about the noise characteristics of the various HP Signal Generator options relative to their deviation setting.)
3. If you are using a synthesizer with Electronic-Frequency-Control (EFC) capability such as the HP 8662A or HP 8663A, it is possible to increase the tuning range of these sources using a VCO as an external time base. When a compatible VCO source is connected to the EXT INPUT on the HP 8662/3, the tuning capability of the VCO source is transferred to the synthesizer. A demonstration for using the HP 11848A's internal 10 MHz sources to increase the tuning range of an HP 8662/3 is provided in the *RF Synthesizer* measurement example in this chapter.

Minimizing Injection Locking

Injection locking occurs when a signal feeds back into an oscillator through its output path. This can cause the oscillator to become locked to the injected signal rather than to the reference signal for the phase locked loop.

Injection locking is possible whenever the buffering at the output of an oscillator is not sufficient to prevent a signal from entering. If the injection locking occurs at an offset frequency that is not well within the PLL bandwidth set for the measurement, it can cause the system to lose phase lock. The system informs you when this has happened by lighting the Out of Lock light on the front panel of the HP 11848A and placing an error message in the computer display.

Adding Isolation

The best way to prevent injection locking is to isolate the output of the source being injection locked (typically the unit-under-test) by increasing the buffering at its output. This can be accomplished by inserting a low noise amplifier and/or an attenuator between the output of the source being injection locked and the HP 11848A. (For information on determining the effect that the amplifier noise will have on the measurement noise floor, refer to *Inserting a Device* in this section.)

Increasing the PLL Bandwidth

If the injection locking bandwidth is $\leq$ to the PLL bandwidth, it may be possible to increase the PLL bandwidth sufficiently to complete the measurement. The PLL bandwidth is increased by increasing the Peak Tuning Range (PTR) for the measurement.

Note

The PTR for the measurement is set by the tuning characteristics of the VCO source you are using. Notice in Figure 3-42 that increasing the PLL bandwidth can require a substantially larger increase in the PTR. For information on the limitations of increasing the PTR, refer to *Changing the PTR* in this section.

To estimate the PTR needed to prevent injection locking from causing the system to lose lock:

1. Determine the injection locking bandwidth. Tune the beatnote toward 0 Hz using the procedure described in the *Checking the Beatnote* section of each Phase Lock Loop measurement example in this chapter. When the injection locking occurs, the beatnote will disappear. The injection locking bandwidth is the frequency of the beatnote just prior to where the injection locking occurs as the beatnote is tuned toward 0 Hz.
2. Multiply the injection locking bandwidth by 2 to determine the minimum PLL bandwidth required to prevent the injection locking from causing the system to lose lock. (To prevent accuracy degradation, it may be necessary to increase the PLL bandwidth to $4 \times$ the injection locking bandwidth. The computer will inform you during the measurement if the possibility of accuracy degradation exists.)
3. Locate the required PLL bandwidth in Figure 3-42 to determine the PTR required for the measurement. (For details on increasing the PTR, refer to *Changing the PTR* in this section.

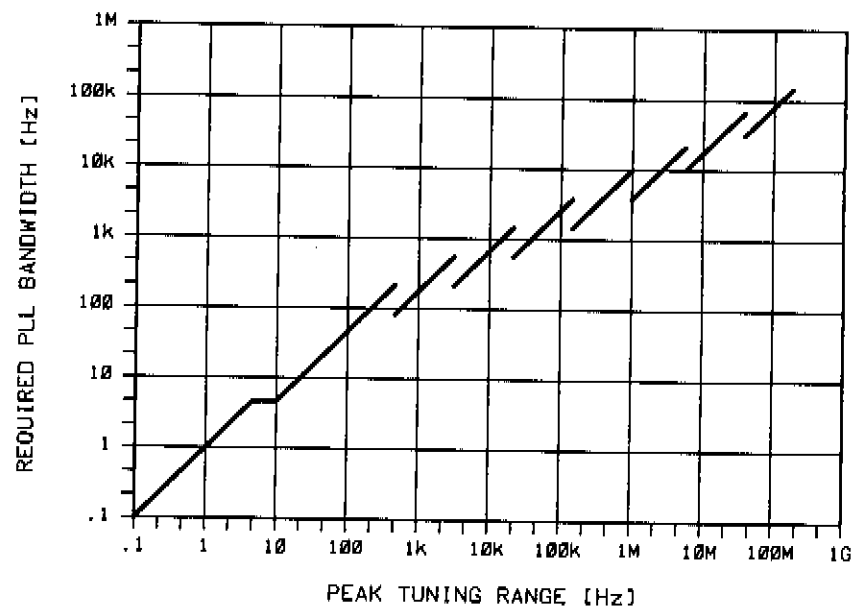


Figure 3-42. Peak Tuning Range (PTR) Required by Injection Locking.

Inserting a Device An Attenuator

You may find that some of your measurement setups require an in-line device such as an attenuator in one of the signal source paths. (For example, you may find it necessary to insert an attenuator at the output of a unit-under-test (UUT) to prevent it from being injection locked to the reference source.) The primary consideration when inserting an attenuator is that the signal source has sufficient output amplitude to maintain the required signal level at the HP 11848A's Phase Detector input port (as shown in Figure 3-43). The signal level required for the measurement depends on the noise floor level needed to measure the UUT.

Figure 3-44 shows the relationship between the signal level at the R port and the measurement noise floor.

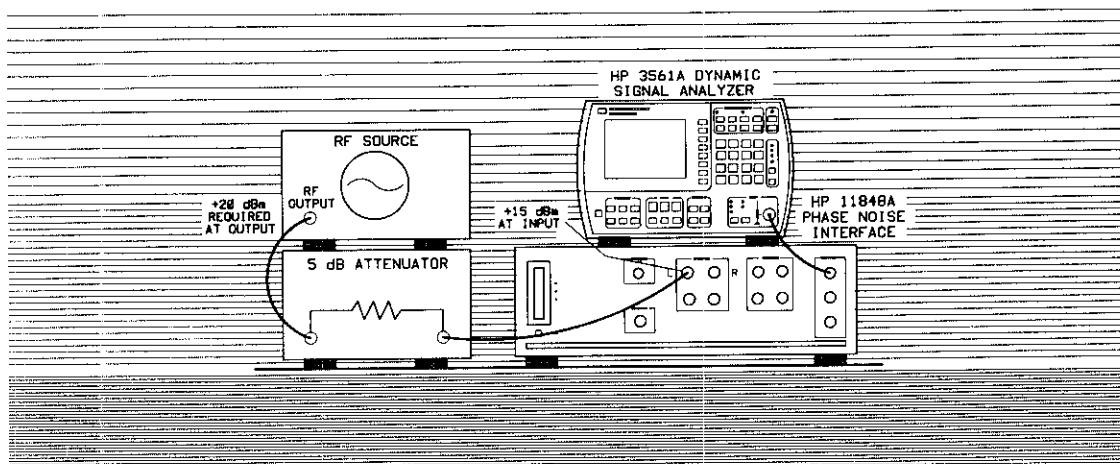


Figure 3-43. Output Level Required From Signal Source with In-line Attenuator.

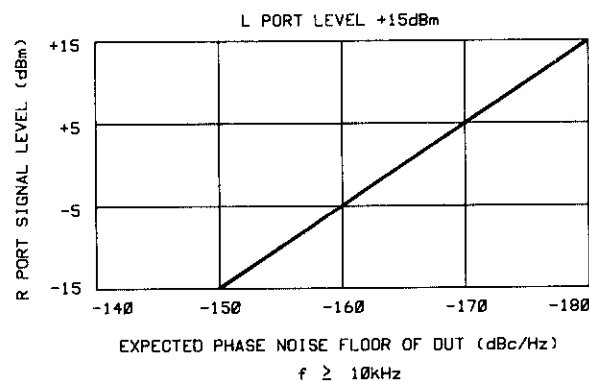


Figure 3-44. Measurement Noise Floor Relative to R Port Signal Level.

An Amplifier

If a source is not able to provide a sufficient output level, or if additional isolation is needed at the output, it may be necessary to insert a low phase-noise RF amplifier at the output of the source.

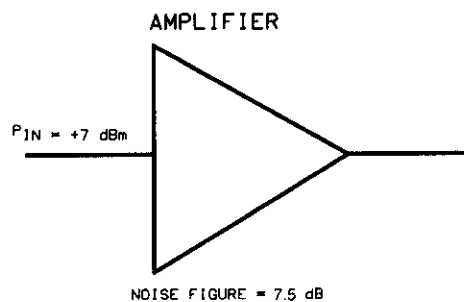
Note, however, that the noise of the inserted amplifier will also be summed into the measured noise level along with the noise of the source.

The HP 3048A Option K22 Dual RF Amplifier was designed specifically for this purpose. It has a noise figure of <7.5 dB ($f_c > 50$ MHz), a frequency range of 5-1500 MHz, and a gain of 9 dB (± 1.5 dB); meeting all HP 3048A System Phase Noise Specifications for $f_c > 50$ MHz. This instrument is the preferred solution for tests requiring an external amplifier.

The following equation can be used to estimate what the measurement noise floor is as a result of the added noise of an inserted amplifier:

$$\mathcal{L}(f)_{out} = -174 \text{ dB} + \text{Amplifier Noise Figure} - \text{Power into the Amplifier} - 3 \text{ dB}$$

For Example,



$$\begin{aligned}\mathcal{L}(f) &= -174 \text{ dBm} + 7.5 \text{ dB} - (+7 \text{ dBm}) - 3 \text{ dB} \\ \mathcal{L}(f) &= -176.5 \text{ dBc/Hz}\end{aligned}$$

Evaluating Noise Above the Small Angle Line

If the average noise level on the input signals exceeds approximately 0.1 radians RMS integrated outside of the Phase Lock Loop (PLL) bandwidth, it can prevent the system from attaining phase lock.

The following procedure allows you to evaluate the beatnote created between the two sources being measured. The intent is to verify that the PLL bandwidth is adequate to prevent the noise on the two sources from causing the system to lose lock.

If the computer is displaying the hardware *Connect Diagram* you are ready to begin this procedure. (If it is not, begin a New Measurement and proceed until the hardware Connect Diagram appears on the display.)

Determining the Phase Lock Loop Bandwidth

1. Determine the Peak Tuning Range (PTR) of your VCO by multiplying the VCO Tuning Constant by the Tune Range of VCO value entered. (If the HP 3048A has measured the VCO Tuning Constant, use the measured value.)

$$PTR = \text{VCO Tuning Constant} \times \text{Voltage Tuning Range}$$

For Example,

$$PTR = 100 \frac{\text{Hz}}{\text{V}} \times 10\text{V} = 1\text{ kHz}$$

2. Estimate the Phase Lock Loop (PLL) bandwidth for the measurement using the PTR of your VCO and the graph in Figure 3-45.

Observing the Beatnote

If the beatnote frequency is below 100 kHz it will appear on the HP 3561A's display in both the frequency domain and the time domain. If the beatnote does not appear on the HP 3561A, then the beatnote is either greater than 100 kHz or it does not exist.

If incrementing the frequency of one of the sources does not produce a beatnote within 100 kHz, you will need to verify the presence of an output signal from each source before proceeding.

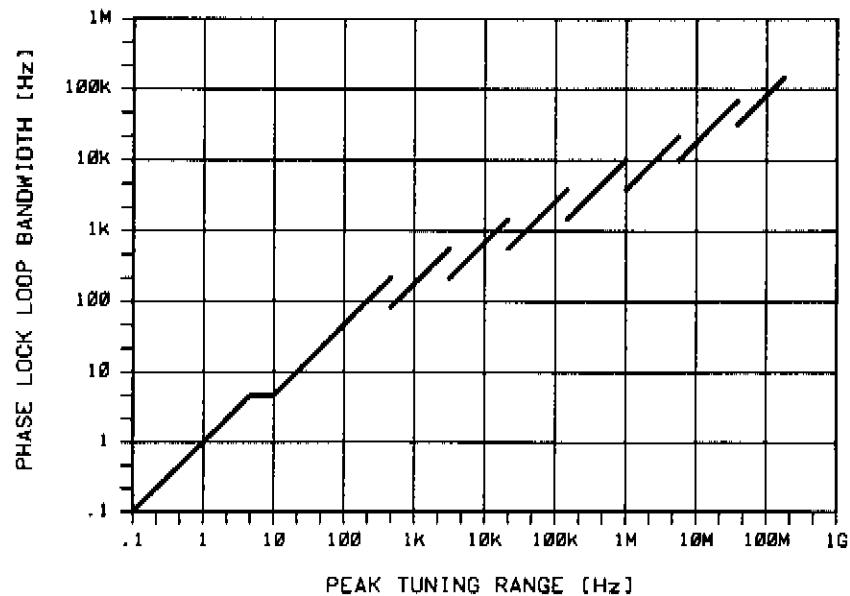


Figure 3-45. Graph of Phase Lock Loop Bandwidth Provided by the Peak Tuning Range

1. Once the beatnote is displayed, press the **RANGE**, **AUTO RANGE OFF**, and **SINGLE AUTO RANGE** keys on the HP 3561A.
2. Set the span width on the HP 3561A to approximately $4 \times$ PLL bandwidth. Adjust the beatnote to position it near the center of the display.

Note

If you are not able to tune the beatnote to $2 \times$ PLL bandwidth (center of display) due to frequency drift, refer to *Tracking Frequency Drift* in this section for information about measuring drifting signals.

If you are able to locate the beatnote, but it distorts and then disappears as you adjust it towards 0 Hz, then your sources are injection locking to each other. Set the beatnote to the lowest frequency possible before injection locking occurs and then refer to *Minimizing Injection Locking* in this section for recommended actions.

-
3. Press the **AVG** key, and then the **RMS** key. Wait for the trace to return and then press **MKR** and **MKR to Peak**.
 4. Press **REL MKR**, and **MKR REF**.
 5. Press the **DEFINE TRACE** and the **MATH FUNCTION** keys.

6. Using the $\Rightarrow$ key on the HP 3561A, offset the marker by the PLL bandwidth. Read the offset frequency and noise level indicated at the bottom of the display. (If the noise level falls below the bottom of the display, the marker reading will still be correct. To increase the vertical scale, press **VERT SCALE**, **DEFINE DB/DIV**, and enter 20 dB.)
7. Compare the average noise level at the PLL bandwidth offset to the small angle criterion level shown on the graph in Figure 3-46. The average noise level of the signal must remain below the small angle line at all offset frequencies beyond the PLL bandwidth. (The small angle line applies only to the level of the average noise. Spur levels that exceed the small angle line will not degrade measurement accuracy provided they do not exceed -40 dBc.)

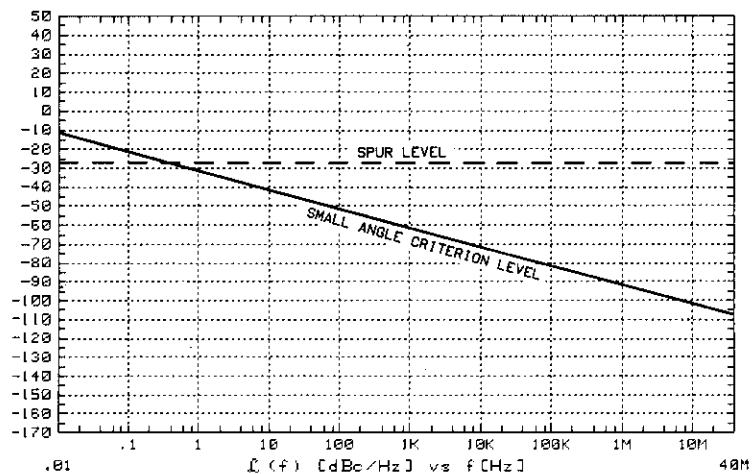


Figure 3-46. Graph of Small Angle Line and Spur Limit

8. Continue moving the marker to the right to verify that the average noise level remains below the small angle line.
9. Increase the span by a factor of ten by selecting **FREQ** and **DEFINE SPAN**. Continue comparing the noise level to the graph.
10. Continue to increase the span width and compare the noise level out to 100 kHz. (If the noise level exceeds the small angle line at any offset frequency beyond the PLL bandwidth, note the offset frequency and level of the noise. Use the graph in Figure 3-47 to determine the Peak Tuning Range (PTR) necessary to provide a sufficient PLL bandwidth to make the measurement.

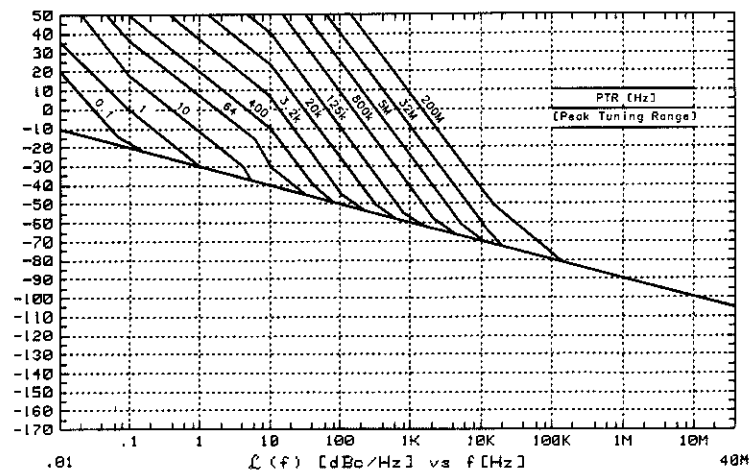


Figure 3-47. Graph Showing Peak Tuning Range Requirements for Noise that Exceeds the Small Angle Limit

Measurement Options

If the observed level exceeded the small angle line at any point beyond the PLL bandwidth set for the measurement, you will need to consider one of the following measurement options.

- Evaluate your source using the noise data provided by the HP 3561A in the procedure you just performed.
- Increase the PTR if possible, to provide a sufficient PLL bandwidth to suppress the noise. (For information on increasing the PTR, refer to *Changing the PTR* in this section.)
- Reduce the noise level of the signal sources.
- Use the Discriminator technique to measure the phase noise level of your source.

4

Two-Port Device Measurement Fundamentals

What is Residual Noise?

Residual or two-port noise is the noise added to a signal when the signal is processed by a two-port device. Such devices include: amplifiers, dividers, filters, mixers, multipliers, phase-locked loop synthesizers or any other two-port electronic networks. Residual noise is composed of both AM and Φ M components.

The Noise Mechanisms

Residual noise is the sum of two basic noise mechanisms:

1. **Additive noise:** the noise generated by the two-port device at or near the signal frequency which adds in a linear fashion to the signal.

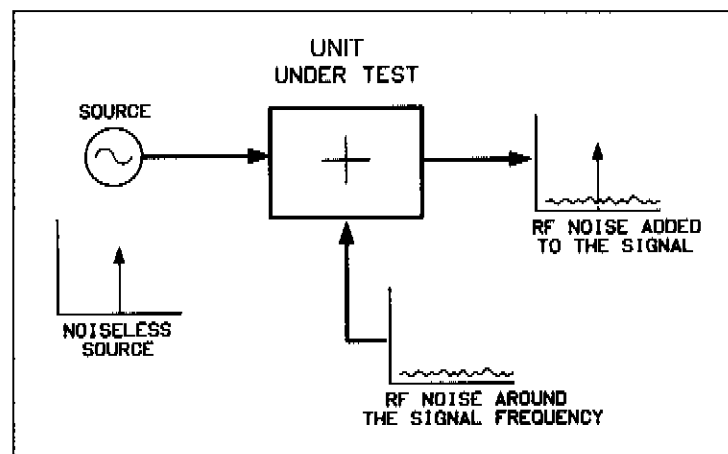


Figure 4-1. Additive Noise Components

2. **Multiplicative noise:** This noise has two known causes. The first, is an intrinsic, direct, phase modulation with a $1/f$ spectral density and the exact origin of this noise component is unknown. The second, in the case of amplifiers or multipliers, is noise which may modulate an RF signal by the multiplication of baseband noise with the signal. This mixing is due to any non-linearities in the two-port network. The baseband noise may be produced by the active device(s) of the internal network, or may come from low-frequency noise on the signal or power supply.

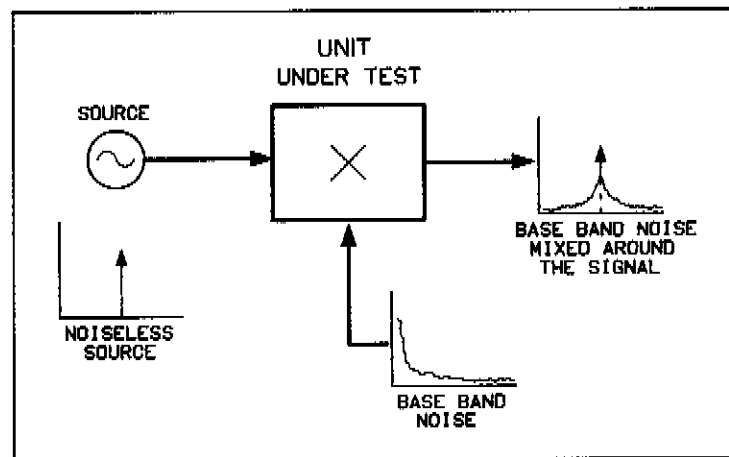


Figure 4-2. Multiplicative Noise Components

The Importance of Residual and AM Noise Measurements

The following are reasons why the residual and AM noise levels of your two-port devices may be important to you:

- In recent years, it has become apparent to manufacturers that overall system and subsystem noise performance, including residual noise, must be measured and specified for all systems and subsystems.
- The absolute noise of an oscillator is set by the residual noise of the active device, the residual noise of the resonator and the bandwidth of the resonator.
- Oscillator noise is further degraded by the residual noise of all the devices that follow it: amplifiers, dividers, filters, mixers, multipliers, phase-locked loops, synthesizers, etc.
- When troubleshooting unsatisfactory phase noise performance it may be necessary to measure both the AM noise and residual phase noise of the system components to locate the problem.
- AM noise is important in its own right in some applications such as in signal generators used for residual phase noise testing or adjacent channel receiver testing.
- Any active or non-linear device produces some level of AM to phase noise conversion. This AM noise can contribute to the residual phase noise. This includes AM noise in phase detectors.

Basic Assumptions Regarding Residual Phase Noise Measurements

The following are some basic assumptions regarding Residual Phase Noise measurements. If these assumptions are not valid they will affect the measured results.

- **The source noise in each of the two phase detector paths is correlated at the phase detector for the frequency offset range of interest.** When the source noise is correlated at the phase detector, the source phase noise cancels, leaving only the residual phase noise of the UUT.
- **Source AM noise is comparatively small.** A typical mixer-type phase detector only has about 20 to 30 dB of AM noise rejection. If the AM component of the signal is greater than 20 to 30 dB above the residual phase noise, it will contribute to the residual phase noise measurement and show the residual phase noise as being greater than it really is.
- **The UUT does not exhibit a bandpass filter function.** A bandpass filter type response will cause the source noise to be decorrelated at the edge of the filter. This decorrelation of the noise causes the system to measure the source noise level directly at offsets beyond the filter bandwidth.

Given these assumptions, when the unit-under-test (UUT) is connected to either of the two inputs of the Phase Detector, all of the source noise will cancel and only the residual noise of the UUT will be measured.

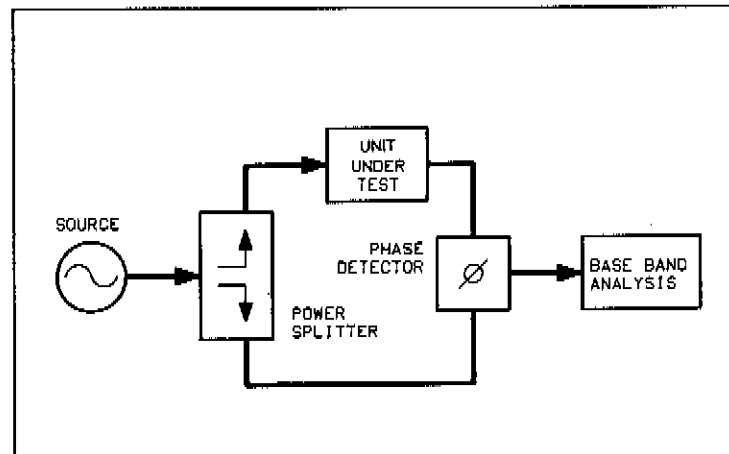


Figure 4-3. Setup for Typical Residual Phase Noise Measurement

Frequency Translation Devices

If the UUT is a frequency translating device (such as a divider, multiplier, or mixer), then one UUT must be put in each path. The result will be the sum of the noise from each UUT. In other words, each UUT is at least as quiet as the measured result.

If the UUT's are identical, a possible (but not recommended) assumption is that the noise of each UUT is half the measured result, or 3 dB less. All that really can be concluded is that the noise level of one of the UUT's is at least 3 dB lower than the measured result at any particular offset frequency.

If a more precise determination is required at any particular offset frequency, a third UUT must also be measured against the other two UUT's. The data from each of the three measurements can then be processed by the HP 3048A to give the noise of each of the individual UUT's.

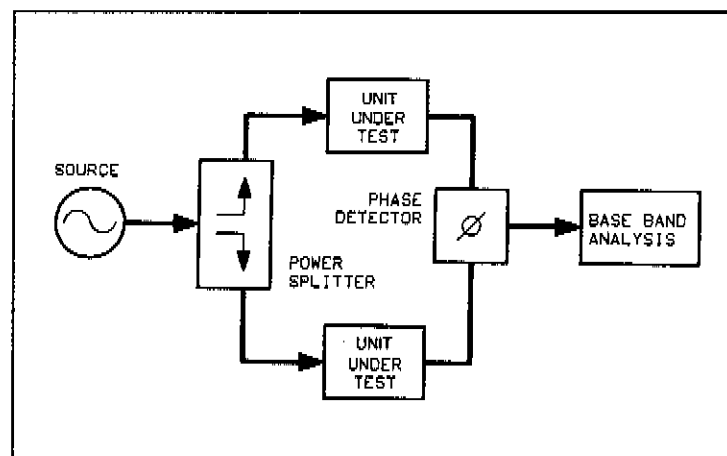


Figure 4-4. Measurement Setup for Two Similar UUTs

Calibrating the Measurement

In the HP 3048A System, residual phase noise measurements are made by selecting "Phase Noise Measurement without Phase-Lock Loop" because no phase locking is required.

There are five calibration methods available for use when making residual phase noise measurements. They are:

- User Entry of Phase Detector Constant
- Measured $\pm$ DC Peak
- Beatnote
- Double-Sided FM or Φ M Spur
- Single-Sided Spur

The method used will mainly be determined by the sources and equipment available to you.

When calibrating the system for measurements, remember that the calibration is only as accurate as the data input to the system software.

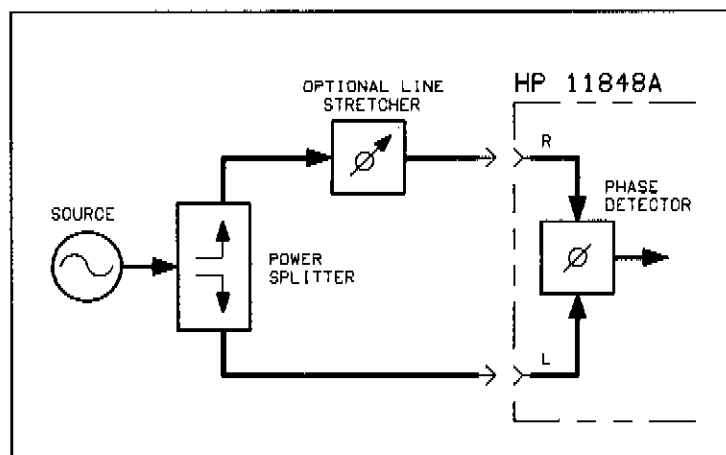


Figure 4-5. General Equipment Setup for Making Residual Phase Noise Measurements

Calibration and Measurement General Guidelines

The following general guidelines should be considered when setting up and making a residual two-port phase noise measurement.

1. For residual phase noise measurements, the source noise must be correlated.
 - a. The phase delay in the paths between the power splitter and the phase detector must be kept to a minimum when making residual noise measurements. In other words, by keeping the cables between the phase detector and power splitter short, τ will be small. The attenuation of the source noise is a function of the carrier offset frequency, and the delay time (τ) and is equal to:

$$\text{Attenuation(dB)} = 20 \log |2 \sin(\pi \times f \times \tau)|$$

where

f = carrier offset frequency

π = 3.14159

τ = time delay (sec.)

Note

For $f = 1/(2\pi\tau)$ the attenuation of the source is 0 dB.

For $f < 1/(2\pi\tau)$ the source noise is attenuated at the rate of 20 dB per decade.

For $\frac{1}{(2\tau)}$ there is 6 dB gain.

-
- b. The source should also have a good broadband phase noise floor because at sufficiently large carrier offsets it will tend to decorrelate when measuring components with large delays. A source with a sufficiently low noise floor may be able to hold an otherwise impossible measurement within the region of validity. Examples of sources which best meet these requirements are the HP 8640B and HP 8642A/B.

2. The source used for making residual phase noise measurements must be low in AM noise because:
 - a. Source AM noise can cause AM to Φ M conversion in the UUT.
 - b. Mixer-type phase detectors only provide about 20 to 30 dB of rejection to AM noise in a Φ M noise measurement.
3. It is very important that all components in the test setup be well shielded from RFI. Unwanted RF coupling between components will make a measurement setup very vulnerable to external electric fields around it. The result may well be a setup going out of quadrature simply by people moving around in the test setup area and altering surrounding electric fields. A loss of quadrature stops the measurement.
4. When making low-level measurements, the best results will be obtained from uncluttered setups. Soft foam rubber is very useful for isolating the UUT and other phase-sensitive components from mechanically-induced phase noise. The mechanical shock of bumping the test set or kicking the table will often knock a sensitive residual phase noise measurement out of quadrature.
5. When making an extremely sensitive measurement it is essential to use semi-rigid cable between the components. The bending of a flexible cable from vibrations and temperature variations in the room can cause enough phase noise in flexible connecting cables to destroy the accuracy of a sensitive measurement. The connectors also must be tight; a torque wrench is the best tool.
6. When measuring a low-noise device, it is important that the source and any amplification, required to achieve the proper power at the phase detector, be placed before the splitter so it will be correlated out of the measurement. In cases where this is not possible; remember that any noise source, such as an amplifier, placed after the splitter in either phase detector path, will contribute to the measured noise.

7. An amplifier must be used in cases where the signal level out of the UUT is too small to drive the phase detector, or the drive level is inadequate to provide a low enough system noise floor. In this case the amplifier should have the following characteristics:
 - a. It should have the lowest possible noise figure, and the greatest possible dynamic range.
 - b. The signal level must be kept as high as possible at all points in the setup to minimize degradation from the thermal noise floor.
 - c. It should have only enough gain to provide the required signal levels. Excess gain leads to amplifiers operating in gain compression, making them very vulnerable to multiplicative noise problems. The non-linearity of the active device produces mixing which multiplies the baseband noise of the active device and power supply noise around the carrier.
 - d. The amplifier's sensitivity to power supply noise and the power supply noise itself must both be minimized.

The Calibration Options

There are five calibration methods that you can choose from for calibrating your two-port measurements. The procedures for each method are provided on the following pages. The advantages and disadvantages of each method are also provided to help you select the best method for your application. The primary considerations for selecting a calibration method are:

- Measurement Accuracy
- Equipment Availability

User Entry of Phase Detector Constant

This calibration option requires that you know the phase detector constant for the specific measurement to be made. The phase detector constant can be estimated from the source power levels or it can be determined using one of the other calibration methods.

Once determined, the phase detector constant can be entered directly into the system software without going through a calibration sequence. Remember, however, that the phase detector constant is unique to a particular set of sources, the RF level into the phase detector and the test configuration.

Advantages:

Easy method for calibrating the measurement system.

Requires little additional equipment: only an RF power meter to manually measure the drive levels into the phase detector.

Fastest method of calibration. If the same power levels are always at the phase detector, (as in the case of leveled outputs), the phase detector sensitivity will always be essentially the same (within a dB or two). If this accuracy is adequate, it is not necessary to recalibrate.

Only one RF source is required.

Super-quick method of estimating the phase detector constant and noise floor to verify other calibration methods and check available dynamic range.

Disadvantages:

The user entry of the phase detector constant is the least accurate of all the calibration methods.

It does not take into account the amount of power at harmonics of the signal.

It does not take into account power which may be generated by spurious oscillations, causing the power meter to measure much more power than is at the distinct phase detector frequency.

Procedure

1. Connect circuit as per Figure 4-6, and tighten all connections.

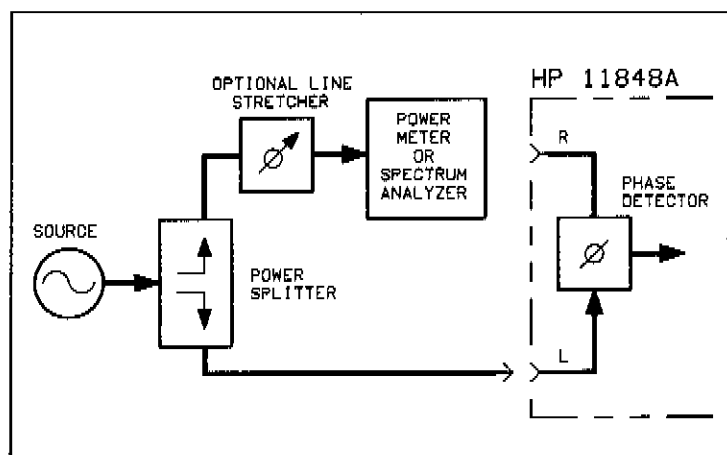


Figure 4-6. Measuring Power at Phase Detector R Port

- Measure the power level that will be applied to the R port of the HP 11848A's Phase Detector. The following chart shows the acceptable amplitude ranges for the HP 11848A Phase Detectors.

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm

- Locate the power level you measured on the left side of the Phase Detector Sensitivity Graph (Figure 4-7). Now move across the graph at the measured level and find the corresponding Phase Detector constant along the right edge of the graph. This is the value you will enter as the "Current Detector Constant" when you define your measurement. (Note that the approximate measurement noise floor provided by the R port level is shown across the bottom of the graph.)

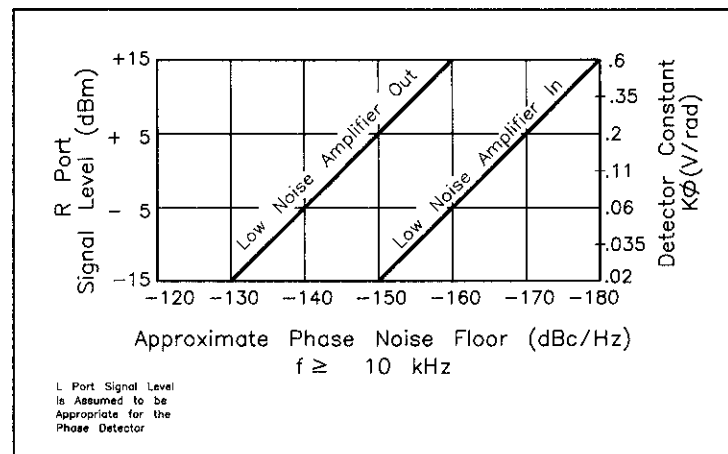


Figure 4-7. Phase Detector Sensitivity

4. If you are not certain that the power level at the L input port is within the range shown in the preceding graph, measure the level using the setup shown in Figure 4-8.
5. After you complete the measurement set up procedures and begin running the measurement, the computer will prompt you to adjust for quadrature. Adjust the phase difference at the phase detector to 90 degrees (quadrature) by either adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is attained when the meter on the front panel of the phase noise interface is set to center scale, zero.

Note

For the system to accept the adjustment to quadrature, the meter must be within the first small divisions around zero, and for the system to continue to take data it must stay within the second small divisions.

6. Once you have attained quadrature, you are ready to proceed with the measurement.

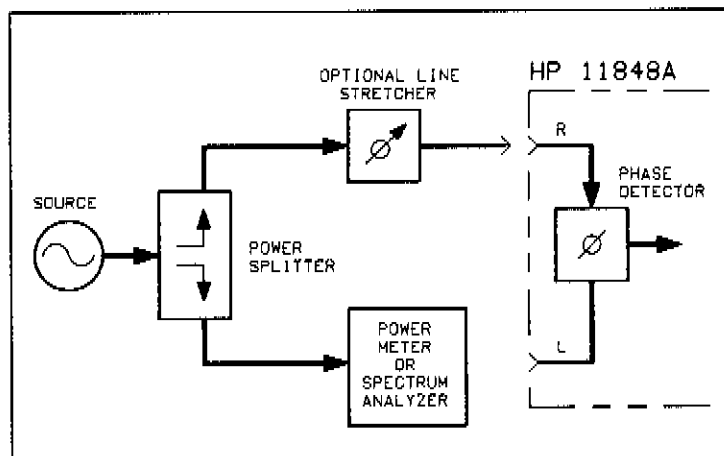


Figure 4-8. Measuring Power at Phase Detector L Port

Measured $\pm$ DC Peak Voltage

Advantages:

Easy method for calibrating the measurement system.

This calibration technique can be performed using the HP 3561A.

Fastest method of calibration. If, for example, the same power levels are always at the phase detector, as in the case of leveled, or limited outputs, the phase detector sensitivity will always be essentially equivalent (within one or two dB). Recalibration becomes unnecessary if this accuracy is adequate.

Only one RF source is required.

Measures the phase detector gain in the actual measurement configuration. This technique requires you to adjust off of quadrature to both the positive and the negative peak output of the Phase Detector. This is done by either adjusting the phase shifter or the frequency of the source. An oscilloscope or voltmeter can optionally be used for setting the positive and negative peaks.

Disadvantages:

Has only moderate accuracy compared to the other calibration methods.

Does not take into account the amount of phase detector harmonic distortion relative to the measured phase detector gain, hence the phase detector must operate in its linear region.

Requires manual adjustments to the source and/or phase shifter to find the phase detector's positive and negative output peaks. The system will read the value of the positive and negative peak and automatically calculate the mean of the peak voltages which is the phase detector constant used by the system.

Procedure

1. Connect circuit as per Figure 4-9, and tighten all connections.
2. Measure the power level that will be applied to the R port of the HP 11848A's Phase Detector. The following chart shows the acceptable amplitude ranges for the HP 11848A Phase Detectors.

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm

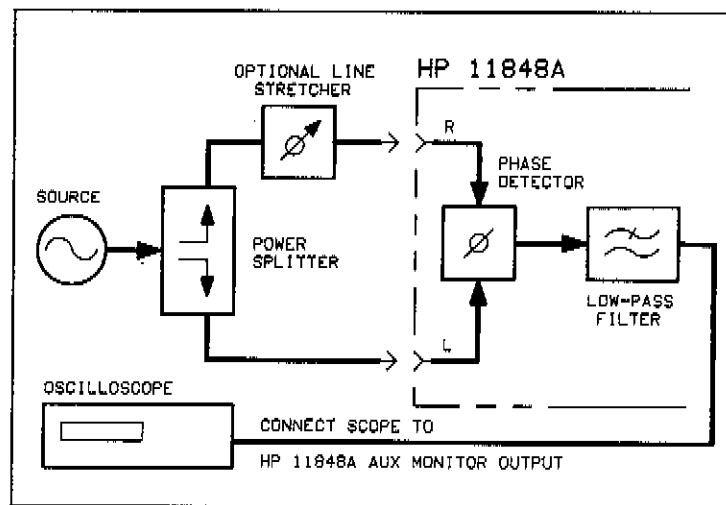


Figure 4-9. Connection to Optional Oscilloscope for Determining Voltage Peaks

3. Adjust the phase difference at the phase detector over a 360 degree range.
4. The system will measure the positive and negative peak voltage of the phase detector using the signal displayed on the HP 3561A. For more sensitivity, an oscilloscope or voltmeter can be connected to the AUX MONITOR port on the HP 11848A for determining the peaks. The phase may be adjusted either by varying the frequency of the source or by adjusting a variable phase shifter or line stretcher.

Note Connecting an oscilloscope to the AUX MONITOR port is recommended because the signal can then be viewed to give visual confidence in the signal being measured. As an example, noise could affect a voltmeter reading, whereas, on the oscilloscope any noise can be viewed and the signal corrected to minimize the noise before making the reading.

5. The system software will then calculate the phase detector constant automatically using the following algorithm.

$$\text{Phase Detector Constant} = \frac{((+V_{peak}) - (-V_{peak}))}{2}$$

6. The system software will then adjust the phase detector to quadrature if the source can be controlled automatically, or will prompt you to set the HP 11848A meter to quadrature if the source is a manual instrument.
7. The system will now measure the noise data.

Measured Beatnote

This calibration option requires that one of the input frequency sources be tunable such that a beatnote can be acquired from the two sources. For the system to calibrate, the beatnote frequency must be within the following ranges. (You should also note that for beatnote frequencies below 20 Hz, it will take the system longer to determine the calibration constant.)

Carrier Frequency	Beatnote Frequency Range (f_B)
< 95 MHz	1 Hz < f_B < 1 MHz
> 95 MHz	1 Hz < f_B < 20 MHz

Advantages:

Does not require an RF spectrum analyzer if the beatnote is <100 kHz.

Simple method of calibration.

Disadvantages:

It does not take into account the harmonics of the phase detector and all non-linearities thereof, when using the HP 3048A.

It requires two RF sources, separated by 1 Hz to 20 MHz at the phase detector. The calibration source output power must be manually adjusted to the same level as the power splitter output it replaces (requires a power meter).

It is less accurate than either the phase modulation or single-sided spur methods.

Procedure

1. Connect circuit as per Figure 4-10, and tighten all connections.

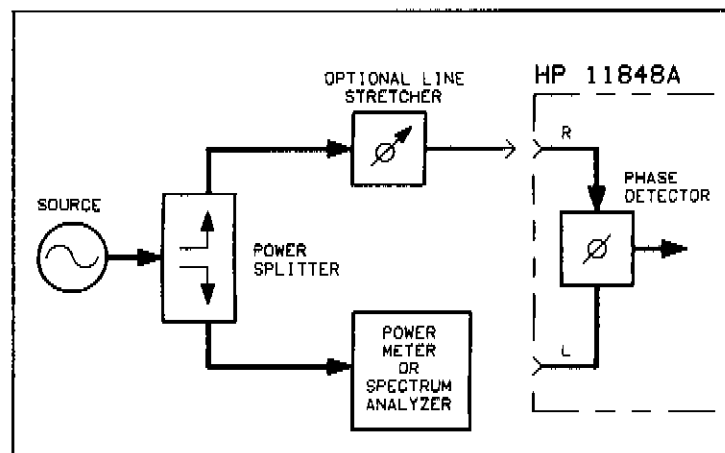


Figure 4-10. Measuring Power from Splitter

2. Measure the power level that will be applied to the R port of the HP 11848A's Phase Detector. The following chart shows the acceptable amplitude ranges for the HP 11848A Phase Detectors.

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm

3. Measure the output power at one side of the power splitter, then terminate in 50 ohms.
4. Adjust the calibration source to the same output power as the measured output power of the power splitter.

5. Adjust the output frequency such that the beatnote frequency is between 1 Hz and 100 kHz, or to between 1 Hz and 20 MHz if an RF spectrum analyzer is included in the system. (Note that the beatnote frequency may be measured on the system spectrum analyzers.)
6. The system can now measure the calibration constant.
7. Disconnect the calibration source and reconnect the power splitter.
8. Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is achieved when the meter on the front panel of the phase noise interface is set to zero.

Note For the system to accept the adjustment, the meter needle must be between the first two small divisions around center scale (zero). For the system to continue to take data, the needle must stay within the second two small divisions around center scale.

9. Reset quadrature and measure phase noise data.

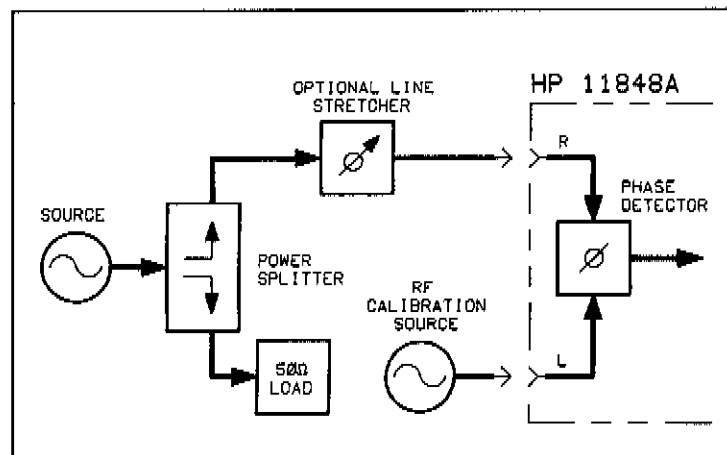


Figure 4-11. Calibration Source Beatnote Injection

Double-Sided Spur

This calibration option has the following requirements:

- One of the input frequency sources must be capable of being frequency or phase modulated.
- The resultant sideband spurs from the FM or Φ M modulation must have amplitudes that are > -100 dB and < -20 dB relative to the carrier amplitude.
- The offset frequency or modulation frequency must be between 20 Hz and 100 kHz if only the HP 3561A analyzer is configured in the system, or between 20 Hz and 20 MHz if an RF spectrum analyzer is also configured in the system.

Advantages:

Requires only one RF source

Calibration is done under actual measurement conditions so all non-linearities and harmonics of the phase detector are calibrated out.

Note

Because the calibration is performed under actual measurement conditions, the *Double-sided Spur Method* and the *Single-sided Spur Method* are the two most accurate calibration methods.

Disadvantages:

Requires a phase modulator which operates at the desired carrier frequency.

Requires audio calibration source.

Requires RF spectrum analyzer for manual measurement of Φ M sidebands

Note

Most phase modulators are narrow-band devices; therefore, a wide range of test frequencies will require multiple phase modulators.

Procedure

1. Connect circuit as per Figure 4-12, and tighten all connections.

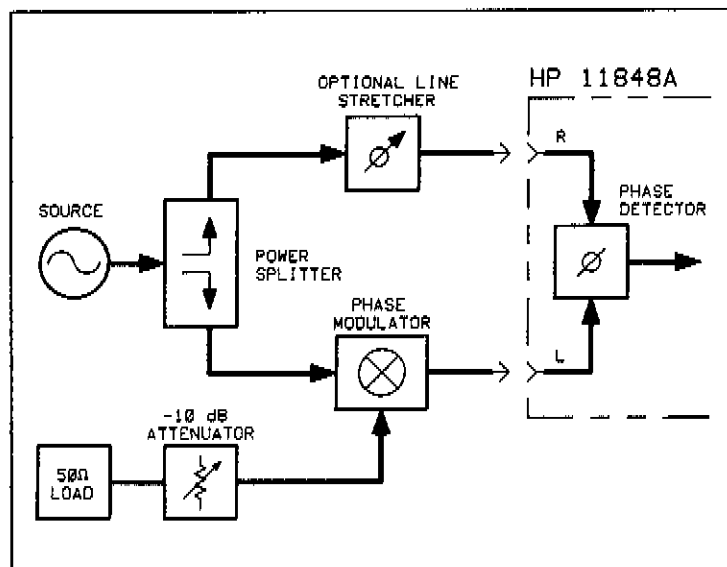


Figure 4-12. Calibration Setup

2. Measure the power level that will be applied to the R port of the HP 11848A's Phase Detector. The following chart shows the acceptable amplitude ranges for the HP 11848A Phase Detectors.

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm

3. Using the RF spectrum analyzer, measure the carrier-to-sideband ratio of the phase modulation at the phase detector's modulated port and the modulation frequency. The audio calibration source should be adjusted such that the sidebands are between -30 and -60 dB below the carrier and the audio frequency is between 20 Hz and 100 kHz (or between 20 Hz and 20 MHz if an RF spectrum analyzer is included in the system).

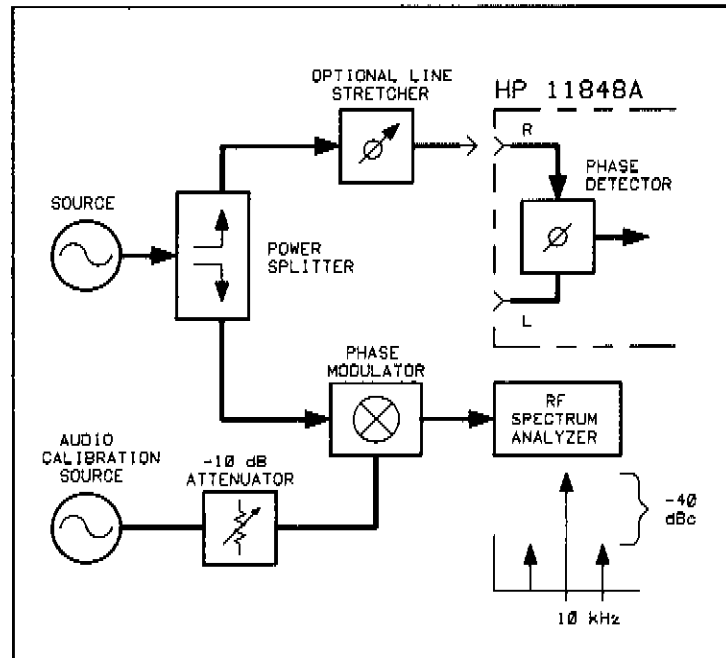


Figure 4-13. Measuring Carrier-to-sideband Ratio of the Modulated Port

4. Measure the carrier-to-sideband ratio of the non-modulated side of the phase detector. It must be at least 20 dB less than the modulation level of the modulated port. This level is necessary to prevent cancellation of the modulation in the phase detector. Cancellation would result in a smaller phase detector constant, or a measured noise level that is worse than the actual performance. The modulation level is set by the port-to-port isolation of the power splitter and the isolation of the phase modulator. This isolation can be improved at the expense of signal level by adding an attenuator between the phase modulator and the power splitter. This isolation can be improved at the expense of signal level by adding an attenuator between the phase modulator and the power splitter.
5. Connect the phase detector.

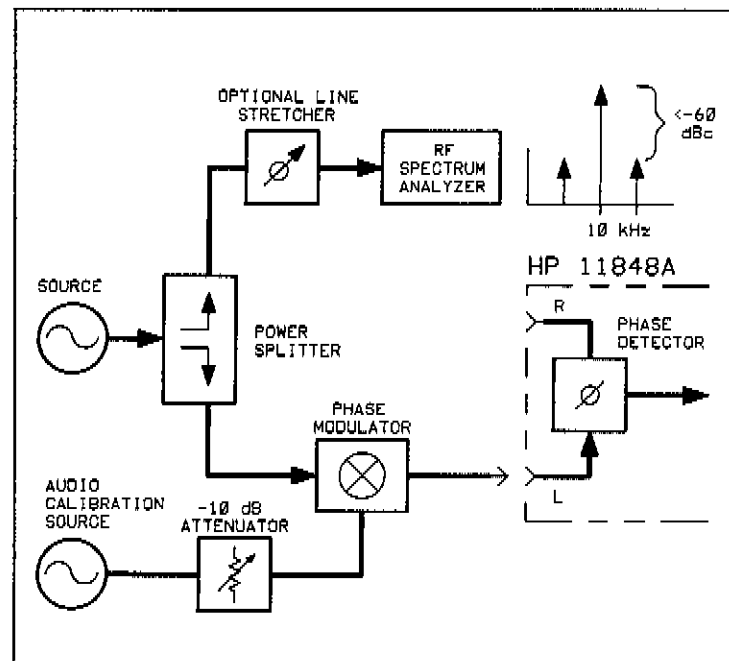


Figure 4-14. Measuring Carrier-to-sideband Ratio of the Non-modulated Port

6. Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is achieved when the meter on the front panel of the HP 11848A is set to center scale.

Note

For the system to accept the adjustment, the meter needle must be between the first two small divisions around center scale (zero). For the system to continue to take data, the needle must stay within the second two small divisions around center scale.

7. Set the Type of Measurement to *Phase Noise Without Using a PLL*.
8. Set the Calibration Technique to *Derive From Double-sided Spur* and enter the sideband amplitude and offset frequency.
9. Select **New Measurement**.
10. Check quadrature and measure the phase detector constant by pressing **Y** to proceed.
11. Remove audio source.
12. Reset quadrature and measure phase noise data.

Single-Sided Spur

This calibration option has the following requirements:

- A third source to generate a single sided spur.
- An external power combiner (or adder) to add the calibration spur to the frequency carrier under test. The calibration spur must have an amplitude > -100 dB and < -20 dB relative to the carrier amplitude. The offset frequency of the spur must be >20 Hz and <20 MHz.
- A spectrum analyzer or other means to measure the single sided spur relative to the carrier signal.

You will find that the equipment setup for this calibration option is similar to the others except that an additional source and a power splitter have been added so that the spur can be summed with the input carrier frequency.

Advantages:

Calibration is done under actual measurement conditions so all non-linearities and harmonics of the phase detector are calibrated out.

Note

The *Single-sided Spur Method* and the *Double-sided Spur Method* (Option 4) are the two most accurate methods.

Broadband couplers with good directivity are available, at reasonable cost, to couple in the calibration spur.

Disadvantages:

Requires two RF sources that must be between 20 Hz and 100 kHz if only an HP 3561A analyzer is configured in the system, or between 20 Hz and 20 MHz if an RF spectrum analyzer is configured in the system.

Requires an RF spectrum analyzer for manual measurement of the signal-to-spur ratio and the spur offset frequency.

Procedure

1. Connect circuit as per Figure 4-15, and tighten all connections.

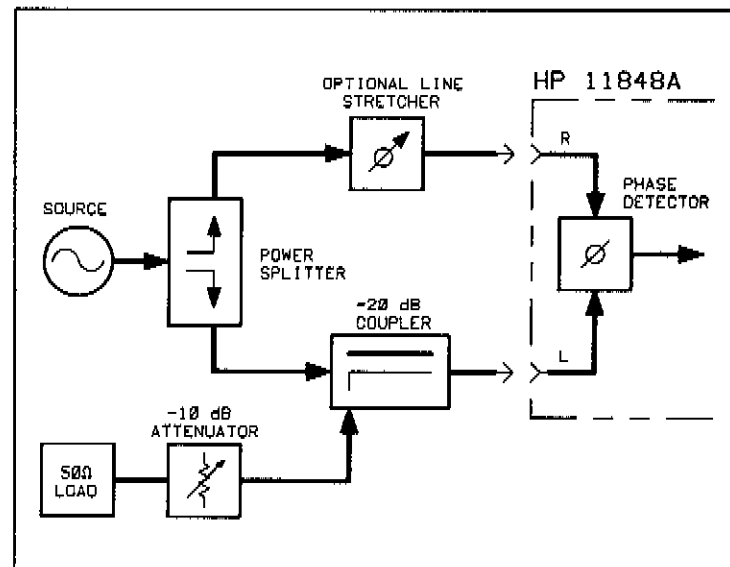


Figure 4-15. Calibration Setup

2. Measure the power level that will be applied to the R port of the HP 11848A's Phase Detector. The following chart shows the acceptable amplitude ranges for the HP 11848A Phase Detectors.

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	0 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +5 dBm

3. Measure the carrier-to-single-sided-spur ratio out of the coupler at the phase detector's modulated port and the offset frequency with the RF spectrum analyzer. The RF calibration source should be adjusted such that the sidebands are between -30 and -60 dB below the carrier and the frequency offset of the spur between 20 Hz and 100 kHz (or between 20 Hz and 20 MHz if an RF spectrum analyzer is connected in the system).

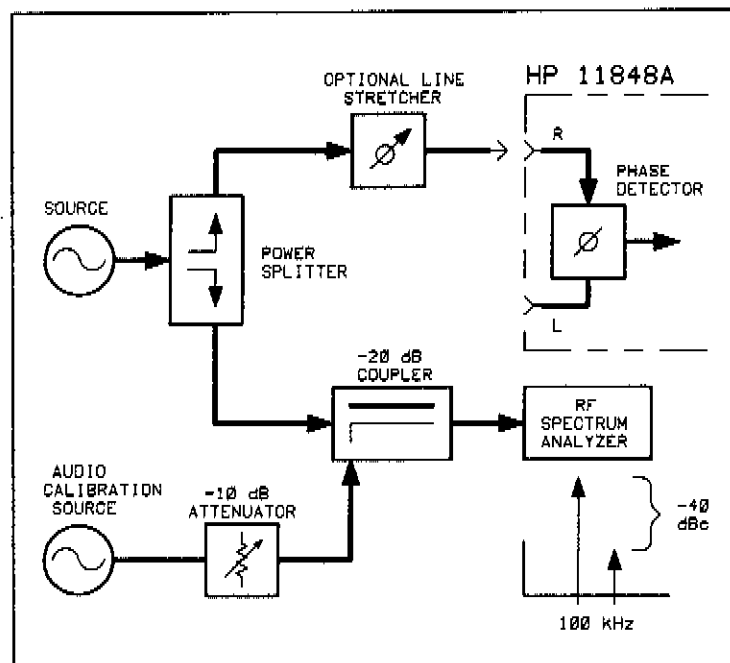


Figure 4-16. Carrier-to-spur Ratio of Modulated Signal

4. Measure the carrier-to-spur ratio of the non-modulated side of the phase detector. It must be at least 20 dB less than the spur ratio of the modulated port. This level is necessary to prevent cancellation of the modulation in the phase detector. Cancellation would result in a smaller phase detector constant, or a measured noise level that is worse than the actual performance. The isolation level is set by the port-to-port isolation of the power splitter and the isolation of the -20 dB coupler. This isolation can be improved at the expense of signal level by adding an attenuator between the coupler and the power splitter.

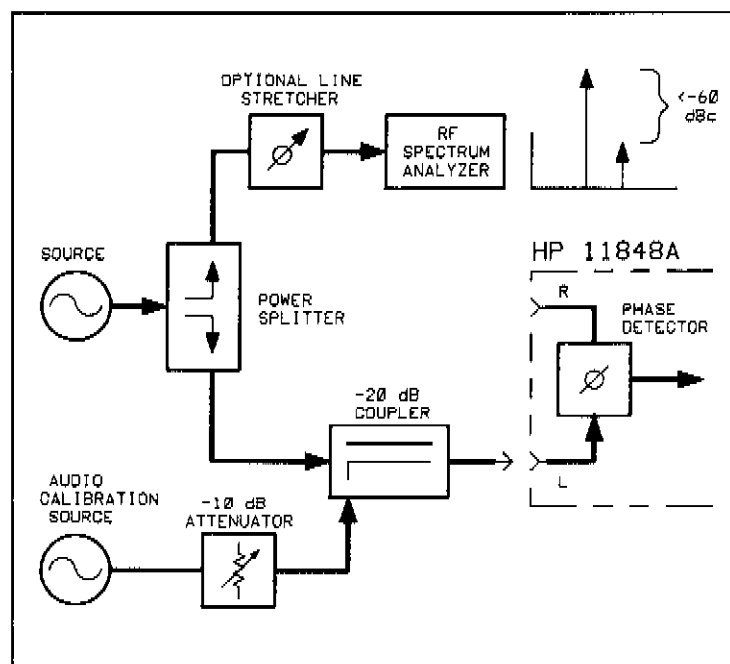


Figure 4-17. Carrier-to-spur Ratio of Non-modulated Signal

5. Connect the phase detector.
6. Adjust the phase difference at the phase detector to 90 degrees (quadrature) either by adjusting the test frequency or by adjusting an optional variable phase shifter or line stretcher. Quadrature is achieved when the meter on the front panel of the HP 11848A is set to center scale.

Note

For the system to accept the adjustment, the meter needle must be between the first two small divisions around center scale (zero). For the system to continue to take data, the needle must stay within the second two small divisions around center scale.

7. Enter sideband level and offset.
8. Check quadrature and measure the phase detector constant.
9. Remove audio source.
10. Reset quadrature and measure phase noise data.

Measurement Difficulties

This section will cover some of the problems and errors that can be made during the set-up and the measurement procedure. Chapter 6, Evaluating Results, contains troubleshooting information to be used after the measurement has been made, and a plot has been obtained.

Note

When making phase noise measurements it is important to keep your equipment connected until the measurements have been made, all problems corrected, and the results have been evaluated to make sure that the measurement is valid. If the equipment is disconnected before the results have been fully evaluated, it may be difficult to troubleshoot the measurement.

System Connections

The first thing to check if problems occur is the instrument connections and settings as this is the most common error. If the connections are not made properly, the meter on the HP 11848A will not zero. It is also important to make sure the levels are correct into the HP 11848A Phase Detector Inputs.

“OVERLOAD” Indicator on HP 11848A is tripped

This is caused when the output signal from the phase detector is greater than 6 dBm. The internal phase detectors will usually not produce a signal greater than 6 dBm due to the limiting action of the internal mixers. A signal applied to the Noise Input port on the HP 11848A can, however, be large enough to cause the “Overload” indicator on the 11848A to trip. The proper corrective action would be to reduce the level to the Noise Input port, by reducing the level of the sources feeding the external mixer, or by adding attenuation between the external signal source and the HP 11848A Signal Input port.

DC Level Check

The software will check the dc level of the signal at the output of the phase detector, or Noise Input to determine if the signals are still in quadrature after each data segment is measured. If the meter on the HP 11848A is not within ± 2 divisions of zero, you will be requested to re-zero the meter before the measurement can continue.

5

Two-Port Device Applications

Amplifier Measurement Example

This chapter contains information about measuring the *residual* noise of two-port devices.

This example demonstrates a residual phase noise measurement for an HP 8447E Amplifier.

Required Equipment

The following equipment is required for this example *in addition to* the standard HP 3048A system and your unit-under-test (UUT).

Table 5-1. Additional Equipment Required to Perform This Measurement Example

Equipment	Qty.	Comments
HP 8640B/ HP 8642A/B	1	
Power Splitter	1	
Coax Cables	3	2-foot BNC coaxial cables and adequate adapters to connect to the UUT.
Attenuators	2	Two 10 dB attenuators or one 20 dB attenuator. The attenuators are used to negate the gain of the UUT so the UUT and the internal HP 11848A circuitry will not be over-driven.

Note To ensure accurate measurements, you should allow the UUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

Defining the Measurement

1. Select the **File System** function from the Main Menu, and select **Load File**. Enter ***.PRM** for the path information to list all of the Parameter files.
2. Select the file titled **HP 8447E NOISE FLOOR USING AN HP 8642B**, and press **Enter**. The appropriate measurement parameters for this example have been pre-stored in this file. (Table 5-2 lists the parameters loaded from this test file.)
3. Press **Esc** to return to the Main Menu.

Note The stop frequency for the stored measurement is 100 kHz so the example will run on a standard HP 3048A system. If you have an RF analyzer configured in your system, you may want to change the stop frequency to 40 MHz in the Parameter menu. This will allow you to see the entire range of the test system.

Table 5-2. Parameter Data for the HP 8447E Amplifier Measurement Example

Step	Parameters	Data
1	Measurement Type	Phase Noise without Using a PLL
	Frequency Range	
	Start Freq.	1 Hz
	Stop Freq.	100 E + 3 Hz
2	Averages	4
	Parameters	
	Carrier Frequency	435 E + 6 Hz
	Detector/Discr. Input Frequency	435 E + 6 Hz
3	Internal Phase Detector	5 MHz to 1600 MHz
	Calibration Technique	
	Phase Detector Constant	Derive From Measured +/- DC Peak
	Instrument Control	
4	Quadrature will be established by tuning the source frequency.	
5	Define Graph	
	Title	HP 8447E NOISE FLOOR USING AN 8642B
	Minimum X	1 Hz
	Maximum X	100 E + 3 Hz
	Minimum Y	-170
	Maximum Y	0
	Graph Type	Single Sideband Phase Noise (dBc/Hz)

Beginning the Measurement

1. Select **New Measurement** from the Main Menu, and press the **Y** key to proceed.
2. The System now addresses each of the instruments listed in its Instrument Addresses table. If it does not receive a response at the address listed for an instrument, it will inform you with a displayed warning. (Refer to Appendix A if you need information about adding or changing an instrument in the HP 3048A System Configuration - Instrument Addresses table.)
3. When the Connect Diagram appears, connect the signal paths as shown in Figure 5-1. Figure 5-1 differs from the Connect Diagram shown on the computer's display. (The setup considerations provided in Table 5-3 will help you ensure that your measurement results are valid.)

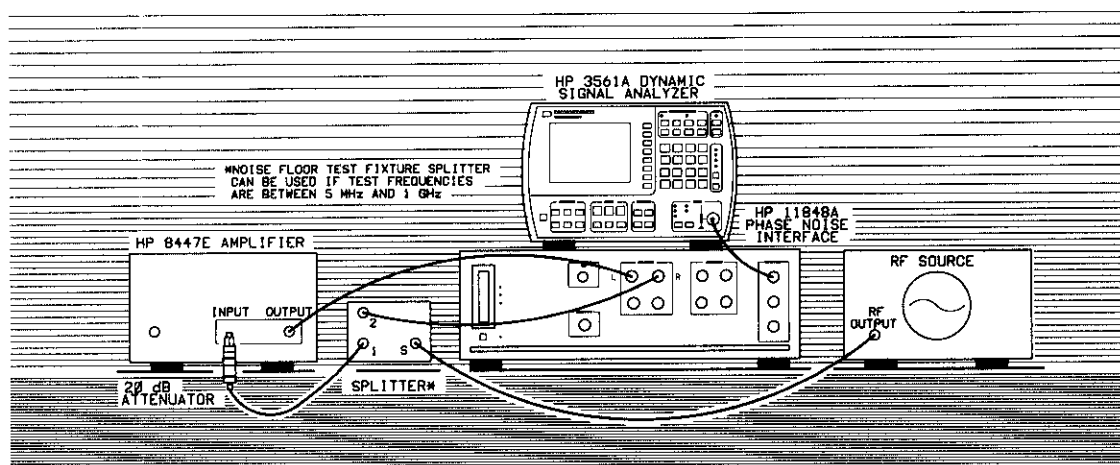


Figure 5-1. Setup diagram for the HP 8447E Amplifier Measurement Example.

Calibrating the Measurement

4. After the connections have been made and checked, press **F1** to proceed.

Since the "Derive From Measured $\pm$ DC Peak" calibration option was chosen. The software will prompt you for a positive peak and a negative peak from which to determine the phase detector constant.

5. When a prompt is displayed for you to set a calibration peak, increase the source frequency. Observe the level on the HP 3561A as you increase the source frequency. The level will move up or down (depending on whether the peak is positive or negative) until you reach a peak. The value the HP 3561A is reading is displayed on the bottom of the analyzer screen. When the reading is at its maximum, press **F1** to proceed.

Table 5-3. Setup Considerations for the HP 8447E Amplifier Measurement Example.

Setup Considerations	Comments
Connecting Cables	The best results will be obtained if semi-rigid coaxial cables are used to connect the components used in the measurement; however, BNC cables have been specified because they are more widely available. Using BNC cables may degrade the close-in phase noise results and, while adequate for this example, should not be used for an actual measurement on an unknown device unless absolutely necessary.
Measurement Environment	The low noise floors typical of these devices may require that special attention be given to the measurement environment. The following precautions will help ensure reliable test results: 1. Filtering on power supply lines 2. Protection from microphonics 3. Shielding from air currents may be necessary.

Note

The meter on the HP 11848A Phase Noise Interface can be used for a coarse peak adjustment; however, it will go off scale as the maximum peak is approached. Then either the HP 3561A or an oscilloscope connected to the HP 11848A AUX MONITOR output should be used to determine the exact peak.

6. When a prompt is displayed for you to tune to the other peak, decrease the source frequency. The level on the HP 3561A will go through zero and then reach a peak. The value the HP 3561A is reading will be displayed on the bottom of the analyzer screen. When the reading is at its maximum, press **F1** to proceed.

After the phase detector constant has been calculated, the system will establish quadrature automatically if the source is under system control; otherwise you will be prompted to set the HP 11848A meter to zero (± 1 division) on the meter scale.

The system can now run the measurement. The segment data will be displayed on the computer screen as the data is taken until all segments have been taken over the entire range you specified in the Type/Range of Measurement menu.

When the Measurement is Complete

When the measurement is complete, refer to *Chapter 6* for help in evaluating your measurement results. (If the test system has problems completing the measurement, it will inform you by placing a message on the computer display.

Figure 5-2 shows a typical phase noise curve for an HP 8447E Amplifier.

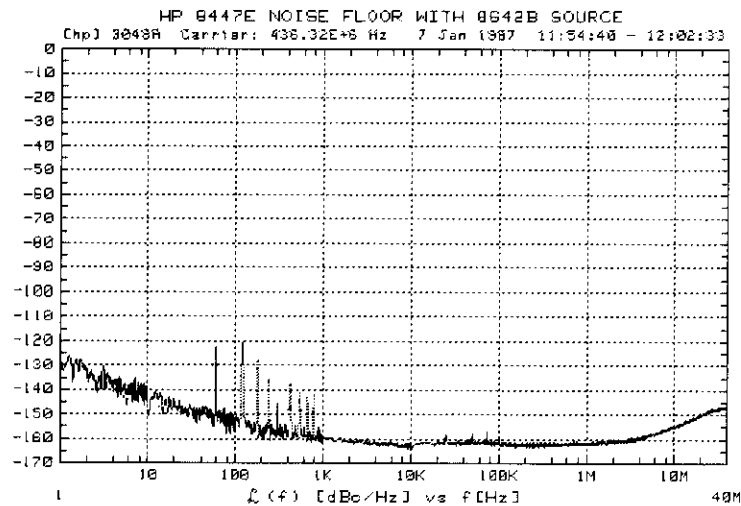


Figure 5-2. Typical Phase Noise Curve for an HP 8447E Amplifier.

6

Evaluating the Measurement Results

In This Chapter

This chapter contains information to help you evaluate and output the results of your noise measurements. To use the information in this chapter, you should have completed your noise measurement, and the computer should be displaying a graph of its measurement results. Storing the measurement results in the Result File is recommended for each measurement.

To help you reference directly to the information you need, this chapter has been organized into three sections:

- **Evaluating the Results** – Refer here for information that will help you confirm the validity of your measurement results. (Page 6-2.)
- **Outputting the Results** – Refer here for information about the graphics and hard copy functions. (Page 6-8.)
- **Problem Solving** – Refer here for help in solving specific problems on the noise graph. (Page 6-11.)

Evaluating the Results

This section contains information that will help you evaluate the results of your measurement. The purpose of the evaluation is to verify that the noise graph accurately represents the noise characteristics of your unit-under-test (UUT). At this point, you should have a graph showing the results of your measurement. The following steps provide an overview of the evaluation process.

- Look for obvious problems on the graph such as discontinuity (breaks).
- Compare the graph against known or expected data.
- If necessary, gather additional data about the noise characteristics of the UUT.

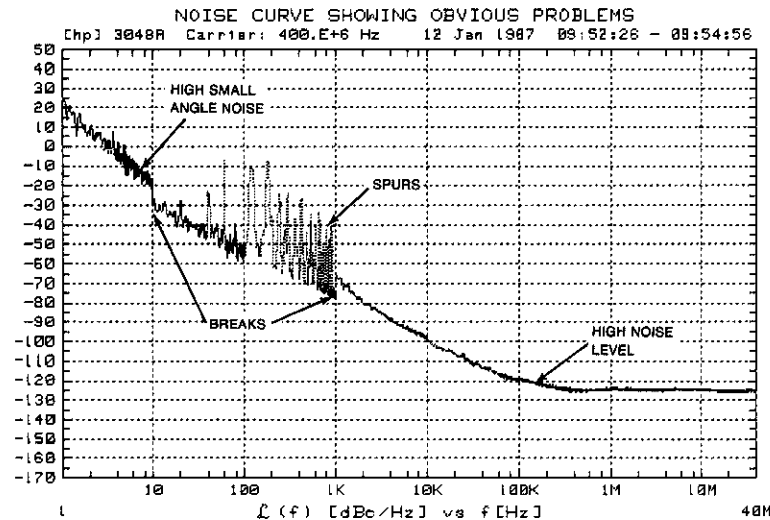


Figure 6-1. Noise Plot Showing Obvious Problems

Looking For Obvious Problems

Some obvious problems on a graph are as follows:

- Discontinuities or breaks in the graph.
- A higher than expected noise level.
- Spurs that you cannot account for.
- Noise that exceeds the small angle criterion line (on a $\mathcal{L}(f)$ graph).

Figure 6-1 provides a graphical example of these problems. If one or more of these problems appear on your graph, refer to the *Problem Solving* section of chapter 3 for recommended actions.

Comparing Against Expected Data

If none of the problems shown appear on your graph, there still may be problems or uncertainties that are not obvious at first glance. These uncertainties can be evaluated by comparing your measurement results against the following data:

- The noise characteristics expected for your unit-under-test.
- The noise floor and accuracy specifications of the HP 3048A test system.
- The noise characteristics of the signal source used as the reference source.

The Unit-Under-Test

If you are testing a product for which published specifications exist, compare the measurement results against the noise and spur characteristics specified for the product. If the product is operating correctly, the noise graph provided by the HP 3048A system should be within the noise limits specified for the product.

If the device is a prototype or breadboard circuit, it may be possible to estimate its general noise characteristics using the characteristics of a similar type of circuit operating in a similar manner.

The HP 3048A Phase Noise Measurement System

The noise specifications for the HP 3048A Phase Noise Measurement System are generally much lower than the noise levels of most devices being tested. (Refer to Chapter 1 for the noise and accuracy specifications of the system.) It is possible, however, that with new technology the unit-under-test may have similar or lower noise floor specifications than the System. If this is the case, it is important to determine what part of the phase noise plot is due to the system limits and what part shows the actual level of the unit-under-test by comparing the measurement results with a plot of the systems noise floor.

You can obtain a plot of the system's noise floor by running the Noise Floor Test. The noise floor test procedure is contained in the *HP 3048A Option 301 Phase Noise Measurement Software - Calibration Manual*. However, to get a curve that can be compared directly against your measurement results, you must observe the following considerations when setting up your Noise Floor test.

- The same source that you used to measure your unit-under-test should be used for the noise floor test.
- The signal levels at the R and L input ports on the HP 11848A should be the same during the noise floor test as they were during your measurement. (If the levels at the two input ports were not the same, you will need to insert an attenuator or amplifier in the signal path between the noise floor test fixture output and the input port).

When you have obtained a noise floor curve for the system, compare it against the measurement results for your UUT. Check for areas on the UUT graph that are at or near the system noise level.

The Reference Source

It is important that you know the noise and spur characteristics of your reference source when you are making phase noise measurements. (The noise measurement results provided when using this technique reflect the sum of all contributing noise sources in the system.)

The best way to determine the noise characteristics of the reference source is to measure them. If three comparable sources are available, the Three Source Comparison technique can be used to determine the absolute noise level of each of the three sources. Refer to your *HP 3048A Option 301 Reference Manual* for details on this measurement technique. If you are using as your reference source, a source for which published specifications exist, compare your measurement results against the noise and spur characteristics specified for that source.

If you have obtained an actual (measured) noise curve for the reference source you are using, you can use it to determine if your measurement results have been increased by the noise of the reference source. To do this, determine the difference (in dB) between the level of the results graph and that of the reference source. Then use the graph shown in Figure 6-3 to determine if the measurement results need to be decreased to reflect the actual noise level of the UUT.

For example, applying the 7 dB difference in noise levels, shown in Figure 6-2 at 10 kHz, to the graph, reveals that the measured results should be decreased by about 1 dB at 10 kHz to reflect the actual noise of the UUT.

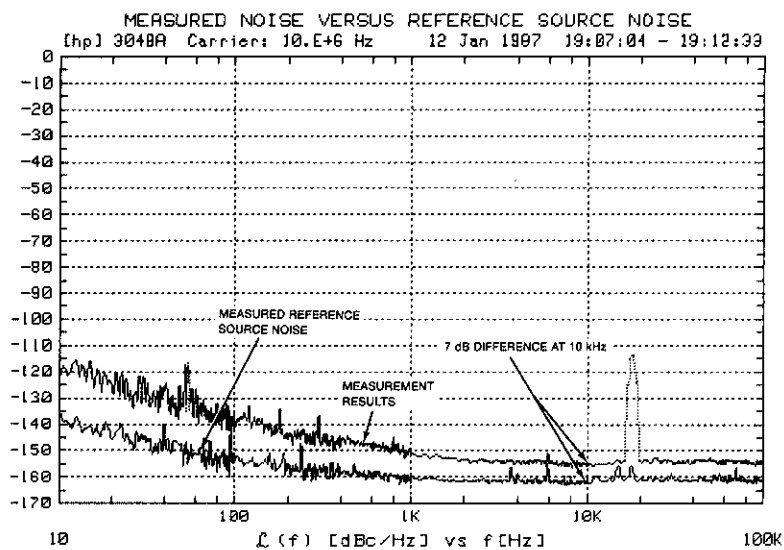


Figure 6-2. Example Comparison of Measurement Results and Reference Source Noise.

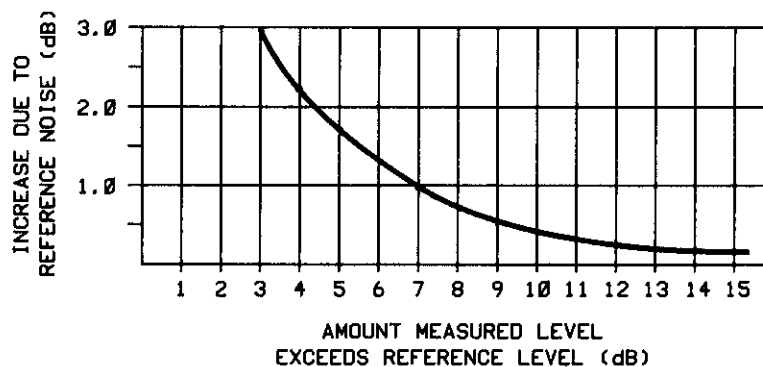


Figure 6-3. Graph Showing How Much to Decrease Measured Noise to Compensate for Added Reference Source Noise.

Gathering More Data

Repeating the Measurement

Making phase noise measurements is often an iterative process. The information derived from the first measurement will sometimes indicate that changes to the measurement setup are necessary for measuring a particular device. When you make changes to the measurement setup (such as trying a different signal source, shortening cables, or any other action recommended in the *Problem Solving* section), repeating the measurement after each change allows you to check the effect that the change has had on the total noise graph.

Doing More Research

If you are still uncertain about the validity of the measurement results, it may be necessary to do further research to find other validating data for your measurement. Additional information (such as typical noise curves for devices similar to the unit-under-test or data sheets for components used in the device) can often provide insights into the expected performance of the unit-under-test.

Outputting the Results

This section describes the HP 3048A's capabilities for generating a printed hardcopy of your test results. You must have a printer must be connected to the computer to generate hard copies. Also the GRAFPLUSTM software (included with the System) must be used. Refer to appendix A for information about using GRAFPLUS.

Using a Printer

The method used for printing the displayed information depends on which screen you want to print.

All graphics screens are printed by displaying the desired screen on the computer and pressing the **F4** key. These screens include the Graph of Results plot, Instrument Control diagram, Instrument Connect diagram, and the PLL Suppression diagram.

While the Graph of Results screen is displayed, you can print the Graph of Results and the Parameter Summary screens by simultaneously pressing the **SHIFT** and **F4** keys. This is the recommended procedure.

Some screens, such as the Parameter Summary or List of Spurs, may also be printed using the **F1** key.

Graphics Display Functions

Different graphics functions are provided to help you display measurement definitions and results. A brief summary of their functions is given here. A more detailed explanation of these functions is provided in section 3 of the *HP 3048A Option 301 Reference Manual*.

Define Graph

The Define Graph functions are accessed from the Main Menu. These functions define the title, X and Y coordinates, and graph type for the Graph of Results display.

Graph of Results

The Graph of Results functions are accessed from the Main Menu, and are used to display and evaluate the measurement results. This screen is automatically displayed as a measurement is being made. You can also load a result file using the File System functions, and then display the results.

The following additional graphics features can be accessed by pressing the **M** key (for Menu) while the Graph of Results screen is displayed:

Marker - allows you to display the exact frequency and amplitude of any point on the results graph.

New Graticule - erases the current graticule and results plot, and draws a new graticule.

Plot Data - plots the currently loaded results.

Omit Spurs - plots the currently loaded results without displaying any spurs that may be present.

Noise Spec Lines

Noise Spec Lines are accessed from the Manipulate Results menu, and are used to display user-defined lines on the Graph of Results screen. These lines are typically used compare specifications and measured results.

Plotter Pens

The Plotter Pens are selected in the System Configuration menu, and are used to specify the colors used when displaying the results. By changing plotter pen colors as you overlay two or more noise result traces, you can display several result traces in different colors at the same time. This makes it much easier to keep track of each trace where two or more traces intersect.

Parameter Summary

The Parameter Summary function allows you to quickly review the measurement parameter entries that were used for this measurement. This menu also includes a listing of the calibration data created for this measurement by the software. We recommend that you include a printed copy of this menu with any copies of the measurement results that you create for your records.

Problem Solving

<i>If you need to know:</i>	<i>Refer to:</i>
• <i>What to do about breaks in the noise graph</i>	<i>Discontinuity in the Graph (6-12)</i>
• <i>How to verify a noise level that is higher than expected</i>	<i>High Noise Level (6-14)</i>
• <i>How to verify unexpected spurs on the graph</i>	<i>Spurs on the Graph (6-17)</i>
• <i>How to interpret noise above the small angle line.</i>	<i>Small Angle Line (6-20)</i>

Discontinuity in the Graph

Because noise distribution is continuous, a break in the graph is evidence of a measurement problem. Discontinuity in the graph will normally appear at the sweep-segment connections.

Table 6-2 identifies the circumstances that can cause discontinuity in the graph.

Table 6-2. Potential Causes of Discontinuity in the Graph (1 of 2)

Circumstance	Description	Recommended Action
Break between segments where closely spaced spurs are resolved in one segment but not in the next.	Closely spaced spurs that are resolved in one sweep-segment but not in the next can cause an apparent jump in the noise where they are not resolved.	Use the Real-time Monitor to evaluate the noise spectrum at the break frequency on the graph. (Refer to the <i>HP 3048A Option 301 Reference Manual</i> in the <i>Advanced Functions</i> section details on using the Noise Monitor Mode.) To eliminate the break in the graph, you may find it necessary to change the Sweep-Segment Ranges so that the measurement resolution remains constant over the frequency range where the spurs are located.
Erratic Noise: One or more segments out of line with the rest of the graph.	This occurs when the noise level of the source being used is inconsistent over time. The time-varying noise level causes the overall noise present when one segment is being measured to differ from the level present during the period when the next segment is measured.	Repeat the noise measurement several times for the segment that does not match the rest of the graph, and check for a change in its overall noise level.

Table 6-2. Potential Causes of Discontinuity in the Graph (1 of 2)

Circumstance	Description	Recommended Action
Break at the upper edge of the segment below PLL Bandwidth $\div$ 4	Accuracy degradation of more than 1 or 2 dB can result in a break in the graph at the internal changeover frequency between the phase detector portion of the measurement and the voltage controlled oscillator tune line measurement. The accuracy degradation can be caused by: 1) An inaccurate Tuning or Phase Detector Constant, 2) Injection locking, or 3) Noise near or above the small angle line at an offset equal to the PLL Bandwidth for the measurement.	Check the Parameter Summary list provided for your results graph to see if any accuracy degradation was noted. If the Tuning constant and Phase Detector constant were not <i>measured</i> by the HP 3048A, verify their accuracy by selecting the "Measured" calibration method and then initiating a New Measurement. If you suspect injection locking or noise above the small angle line, refer to the <i>Problem Solving</i> section of Chapter 3 for specific actions.
Small Break at 100 kHz, 10 kHz, or 1 kHz	May occur when the HP 11848A calibration data sent from the factory is not being used.	Check to be sure that the serial number on the data disc matches the serial number on the HP 11848A you are using.

High Noise Level

The noise level measured by the test system reflects the sum of all of the noise sources affecting the system. This includes noise sources within the system as well as external noise sources. If the general noise level measured for your device is much higher than you expected, begin evaluating each of the potential noise sources. The following table will help you identify and evaluate many of the potential causes of a high noise floor.

Table 6-3. Potential Causes of a Higher than Expected Noise Floor (1 of 3)

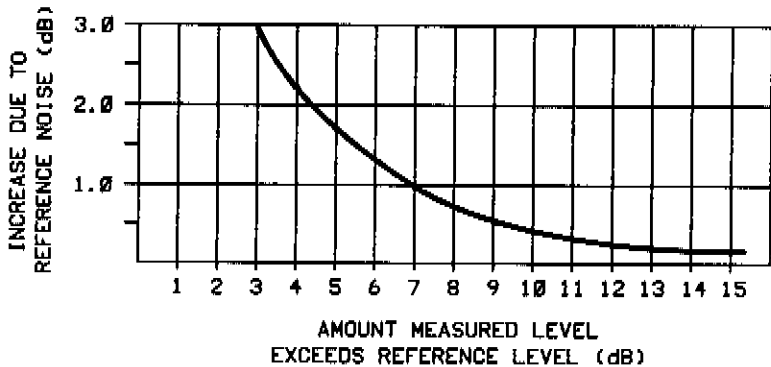
Cause	Recommended Action																												
Reference Source	Compare the noise specifications for the reference source to the measured noise graph. Use the graph shown below to determine if reference source noise has increased the measured noise level above the actual level of the UUT.  <table border="1"> <caption>Data points estimated from the graph</caption> <thead> <tr> <th>Amount Measured Level Exceeds Reference Level (dB)</th> <th>Increase Due to Reference Noise (dB)</th> </tr> </thead> <tbody> <tr><td>3</td><td>3.0</td></tr> <tr><td>4</td><td>2.5</td></tr> <tr><td>5</td><td>2.0</td></tr> <tr><td>6</td><td>1.7</td></tr> <tr><td>7</td><td>1.4</td></tr> <tr><td>8</td><td>1.2</td></tr> <tr><td>9</td><td>1.0</td></tr> <tr><td>10</td><td>0.8</td></tr> <tr><td>11</td><td>0.7</td></tr> <tr><td>12</td><td>0.6</td></tr> <tr><td>13</td><td>0.5</td></tr> <tr><td>14</td><td>0.4</td></tr> <tr><td>15</td><td>0.3</td></tr> </tbody> </table> If a second source is available, try repeating the measurement using the second source as the reference source. If two additional sources are available, perform the Three Source Comparison technique (described in the <i>HP 3048A Option 301 Reference Manual</i>) to determine the absolute noise level of each source.	Amount Measured Level Exceeds Reference Level (dB)	Increase Due to Reference Noise (dB)	3	3.0	4	2.5	5	2.0	6	1.7	7	1.4	8	1.2	9	1.0	10	0.8	11	0.7	12	0.6	13	0.5	14	0.4	15	0.3
Amount Measured Level Exceeds Reference Level (dB)	Increase Due to Reference Noise (dB)																												
3	3.0																												
4	2.5																												
5	2.0																												
6	1.7																												
7	1.4																												
8	1.2																												
9	1.0																												
10	0.8																												
11	0.7																												
12	0.6																												
13	0.5																												
14	0.4																												
15	0.3																												

Table 6-3. Potential Causes of a Higher than Expected Noise Floor (2 of 3)

Cause	Recommended Action						
HP 3048A System	Refer to Chapter 1 for the noise and accuracy specifications of the HP 3048A hardware. If you suspect that the test system is not meeting its noise level specifications, run the Noise Floor Test. Refer to the HP 3048A Option 301 System Calibration Manual for the Noise Floor Test Procedure. The actual noise floor of the system is set by the signal level at the Phase Detector R input port on the HP 11848A. (This assumes that the signal level at the L input port is within the +15 to +23 dBm range required for the Phase Detector to operate properly; +7 to +10 dBm for the option 201 High Frequency Detector.) The following graph will help you determine the signal level needed at the R input to measure your UUT. The graph plots R Port Signal Level (dBm) on the y-axis against Expected Phase Noise Floor of DUT (dBc/Hz) on the x-axis for frequencies $f \geq 10\text{kHz}$. The y-axis ranges from -15 to +15 dBm in increments of 10. The x-axis ranges from -140 to -180 dBc/Hz in increments of 10. A solid line starts at (-150, -15) and rises linearly to (-155, +15). <table border="1"> <caption>Data points from the graph</caption> <thead> <tr> <th>Expected Phase Noise Floor of DUT (dBc/Hz)</th> <th>R Port Signal Level (dBm)</th> </tr> </thead> <tbody> <tr> <td>-150</td> <td>-15</td> </tr> <tr> <td>-155</td> <td>+15</td> </tr> </tbody> </table>	Expected Phase Noise Floor of DUT (dBc/Hz)	R Port Signal Level (dBm)	-150	-15	-155	+15
Expected Phase Noise Floor of DUT (dBc/Hz)	R Port Signal Level (dBm)						
-150	-15						
-155	+15						

Table 6-3. Potential Causes of a Higher than Expected Noise Floor (3 of 3)

Cause	Recommended Action
Unit-Under-Test	Sometimes the unit-under-test does not provide the performance expected or hoped for. If possible, try verifying the measurement setup by measuring another device about which the noise characteristics are known. If your device is a breadboard or prototype circuit, it may be helpful to obtain noise performance data about similar devices or the components used in your design.
Environment	The lower the noise level of the unit-under-test or the wider the Peak Tuning Range set by the VCO source (PLL technique), the higher the possibility that noise sources external to the system may be contributing to the measured noise level. The following precautions may be necessary to prevent added noise due to external sources. 1. Filtering on power supply lines. 2. Protection from microphonics. 3. Protection from external noise sources on unshielded oscillators. 4. Shorter coax cable lengths or semi-rigid cable (particularly for the Tune Voltage Output). 5. Shielding from air currents may even be necessary for very low noise devices.
Inserted Amplifier	If your measurement setup required inserting an external amplifier to increase the signal level to the Phase Detector input on the HP 11848A, the added noise of the amplifier will also contribute to the measured noise level. The following equation can be used to estimate the resulting noise floor of the system ($\mathcal{L}_{(f)out}$) with the added noise of the amplifier. $\mathcal{L}_{(f)out} = -174 \text{ dB} + \text{Amplifier Noise Figure} - \text{Power into the Amplifier} - 3 \text{ dB}$
AM Noise	To ensure that a high phase noise level is not due to high AM noise, measure the AM noise of the unit-under-test. If the AM noise exceeds the expected phase noise result by more than 20 dB when using the 5 MHz to 1.6 GHz Detector (or by 0 dB if you are using the 1.2 to 18 GHz Detector), then the AM noise may be causing an increase in the measured phase noise level.

Spurs on the Graph

Except for marked spurs, all data on the graph is normalized to a 1 Hz bandwidth. This bandwidth correction factor makes the measurement appear more sensitive than it really is. Marked spurs are plotted without bandwidth correction however, to present their true level as measured.

The spur marking criterion is a detected upward change of more than X dB (where X is the value shown below) within 4 data points (a single data point noise peak will not be marked as a spur). Note that the effective noise floor for detecting spurs is above the plotted 1 Hz bandwidth noise by the bandwidth correction factor.

Offset Frequency	Number of Averages	Upward Change For Marking Spurs (dB)
< 100 kHz	< 4	30
	≥ 4	17
	≥ 8	12
	≥ 30	6
> 100 kHz	Any	4

To List the Marked Spurs

A list of spurs can be displayed by accessing the List of Spurs function in the Manipulate Results menu.

Forest of Spurs

A so called "forest" of spurs is a group of closely spaced spurs on the phase noise plot. A forest of spurs is often caused by improper shielding that allows stray RF energy to be picked up by the unit-under-test wiring, etc. A breadboarded or prototype circuit should be well shielded from *external* RF fields when phase noise measurements are being made.

Table 6-4. Potential Spur Sources (1 of 2)

Spur Sources	Description	Recommended Action
Internal	Potential spur sources within the measurement system include the HP 3048A System, the unit-under-test, and the reference source. Typical system spurs are < -120 dBc, and they occur at the power line and system vibration frequencies in the range of from 25 Hz to 1 kHz, and above 10 MHz.	If you do not have a plot of the system's noise and spur characteristics, perform the system Noise Floor Test described in the <i>HP 3048A Option 301 System Calibration Manual</i> . If you suspect that the unit-under-test or the reference source may be the spur source, check each source using a spectrum analyzer or measuring receiver (such as an HP 8902A). Also, if additional sources are available, try exchanging each of the sources and repeating the measurement.
External	Spur sources external to the system may be either mechanical or electrical. When using the Phase Lock Loop measurement technique, the system's susceptibility to external spur sources increases with increases in the Peak Tuning Range set by the VCO source.	Shorten coax cables as much as possible (particularly the Tune Voltage Output cable). Make sure all cable connections are tight. It may be possible to identify an external spur source using a spectrum analyzer with a pick-up coil or an antenna connected to it.

Table 6-4. Potential Spur Sources (2 of 2)

Spur Sources	Description	Recommended Action
Electrical	Electrically generated spurs can be caused by electrical oscillation, either internal or external to the measurement system. The list of potential spur sources is long and varied. Many times the spur will not be at the fundamental frequency of the source, but may be a harmonic of the source signal. Some typical causes of electrical spurs are power lines, radio broadcasting stations, computers and computer peripherals (any device that generates high frequency square waves), and sum and difference products of oscillators that are not isolated from one another in an instrument such as a signal generator.	The frequency of the spur and patterns of multiple spurs are the most useful parameters for determining the source of spurs. The spur frequency can be estimated from the graph, or pinpointed using either the Marker graphic function which provides a resolution of from 0.1% to 0.2% or by using the spur listing function.
Mechanical	Mechanically generated spurs are usually at frequencies below 1 kHz. The source of a mechanically generated spur is typically external to the measurement system.	Try turning off or moving fans, motors, or other mechanical devices that oscillate at a specific frequency. (Temporarily blocking the airflow through a fan may alter its speed enough to discern a frequency shift in a spur that is being caused by the fan.)

Small Angle Line

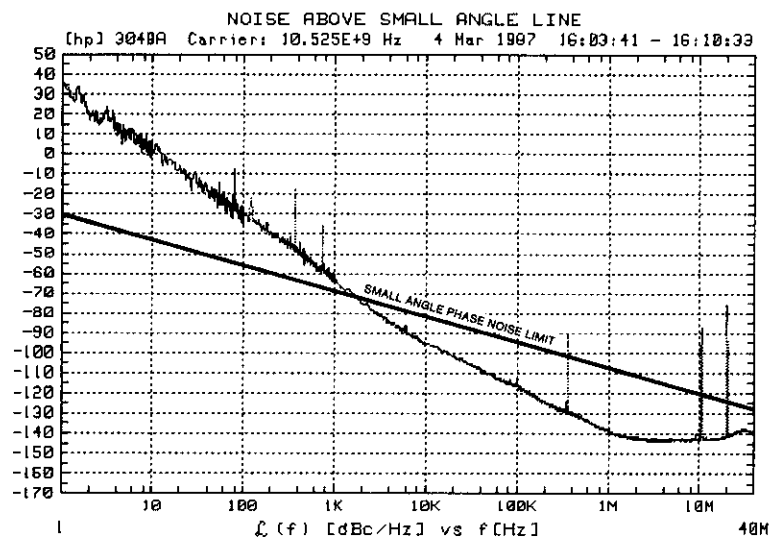


Figure 6-4. $L(f)$ Is Only Valid for Noise Levels Below the Small Angle Line

Caution must be exercised when $L(f)$ is calculated from the spectral density of the phase modulation ($S_\phi(f)/2$) because of the small angle criterion. Below the line, the plot of $L(f)$ is correct; above the line, $L(f)$ is increasingly invalid and $S_\phi(f)$ must be used to accurately represent the phase noise of the signal. To accurately plot noise that exceeds the small angle line, select the *Phase Modulation Spectral Density* graph type.

The -10 dB per decade line is drawn on the plot for an instantaneous phase deviation of 0.2 radians integrated over any one decade of offset frequency. At approximately 0.2 radians, the power in the higher order sideband of the phase modulation is still insignificant compared to the power in the first order sideband. This ensures that the calculation of $L(f)$ is still valid.

A

Installation

Setting Up the System

This appendix is intended to help you set up your HP 3048A Option 301 Phase Noise Measurement System.

The topics covered in this section include:

- Preparing the site
- Unpacking the system
- Preparing the system hardware
- Installing the system software
- Setting the HP-IB addresses
- Verifying Operation

After you set up your system, return to Chapter 1 for details about making noise measurements.

Preparing the Site

These factors must be considered when preparing the site for your system:

- Environmental limitations of the system
- System placement
- HP-IB cable length limitations
- System power requirements

Table A-1, *Site Preparation Considerations*, lists specific concerns for each of these considerations.

Warning

To ensure safe operation, be sure to review the installation documentation for each instrument.

If the system is placed on metal or other conductive surfaces with improper grounding, personal injury could result.

Unpacking, Storing, and Shipping the System

While unpacking the instruments from the boxes, follow the guidelines in Table A-2, *Unpacking, Storing, and Shipping Considerations*. For more specific receiving information for each instrument, refer to each instrument manual. Table A-2 also gives guidelines to consider when storing or shipping the system.

Caution

When opening boxes, do not use long-bladed knives, screwdrivers, or tools that could pierce the protective foam and damage the instrument.

Warning

To avoid hazardous electrical shock, do not connect up the system when there are signs of shipping damage to any portion of the outer enclosure (covers and panels).

Note

It is not necessary to run the system Performance Tests after the system is installed. These tests are performed at the factory before shipment. However, Performance Tests should be run every 12 months or after a repair of the HP 11848A Phase Noise Interface. Also, whenever a temperature change exceeds $\pm 10^{\circ}\text{C}$, calibration should occur using test Option 1. (Refer to the HP 3048A Option 301 Phase Noise Measurement System Calibration Manual for more detailed information about accessing calibration and, performance tests.)

Table A-1. Site Preparation Considerations

Environmental Limits Temperature: Relative humidity: Altitude: Magnetic field strength: Adding Equipment: Avoid these characteristics:	For the standard system or Option 201 0°C to +55°C (Recalibration (option 1) is required for a temperature change greater than $\pm 10^\circ\text{C}$.) < 95% (maximum wet bulb temperature = 40°C) < 4600 meters (15 000 ft) < 0.04 gauss p-p If more instruments are added to the system, the range of environmental limits is the tightest specification of either the system or the additional equipment. Mechanical vibration Low frequency magnetic fields Electromagnetic interference (EMI)
System Placement Instrument table: Air Flow: Area:	Review the installation documentation for each instrument Choose a table that can handle the weight of the system: from 31 to 275 kg (68 to 603 lbs) depending on options ordered. Provide at least 10 cm (4 in.) of space behind each instrument to allow adequate air flow to internal circuitry. Allow enough clearance around the system and the device under test so they will not be accidentally bumped during a measurement.
HP-IB Requirements Total cable length:	Total cable length should be less than or equal to 20 meters (65.5 feet) or 2 meters (6 feet) times the number of devices connected to the bus. (The smaller number should always be used in determining the cable length limits for the system.)
Power Requirements Maximum power consumption: Power source required: Grounding: Minimum Interference:	Between 190 and 900 VA depending on the options included. Either 100, 120, 220, 240 VAC (at +5%, -10%, 48 to 66 Hz single phase). AC power cords for the instruments and service outlets are the three-conductor type (which include a safety earth-ground conductor). Safe operation of the system requires that the (mains) power cord be connected only to an outlet with a protective earth contact. For minimum power line interference in the measurements, all instruments and the device-under-test should be plugged in to the same power circuit. Preferably, no other equipment should be connected to the same circuit.

Table A-2. Unpacking, Storing, and Shipping Considerations

Initial Inspection Inspect for damage:	If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard office. Keep the shipping materials for the carrier's inspection.
Unpacking Procedure for each box:	1) Carefully cut the reinforced tape sealing the top box flaps. 2) Remove foam or Polystyrene from the top of the instrument. 3) Lift the instrument from the box. 4) Remove all miscellaneous items from the box.
Checking the Contents For completeness: For electrical defect: If problems exist:	If covers or panels show signs of damage, do not perform electrical tests. Check the System checklist included with the HP 11848A for proper instruments, accessories, and options. If no external damage is evident, complete the installation and operation verification procedures provided in this appendix. Notify the nearest Hewlett-Packard office.
Warranty Information	Warranty information for each instrument is available inside the front cover of the instrument manual.
Storing the System General: Temperature: Relative Humidity: Altitude:	The following environmental limits apply to both storage and shipment. Store in a clean, dry environment. -55°C to +75°C <95% relative; maximum wet bulb temperature = 40°C <15 000 meters (50 000 feet).
Shipping the System Packaging instructions: If shipping to HP: Corresponding about the package:	Use the original packaging material or: 1) Wrap the instrument in heavy paper or plastic. 2) Use a strong shipping container: A double-wall carton made of 2.4 mPa (350 psi) test material is adequate. 3) Use a layer of shock-absorbing material, 70 to 100 mm (3 to 4 in.) around all sides of the instrument to provide firm cushioning and prevent movement inside container. Protect the control panel with cardboard. 4) Seal the shipping container securely. 5) Mark the shipping container "FRAGILE" to ensure careful handling. If shipping to an HP office or a service center, attach a tag indicating: The type of service required, return address, model number, and full serial number of each instrument. In any correspondence, refer to the instrument by model number and full serial number.

Preparing the System Hardware

Preparing the Computer

The HP 3048A Option 301 Software runs on any IBM PC-AT/XT compatible computer using the MS-DOS® 3.0 or later operating system. The software requires a minimum of 640 kilobytes of RAM, and a $5\frac{1}{4}$ -inch 1.2 Mbyte floppy disk drive. An EGA compatible display is required. A General Purpose Interface Bus (GPIB) device driver card and associated software must also be used.

If hard copies of the measurements are desired, a printer must be connected to the computer. Also, the GRAFPLUS™ software (included with this system) must be used.

Refer to your computer's manuals for instructions on setting up the computer and installing MS-DOS. (You must install MS-DOS before attempting to load the GPIB driver, GRAFPLUS, and HP 3048A Option 301 software.)

Installing the GPIB Card

The GPIB card is used to control the instruments in the test system, and may be used to control the unit-under-test (UUT). The HP 3048A Option 301 software supports only two GPIB interface cards, the Hewlett-Packard 82335A and the National Instruments PC-II/IIA.

Installing the HP 82335A

Before installing the HP-IB (GPIB) hardware and software, consider the following setup parameters.

- The recommended address (or select code) is 7.
- The associated software is not needed. The HP 3048A Option 301 software has its own HP-IB driver for the HP 82335A.

Refer to the HP 82335A manual for information concerning installation of the hardware.

Installing the National Instruments PCII/IIA

Before installing the GPIB hardware and software, consider the following setup parameters.

- The HP 3048A Option 301 software will operate using GPIB port 0 (zero) only.
- The GPIB (HP-IB) addresses that you define when installing the GPIB software must match the addresses set for the test system instruments you will be using. For example, if the HP-IB address of the HP 11848A is set to 20, set up DEV20 in the GPIB card software.

Refer to the National Instruments PCII/IIA manual for information concerning installation of the hardware and software.

Interconnecting Instruments

The following diagrams are examples of interconnections between instruments in the system.

Caution

BEFORE PLUGGING ANY INSTRUMENTS into the Mains (line) voltage, be sure the correct voltage and fuse have been selected for each instrument. Refer to each instrument's installation manual if you need fuse size and power connection information.

Rear-Panel Interconnections

Figure A-1 shows an example of rear-panel interconnections for the test instruments. If you add other allowed instruments, connect the HP-IB cables to those instruments as well.

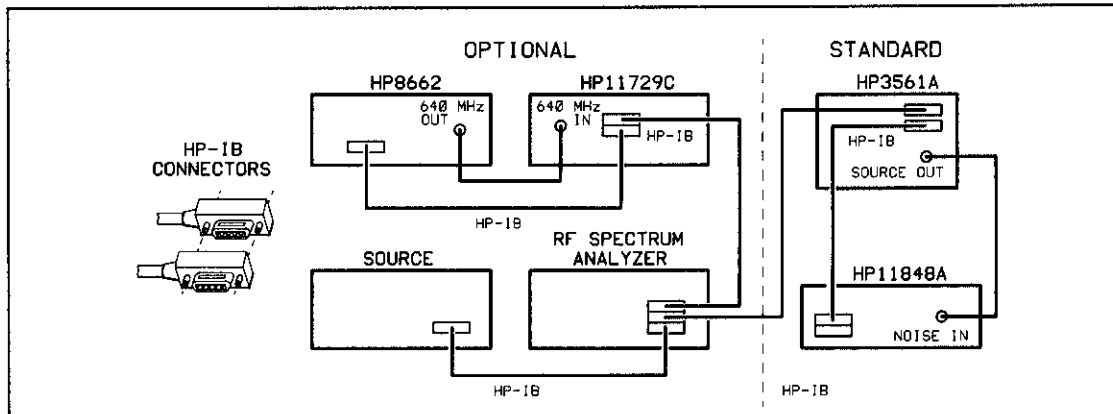


Figure A-1. Example of Instrument Rear-Panel Interconnections

Front-Panel Interconnections

Connect the instruments as shown in Figure A-2.

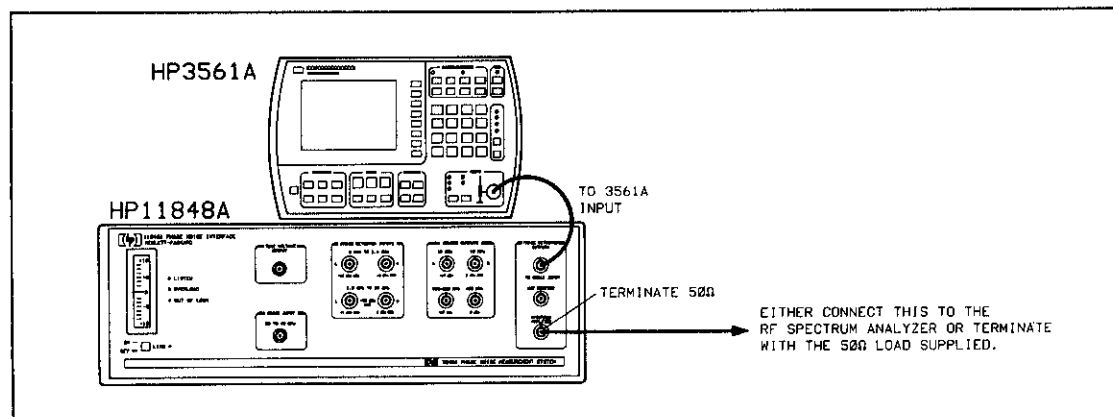


Figure A-2. Front-Panel Interconnections for the Test Instruments

Using the GRAFPLUS Software

The GRAFPLUS software is used to print phase noise graphs to any GRAFPLUS supported printer. GRAFPLUS is a terminate-but-stay-resident (TSR) program. You must execute GRAFPLUS at least once each time you turn on or reboot your computer and before you run the HP 3048A Option 301 software. Once GRAFPLUS has been executed, you may change disks, disk drives, or subdirectories without re-executing it. The examples used in this manual are for the HP 2228A QuietJet Printer and the HP 3630A Option 004 PaintJet Color Graphics Printer. (To use the GRAFPLUS software with any other printer, refer to the GRAFPLUS manual.)

Making Back-Up Copies

It is strongly recommended that you make a back-up copy of your software. Refer to your MS-DOS manual for information on copying flexible disks.

GRAFPLUS with the HP 2228A QuietJet Printer

In the following procedure, the flexible-disk drive is designated as the **A** drive. Use the designation appropriate for your computer. For information about installing the GRAFPLUS software on your computer's hard disk, refer to the GRAFPLUS manual.

Note

The printer should be connected to the first parallel port of the computer. To use the printer at any other port, refer to the GRAFPLUS manual.

1. Insert the GRAFPLUS program disk into the **A** drive.
2. Type **A:** and then press **ENTER** to select the **A** drive.
3. Configure the *GRAFLASR* program. (This step only needs to be performed the first time the GRAFPLUS software is used with this printer.)

- a. Type **EDITGRAF** and press **ENTER**.

A series of menus will now be displayed.

- b. Press **2** to select the *GRAFLASR* program.

- c. Press **0** and then **2** to select the ThinkJet printer (QuietJet printer) driver.
 - d. Press **1** to select the Horizontal printing driver.
 - e. Press **3** to select the gray scale printer driver.
 - f. Press **1** to select black and white printing.
 - g. Press **7** to exit the *EDITGRAF* program.
 - h. Press **Y** to save the changes to the *GRAFLASR* program.
4. Type *GRAFLASR* =2 and press **ENTER** to execute the program.
 5. Remove the *GRAFPLUS* program disk from the A drive.

GRAFPLUS with the HP 3630A Option 004 PaintJet Printer

The HP 3630A Option 004 PaintJet printer can be used to print in color or black-and-white. The flexible-disk drive from which the program will be run is designated as the **A** drive. Use the appropriate designation for your computer. (To install *GRAFPLUS* on your hard disk, refer to the *GRAFPLUS* manuals for instructions.)

Note

The printer should be connected to the first parallel port of the computer. To use the printer at any other port, refer to the *GRAFPLUS* manual.

1. Insert the *GRAFPLUS* program disk into the **A** drive.
2. Type **A:** and press **ENTER** to select the **A** drive.
3. Configure the *GRAFLASR* program. (This step only needs to be performed the first time the *GRAFPLUS* software is used with this printer.)
 - a. Type *EDITGRAF* and press **ENTER**.
A series of menus will now be displayed.
 - b. Press **2** to select the *GRAFLASR* program.
 - c. Press **1** and then **6** to select the PaintJet printer driver.
 - d. Press **1** to select the Horizontal printing driver.

- e. Press **3** to select the gray scale printer driver.
 - f. Press **1** to select black and white printing.
 - g. Press **7** to exit the *EDITGRAF* program.
 - h. Press **Y** to save the changes to the *GRAFLASR* program.
4. Choose the printing mode.
 - a. To print in color, type *GRAFLASR &=I16* and press **ENTER** to execute the program.
 - b. To print in black-and-white, type *GRAFLASR =I16* and press **ENTER** to execute the program.
 5. Remove the *GRAFPLUS* program disk from the **A** drive.
-

Installing the HP 3048A Option 301 Software

If you have not installed MS-DOS in your computer, consult your software manuals and install MS-DOS before proceeding.

It is strongly recommended that you make a back-up copy of your software. Refer to your MS-DOS manual for information on copying flexible disks.

Installing the Software on a Hard Disk

In the following procedure, the hard disk is designated as the **C** drive, and the flexible-disk drive is designated as the **A** drive. If your drive designations are different, use the appropriate designations for your computer.

1. Insert the HP 3048A Option 301 program disk into drive **A**.
2. Select drive **A** by typing **A:** and pressing **ENTER**.
3. Type **INSTALL C** and press **ENTER**.

Load and Run the Program

1. Select drive C by typing C: and pressing **ENTER**.
2. Set the directory path to 3048 by typing CD \3048 and pressing **ENTER**.
3. Type PN and press **ENTER**.

If you are using a National Instruments GPIB interface card, type PN /N and press **ENTER**.

Note

There are two executable files in the 3048 subdirectory. PN.EXE is the file used to make phase-noise measurements and is the program referred to when the HP 3048A Option 301 software is mentioned.

The computer loads the HP 3048A Option 301 Software from your hard disk and displays the Main Menu when it has finished.

Running the Software From a Flexible Disk

In the following procedure, the flexible-disk drive is designated as the A drive. If your drive designation is different, use the appropriate designations for your computer.

1. Insert the HP 3048A Option 301 program disk into the A drive.
2. Select drive A by typing A: and pressing **ENTER**.
3. Type PN and press **ENTER**.

If you are using a National Instruments GPIB interface card, type PN /N and press **ENTER**.

Note

The HP 3048A Option 301 program disk must be left in the flexible-disk drive so the program can access the disk.

There are two executable files in the 3048 subdirectory. PN.EXE is the file used to make phase-noise measurements and is the program referred to when the HP 3048A Option 301 software is mentioned.

The computer loads the HP 3048A Option 301 Software from your flexible disk and displays the Main Menu when it has finished.

Operating the HP 3048A Option 301 Software

With the HP 3048A Option 301 Main Menu displayed on your computer, use the following operating instructions.

1. Select a Main Menu item using one of two methods:
 - a. Press the first capitalized letter of the item you want.
 - b. Use the Δ or ∇ keys to move the inverse video box over the item you want, then press the **ENTER** key.
2. When a Main Menu item is selected, a pop-up window or diagram is superimposed over the Main Menu to provide you with further selections, or with entry fields or diagrams for input.
3. More pop-up windows may appear as you make selections. Press the **ESC** (escape) key to return to the previous window.

To reduce keystrokes as you move between windows or diagrams, press and hold the **Alt** key, and then the first capitalized letter of the Main Menu item that you want.
4. To abort a measurement, press the **CNTL** and **BREAK** keys simultaneously. The measurement will stop and the software will return to the Main Menu.
5. To print a hard copy of a phase noise graph, press **SHIFT** and **F4** simultaneously.

6. At the Main Menu level, you may press the Q key to exit the HP 3048A Option 301 software.

Setting Up the HP-IB Addresses

To allow the computer to address the instruments in the system, you need to set the HP-IB (GPIB) address for each instrument that you have connected via HP-IB. You also need to enter these addresses in the System Configuration - Instrument Addresses table.

The Instrument Addresses table is used to tell the software what instruments are available in the test system for each test, and to control the instruments via HP-IB (GPIB). This table is stored in the System Configuration file, and is automatically loaded whenever the HP 3048A Option 301 software is loaded. This file can be re-loaded at any time by using the **Load Config** function.

To access the Instrument Addresses table, select System Configuration from the Main Menu. Next, select the Instrument Addresses function to display the table.

Main Menu			
Instrument Addresses			
Instrument	Model	Address	Serial # / Option
FFT Analyzer	3561A	712	
RF Analyzer			
Interface	11848A	720	2924A00450
Signal Srce 1	8662A	719	
Signal Srce 2	USER'S	707	FR10MZ;AP15.5DM;FM;M4
Down Converter	11729C	706	H33
Freq Counter			
DVM			
Function Gen.			

Figure A-3. Entering Information in the Instrument Addresses Table

Editing the Instrument Addresses Table

The Instrument Addresses table contains four (4) types of information. Three of these fields contain information supplied by the user.

To enter or change this information, use the **ENTER**, **TAB**, **SHIFT-TAB**, and $\triangle \nabla \triangleleft \triangleright$ keys to move the cursor to the desired area, and enter the new information.

Instrument

This column lists the types of instruments that can be connected to the system. These names are pre-defined, and can not be changed.

Model

This column lists the model numbers of the different instruments. When entering the instrument model numbers, do not include the initials "HP".

Most of the instruments you will use are already supported in the software and do not require HP-IB codes to be provided by the user*. If you are using an unsupported instrument, enter "USERS" in this column. USERS tells the software that you have provided HP-IB commands in the *Options* column if you want that instrument to be controlled by the test system. If you do not supply these codes, you must manually set the instrument for the test.

*Refer to chapter 6 of the *HP 3048A Option 301 Phase Noise Measurement System - Reference Manual* for more information regarding supported instruments.

Address

This column specifies the instrument address data for each instrument in the Instrument Address table. The instrument address data consists of two parts. The first part is the HP-IB (GPIB) Instrument Select Code. The second part is the actual instrument's address. How data is entered in the Address column depends on whether an HP-IB or GPIB card is being used.

HP 82335A Interface Card

The Instrument Select Code must match the one set on the HP 82335A installed in the computer. (Refer to Installing the GPIB Card in this chapter.)

The instrument address must consist of two digits. Use a leading zero for single digit addresses.

For example, an HP-IB card with an Instrument Select Code of 7 and an HP 11729C with an address of 6 would be entered as 706.

National Instrument PCII/IIA Interface Card

The Instrument Select Code must be entered as DEV (device).

The instrument address must match the address set in the GPIB set-up menu. (Refer to Installing the GPIB Card in this chapter.)

For example, a GPIB card (select code DEV) with an HP 11729C address of 6 would be entered as DEV6 (DO NOT use a leading zero for single digit addresses).

If the software cannot locate the specified instrument on the control bus, the address data will flash. If this happens, verify that you have:

1. Turned the instrument on,
2. Connected the instrument to the control bus (HP-IB),
3. Specified the correct Instrument Select Code,
4. Specified the correct address for your instrument,

5. Installed the GPIB driver software (for National Instruments PCII/IIA GPIB card only).

Next, move the cursor to the flashing address data and press **Enter**. If your instrument is working properly, and you have met the five conditions listed above, the address will stop flashing.

Note

The computer checks for any instrument at the address indicated. However, the system does not confirm that the responding instrument corresponds to its indicated address. For example, you may have listed the FFT analyzer at address 11. The computer will check to see if an instrument is responding at address 11, but it will not verify that the instrument is an FFT analyzer.

You can verify that the correct instrument is responding by turning its power off, moving the cursor to the address column for that instrument, and pressing **ENTER**. If you have turned off the correct instrument, its address will flash in the table.

Verifying Instrument Addresses

The following table will help you verify the actual HP-IB address settings of your instruments.

Instrument	To Read the Address
HP 3561A	Press the LCL key. Address will appear in upper left corner
HP 3585A	(Requires access to interior of the instrument. Refer to the instrument manual.) Factory set as 11.
HP 3585B	Press the Blue key, then the LCL (address) key. The address appears on the display.
HP 8566A,B HP 8567A HP 8568A,B	Switch the LINE power from STANDBY to ON. The address appears in the display.
HP 8642A/B	Press the SHIFT key, then ENT ADRS (LOCAL key).
HP 8662/3	Press the Blue key, the Special key and then 82.
HP 11729C	Read binary switches on rear panel (1, 2, 4, 8, 16). Factory set as 06
HP 11848A	Read binary switches on rear panel (1, 2, 4, 8, 16). Factory set as 20
HP 71100A HP 71200A	Switch the LINE power from STANDBY to ON. The address appears in the display.

Serial #/Option

This column is used to define three different types of information:

Instrument Serial Number - List the serial numbers of the instruments in the HP 3048A Phase Noise Measurement System (optional).

Note

It is recommended that the serial number of the HP 11848A be listed.

Instrument Options - The presence of certain instrument options allows alternative test setups. List these options here to inform the software of these capabilities. (Any HP 11848A with a serial prefix 2830A or below, must have -BA entered whether or not the serial number is entered.)

HP-IB Codes for System Control - If you have specified "USERS" for the model of either Source 1 or 2, and you want that source to be controlled by the test system, you must enter the HP-IB codes required to setup the source for system control. These codes may include setting for:

- Amplitude
- Frequency
- enabling DCFM
- enabling Electronic Frequency Control (EFC)

Note

Whenever you make a valid entry into one of the fields and exit that field, the entry will be stored in the computer's RAM (Random Access Memory). RAM storage keeps the changes until you exit the program.

If you want the Instrument Addresses information to be permanent, you can use the **Store Config** function in the System Configuration menu to alter the System Configuration disk file. Since only one System Configuration file is maintained by the system, the old configuration file will be overwritten by the new information.

Verifying Operation

Once you have completed the installation procedures, you can verify the system's operation by performing the following test. Completion of this measurement verifies that the system is functioning properly. The parameters for this test are contained in the file named "DEFAULT.PRM".

Note

The performance tests in the *HP 3048A Option 301 Phase Noise Measurement System Calibration Manual* provide a complete verification of the HP 3048A performance specifications. It is not necessary to run the system Performance Tests after the system is installed. These tests are performed at the factory before shipment. However, Performance Tests should be run every 12 months or after a repair of the HP 11848A Phase Noise Interface. Also, whenever a temperature change exceeds $\pm 10^{\circ}\text{C}$, calibration should occur using test Option 1.

-
1. From the Main Menu, select **File System**.
 2. Select **Directory**.
 3. Type *.PRM and press **ENTER**.
 4. Using the Δ or ∇ keys, select **DEFAULT.PRM** and then press **ENTER**.
 5. Select **Load File**.
 6. Press **ENTER** to load the file.
 7. Press **ESC** to return to the Main Menu.
 8. Select **New Measurement**.
 9. Press **Y** to indicate that new measurement data is desired.

The System now addresses each instrument listed in the its Configuration Table. If an instrument does not respond to the HP-IB address listed for it, the computer will inform you with a message on its display.

10. Connect the HP 3561A input and the two 10 MHz source outputs to the HP 11848A as shown on the computer display.

Note Although not shown on the computer display, the Noise Source connections between the HP 3561A and HP 11848A must be made prior to making the measurement. See figure A-1 for an illustration of this connection.

Also, if an RF Analyzer is not connected to the HP 11848A's Spectrum Analyzer output, you must terminate this connection into a 50 Ω load. See figure A-2 for an illustration of this connection.

-
11. Press **F1** to run the test.

If the measurement proceeds without any error messages, and the measured noise is within 10 dB of that in Figure A-4, the HP 3048A Option 301 software and HP 3048A hardware are functioning properly.

Note A graph of the loop-suppression curve will be displayed before the actual measurement begins. This is normal for this measurement.

-
12. Press **F1** to proceed.
 13. When the measurement is complete, the computer will sound a short beep and display the message MEASUREMENT COMPLETE for approximately 5 seconds.
 14. Press **ESC** to return to the Main Menu.

HP3048A DEMO: 10 MHz "A" vs. 10 MHz "B"

[HP] 3048A Carrier: 10.E+6 Hz

9/06/90 15:48:37 - 15:50:52

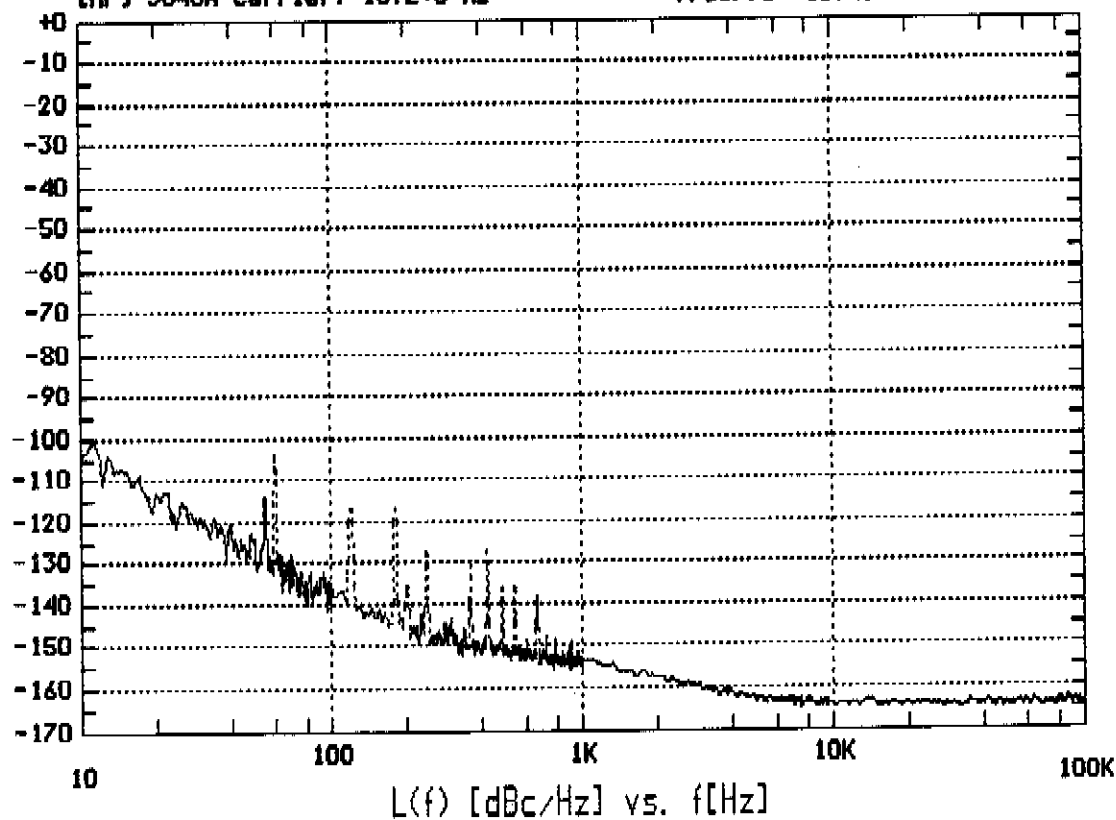


Figure A-4. Typical Noise Curve Obtained by System Verification

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