

## Errata

**Title & Document Type:** 3048A Phase Noise Measurement System Operating Manual

**Manual Part Number:** 03048-61004

**Revision Date:** June 1990

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### HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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**HP 3048A  
Phase Noise  
Measurement System**

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**Operating Manual**

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

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# 1

## Getting Started



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### Designed to Meet Your Needs

The HP 3048A 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 is designed to provide 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 HP 3048A to a proficient user of the system's basic measurement capabilities.

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#### Note

If you have just received your HP 3048A 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 HP 3048A.

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### **As You Begin**

As you begin to learn about the HP 3048A, you will find that *HP 3048A Operation; A Guided Tour* contains a step-by-step procedure for completing a phase noise measurement using the HP 3048A. This measurement demonstration introduces operating fundamentals you should be aware of no matter what 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 the measurement application chapters (3 and 5) 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 Reference Manual. Refer to the reference manual after you are familiar with the basic operating capabilities presented in this manual.

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## HP 3048A Operation; A Guided Tour



This measurement demonstration will introduce you to the HP 3048A'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 offers enormous flexibility for measuring the noise characteristics of your signal sources and two-port devices.

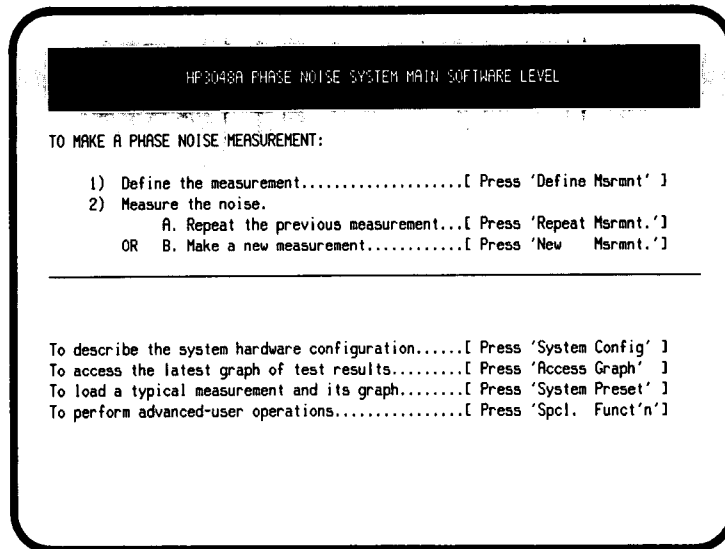
### Required Equipment

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

### How to Begin

Complete 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.

## Setting Up the Measurement



You should be at the Main Software Level to begin this procedure. (If you are not, press the **Done** or **Abort** softkey.)

The Main Software Level menu provides access to each of the HP 3048A's main functions. You will always return to this menu when you exit any of the main function menus.

Figure 1-1 illustrates how the main functions are accessed from the Main Software Level, and how you return to the Main Software Level when you exit the selected function.

1. Press the **System Preset** softkey. This causes the system to automatically load all the parameters required for running this measurement demonstration. (You will learn more about entering measurement parameters later in this demonstration.)

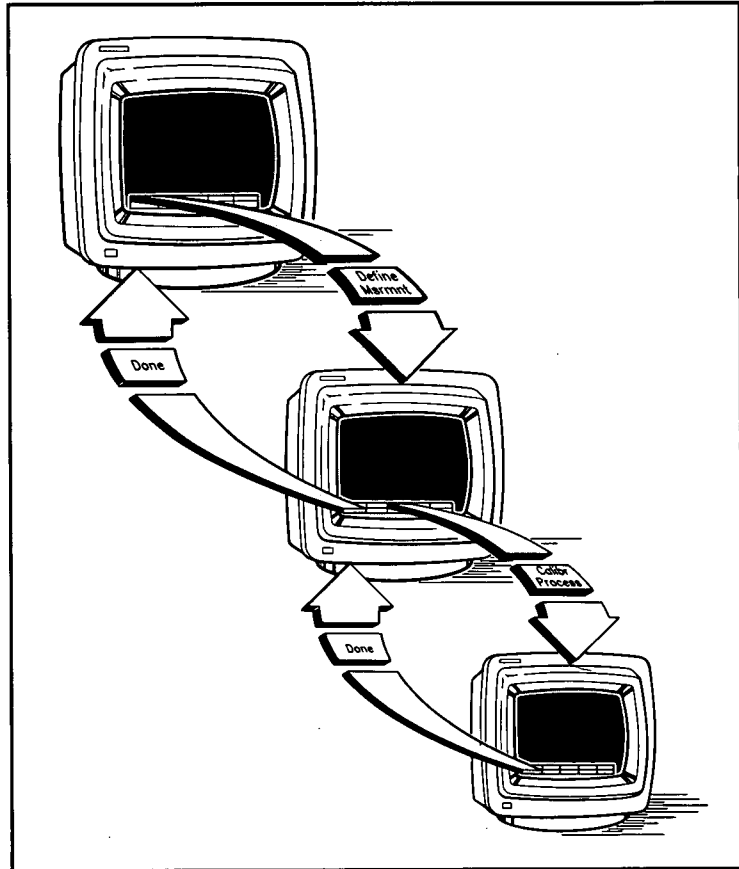


Figure 1-1. Example of Menu Accessing Hierarchy

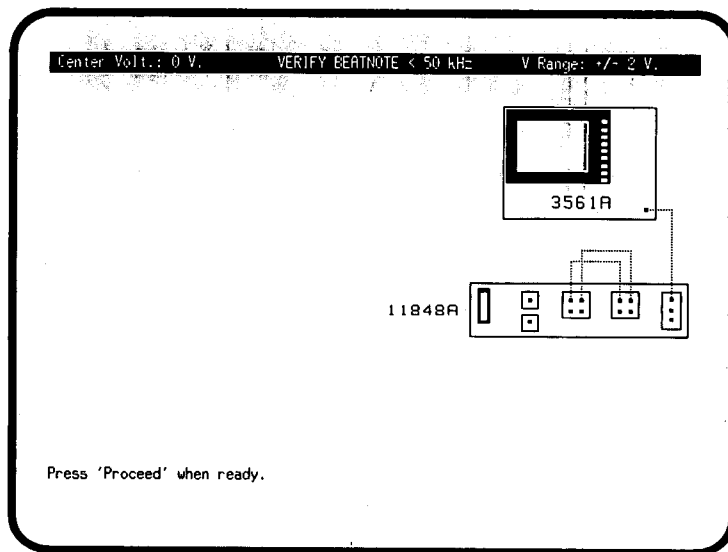
2. Press **Yes, Proceed**.
3. Press the **New Msrmt** key.
4. Press **Yes, Proceed**. The HP 3048A now presets each instrument that has been listed in the HP 3048A's System Configuration table.



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The HP 3048A 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.)

### Connecting the RF Cables



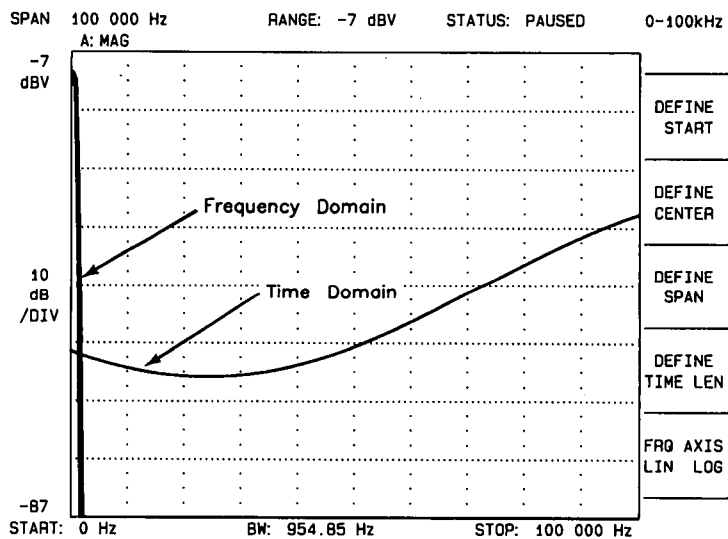
1. When the **Connect Diagram** appears on the display, connect coax cables to the front panel of the HP 11848A as shown in the diagram.

---

**Note** Although not shown, the rear-panel interconnection (SOURCE OUT to NOISE INPUT) described in Appendix A is required. Also, the 50 $\Omega$  Load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF Spectrum Analyzer is not being used.

---

## Checking the Beatnote



**Figure 1-2. HP 3561A Display Showing Low Frequency Beatnote in Frequency and Time Domains**

1. 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 1-2.

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 1-3. The frequency of the beatnote signal represents the difference in frequency between the two 10 MHz sources.

2. Press the **3561A Span** softkey shown on the HP 3048A's controller display. Note that you decrement the HP 3561A's display span width each time you press this key. The span width setting is shown in the upper left corner of the HP 3561A's display.

To increment the span width, press the **Shift** key on your keyboard and the **3561A Span** key at the same time. (In Chapter 3 you will be shown how to use this capability to set the center frequencies of the input signals to within the tuning range limits of the system.)

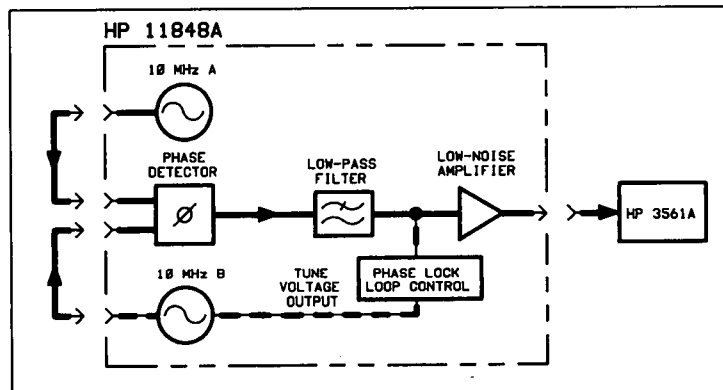


Figure 1-3. Simplified Block Diagram of Measurement Setup

---

## Running the Measurement

1. Press **Proceed** when you are ready to run the measurement. Because you selected the **New Msrmnt** key to begin this measurement, the HP 3048A starts by running the routines required to calibrate the current measurement setup.

The following messages will appear on the display as the HP 3048A performs the calibration routines. (You will have ample time to read through the message descriptions while the HP 3048A 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 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 HP 3048A 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 HP 3048A 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.

**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.

When the HP 3048A has completed the calibration procedures, it will lock the loop and begin its noise measurement. The Out of Lock light on the front panel of the HP 11848A turns off after the loop has been tested to verify phase lock.

### **Sweep-Segments**

When the HP 3048A begins measuring noise, it places the noise graph on its display. As you watch the graph, you will see the HP 3048A plot its measurement results in frequency segments.

The HP 3048A measures the noise level across its frequency offset range by averaging the noise within smaller frequency segments. This technique enables the HP 3048A to optimize measurement speed while providing you with the measurement resolution needed for most test applications.

### **Out of Lock Detection**

Before and after the HP 3048A measures each frequency segment, the system verifies that its Out of Lock Detector has not been set. If the detector has been set, the HP 3048A 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 HP 3048A has completed the noise measurement, the graphics softkeys will appear at the bottom of its display. You will find that these keys access powerful graphics capabilities to help you with your analysis and presentation of the measurement 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 HP 3048A has measured and plotted both the random noise and deterministic (spurious) signals for the 10 MHz sources. The HP 3048A differentiates the random noise (which has been normalized to a 1 Hz bandwidth) from the spurs (which are not normalized) by using a broken line to plot the spurs on the graph.

1. Press **Done** to return to the Main Software Level.

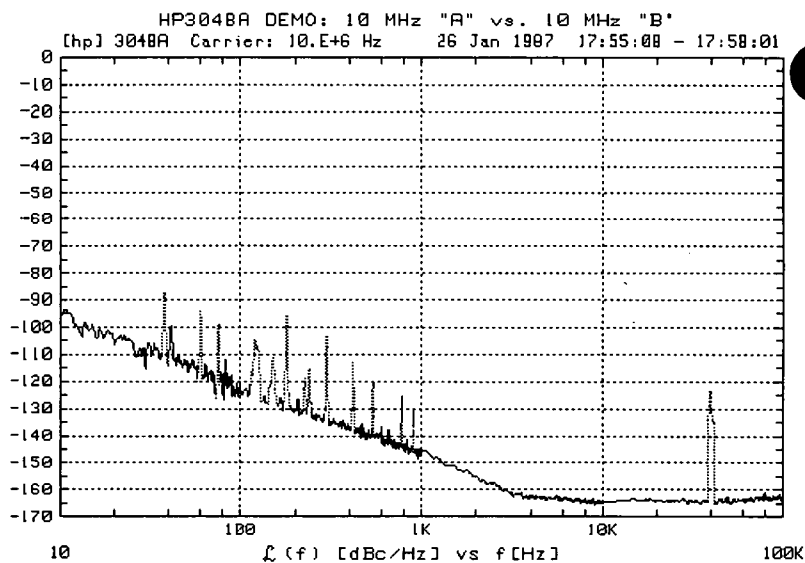


Figure 1-4. Typical Noise Curve for a 10 MHz A versus 10 MHz B Measurement

---

## 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 HP 3048A's 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 softkeys are available for beginning a measurement, **Repeat Msrmnt** and **New Msrmnt**. When you begin your measurement by pressing the **New Msrmnt** key, as you did for this demonstration, you cause the HP 3048A to perform the routines necessary for calibrating the system before it begins its noise measurement. If you press the **Repeat Msrmnt** key, the HP 3048A will use the same calibration data it used for the previous measurement.

---

### Note

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

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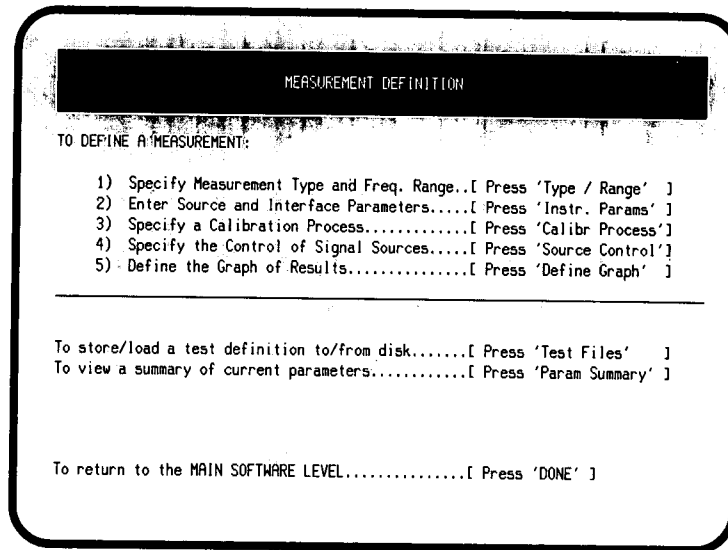


## Designing Your Own Measurement

To set up the demonstration measurement, you pressed the **System Preset** key. This caused the system to automatically load a predefined "test definition" file containing the measurement parameters required for this example. If you plan to set up your own noise measurements, you will need to determine and enter the parameter data required for your measurement. This process is called "Defining a Measurement".

## Defining a Measurement

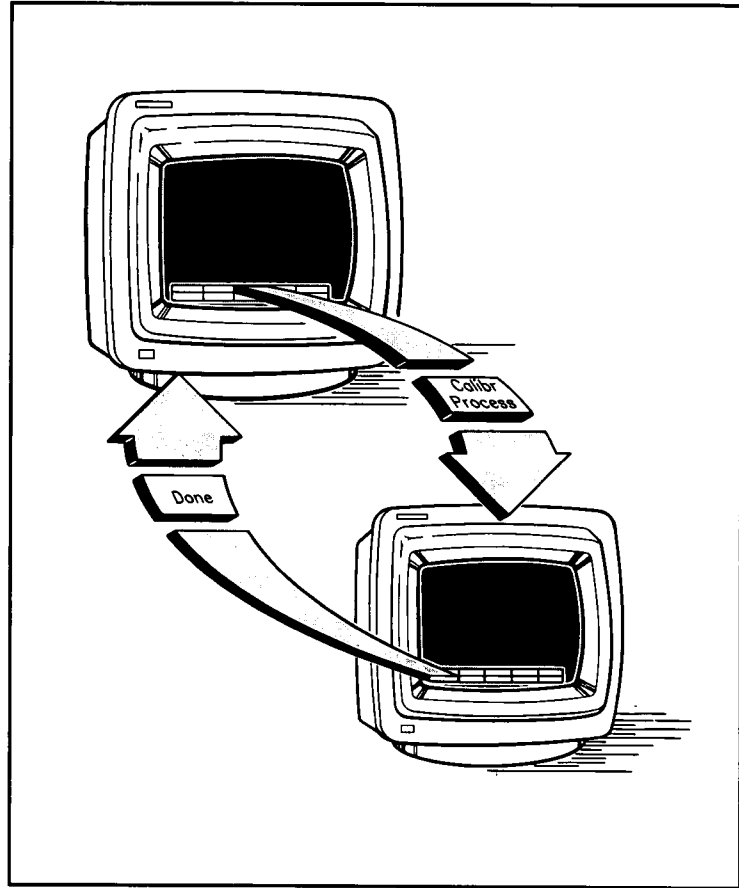
1. Press the **Define Msrmnt** key.



Notice steps 1 through 5 on the Measurement Definition Menu. When you setup your own noise measurements, you will need to define the measurement you wish to make by completing these five steps.

---

You will find that the softkey for accessing the appropriate entry menu is listed with each step. As shown in the following diagram, you will always return to this menu after you exit an entry menu.



## The Measurement Type and Frequency Range

1. Press the **Type/Range** key now to access the procedures for step 1 on the menu.

MEASUREMENT TYPE AND FREQUENCY RANGE SPECIFICATION

<p>MEASUREMENT TYPE: TO SELECT..[ Press 'Next Type' ]</p> <p>Phase Noise Using a Phase Lock Loop Phase Noise Without Using a PLL Phase Noise Using an FM Discriminator AM Noise Noise Measurement Using HP3561A Only</p>	<p>OFFSET FREQUENCY RANGE: ENTER THE FOLLOWING.....</p> <p>Start Freq..[ 10 ] Hz Stop Freq..[ 100.E+3 ] Hz Averages....[ 4 ]</p> <p>Acceptable Values: 1.E-3 TO 40.E+6</p>
--	--

To return to 'MEASUREMENT DEFINITION'.....[ Press 'DONE' ]

This menu allows you to specify which one of the HP 3048A's five 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 HP 3048A to make for *averaging* the noise level.

---

The Measurement Application 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. Press the **Next Type** key. You will see the measurement type selection change each time you press this key.
3. 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.

- 
4. Press **Done** to return to the Measurement Definition menu.

---

## Signal Source Operation

1. Press the **Instr Params** key.

```
SOURCE AND INTERFACE PARAMETER ENTRY

ENTER THE FOLLOWING PARAMETERS:

Carrier Frequency.....[ 10.E+6      ] Hz
Detector/Discr. Input Frequency.....[ 10.E+6      ] Hz
VCO Tuning Constant.....[ 100        ] Hz/Volt
Center Voltage of VCO Tuning Curve.....[ 0          ] Volts
Voltage Tuning Range of VCO..... +/- [ 2          ] Volts
VCO Tune-port Input Resistance.....[ 1.E+6       ] Ohms

Acceptable Values: 1 TO 110.E+9

SELECT A PHASE DETECTOR.....[ Press 'Select Detect.' ]
Internal Phase Detector: 5 MHz to 1600 MHz
Internal Phase Detector: 1.2 GHz to 18 GHz
External Phase/AM Detector

-----

To return to 'MEASUREMENT DEFINITION'.....[ Press 'DONE' ]
```

---

**Note** If your display does not list the same six parameter types shown in the menu above, you need to return to the Type/Range menu and select the "Phase Noise using a Phase Lock Loop" measurement before you proceed with this demonstration.

---

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 the **Done** key.

---

## The Calibration Methods

1. Press the **Calibr Process** key.

DETERMINATION OF PHASE DETECTOR CONSTANT AND VCO TUNING CONSTANT

Select a method for determining the PHASE DETECTOR CONSTANT.

Use the current Detector Constant  
**Measure the Detector Constant**

Select a method for determining the VCO TUNING CONSTANT.

Use the current Tuning Constant  
**Measure the VCO Tuning Constant**  
Compute from expected T. Constant

The computed PLL suppression **WILL** be verified.

To return to the previous menu.....[ Press 'DONE' ]

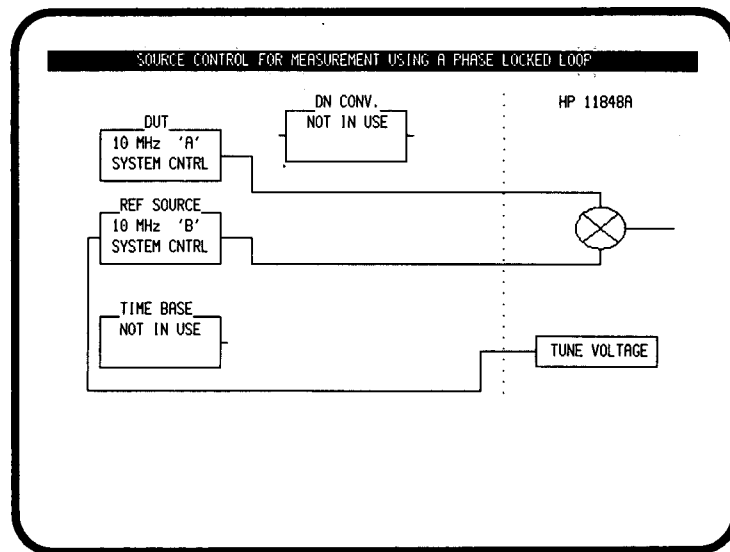
This menu allows you to choose the calibration method most suitable for your measurement situation. When you are setting up a new measurement, you will typically select the *measure method* for determining the calibration constants and have the HP 3048A *verify* PLL suppression. (The criteria for selecting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

2. Press the **Done** key.

---

## The Measurement Setup

1. Press the **Source Control** key.



When you set up your own measurements, you will use the softkeys shown on the screen to configure a block diagram of the measurement setup you plan to use. The purpose of this diagram is to tell the HP 3048A:

- What hardware you will be using.
  - Which instruments will be under HP-IB system control. (The **Control** softkey enables you to specify the control you desire for the instrument selected in the diagram.)
  - What the interconnecting signal paths will be.
2. Press the **Done** key.

## The Results Graph

1. Press the **Define Graph** key.

GRAPH DEFINITION

ENTER THE FOLLOWING PARAMETERS:

Title..	[ HP3048A DEMO: 10 MHz "A" vs. 10 MHz "B"	[ ]
Minimum X coordinate.....	[ 10	Hz ]
Maximum X coordinate.....	[ 100.E+3	Hz ]
Minimum Y coordinate.....	[ -170	] ]
Maximum Y coordinate.....	[ 0	] ]

SELECT A GRAPH TYPE.....[ Press 'Graph Type' ]

- Single Sideband Phase Noise (dBc/Hz)
- Phase Modulation Spectral Density (dB/Hz)
- FM Spectral Density (Hz/SQR(Hz))
- Spectral Density of Fractional Freq. Fluctuations (1/SQR(Hz))

---

To return to 'MEASUREMENT DEFINITION'.....[ Press 'DONE' ]

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

The HP 3048A 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 the **Done** key.



---

## The Test Files

1. Press the **Test Files** key.

FILES OF MEASUREMENT-DEFINING PARAMETERS Page 1 of 2			
FILE	NAME	DATE STORED	STORED AS
2	DEFAULT	16 Mar 1987	PARAM_6
	HEWLETT-PACKARD FACTORY NOISE FLATNESS TEST	26 Jan 1987	PARAM_5
	HEWLETT-PACKARD FACTORY NOISE FLOOR TEST 100 K	13 Feb 1987	PARAM_3
	HEWLETT-PACKARD FACTORY NOISE FLOOR TEST 40 M	13 Feb 1987	PARAM_2
	HEWLETT-PACKARD FACTORY SPUR ACC. TEST 100K	26 Jan 1987	PARAM_4
	HEWLETT-PACKARD FACTORY SPUR ACC. TEST 500K	26 Jan 1987	PARAM_1
	HP EXAMPLE 10 MHZ FREQUENCY STANDARD	12 Mar 1987	PARAM_8
	HP EXAMPLE AM NOISE (HP 8662/3 AND HP 11729C)	26 Jan 1987	PARAM_9
	HP EXAMPLE AM NOISE (HP 8662/3 AND HP 33330C)	26 Jan 1987	PARAM_10
	HP EXAMPLE DESIGNING A MEASUREMENT	26 Jan 1987	PARAM_13

To return to 'MEASUREMENT DEFINITION'.....[ Press 'DONE' ]

Note the test file labeled "Default". This file contains all the measurement parameters required to perform this measurement example. The HP 3048A automatically loaded this file when you pressed the **System Preset** key.

Notice the test files that are labeled as examples. You will find that these files contain the measurement parameters for measuring many of your signal sources and two-port devices. (The Measurement Application chapters (3 and 5) in this manual contain the procedures for measuring your own instruments using these example test files.)

You can also create your own test files by entering a test file name and then pressing the **Store File** key. When you press the **Store File** key, a test file will be created which contains the current contents of each of the five parameter entry menus.

2. Press **Done** once to return to the Measurement Definition Menu, and then press **Done** again to return to the Main Software Level.

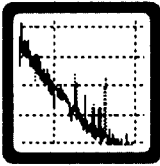
If you now wish to make a noise measurement using a device of your own, refer to the remaining chapters in this manual.

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

---

## Fast, Accurate, and Flexible; The HP 3048A Solution

### Fast Measurements



The HP 3048A is a flexible system designed to provide a simple solution to your absolute and residual noise measurement needs. It provides phase, frequency, and amplitude noise characterization for both signal sources (such as oscillators and signal generators) and two-port devices (such as dividers, mixers, and amplifiers).

The HP 3048A features rapid measurement speed. As you follow the measurement procedures presented in this manual, you will find that you are able to set up and complete your noise measurements in a fraction of the time it takes to make comprehensive noise measurement using other techniques.

The following table shows approximate system run times for measuring various frequency offsets.

Measurement Range	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

## 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	$\pm 2$ dB
1 MHz to 40 MHz	$\pm 4$ 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.

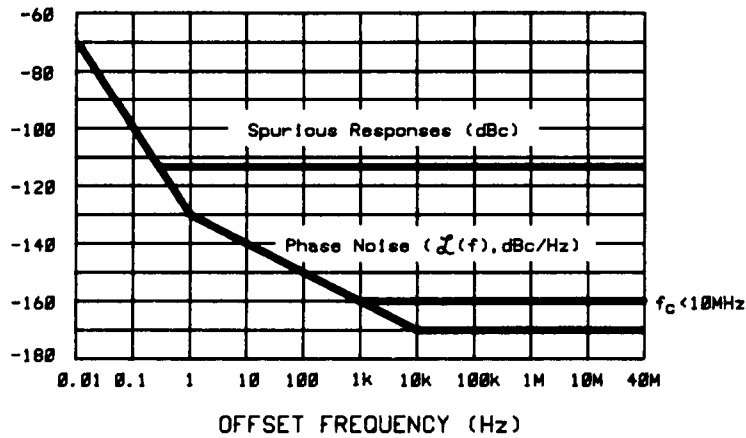


Figure 1-5. Graph of System Phase Noise and Spurious Responses

## 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.

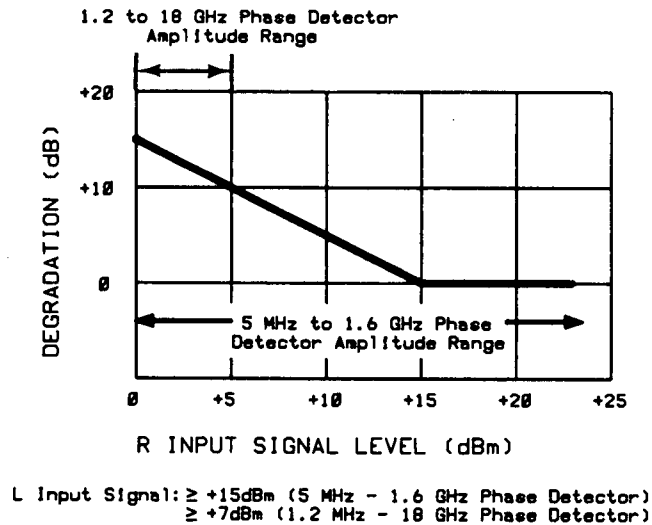


Figure 1-6. Increase in System Noise and Spurious Response Due to Decreased Input Level

## 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 <sup>1</sup>	0.01 Hz to 100 kHz <sup>2</sup>
<sup>1</sup> Option 201 extends the carrier frequency range to 18 GHz <sup>2</sup> When using a supported RF Analyzer).	

### Amplitude Ranges

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz <sup>1</sup>	
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
<sup>1</sup> 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	$\pm 100$ Hz
10 MHz B	+6 dBm	$\pm 1$ kHz
350–500 MHz	+17 dBm	$\pm 20$ MHz
400 MHz	–5 dBm	Fixed Frequency





---

# ● 2

## Signal Source Fundamentals



---

### In This Chapter

This chapter contains information about making absolute phase noise measurements of signal sources that is fundamental to using the HP 3048A. 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 HP3048A Reference Manual for detailed information on the Calibration Process for the Disc Measurement Method.

## **AM Noise Measurements**

You can also characterize the AM noise level of a signal source using the HP 3048A system. Although an AM noise measurement is generally of less concern for signal sources, it can be useful for verifying your measurement results when the measured phase noise is considerably higher than what you expected. (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 device-under-test (DUT). The second source serves as the reference against which the DUT is measured. (One of the two sources must be a VCO source capable of being frequency tuned by the HP 3048A.) Figure 2-1 shows a simplified diagram of the PLL configuration used for the measurement.

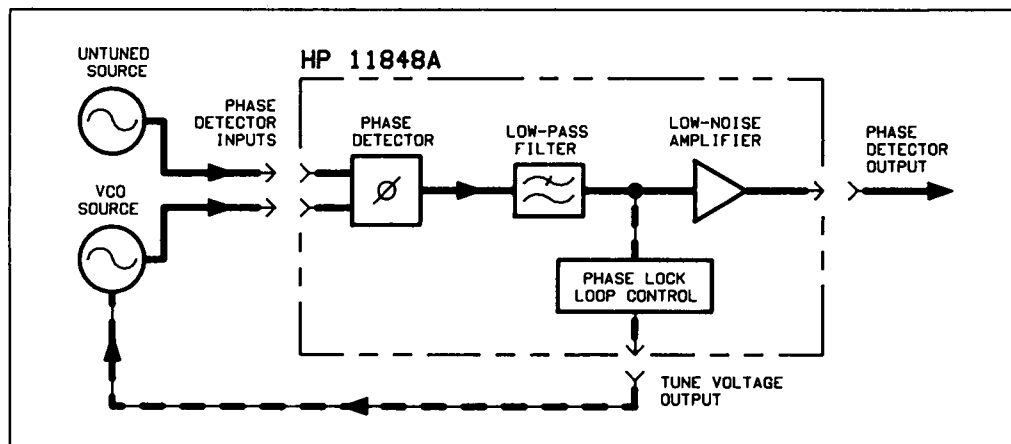


Figure 2-1. Simplified Block Diagram of the Phase Lock Loop Configuration

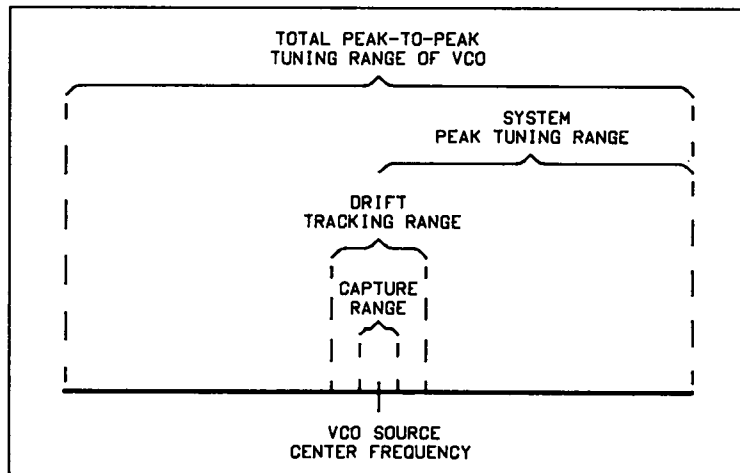
### The Phase Lock Loop Circuit

### 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.

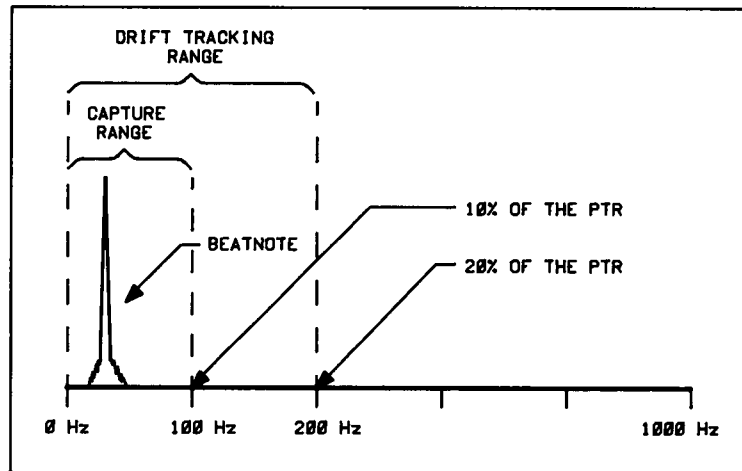


Figure 2-3. Relationship of Capture and Drift Tracking Ranges to Beatnote Frequency

If the beatnote does not remain within the *Drift Tracking Range* during the measurement the out of lock detector will be set and the HP 3048A 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 HP 3048A 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)
- **Peak Voltage Tuning Range**, ( $\pm V$ )
- **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.

---

## What Sets the Measurement Noise Floor?

### The Noise Floor of the HP 3048A

The noise floor for your measurement will be set by two things:

- The noise floor of the HP 3048A
- The noise level of the reference source you are using

The noise floor of the HP 3048A is directly related to the amplitude of the input signal at the R input port of the HP 11848A's Phase Detector.

The following table shows the amplitude ranges for the L and R ports.

Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz <sup>1</sup>	
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

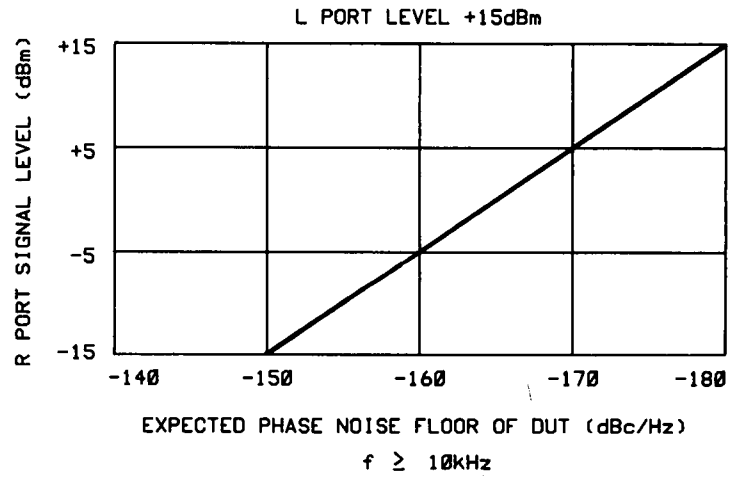
<sup>1</sup> Option 201 adds the 1.2 to 18 GHz High Frequency Phase Detector.



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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.

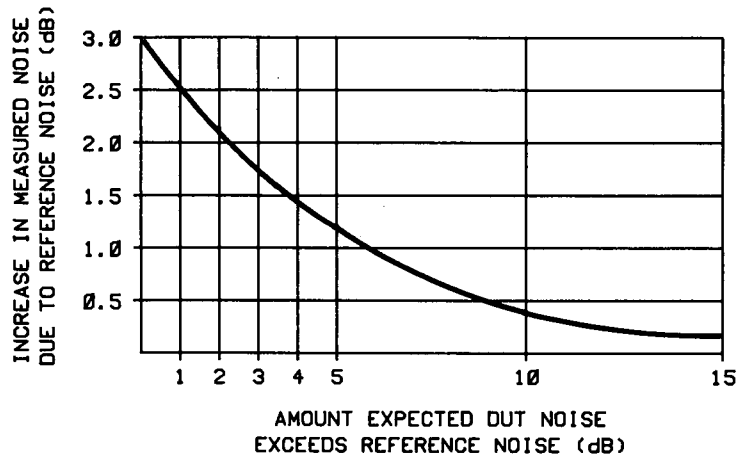
The following graph shows the relationship between the R input level and the system noise floor.



## 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 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 DUT, the level measured by the HP 3048A (which is the sum of all noise sources affecting the system) is increased above the actual noise level of the DUT.



**Figure 2-4. Increase in Measured Noise as Reference Source Noise Approaches DUT 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 Reference Manual*.

---

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## 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.

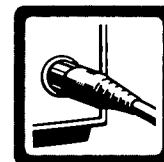
When you wish to measure the *phase* or *AM* noise of your own source, turn to Chapter 3 and select the example provided for measuring your device type.



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# ● 3

## Signal Source Applications



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### 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 to the next 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.

---

## Phase Lock Loop Measurements

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**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.

---

### 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 Instr Params section of Chapter 2 Measurement Definitions of the HP3048A Reference Manual.

<i>When you need to know how to measure:</i>	<i>Refer to:</i>
<b>Phase Lock Loop Measurements</b>	
• <i>A very stable 10 MHz oscillator (drift &lt; 0.1 Hz) such as a frequency standard.....</i>	<b>10 MHz Frequency Standard (pg. 3-3)</b>
• <i>A stable RF oscillator (drift &lt; 20 ppm) such as a VHF crystal, RF crystal, SAW, or DRO. ....</i>	<b>Stable RF Oscillator(pg. 3-15)</b>
• <i>A free-running RF oscillator (drift &gt; 20 ppm) such as an LC or cavity tuned oscillator or a SAW delay line oscillator.....</i>	<b>Free-Running RF Oscillator(pg. 3-28)</b>
• <i>An RF synthesizer using the HP 8662A or HP 8663A. .</i>	<b>RF Synthesizer (pg. 3-42)</b>
• <i>A microwave source (2.5 to 18 GHz) such as a synthesizer, multiplier chain, or phase-locked cavity tuned oscillator.....</i>	<b>Microwave Source (pg. 3-60)</b>
• <i>An RF source using a different reference source than is specified in the examples .....</i>	<b>Designing a Measurement (pg. 3-72)</b>
<b>Discriminator Measurement</b>	
• <i>An RF source using the Discriminator measurement technique. ....</i>	<b>Discriminator Measurement (pg. 3-95)</b>
<b>AM Noise Measurements</b>	
• <i>The AM noise of an RF source using an HP 11792C (Option 130) Carrier Noise Test Set. ....</i>	<b>AM Noise Using an HP 11729C (pg. 3-104)</b>
• <i>The AM noise of an RF source using an HP 33330C Detector. ....</i>	<b>AM Noise Using an HP 33330C (pg. 3-111)</b>



## 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 standard HP 3048A system and your device-under-test (DUT).

### Note

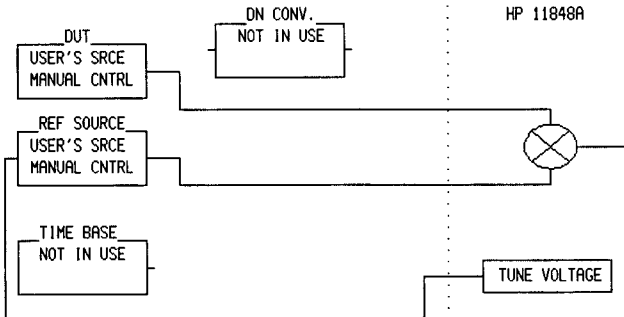
To ensure accurate measurements, you should allow the DUT and measurement equipment to warm up at least thirty minutes before making the noise measurement.

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

### Defining the Measurement

1. Press the **Define Msrmnt** key which is available at the Main Software Level on the HP 3048A.
2. Press the **Test Files** key.
3. Move the cursor down until it is positioned at the file labeled **HP EXAMPLE 10 MHZ FREQUENCY STANDARD**. The appropriate measurement parameters for this example have been prestored in this file.
4. Press the **Load File** key.
5. After the system has completed the file loading sequence, press the **Done** key. Parameter entry is now completed for this measurement example. (Table 3-1 lists the parameter data that has been entered for this measurement example.)
6. Press **Done** to return to the Main Software Level.

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

Step	Parameters	Data
1	<b>Measurement Type</b> <b>Frequency Range</b> Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop  1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning 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	Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	<b>Source Control</b>   <p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String, including: Address, frequency, and amplitude settings.</p>	HP 11848A
5	<b>Define Graph</b> Title  Minimum X Maximum X Minimum Y Maximum Y  Graph Type	10 MHz FREQUENCY STANDARD VERSUS 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. Press the **New Msrmt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 HP 3048A's System Configuration table.)
3. **When the Connect Diagram appears on the HP 3048A's display, connect the signal paths as shown in Figure 3-1.** (Figure 3-1 differs from the Connect Diagram shown on the HP 3048A's 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 $\Omega$  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.

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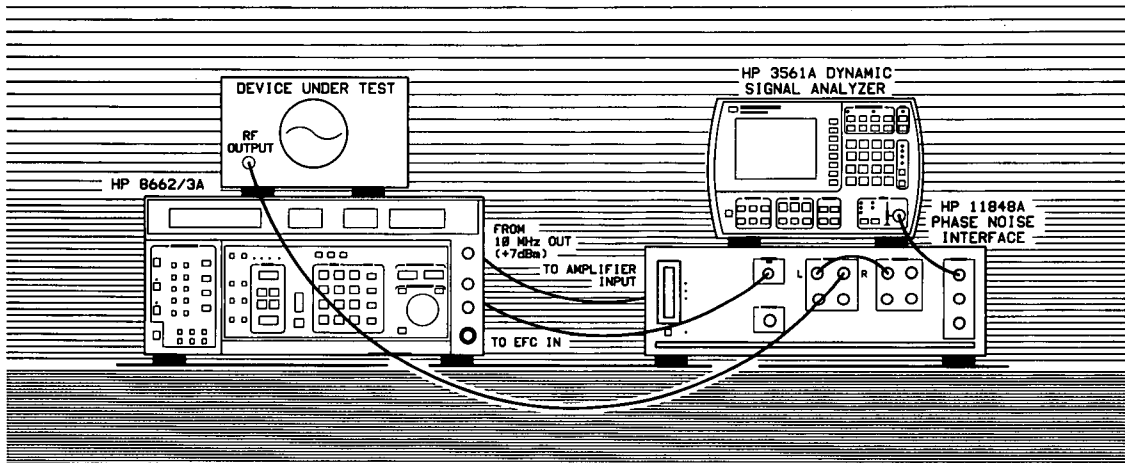


Figure 3-1. Setup Diagram for the 10 MHz Frequency Standard Measurement Example.

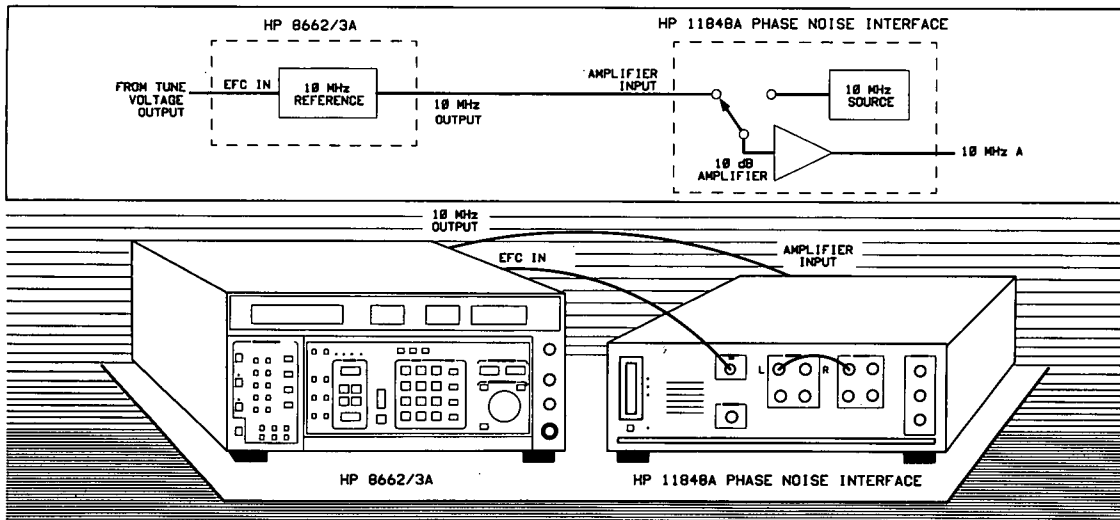


Figure 3-2. Simplified Diagram of the HP 8662/3A's Reference Oscillator and HP 11848A's Internal Amplifier Setup.

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

Setup Considerations	Comments										
<p><b>Measurement Noise Floor</b></p>	<p>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 DUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your DUT will provide.)</p> <div data-bbox="657 724 1239 1102" data-label="Figure"> <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> </div> <p>If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT 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.)</p>	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).**

<b>Setup Considerations</b>	<b>Comments</b>
<p><b>HP 8662A or HP 8663A VCO Reference</b></p>	<p>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 DUT, the noise level of the reference source should be below the expected noise level of the DUT. 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 Reference Manual</i>.</p>
<p><b>Measurement Environment</b></p>	<p>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:</p> <ol style="list-style-type: none"> <li>1. Filtering on power supply lines</li> <li>2. Protection from microphonics</li> <li>3. Short coax cable connections</li> <li>4. Shielding from air currents may even be necessary.</li> </ol>

---

### Checking the Beatnote

While the hardware Connect Diagram is being displayed on the HP 3048A, 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 HP 3048A 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. 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.

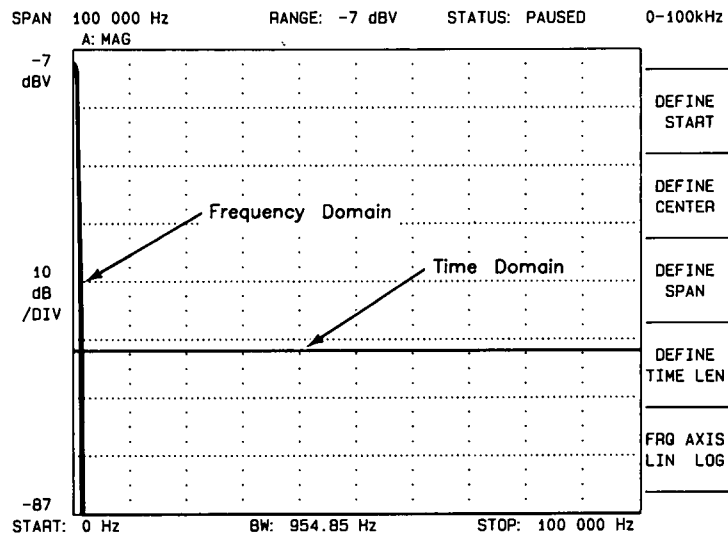


Figure 3-3. HP 3561A Display of a Beatnote Close to 0 Hz

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**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. **When the time domain display on the HP 3561A is showing less than one full cycle, decrement the HP 3561A's span width. The 3561 Span key provided on the HP 3048A's display decrements the HP 3561A's span width each time it is pressed. To increment the span width, press the **SHIFT** key on your keyboard and 3561 Span at the same time.**
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 Capture Range (less than two cycles on the display with the span set to 10 Hz).**

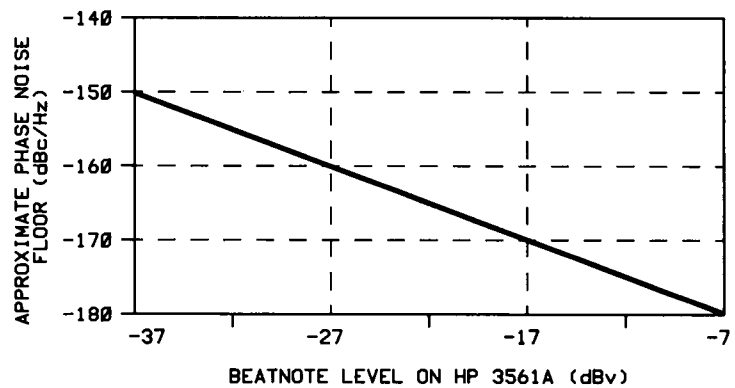
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**Note**

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.**

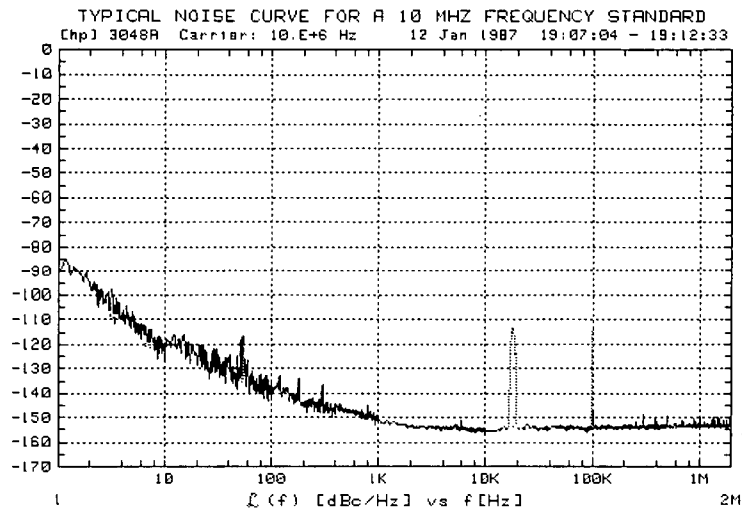
### Running the Measurement

1. Press **Proceed** 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 HP 3048A 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 3-5 shows a typical phase noise curve for a 10 MHz Frequency Standard. This plot was generated by the HP 3048A.



**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 standard HP 3048A system and your device-under-test (DUT).

### Note

To ensure accurate measurements, you should allow the DUT 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 DUT and reference source to HP 11848A.

---

### Defining the Measurement

1. Press the **Define Msrmnt** key which is available at the Main Software Level on the HP 3048A.
2. Press the **Test Files** key.
3. Move the cursor down until it is positioned at the file labeled **HP EXAMPLE STABLE RF OSCILLATOR**.  
The appropriate measurement definition parameters for this example have been pre-stored in this file.
4. Press the **Load File** key.
5. After the system has completed the file loading sequence, press the **Done** key. (Table 3-3 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 appropriate for the sources you are using.
6. To change these values, press the **Instr. Params** key, and enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the Detector Input Frequency.
7. 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.

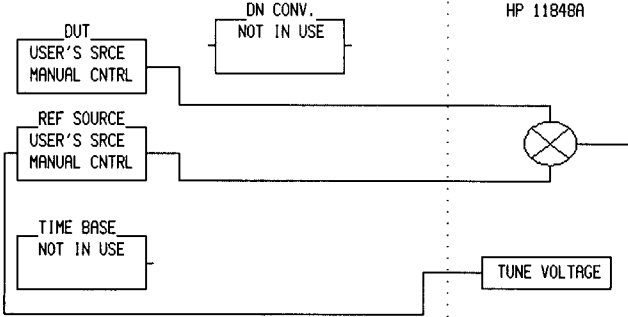
---

#### 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 HP 3048A measure the exact value for you before it makes its noise measurement. If you estimate the Tuning Constant, enter the input resistance as 1 E + 6. If you do know the exact Tuning Constant, enter it and enter the actual input resistance of your VCO.

- 
8. When you have completed these operations, press **Done** to exit the parameter entry menu, and then press **Done** again to return to the Main Software Level.

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

Step	Parameters	Data
1	<b>Measurement Type</b> <b>Frequency Range</b> Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop  1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning 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	Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	<b>Source Control</b>  <p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>	
5	<b>Define Graph</b> Title  Minimum X Maximum X Minimum Y Maximum Y  Graph Type	STABLE RF OSCILLATOR VERSUS SIMILAR REFERENCE SOURCE.  1 Hz 100 E + 3 Hz -170 0  Single Sideband Phase Noise (dBc/Hz)

### Beginning the Measurement

1. Press the **New Msrmt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 HP 3048A's System Configuration table.)
3. **When the Connect Diagram appears on the HP 3048A's display, connect the signal paths as shown in Figure 3-6.** (Figure 3-6 differs from the Connect Diagram shown on the HP 3048A's display.) Table 3-4 provides setup considerations that will help you ensure that your measurement results will be valid.

---

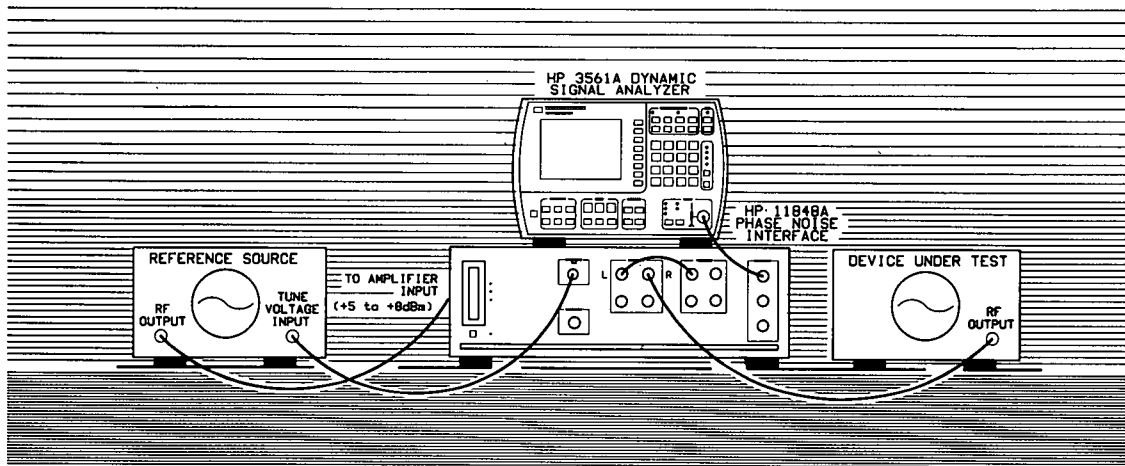
#### Note

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 $\Omega$  load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

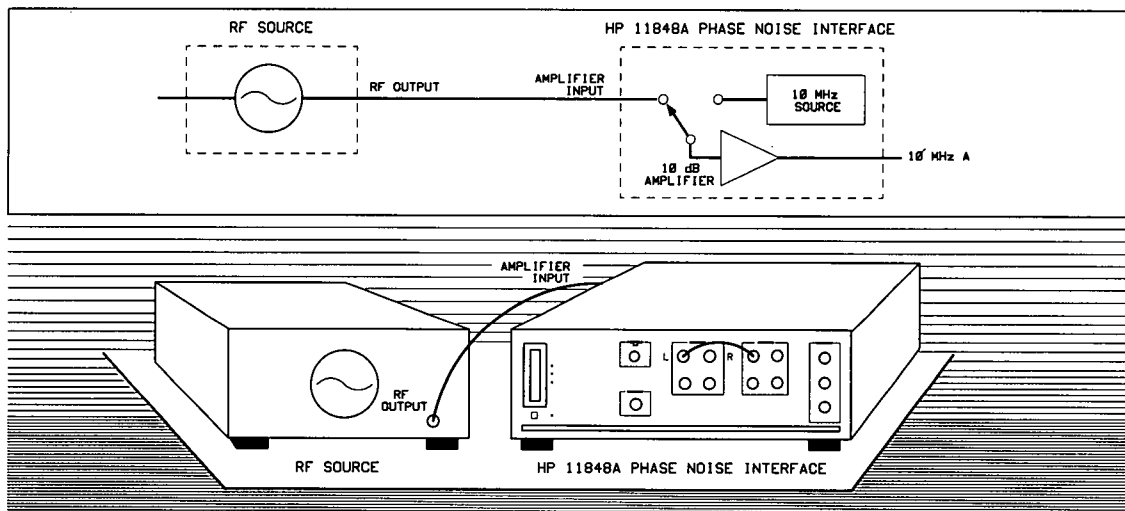
The setup configuration used for this measurement example takes advantage of a 10 dB amplifier available within the HP 11848A. (This low noise amplifier has been designed for use with signal sources whose output level is below the +15 to +23 dBm range required at the L input port on the HP 11848A. The 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										
<p><b>Measurement Noise Floor</b></p>	<p>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 DUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your DUT will provide.)</p> <div data-bbox="685 716 1268 1094" data-label="Figure"> <p style="text-align: center;">L PORT LEVEL +15dBm</p> <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>-14</td> <td>-15</td> </tr> <tr> <td>-15</td> <td>-5</td> </tr> <tr> <td>-16</td> <td>+5</td> </tr> <tr> <td>-17</td> <td>+15</td> </tr> </tbody> </table> <p style="text-align: center;">R PORT SIGNAL LEVEL (dBm)</p> <p style="text-align: center;">-14dB   -15dB   -16dB   -17dB   -18dB</p> <p style="text-align: center;">EXPECTED PHASE NOISE FLOOR OF DUT (dBc/Hz)</p> <p style="text-align: center;"><math>f \geq 10\text{kHz}</math></p> </div> <p>If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT 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 amplifiers noise will have on the measured noise floor.)</p>	Expected Phase Noise Floor of DUT (dBc/Hz)	R Port Signal Level (dBm)	-14	-15	-15	-5	-16	+5	-17	+15
Expected Phase Noise Floor of DUT (dBc/Hz)	R Port Signal Level (dBm)										
-14	-15										
-15	-5										
-16	+5										
-17	+15										
<p><b>VCO Reference Source</b></p>	<p>This setup calls for a second signal source that is a similar type to that of the DUT. The second source is used as the reference source. In order for the noise measurement results to accurately represent the noise of the DUT, the noise level of the reference source should be below the expected noise level of the DUT. (For additional help in selecting an appropriate reference source, refer to <i>Selecting a Reference</i> in the <i>Problem Solving</i> section of this chapter.)</p>										

---

### 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 Voltage Tuning Range. 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 HP 3048A will not be able to complete its measurement.

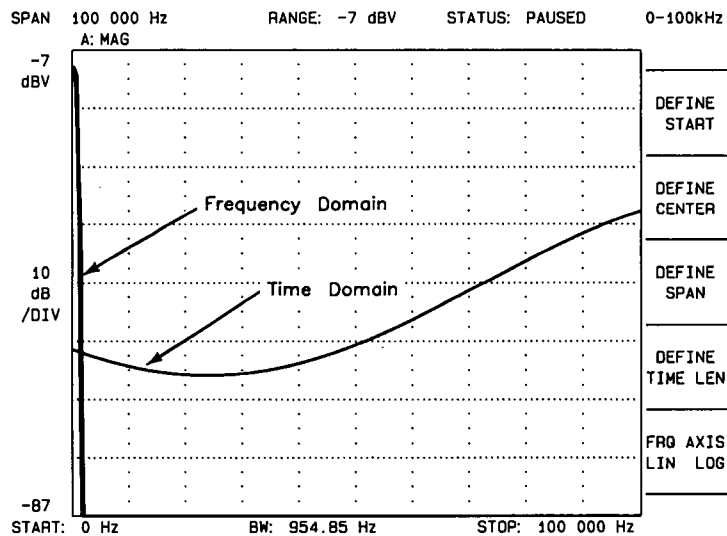
---

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.

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

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

**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** key on the HP 3048A to adjust the center voltage of the tuning signal being sent to the VCO source from the TUNE VOLTAGE OUTPUT on the HP 11848A. (Keep in mind that 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. **When the time domain display on the HP 3561A is showing less than one full cycle, decrement the HP 3561A's span width.** The **3561 Span** key provided on the HP 3048A's display decrements the HP 3561A's span width each time it is pressed. To increment the span width, press the **SHIFT** key on your keyboard and **3561 Span** at the same time.
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.

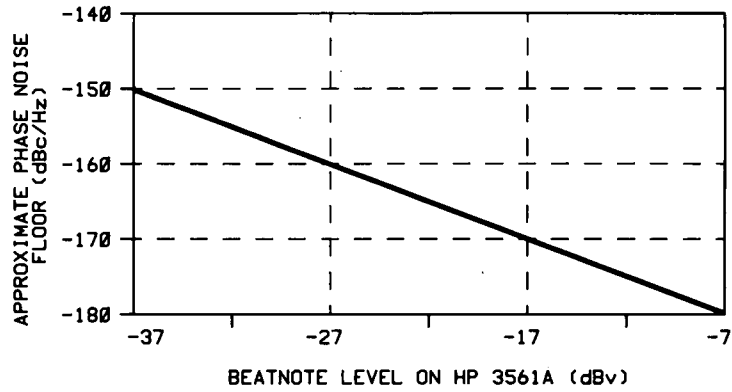
**For example**, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

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

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

### HP 3561A Time Record

Note that the higher the span width setting that you are in is, 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.**



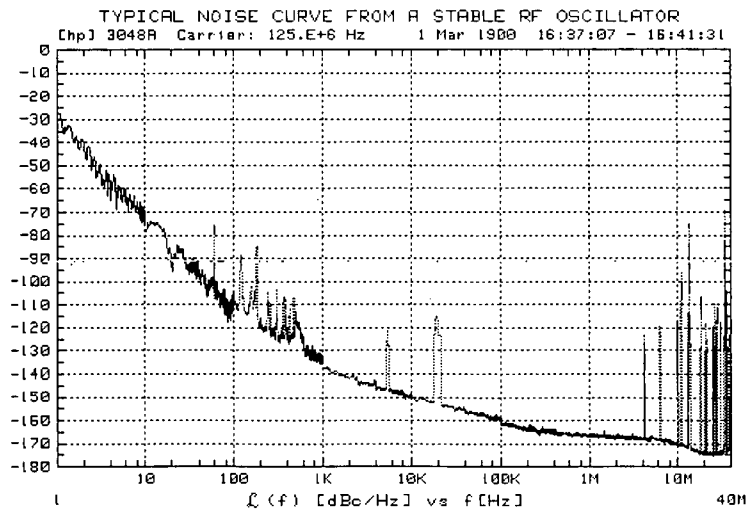
---

### Running the Measurement

1. Press **Proceed** 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 HP 3048A 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. This plot was generated by the HP 3048A.



**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 standard HP 3048A system and your device-under-test (DUT).

### Note

To ensure accurate measurements, you should allow the DUT 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 DUT 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 System Configuration Table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for the procedure).

---

### Defining the Measurement

1. Press the **Define Msrmnt** key which is available at the **Main Software Level** on the HP 3048A.
2. Press the **Test Files** key.
3. Move the cursor down until it is positioned at the file labeled **HP EXAMPLE FREE-RUNNING RF OSCILLATOR**. The appropriate measurement definition parameters for this example have been prestored in this file.
4. Press the **Load File** key.
5. After the system has completed the file loading sequence, press the **Done** key. (Table 3-5 lists the parameter data that has been entered for this measurement example.) Note that the Carrier Frequency and VCO Tuning Constant entered for step 2 on the table may not be appropriate for measuring your device.
6. To change these values, press the **Instr. Params** key.
7. Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz). Enter the same frequency for the Detector Input Frequency.
8. 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 DUT 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 HP 3048A 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.

- 
9. When you have completed this operation, press **Done** to exit the parameter entry menu. The remaining parameter values are correct for this measurement example.
  10. Press **Done** again to return to the Main Software Level.

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

Step	Parameters	Data
1	<b>Measurement Type</b>	Phase Noise Using a Phase Lock Loop
	<b>Frequency Range</b> Start Freq. Stop Freq. Averages	1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning Range of VCO VCO Tune-Port Input Resistance	640 E + 6 Hz 640 E + 6 Hz 5.12 E + 6 Hz/V 0 Volts ±10 Volts 600 ohms
	Internal Phase Detector	5 MHz to 1600 MHz
3	Phase Detector Constant	Measure the Detector Constant
	VCO Tuning Constant PLL Suppression	Computed from expected Tuning Constant Will be verified
4	<b>Source Control</b>	
	<p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>	
5	<b>Define Graph</b>	FREE-RUNNING RF OSCILLATOR VERSUS HP 8640B.
	Title	
	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. Press the **New Msrmnt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 HP 3048A's System Configuration 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 $\Omega$  load must be connected to the SPECTRUM ANALYZER OUTPUT whenever an RF spectrum analyzer is not being used.

---

- 
3. When the Connect Diagram appears on the HP 3048A's display, 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).

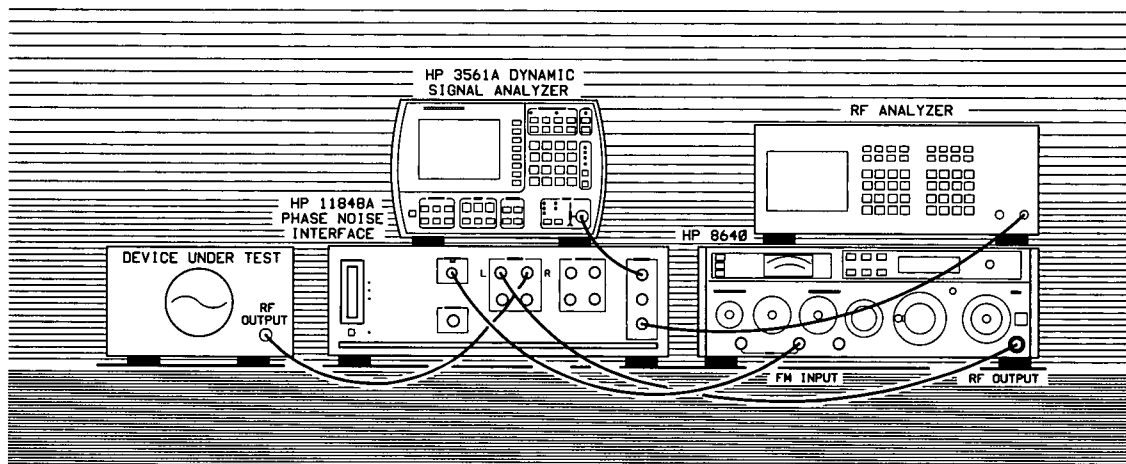


Figure 3-11. Setup Diagram for the Free-Running RF Oscillator Measurement Example.

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

Setup Considerations	Comments										
<p><b>Measurement Noise Floor</b></p>	<p>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 DUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your DUT will provide.)</p> <div data-bbox="683 743 1268 1119" data-label="Figure"> <p style="text-align: center;">L PORT LEVEL +15dBm</p> <table border="1"> <caption>Data points from the graph</caption> <thead> <tr> <th>Expected Phase Noise Floor (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> <p style="text-align: center;">R PORT SIGNAL LEVEL (dBm)</p> <p style="text-align: center;">EXPECTED PHASE NOISE FLOOR OF DUT (dBc/Hz)</p> <p style="text-align: center;"><math>f \geq 10\text{kHz}</math></p> </div> <p>If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT 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.)</p>	Expected Phase Noise Floor (dBc/Hz)	R Port Signal Level (dBm)	-150	-15	-160	-5	-170	+5	-180	+15
Expected Phase Noise Floor (dBc/Hz)	R Port Signal Level (dBm)										
-150	-15										
-160	-5										
-170	+5										
-180	+15										
<p><b>HP 8640B VCO Reference</b></p>	<p>This uses the HP 8640B as the VCO reference source. In order for the noise measurement results to accurately represent the noise of the DUT, the noise level of the reference source should be below the expected noise level of your DUT. 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 Reference Manual</i>.</p>										



---

### Checking the Beatnote

While the hardware Connect Diagram is being displayed on the HP 3048A, 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 Voltage Tuning Range (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 HP 3048A will not be able to complete its measurement.

---

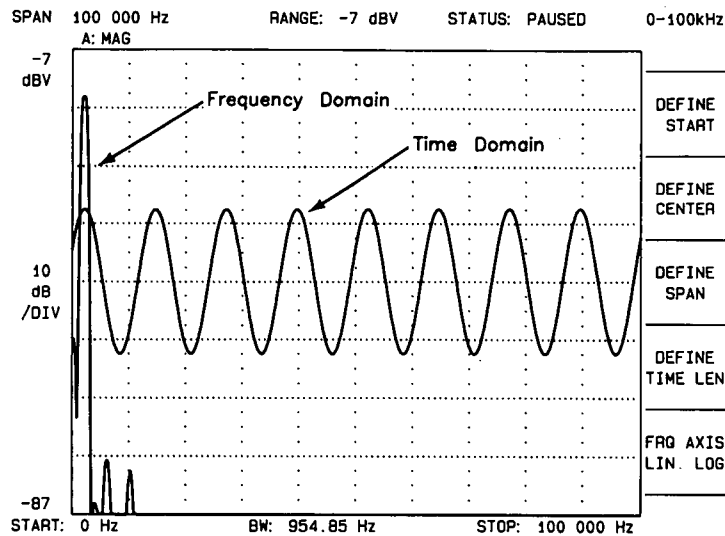
If the beatnote frequency is below 100 kHz it should now appear on the HP 3561A. The HP 3561A is configured to display the beatnote signal in both the frequency domain and the time domain.

If you are using an RF analyzer, and the beatnote is > 100 kHz but < 40 MHz, the beatnote will appear on the RF analyzer's display. 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 DUT 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):

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

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

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. When the time domain display on the HP 3561A is showing less than one full cycle, decrement the HP 3561A's span width. The **3561 Span** key provided on the HP 3048A's display decrements the HP 3561A's span width each time it is pressed. To increment the span width, press the **SHIFT** key on your keyboard and **3561 Span** at the same time.
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.

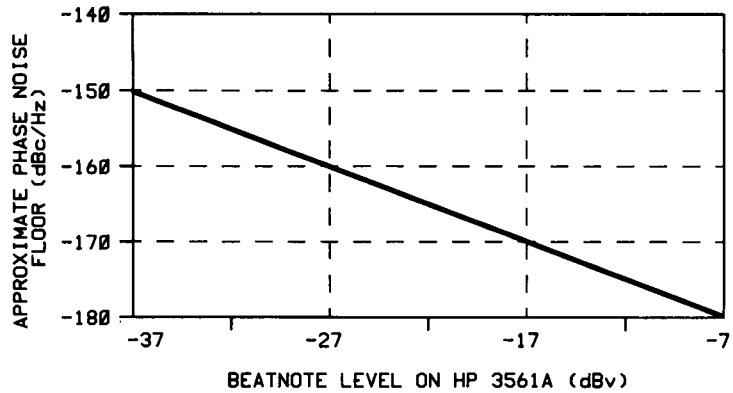
**For example**, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

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

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

### HP 3561A Time Record

Note that the higher the span width setting that you are in is, 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.**

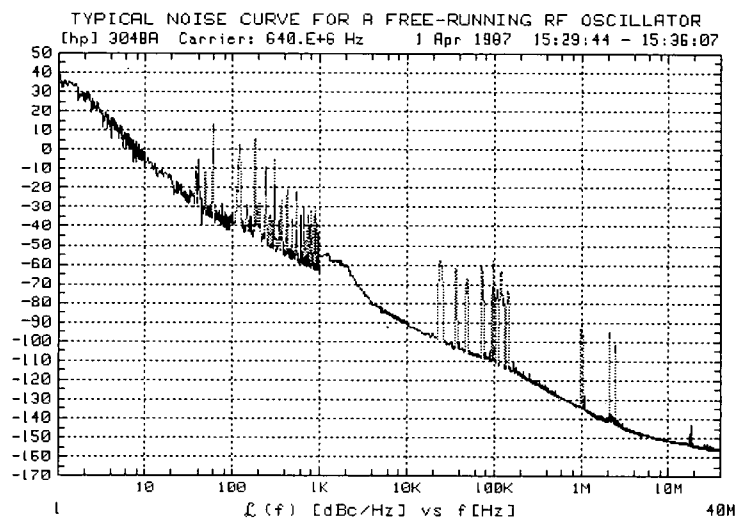
7. As you observe the beatnote, compare its level to the above chart to determine the approximate measurement noise floor for the measurement. If the beatnote level will not provide an adequate measurement noise floor to measure your device, increase the signal level at the R input port of the HP 11848A.

### Running the Measurement

1. Press **Proceed** 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 HP 3048A 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 3-14 shows a typical phase noise curve for a free-running RF oscillator. This plot was generated by the HP 3048A.



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

---

## RF Synthesizer

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

### Required Equipment

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

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### Note

To ensure accurate measurements, you should allow the DUT 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 System Configuration Table (refer to <i>Setting up the HP-IB Addresses</i> in Appendix A for procedure).
Coax Cables	3	And adequate adapters to connect DUT to HP 11848A.

### Defining the Measurement

1. Press the **Define Msrmnt** key which is available at the **Main Software Level** on the HP 3048A.
2. Press the **Test Files** key.



3. Move the cursor down until it is positioned at the files labeled **HP EXAMPLE RF SYNTHESIZER**. Note that four RF Synthesizer measurement examples are listed. 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 %:	Then Select:
$< 10 E - 9 \times v_0$ <sup>1</sup>	(8662/3 EFC)
$< 1 E - 6 \times v_0$	(8662/3 AND 10 MHZ A)
$< 5 E - 6 \times v_0$	(8662/3 AND 10 MHZ B) <sup>2</sup>
$> 5 E - 6 \times v_0$	(8662/3 DC FM)
<sup>1</sup> $v_0$ = center frequency of source-under-test (Hz). <sup>2</sup> Use for measuring carrier frequencies $\leq$ 500 MHz. <sup>3</sup> 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. Position the cursor beside the label of the appropriate example for your measurement. The required measurement definition parameters for this example have been prestored in this file.
5. Press the **Load File** key.
6. After the system has completed the file loading sequence, press the **Done** key. (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.

---

7. To change these values, press the **Instr. Params** key, and 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.)

8. Enter the VCO Tuning Constant.

If you are going to use DC FM tuning, enter an FM deviation setting that will provide the HP 3048A 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 = :

$$EFC = 5 \text{ E} - 9$$

$$10 \text{ MHz A} = 1 \text{ E} - 6$$

$$10 \text{ MHz B} = 10 \text{ E} - 6$$

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

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

9. **Enter the Voltage Tuning Range.** (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.)

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.

$$\text{Voltage Tuning Range} = V \div \text{Carrier Frequency}$$

Where V = :

$$10 \text{ MHz A} = 10 \text{ E} + 9$$

$$10 \text{ MHz B} = 1 \text{ E} + 9 *$$

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

10. **When you have completed these operations, press  to exit this menu, and then press  again to return to the Main Software Level.**

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

Step	Parameters	Data
1	<b>Measurement Type</b>	Phase Noise Using a Phase Lock Loop
	<b>Frequency Range</b>	
	Start Freq.	1 Hz
	Stop Freq.	100 E + 3 Hz
2	<b>Averages</b>	4
	<b>Source Parameters</b>	
	Carrier Frequency	500 E + 6 Hz
	Detector/Discr. Input Frequency	500 E + 6 Hz
	VCO Tuning Constant	500 Hz/V
	Center Voltage of VCO Tuning Curve	0 Volts
	Voltage Tuning Range of VCO	±10 Volts
VCO Tune-Port Input Resistance	1 E + 6 ohms	
3	Internal Phase Detector	5 MHz to 1600 MHz
	Phase Detector Constant	Measure the Detector Constant
	VCO Tuning Constant	Measure the VCO Tuning Constant
4	PLL Suppression	Will be verified
	<b>Source Control</b>	<p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>
5	<b>Define Graph</b>	
	Title	RF SYNTHESIZER VERSUS HP 8662/3A AND 10 MHz A.
	Minimum X	1 Hz
	Maximum X	100 E + 3 Hz
	Minimum Y	-170
Maximum Y	0	
	Graph Type	Single Sideband Phase Noise (dBc/Hz)

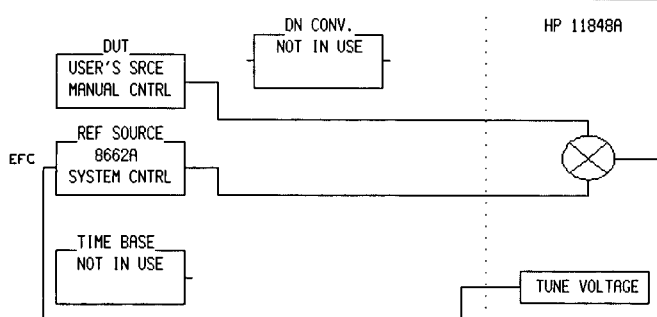
**Table 3-8. Parameter Data for the RF Synthesizer  
(HP 8662/3 And 10 MHz B) Measurement Example**

Step	Parameters	Data
1	<b>Measurement Type</b>	Phase Noise Using a Phase Lock Loop
	<b>Frequency Range</b> Start Freq. Stop Freq. Averages	1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning Range of VCO VCO Tune-Port Input Resistance	500 E + 6 Hz 500 E + 6 Hz 5 E + 3 Hz/V 0 Volts ±2 Volts 1 E + 6 ohms
	Internal Phase Detector	5 MHz to 1600 MHz
3	Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	<b>Source Control</b>	<p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>
5	<b>Define Graph</b> Title	RF SYNTHESIZER VERSUS HP 8662/3A AND 10 MHz B.
	Minimum X Maximum X Minimum Y Maximum Y  Graph Type	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	<b>Measurement Type</b>	Phase Noise Using a Phase Lock Loop
	<b>Frequency Range</b>	
	Start Freq.	1 Hz
	Stop Freq.	100 E + 3 Hz
2	<b>Averages</b>	4
	<b>Source Parameters</b>	
	Carrier Frequency	500 E + 6 Hz
	Detector/Discr. Input Frequency	500 E + 6 Hz
	VCO Tuning Constant	25 E + 3 Hz/V
	Center Voltage of VCO Tuning Curve	0 Volts
	Voltage Tuning Range of VCO	±2 Volts
VCO Tune-Port Input Resistance	600 ohms	
3	Internal Phase Detector	5 MHz to 1600 MHz
	Phase Detector Constant	Measure the Detector Constant
	VCO Tuning Constant	Measure the VCO Tuning Constant
4	PLL Suppression	Will be verified
	<b>Source Control</b>	<p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>
5	<b>Define Graph</b>	
	Title	RF SYNTHESIZER VERSUS HP 8662/3A USING DC FM.
	Minimum X	1 Hz
	Maximum X	100 E + 3 Hz
	Minimum Y	-170
Maximum Y	0	
Graph Type	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	<b>Measurement Type</b> <b>Frequency Range</b> Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop  1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning 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 ±2 Volts 1 E + 6 ohms  5 MHz to 1600 MHz
3	Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	<b>Source Control</b>  <p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>	
5	<b>Define Graph</b> Title  Minimum X Maximum X Minimum Y Maximum Y  Graph Type	RF SYNTHESIZER VERSUS HP 8662/3A USING EFC.  1 Hz 100 E + 3 Hz -170 0  Single Sideband Phase Noise (dBc/Hz)

## Beginning the Measurement

1. Press the **New Msrmt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 HP 3048A's System Configuration table.)
3. **When the Connect Diagram appears on the HP 3048A's display, connect the signal paths as shown on the display.** (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 $\Omega$  load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

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**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.

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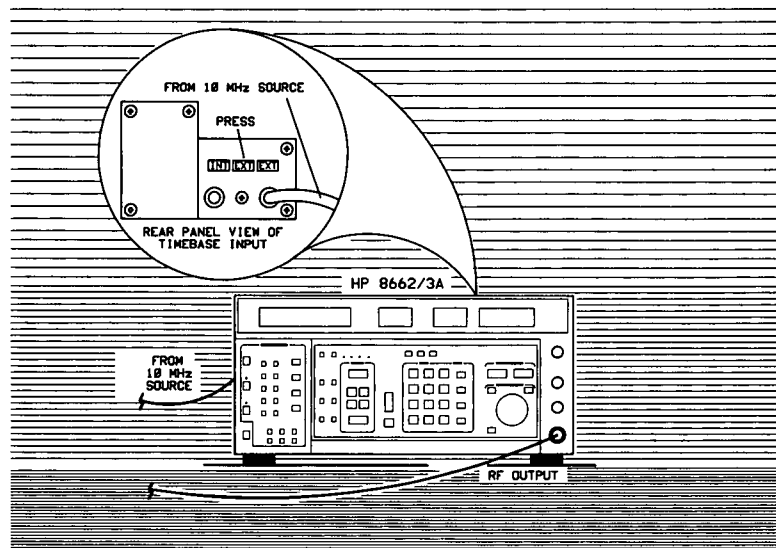


Figure 3-15. 10 MHz External Timebase Input on HP 8662/3.

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

Setup Considerations	Comments										
<p><b>Measurement Noise Floor</b></p>	<p>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 DUT. (The <i>Checking the Beatnote</i> procedure in this section will provide you with an opportunity to estimate the measurement noise floor that your DUT will provide.)</p> <div data-bbox="674 743 1257 1119" data-label="Figure"> <p style="text-align: center;">L PORT LEVEL +15dBm</p> <table border="1"> <caption>Data points from the graph</caption> <thead> <tr> <th>Expected Phase Noise Floor (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> <p style="text-align: center;">R PORT SIGNAL LEVEL (dBm)</p> <p style="text-align: center;">EXPECTED PHASE NOISE FLOOR OF DUT (dBc/Hz)</p> <p style="text-align: center;"><math>f \geq 10\text{kHz}</math></p> </div> <p>If the output amplitude of your DUT is not sufficient to provide an adequate measurement noise floor, it will be necessary to insert a low noise amplifier between the DUT 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.)</p>	Expected Phase Noise Floor (dBc/Hz)	R Port Signal Level (dBm)	-150	-15	-160	-5	-170	+5	-180	+15
Expected Phase Noise Floor (dBc/Hz)	R Port Signal Level (dBm)										
-150	-15										
-160	-5										
-170	+5										
-180	+15										
<p><b>HP 8662A or HP 8663A VCO Reference</b></p>	<p>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 DUT, the noise level of the reference source should be below the expected noise level of your DUT. 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 Reference Manual</i>.</p>										

### Checking the Beatnote

While the hardware Connect Diagram is being displayed on the HP 3048A, we recommend that you check the beatnote being created between the HP 8662/3A 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 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 Voltage Tuning Range (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

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If the center frequencies of the sources are not close enough to create a beatnote within the Capture Range, the HP 3048A will not be able to complete its measurement.

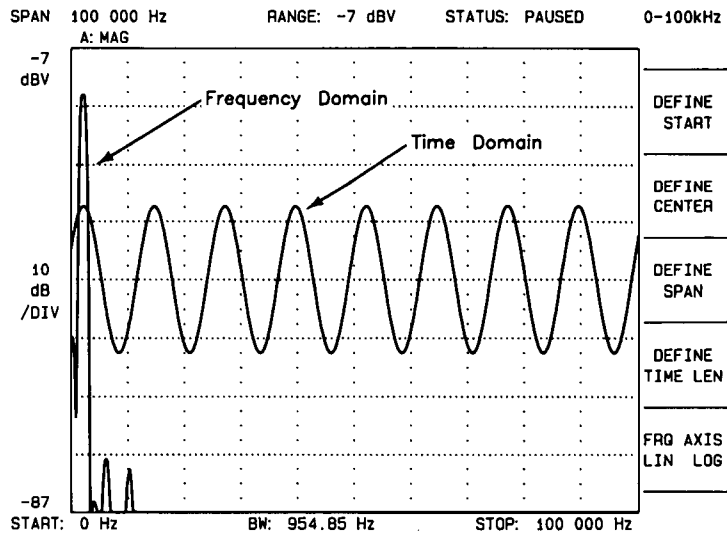
---

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 DUT 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):

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

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. **When the time domain display on the HP 3561A is showing less than one full cycle, decrement the HP 3561A's span width.** The **3561 Span** key provided on the HP 3048A's display decrements the HP 3561A's span width each time it is pressed. (To increment the span width, press the **SHIFT** key on your keyboard and **3561 Span** at the same time.)
  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.

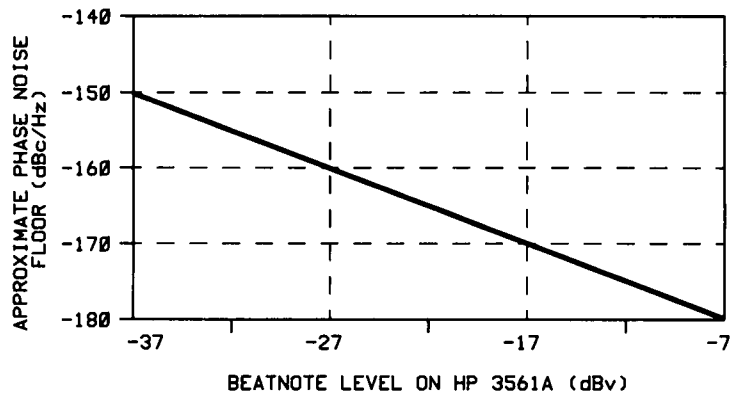
**For example**, to tune the beatnote to within 5 Hz you can use the 1 kHz span width setting by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

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

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

### HP 3561A Time Record

Note that the higher the span width setting that you are in is, 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.**



## Running the Measurement

1. Press **Proceed** 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 HP 3048A 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. This plot was generated by the HP 3048A.

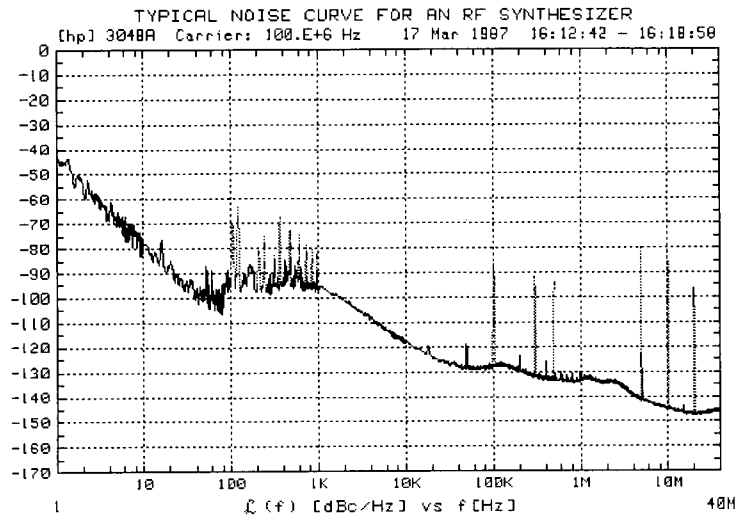


Figure 3-18. Typical Phase Noise Curve for an RF Synthesizer.

## 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  $\leq 10E - 9 \times$  Carrier Frequency over a period of thirty minutes.

### Required Equipment

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

### Note

To ensure accurate measurements, you should allow the DUT 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 System Configuration 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 DUT 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 HP 3048A's System Configuration table. (Refer to Appendix A for details on adding instruments to the table.) After you add the HP 11729C to the table, press the **11729C Specs** key and 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 System Configuration table, press the **Define Msrmnt** key which is available at the Main Software Level on the HP 3048A.
3. Press the **Test Files** key.
4. Move the cursor down until it is positioned at the file labeled HP EXAMPLE MICROWAVE SOURCE. The appropriate measurement definition parameters for this example have been prestored in this file.
5. Press the **Load File** key.
6. After the system has completed the file loading sequence, press the **Done** key. (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.

7. To change these values, press the **Instr. Params** key and enter the carrier (center) frequency of your DUT. The HP 3048A will calculate the correct Detector/Disc. Input Frequency for the measurement.
8. 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:

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

9. When you have completed these operations, press **Done** to exit this menu, and then press **Done** again to return to the Main Software Level.

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

Step	Parameters	Data
1	<b>Measurement Type</b>	Phase Noise Using a Phase Lock Loop
	<b>Frequency Range</b> Start Freq. Stop Freq. Averages	1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning Range of VCO VCO Tune-Port Input Resistance	12 E + 9 Hz 160 E + 6 Hz 60 Hz/V 0 Volts ±10 Volts 1M ohms
	Internal Phase Detector	5 MHz to 1600 MHz
3	Phase Detector Constant	Measure the Detector Constant
	VCO Tuning Constant PLL Suppression	Measure the VCO Tuning Constant Will be verified
4	<p><b>Source Control</b></p> <p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>	
5	<b>Define Graph</b> Title	MICROWAVE SOURCE VERSUS HP 8662 AND HP 11729C.
	Minimum X Maximum X Minimum Y Maximum Y  Graph Type	1 Hz 100 kHz -170 0  Single Sideband Phase Noise (dBc/Hz)

---

### Beginning the Measurement

1. Press the **New Msrmnt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 changing or verifying an HP-IB address in the HP 3048A's System Configuration table.)
3. **When the Connect Diagram appears on the HP 3048A's display, connect the signal paths as shown on the display.** (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.

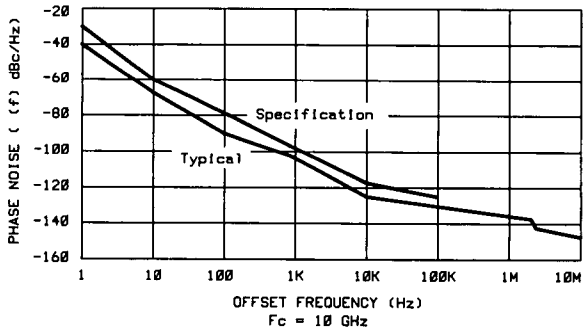
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#### Note

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 $\Omega$  load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

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

Setup Considerations	Comments
<p><b>Measurement Noise Floor</b></p>	<p>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 DUT.</p>  <p style="text-align: center;">OFFSET FREQUENCY (Hz) F<sub>c</sub> = 10 GHz</p>
<p><b>HP 11729C</b></p>	<p>The following performance characteristics of the HP 11729C should be considered when setting up your measurement.</p> <p><b>RF Frequency:</b></p> <ul style="list-style-type: none"> <li>• Unable to measure carrier frequencies within 5 MHz of comb lines.</li> </ul> <p><b>Noise:</b></p> <ul style="list-style-type: none"> <li>• Has an inherent noise rise near 40 MHz.</li> <li>• IF amplifier limits noise floor below 1280 MHz.</li> </ul> <p><b>Spurs:</b></p> <ul style="list-style-type: none"> <li>• Produces down conversion spurs (center frequency of band mixing with carrier frequency).</li> <li>• May have spurs at 10, 20, 30, and 40 MHz offsets when used with HP 8662/3A.</li> <li>• A harmonic of 640 MHz may mix with the carrier frequency to produce spurs on either side of the band center frequency.</li> </ul>

### Checking the Beatnote

While the hardware Connect Diagram is being displayed on the HP 3048A, we recommend that you check the beatnote being created between the HP 8662/3A and the down converted signal from your device-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 Voltage Tuning Range (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.)

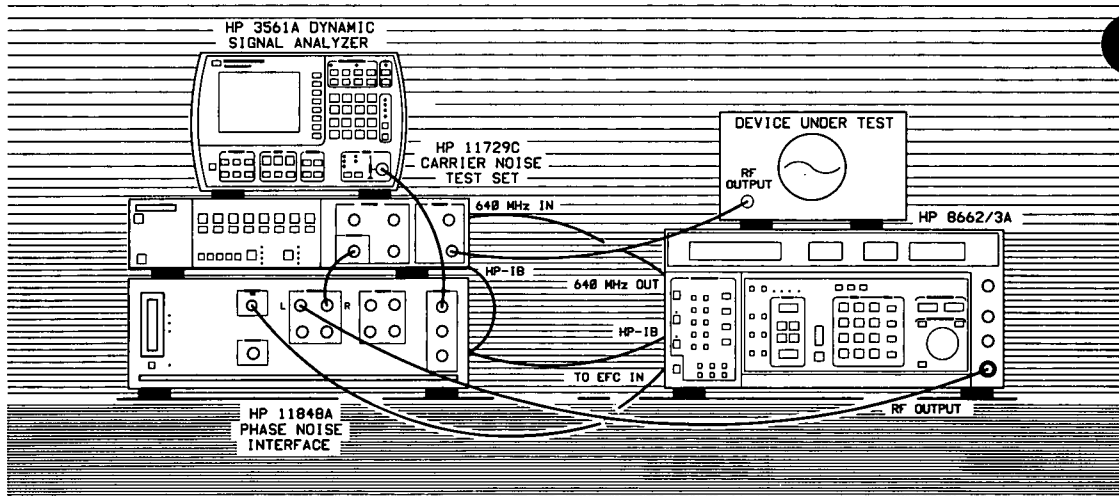


Figure 3-19. Setup Diagram for Microwave Source Measurement Example.

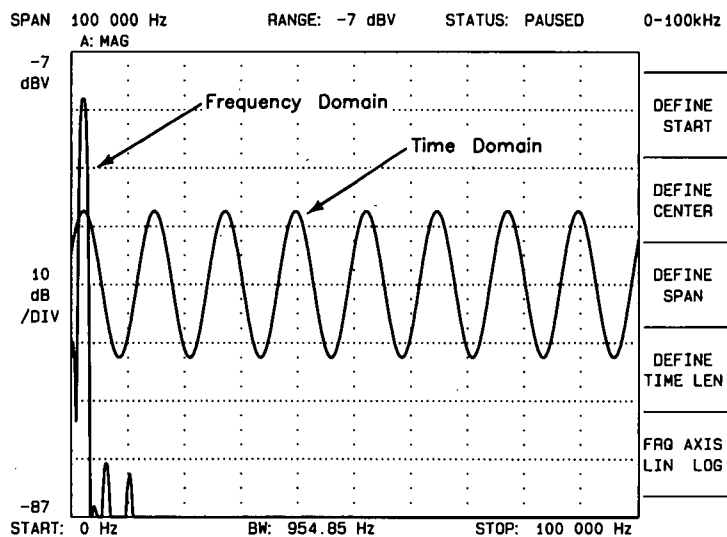


---

**Note** If the input frequencies are not close enough to create a beatnote within the Capture Range, the HP 3048A 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**



- 
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 wave cycle across the screen.**
  4. **When the time domain display on the HP 3561A is showing less than one full cycle, decrement the HP 3561A's span width.** The **[3561 Span]** key provided on the HP 3048A's display decrements the HP 3561A's span width each time it is pressed. (To increment the span width, press the **SHIFT** key on your keyboard and **[3561 Span]** at the same time.)
  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 in is, the faster the HP 3561A will respond to the beatnote frequency changes you make.

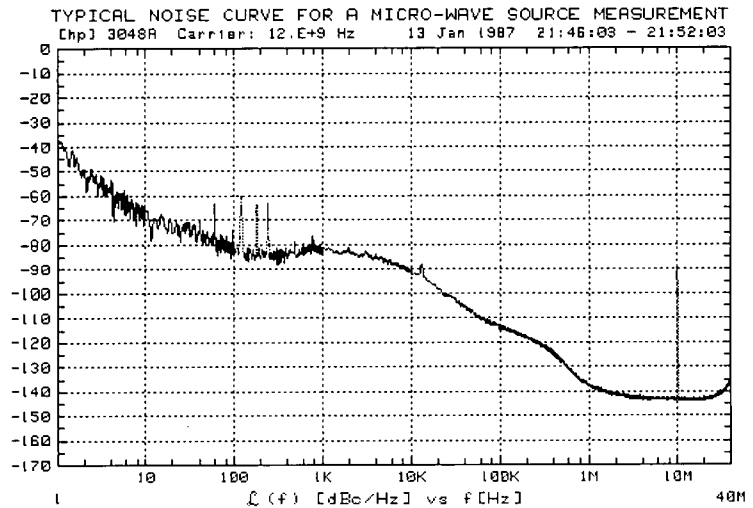
---

### Running the Measurement

1. Press **Proceed** 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 HP 3048A 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. This plot was generated by the HP 3048A using the measurement setup described in this example.



**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.

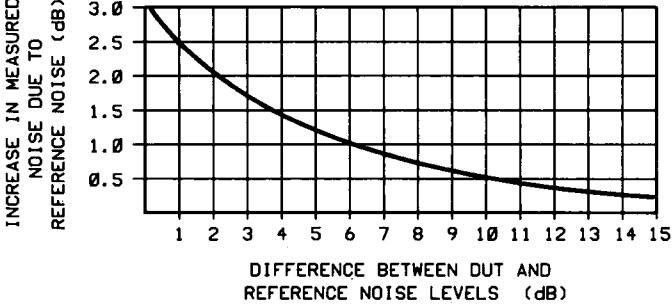
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### **Required Equipment**

- 1. HP 3048A Phase Noise Measurement System
  - a. HP 11848A Phase Noise Interface
  - b. HP 3561A Dynamic Signal Analyzer
  - c. Controller with 3M bytes of memory and a Disc drive.
  - d. Optional RF Analyzer
- 2. Reference Source with better phase noise performance than the DUT.
- 3. Various cables

The following table 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	<p>In order for your noise measurement results to accurately represent the noise of your DUT, the noise level of the reference source should be below the expected noise level of the DUT. The following graph shows how the measured noise level is increased as the reference source noise level approaches the noise level of the DUT.</p>  <table border="1" data-bbox="707 827 1384 1129"> <caption>Data points for the graph in Table 3-14</caption> <thead> <tr> <th>Difference (dB)</th> <th>Increase in Measured Noise (dB)</th> </tr> </thead> <tbody> <tr><td>1</td><td>3.0</td></tr> <tr><td>2</td><td>2.2</td></tr> <tr><td>3</td><td>1.8</td></tr> <tr><td>4</td><td>1.5</td></tr> <tr><td>5</td><td>1.3</td></tr> <tr><td>6</td><td>1.1</td></tr> <tr><td>7</td><td>0.9</td></tr> <tr><td>8</td><td>0.8</td></tr> <tr><td>9</td><td>0.7</td></tr> <tr><td>10</td><td>0.6</td></tr> <tr><td>11</td><td>0.5</td></tr> <tr><td>12</td><td>0.4</td></tr> <tr><td>13</td><td>0.35</td></tr> <tr><td>14</td><td>0.3</td></tr> <tr><td>15</td><td>0.25</td></tr> </tbody> </table> <p>(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 wish for it to be under system control, the signal generator's HP-IB address must be entered in the System Configuration Table. (Refer to <i>Setting Up the HP-IB Addresses</i> in Appendix A for the procedure.)</p>	Difference (dB)	Increase in Measured Noise (dB)	1	3.0	2	2.2	3	1.8	4	1.5	5	1.3	6	1.1	7	0.9	8	0.8	9	0.7	10	0.6	11	0.5	12	0.4	13	0.35	14	0.3	15	0.25
Difference (dB)	Increase in Measured Noise (dB)																																	
1	3.0																																	
2	2.2																																	
3	1.8																																	
4	1.5																																	
5	1.3																																	
6	1.1																																	
7	0.9																																	
8	0.8																																	
9	0.7																																	
10	0.6																																	
11	0.5																																	
12	0.4																																	
13	0.35																																	
14	0.3																																	
15	0.25																																	

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

Equipment	Qty	Comments
<p><b>HP 11848A Interface</b></p>	<p>1</p>	<p>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 DUT. (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.)</p> <div data-bbox="690 709 1239 1123" style="text-align: center;"> <p style="text-align: center;">L Port Level +15dBm</p> <p style="text-align: center;">Expected Phase Noise Floor of DUT (dBc/Hz) f ≥ 10 kHz</p> </div> <p>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.)</p>
<p><b>RF Coax Cables</b></p>	<p>3</p>	<p>And adequate adapters to connect to sources.</p>
<p><b>HP-IB Cable</b></p>	<p>1</p>	<p>If the device-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 HP 3048A and the DUT.</p>



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

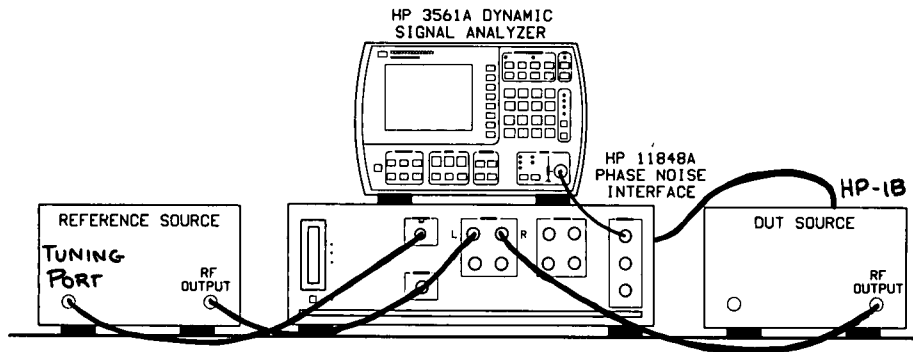
Equipment	Qty	Comments
<b>Voltage-Controlled-Oscillator (VCO) Source</b>	1	<p>The VCO source can be either the device-under-test or the reference source. To configure this phase noise measurement, you will need to know the following information about the VCO source you are using:</p> <ul style="list-style-type: none"> <li>• Tuning Constant (Hz/V) (within a factor of 2)</li> <li>• Tuning Voltage Range (V)</li> <li>• Center Voltage of Tuning Range (V)</li> <li>• Input Resistance of Tuning Port (ohms)</li> </ul> <p>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.)</p>

### Defining the Measurement

Before you begin entering the measurement parameters into the HP 3048A, 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 HP 3048A control your device-under-test, list the required command codes below for addressing your DUT and for setting its frequency and amplitude.

DUT Setup String: OUTPUT 717; "FR100MZAPIO DM".

### 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.)

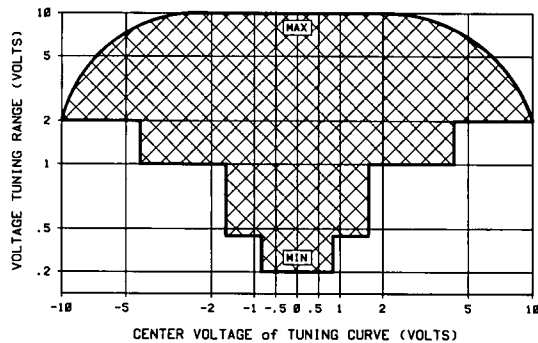
Tuning Constant (sensitivity)	<u>100</u>	Hz/V
Center Voltage of Tuning Range	<u>0</u>	V
Tuning Voltage Range	± <u>10</u>	V
Input Resistance of Tuning Port	<u>1E+6</u>	Ohms

### 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	$\nu_o$	$5 E - 9 \times \nu_o$ 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)	$\nu_o$ $\nu_o$ $\nu_o$ $\nu_o$	10 $1 E - 6 \times \nu_o$ $1 E - 6 \times \nu_o$ $1 E - 6 \times \nu_o$	0 0 0 0	10 10 $10 E + 9 \div \nu_o$ $1 E + 6 \times PTR \div \nu_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$ $1 E + 6$	Measure
10 MHz Source B Direct Multiplied As a Timebase: To HP 8662/3A  To other VCO (PTR known)	$\nu_o$ $\nu_o$ $\nu_o$	100 $10 E - 6 \times \nu_o$ $10 E - 6 \times \nu_o$ $10 E - 6 \times \nu_o$	0 0 0	10 10 $1 E + 9 \div \nu_o$ , (up to 2.5V max.) $100 E + 3 \times PTR \div \nu_o$	$1 E + 6$ $1 E + 6$ $1 E + 6$	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, press the `Define Msrmnt` key which is available at the Main Software Level on the HP 3048A.**
  2. **Press the `Test Files` key.**
  3. **Move the cursor down until it is positioned at the file labeled HP EXAMPLE DESIGNING A MEASUREMENT. Many of the measurement definition parameters required for this measurement technique have been prestored in this file.**
  4. **Press the `Load File` key.**
  5. **After the system has completed the file loading sequence, press the `Done` key. Table 3-16 lists the parameter data that has been loaded from the file.**

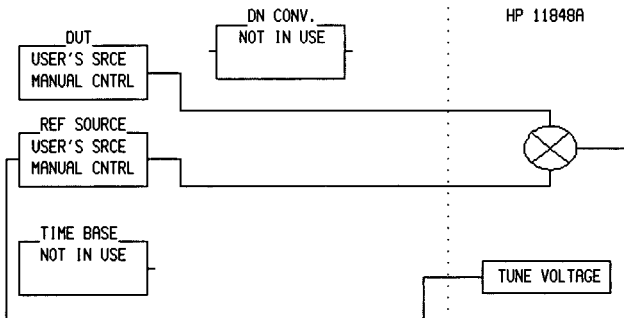
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**Note**

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.

- 
6. **To access the Source Parameters menu, press the `Instr. Params` key. Enter the same frequency for the Detector Input frequency.**
  7. **Enter the carrier (center) frequency of your DUT (5 MHz to 1.6 GHz).**

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

Step	Parameters	Data
1	<b>Measurement Type</b> <b>Frequency Range</b> Start Freq. Stop Freq. Averages	Phase Noise Using a Phase Lock Loop  1 Hz 100 E + 3 Hz 4
2	<b>Source Parameters</b> Carrier Frequency Detector/Discr. Input Frequency VCO Tuning Constant Center Voltage of VCO Tuning Curve Voltage Tuning Range of VCO VCO Tune-Port Input Resistance  Internal Phase Detector	500 E + 6 Hz 500 E + 6 Hz 100 Hz/V 0 Volts ±10 Volts 1 E + 6 ohms  5 MHz to 1600 MHz
3	Phase Detector Constant VCO Tuning Constant PLL Suppression	Measure the Detector Constant Measure the VCO Tuning Constant Will be verified
4	<b>Source Control</b>  <p><b>Note:</b> This example assumes the DUT will be controlled manually. If you wish for the DUT to be controlled by the HP 3048A, select SYSTEM CNTRL for the DUT in the diagram, and enter the appropriate Setup String including: Address, frequency, and amplitude settings.</p>	
5	<b>Define Graph</b> Title  Minimum X Maximum X Minimum Y Maximum Y  Graph Type	SOURCE-UNDER-TEST VERSUS REFERENCE SOURCE.  1 Hz 100 E + 3 Hz -170 0  Single Sideband Phase Noise (dBc/Hz)

- 
8. **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 HP 3048A measure the exact value for you before it makes its measurement. If you estimate the Tuning Constant, enter the VCO Input Resistance as 1 E + 6. If you do know the exact Tuning Constant, enter it and enter the actual input resistance of your VCO.

- 
9. Press **Done** when you have completed these operations.
10. **In Table 3-15, note the column labeled "Tuning Calibration Method".** If "Compute" appears in this column for the VCO source you are using, press the **Calibr Process** key. Change the calibration method for determining the VCO Tuning Constant to "Compute from expected T. Constant." Press **Done** when you have completed this operation.
11. **To access the Source Control diagram, press the Source Control** key.

---

12. **Use the softkeys to configure the diagram to match the test setup you have planned for your measurement.** The purpose of this block diagram is to tell the HP 3048A:

- What hardware you will be using.
- Which instruments will be under HP-IB system control. (The **Control** softkey enables you to specify the control you desire for the instrument selected in the diagram.)
- What the interconnecting signal paths will be.

13. Press **Done** when you have completed this operation.

14. To change the graph title, press the **Define Graph** key.

15. When you have completed the changes, press the **Done** key.

---

**Note**

If you plan to use this same measurement setup again in the future, you may want to store these parameters in a Test File. To do this, simply re-enter the Test File menu and position the cursor at the end of the list of files. Then enter a name for your new file and press the **Store File** key.

---

16. Press the **Done** key to return to the Main Software Level.

---

### Beginning the Measurement

1. Press the **New Msrmnt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 HP-IB address in the HP 3048A's System Configuration table.)
3. **When the Connect Diagram appears on the HP 3048A's display, 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 $\Omega$  load must be connected to the SPECTRUM ANALYZER OUTPUT when an RF spectrum analyzer is not being used.

The HP 3048A 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 DUT 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 being displayed on the HP 3048A, 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.

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 Voltage Tuning Range. 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 HP 3048A will not be able to complete its measurement.

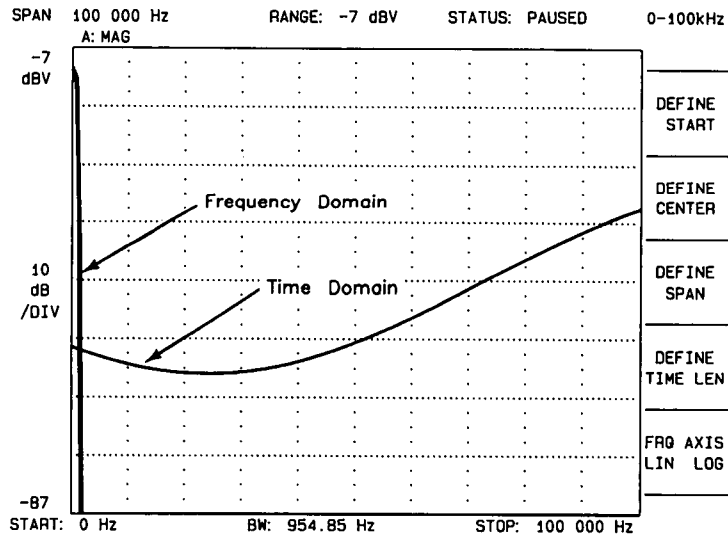
---

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**

1. **Estimate the system's Capture Range (using the VCO source parameter values entered for this measurement).** If you have doubts as to whether the VCO Tuning Constant you entered for this measurement is within a factor of 2 of your VCO's actual Tuning Constant, refer to *Estimating the Tuning Constant* in the *Problem Solving* section of this chapter before continuing with this procedure.

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

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

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** key on the HP 3048A to adjust the center voltage of the tuning signal being sent from the Tune Voltage output on the HP 11848A to the VCO source. (Keep in mind that shifting the center voltage of the tuning range may reduce the available tuning range needed for drift tracking during the measurement.)

---

**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. **When the time domain display on the HP 3561A is showing less than one full cycle, decrement the HP 3561A's span width.** The **3561 Span** key provided on the HP 3048A's display decrements the HP 3561A's span width each time it is pressed. (To increment the span width, press the **SHIFT** key on your keyboard and **3561 Span** at the same time.)
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.

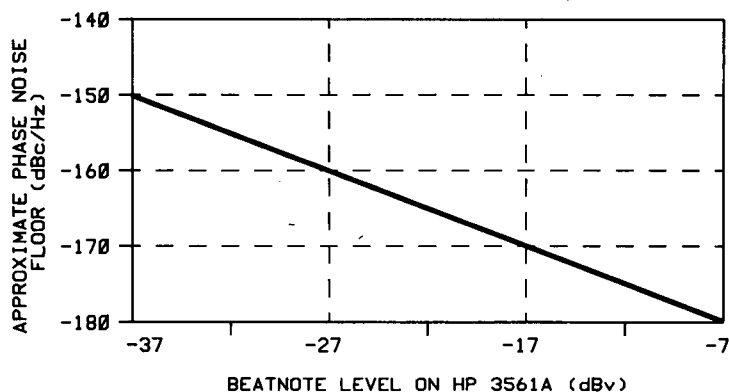
**For example**, to tune the beatnote to within 5 Hz, you can use the 0 to 1 kHz span by reducing the beatnote frequency until the time domain display is showing two cycles or less across the screen:

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

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

### HP 3561A Time Record

Note that the higher the span width setting that you are in is, 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.

#### Running the Measurement

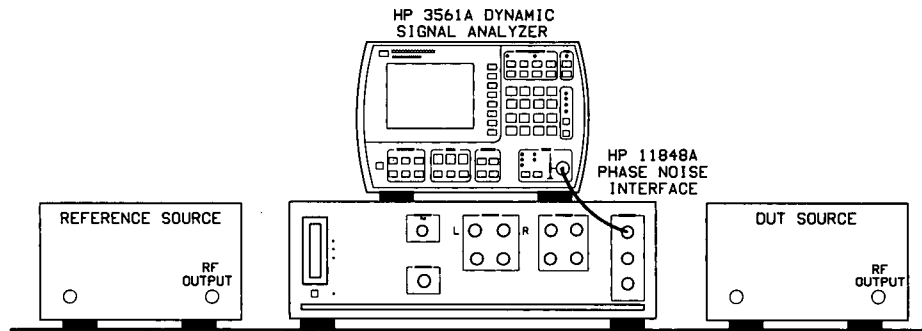
1. Press **Proceed** when you have completed the beatnote check and are ready to run the measurement.

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

If the HP 3048A 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 HP 3048A control your device-under-test, list the required command codes below for addressing your DUT and for setting its frequency and amplitude.

DUT Setup String: \_\_\_\_\_

### VCO Source

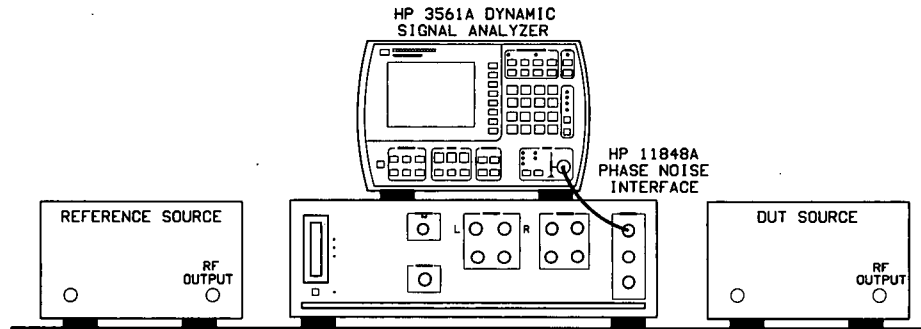
1. Enter the tuning characteristics for the VCO you are using in the spaces below. (Table 3-15 provides the tuning characteristics for several VCO source options.)

Tuning Constant (sensitivity) \_\_\_\_\_ Hz/V  
Center Voltage of Tuning Range \_\_\_\_\_ V  
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 HP 3048A control your device-under-test, list the required command codes below for addressing your DUT and for setting its frequency and amplitude.

DUT Setup String: \_\_\_\_\_

## 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.)

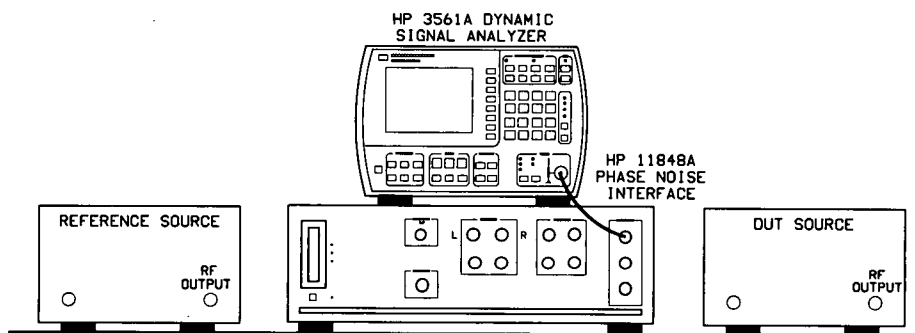
Tuning Constant (sensitivity) \_\_\_\_\_ Hz/V  
 Center Voltage of Tuning Range \_\_\_\_\_ V  
 Tuning Voltage Range  $\pm$  \_\_\_\_\_ V  
 Input Resistance of Tuning Port \_\_\_\_\_ Ohms

## 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 HP 3048A control your device-under-test, list the required command codes below for addressing your DUT and for setting its frequency and amplitude.

DUT Setup String: \_\_\_\_\_

### 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
Tuning Voltage Range	± _____	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 device-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 standard HP 3048A system and your device-under-test (DUT).

**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).

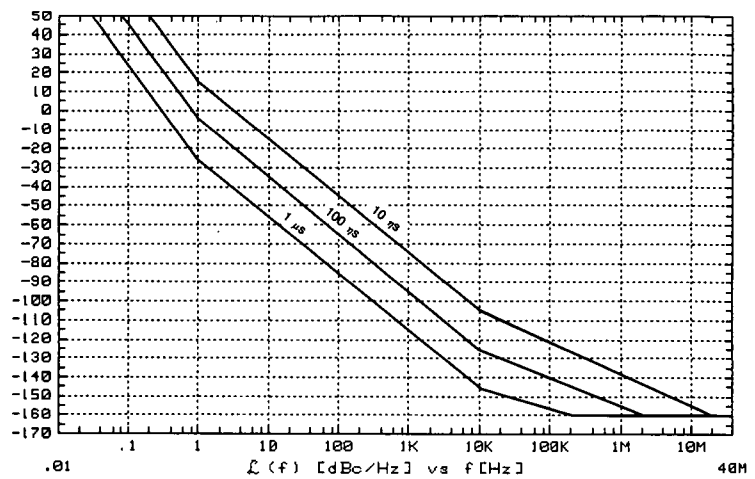
**Note** To ensure accurate measurements, you should allow the DUT and measurement equipment to warm up at least 30 minutes before making the noise measurement.

**Determining the Discriminator (Delay Line) Length**

Perform the following steps to determine the minimum delay line length ( $\tau$ ) 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 DUT.** Figure 3–26 shows the noise floor of the Discriminator for given delay times ( $\tau$ ). (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 ( $\tau$ ). (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. Press the **Define Msrmnt** key which is available at the Main Software Level on the HP 3048A.
5. Press the **Test Files** key.
6. Move the cursor down until it is positioned at the file labeled "HP EXAMPLE DISCRIMINATOR MEASUREMENT". The appropriate measurement parameters for this example have been pre-stored in this file.
7. Press the **Load File** softkey.

---

### 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** parameter menu. This will allow you to measure over the entire offset range of the HP 3048A.

- 
8. After the system has completed the file loading sequence, press the **Done** softkey. Parameter entry is now completed for this measurement example. (Table 3-18 lists the parameter data that has been entered for this measurement example.)
  9. Press **Done** to return to the Main Software Level.

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

Step	Parameters	Data
1	<b>Measurement Type</b>	Phase Noise Using an FM Discriminator
	<b>Frequency Range</b>	
	Start Freq. Stop Freq. Averages	1 Hz 100 E + 3 Hz 4
2	<b>Instrument Parameters</b>	
	Carrier Frequency Detector/Discr. Input Frequency	400 E + 6 Hz 400 E + 6 Hz
	Internal Phase Detector	5 MHz to 1600 MHz
3	<b>Calibration Technique</b>	Derive from FM Rate and Deviation
	<b>FM Deviation</b>	10 E + 3 Hz
	<b>FM Rate</b>	1 E + 3 Hz
4	<b>Source Control</b>	
5	<b>Define Graph</b>	
	Title	350-500 MHz VCO USING 12 NSEC DELAY LINE DISCRIM
	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. Press the **New Msrmt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 (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 HP 3048A's System Configuration table.)

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

3. **When the Connect Diagram appears on the HP 3048A's display, connect the signal paths as shown.** After the connections have been made and checked, press the **Proceed** softkey.

Setup Considerations	Comments
<b>Cable Connections</b>	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 DUT 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 DUT source. It is essential that the substituted calibration source apply the same power to the power splitter as the DUT.

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 Calibr Process parameter 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 ( $\pm 1$  division). Turn on its FM modulation and set the deviation for 10 kHz and the modulation rate to 1 kHz.
2. **Press the `Proceed` softkey.** 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 DUT.**

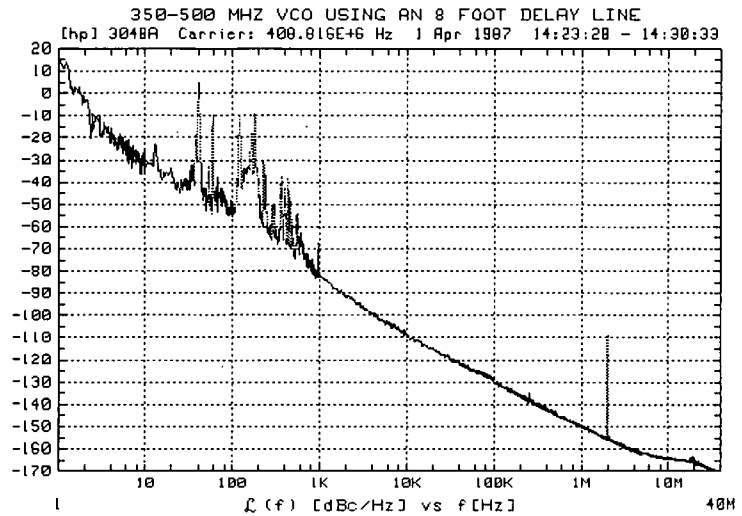
If the DUT source you were measuring was not under system control, the HP 3048A would also prompt you to re-establish quadrature. This is done by adjusting the source frequency until the HP 11848A meter reads center scale ( $\pm 1$  division).

The system is now ready to run 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 HP 3048A has problems completing the measurement, it will inform you by placing a message on its display.

Figure 3-27 shows a typical phase noise curve for the internal HP 11848A 350-500 MHz Source. This plot was generated by the HP 3048A using the measurement setup described in this example.



**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 standard HP 3048A system and your device-under-test (DUT).

---

### Note

To ensure accurate measurements, you should allow the DUT 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 DUT.

---

**Note**

This measurement requires that the HP 11729C Carrier Noise Test Set be included in the system configuration table if the system is to control the HP 11729C automatically. The HP 11729C should be entered with a functional name of "DOWN CONVERTER" and "130" must be entered in the configuration table "OPTION #" field.

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

---

**Defining the Measurement**

1. Press the **Define Msrmnt** key available at the Main Software Level on the HP 3048A.
2. Press the **Test Files** key.
3. Move the cursor down until it is positioned at the file labeled "HP EXAMPLE AM NOISE (HP 8662/3 and HP 11729C)". The appropriate measurement parameters for this example have been pre-stored in this file.
4. Press the **Load File** softkey.
5. After the system has completed the file loading sequence, press the **Done** softkey. Parameter entry is now completed for this measurement example. (Table 3-20 lists the parameter data that has been entered for this measurement example.)

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

Step	Parameters	Data
1	<b>Measurement Type</b> <b>Frequency Range</b> Start Freq. Stop Freq. Averages	AM Noise  1 Hz 100 E + 3 Hz 4
2	<b>Instrument Parameters</b> Carrier Frequency Detector/Discr. Input Frequency  External Phase/AM Detector	500 E + 6 Hz 500 E + 6 Hz  
3	<b>Calibration Technique</b> Phase Detector Constant Amplitude Frequency	Derive From Double Sided Spur -46 dBc 1 E + 3 Hz
4	<b>Source Control</b>	
5	<b>Define Graph</b> 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 parameter 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 Source Control menu under the **Define Msrmnt** the softkey. All other measurements set the source to +16 dBm automatically.

---

6. Press **Done** to return to the Main Software Level.

#### **Beginning the Measurement**

1. Press the **New Msrmnt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 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 HP 3048A's System Configuration table.)
3. **When the Connect Diagram appears on the HP 3048A's display, 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

4. After the connections have been made and checked, press the **Proceed** softkey.

The HP 8662/3A will be set to the proper AM calibration parameters set in the **Calibr. Proc** parameter menu if you selected the calibrate 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 calibrate source (actually the DUT) should be set manually to 1% AM at a 1 kHz rate and press the **Proceed** softkey.

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.

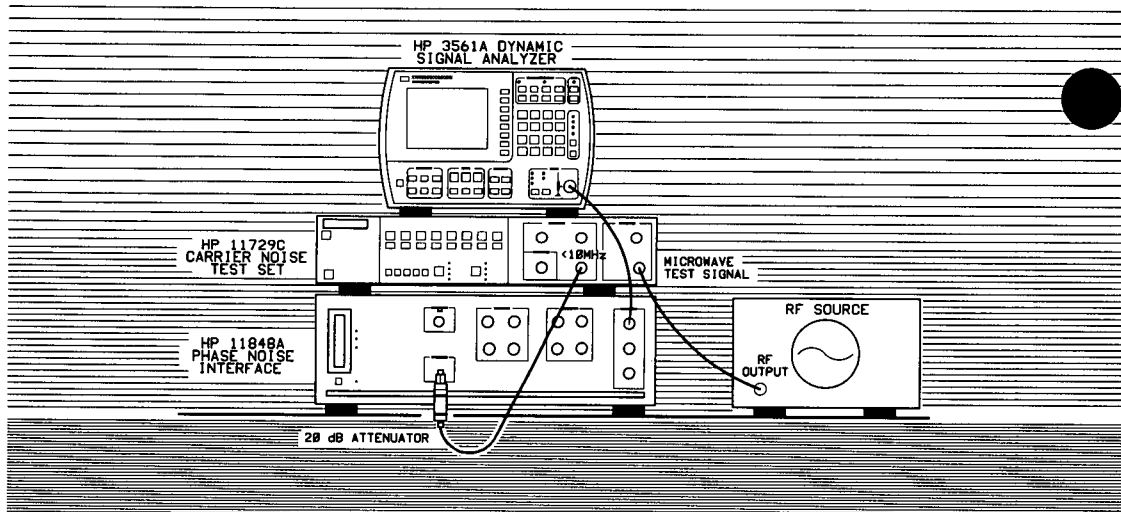


Figure 3-28. Setup diagram for AM Noise Measurement Example.

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

Setup Considerations	Comments
<b>Cable Connections</b>	A special coax cable is supplied with the HP 11729C for making AM noise measurements. It connects the <b>Noise Spectrum &lt;10 MHz</b> output of the HP 11729C to the <b>Noise Input</b> 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.
<b>Ground Loops</b>	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  $\pm 1$  dB. This should be added to the HP 3048A accuracy specification at all offsets other than the calibration offset (1 kHz in this case)

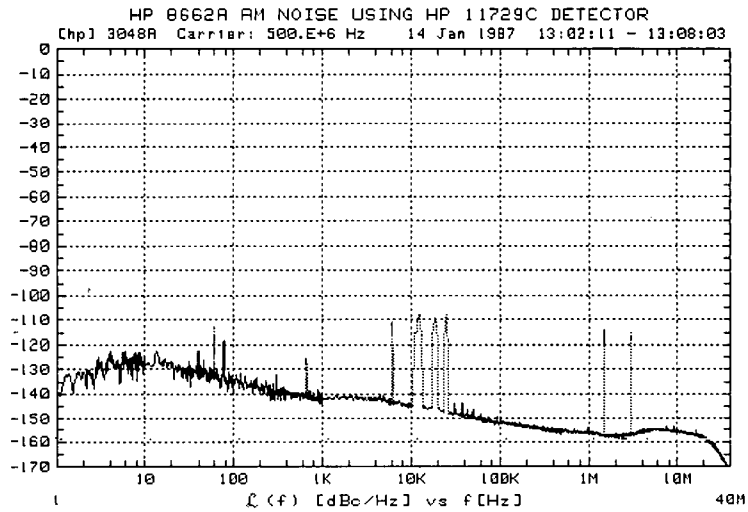
---



### 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.**

---

## 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 standard HP 3048A system and your device-under-test (DUT).

**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 DUT.
Filter Network	1	The schematic for the filter network is shown in Figure 3-31 and must be provided by the user as it is not available from HP. The filter network should be built in a small metal box and should 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.

---

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

---

#### Defining the Measurement

1. Press the **Define Msrmnt** key which is available at the Main Software Level on the HP 3048A.
2. Press the **Test Files** key.
3. Move the cursor down until it is positioned at the file labeled "HP EXAMPLE AM NOISE (HP 8662/3 and HP 33330C)". The appropriate measurement parameters for this example have been pre-stored in this file.
4. Press the **Load File** softkey.
5. After the system has completed the file loading sequence, press the **Done** softkey. Parameter entry is now completed for this measurement example. (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 parameter 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 Source Control menu. All other measurements set the source to +16 dBm automatically.

- 
6. Press **Done** to return to the Main Software Level.

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

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

### Beginning the Measurement

1. Press the **New Msrmnt** key.
2. Press **Yes, Proceed**. The HP 3048A 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 (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 HP 3048A's System Configuration table.)
3. When the **Connect Diagram** appears on the HP 3048A's display, 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.

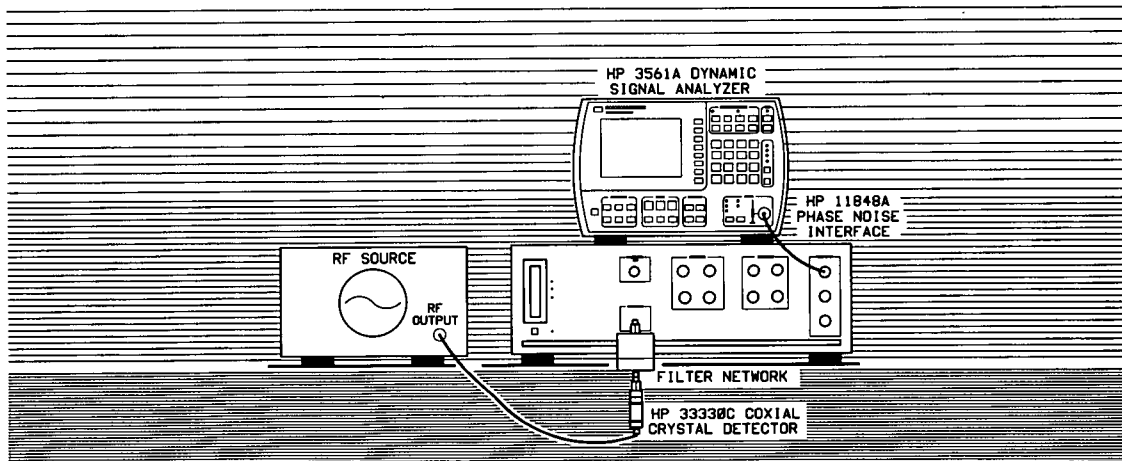


Figure 3-30. Setup Diagram for AM Noise Measurement Example.

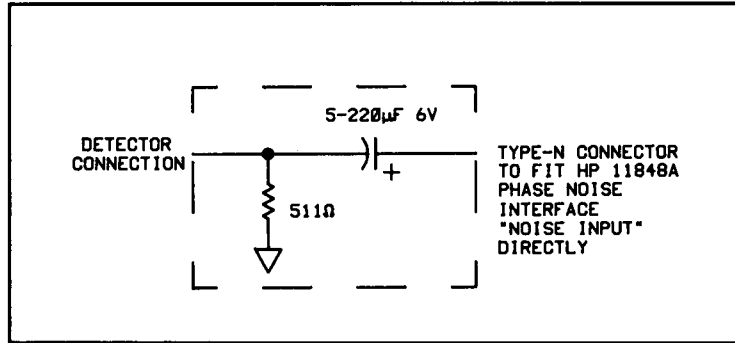


Figure 3-31. Schematic for Required Filter Network.

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

Setup Considerations	Comments
<p><b>Cable Connections</b></p>	<p>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.</p>
<p><b>Ground Loops</b></p>	<p>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 <math>-80</math> dBc.</p>

### Calibrating the Measurement

4. After the connections have been made and checked, press the **Proceed** softkey.

The HP 8662/3A will be set to the AM calibration parameters specified in the Calibr. Proc parameter 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 HP 3048A will prompt you to set the calibration source (actually the DUT) to 1% AM at a 1 kHz rate.

5. When the calibration source has been set, press the **Proceed** softkey.

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**

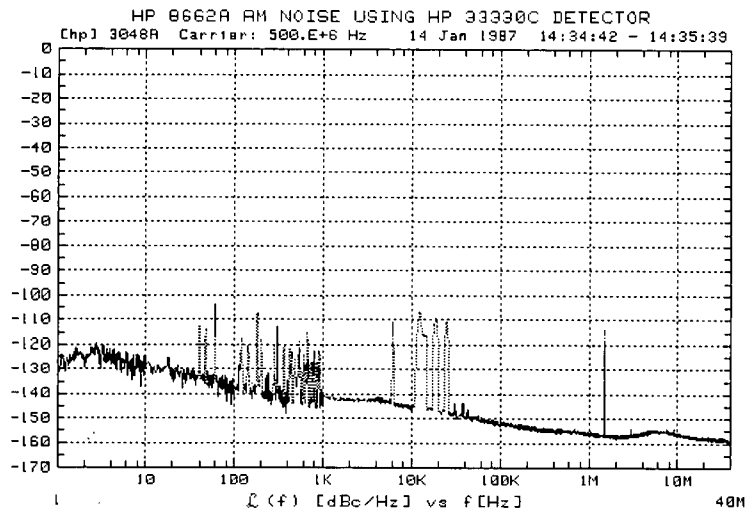
The filter network, if built as specified, will provide accurate results down to an offset of 1 Hz.

---

### When the Measurement is Complete

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

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



**Problem  
Solving**

<i>If you need to know:</i>	<i>Refer to:</i>
• <i>How to interpret a display message</i> .....	<b>Interpreting Display Messages (pg. 3-120)</b>
• <i>What to consider when selecting a reference source.</i> ....	<b>Selecting a Reference (pg. 3-143)</b>
• <i>How to determine the tuning sensitivity of your VCO source</i> .....	<b>Estimating the Tuning Constant (pg. 3-147)</b>
• <i>What the drift tracking capabilities of the system are</i> .....	<b>Tracking Frequency Drift (pg. 3-149)</b>
• <i>How to increase or decrease the Peak Tuning Range (PTR) for your VCO source</i> .....	<b>Changing the PTR (pg. 3-151)</b>
• <i>How to Minimize Injection Locking</i> .....	<b>Minimizing Injection Locking (pg. 3-154)</b>
• <i>What to consider when inserting an attenuator or an amplifier between the source output and the HP 11848A</i> .....	<b>Inserting a Device (pg. 3-156)</b>
• <i>How to determine whether noise near the small angle line exceeds the limits of the system</i> .....	<b>Evaluating Noise Above the Small Angle Line (pg. 3-159)</b>

---

## **Interpreting Display Messages**

The following are lists of the HP 3048A'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 two message lists contain the Error messages. When an Error message is displayed by the HP 3048A, the message may or may not be numbered.

### **Reference Messages**

The reference message list begins after the Error message list. The HP 3048A designates a Reference message by placing the reference number at the end of the message.

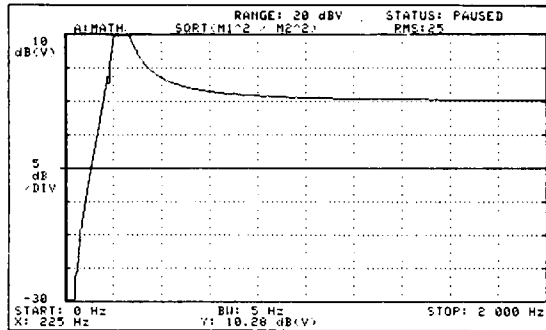
A complete listing of all messages, warnings, and prompts can be found in the Messages Section of the HP 3048A Reference Manual.

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

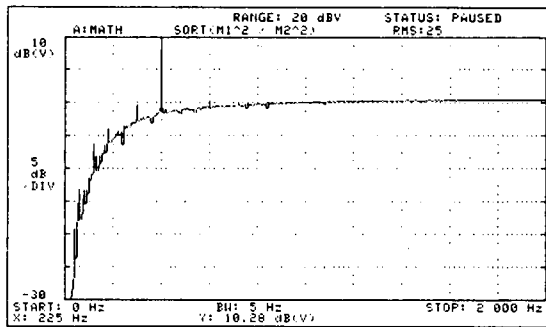
<p><b>1</b></p>	<p><b>The Signal level entering the NOISE INPUT port of the HP 11848A exceeds 1 volt peak.</b></p> <p><b>Action:</b> Press the <b>Retry</b> key. If the overload condition was transient, the system will proceed with the measurement. If Error 1 occurs again, reduce the signal level at the NOISE INPUT port on the HP 11848A.</p> <p>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.</p>
<p><b>2</b></p>	<p><b>The loop suppression peak exceeds 10 dB.</b> 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.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><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. If these ports are not connected, connect them now, press the <b>Retry</b> softkey.</i></p> <p>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 system has completed the loop suppression characterization. Figure 3-33 illustrates the typical curve response for each of the three conditions.</p> <p><b>Action:</b> 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.</p>

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

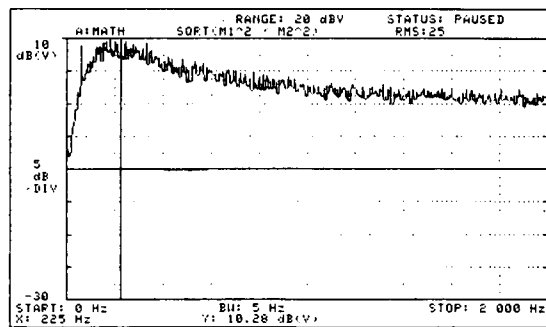
**2**  
(cont'd)



**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)**

<p><b>2</b> (cont'd)</p>	<p><b>1. Narrow Modulation Bandwidth</b></p> <p>A noise hump 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 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 Tuning Constant by its Voltage Tuning Range.)</p> <div style="text-align: center;"> </div> <p style="text-align: center;">* Log/Lead Filter Number</p>
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**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)

<p><b>2</b> (cont'd)</p>	<p>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.</p> <ul style="list-style-type: none"><li>• 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.</li><li>• Use a different VCO source with greater modulation bandwidth.</li><li>• 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 Tuning Voltage Range value entered. Divide the required PTR by the VCO's Tuning Constant to determine the appropriate Voltage Tuning Range to enter. (Keep in mind that reducing the PTR limits the HP 3048A'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 this manual.) 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.<ol style="list-style-type: none"><li>a. Connect a tracking generator output (such as the HP 3585A) to the tuning input port on your VCO.</li><li>b. Set the tracking generator output to sweep the audio spectrum.</li><li>c. Connect the RF output from your VCO to a modulation analyzer (such as an HP 8901A).</li><li>d. Set the modulation analyzer to measure FM.</li><li>e. Connect an audio spectrum analyzer to the MODULATION OUTPUT on the HP 8901A.</li><li>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 <math>\geq</math> ten times the PLL bandwidth for the measurement.</li></ol></li></ul> <p>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.</p>
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Table 3-25. Numbered Error Messages (5 of 17)

<p><b>2</b> (cont'd)</p>	<p><b>2. Large Spur on Input Signal</b></p> <p>A sharp peak on an otherwise correct loop suppression curve is evidence of a large spur (typically &gt; -40 dBc) near the phase lock loop (PLL) bandwidth of the measurement (within a factor of two). Press <b>Proceed</b> 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> provides information that will help you isolate the spur source).</p> <p>If you are not able to reduce the spur level to &lt; -40 dBc, it may be possible to make an accurate noise measurement by changing the PLL bandwidth. Measurement accuracy is only affected by spurs &gt; -40 dBc that are within a factor of 2 of the PLL bandwidth.</p> <p>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 Tuning Constant by the VCO's Voltage Tuning Range entered for the measurement. For further information about changing the PTR, refer to <i>Changing the PTR</i> in Chapter 3 of this manual.</p> <p><b>3. High Noise on Input Signal</b></p> <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;"><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. If these ports are not connected, connect them now, press the <b>Retry</b> softkey.</i></p> <p>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 <i>Evaluating Noise Above the Small Angle Line</i> in Chapter 3 of this manual.</p>
<p><b>3</b></p>	<p><b>Unable to detect the presence of a beatnote.</b></p> <p><b>Action:</b></p> <ol style="list-style-type: none"> <li>1. Check to be sure that the correct Phase Detector is selected in the Inst. Params menu.</li> <li>2. Check sources to verify the frequency of each output signal.</li> <li>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 this manual. An oscilloscope connected to the HP 11848A AUX MONITOR port can be helpful for monitoring and zeroing the beatnote.)</li> </ol>

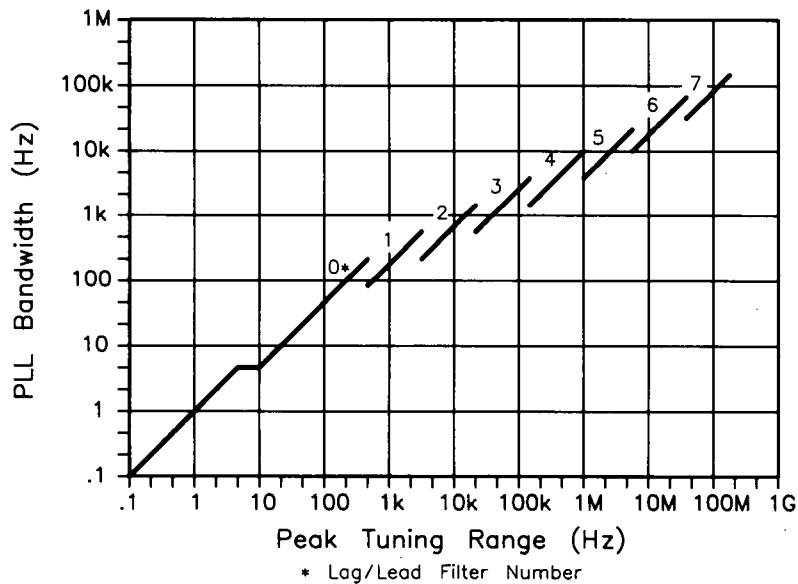


Table 3-25. Numbered Error Messages (6 of 17)

<b>4</b>	<p><b>Unable to close the Phase Lock Loop.</b></p> <p><b>Action:</b> There are several possible conditions that can prevent the HP 3048A 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.</p> <ol style="list-style-type: none"><li>1. The system is not able to tune the beatnote to within the Capture Range set for the measurement. This possibility can be minimized by carefully following the <i>Checking the Beatnote</i> procedure provided in each measurement example in Chapter 3 of this manual. 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 in the HP 3048A's 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 system attempts to adjust it to 0 Hz can provide clues about tuning problems that may exist.</li><li>2. The beatnote drifted beyond the system's Capture Range before the HP 3048A was able to acquire lock. For further information on verifying the frequency stability of the beatnote, refer to <i>Tracking Frequency Drift</i> in Chapter 3 of this manual.</li><li>3. The VCO Tuning Constant entered for the measurement was not within a factor of 2 of the actual Tuning Constant, and the HP 3048A was not configured to <i>measure</i> the Tuning Constant for verification. For details on verifying the Tuning Constant of your VCO, refer to <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</li><li>4. The Peak Tuning Range set for the measurement is <math>&gt; 10</math> MHz and is causing the loop dynamics to be non-linear. When this condition exists, the non-linear response of the beatnote as the 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.</li><li>5. One of the sources is being injection locked as the HP 3048A is tuning the beatnote to 0 Hz. (Refer to <i>Minimizing Injection Locking</i> in Chapter 3 of this manual for recommended actions.)</li><li>6. The modulation bandwidth of the VCO source's tuning port is not wide enough to provide adequate phase margin for the 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 Tuning Constant by its Voltage Tuning Range.)</li></ol>
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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 Tuning Voltage Range value entered. Divide the required PTR by the VCO's Tuning Constant to determine the appropriate Voltage Tuning Range to enter. (Keep in mind that reducing the PTR limits the HP 3048A's Frequency Drift Tracking Range for the measurement. For further information about changing the PTR, refer to *Changing the PTR* in Chapter 3 of this manual.)

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

<p><b>4</b> (cont'd)</p>	<p>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.</p> <ol style="list-style-type: none"> <li>a. Connect a tracking generator output (such as the HP 3585A) to the tuning input port on your VCO.</li> <li>b. Set the tracking generator output to sweep the audio spectrum.</li> <li>c. Connect the RF output from your VCO to a modulation analyzer (such as an HP 8901A).</li> <li>d. Set the modulation analyzer to measure FM.</li> <li>e. Connect an audio spectrum analyzer to the MODULATION OUTPUT on the HP 8901A.</li> <li>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 <math>\geq</math> ten times the PLL bandwidth for the measurement.</li> </ol> <p>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.</p> <ol style="list-style-type: none"> <li>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 <i>Evaluating Noise Above the Small Angle Line</i> in Chapter 3 of this manual. For information about measuring sources with high close-in noise, refer to Ignore Out of Lock in the Test Mode Section of Chapter 5 of the HP 3048A Reference Manual.</li> </ol>
<p><b>5</b></p>	<p><b>Measured VCO peak tuning range exceeds 500 kHz (or 200 MHz.)</b> The Peak Tuning Range limit for the system is 500 kHz (or 200 MHz if an RF analyzer is configured in the system). The Peak Tuning Range is the product of the VCO Tuning Constant multiplied by the Voltage Tuning Range of the VCO. (If the system <i>measures</i> the VCO's Tuning Constant, it will use the measured value to compute the Peak Tuning Range for the measurement.)</p> <p><b>Action:</b> Reduce the Voltage Tuning Range entered for the VCO source you are using, or select a VCO source with a lower Tuning Constant.</p>
<p><b>6</b></p>	<p><b>Unable to establish quadrature.</b> Occurs when source is under system control and system is unable to acquire quadrature. The 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.</p> <p><b>Action:</b> 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.</p>

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

<b>7</b>	<p><b>Measured beatnotes depict non-linear VCO Tuning Constant.</b> (Error 7 only occurs when the HP 3048A has been configured to <i>Measure the VCO Tuning Constant.</i>)</p> <p>The values shown on the display represent the measured beatnote frequencies for four tune voltage settings. The tune voltage settings are each derived as a percentage of the entered Voltage Tuning Range of the VCO (-45%, -15%, +15%, +45%) relative to the entered Center Voltage of the VCO Tuning Curve. For Example:</p> <p style="padding-left: 40px;">Voltage Tuning Range of VCO = <math>\pm 10V</math> Center Voltage of VCO Tuning Curve = <math>0V</math> Tune Voltage Settings = <math>-4.5V, -1.5V, +1.5V, +4.5V</math>.</p> <p>Refer to the HP 3048A Reference Manual <i>Instrument Parameters</i> in Chapter 2, Measurement Definitions for system requirements for VCO linearity.</p> <p>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.)</p> <p><b>Action:</b></p> <ol style="list-style-type: none"><li>1. This error will occur if a Tuning Voltage Range of <math>\pm 10</math> volts has been defined for a source with calibrated DC FM, and the HP 3048A is configured to <i>Measure</i> the VCO Tuning Constant rather than to <i>Compute</i> it. Refer to the HP 3048A Reference Manual "Enhanced Tuning" in the <i>Instrument Parameters</i> section of Chapter 2, Measurement Definitions for details on extending the Tuning Voltage Range of calibrated DC FM.</li><li>2. If Interval 2 (described above) <math>\gg 1</math>, and Interval 2 <math>\gg 3</math>, then: Reduce the value entered for the Voltage Tuning Range of the VCO and then initiate a New Measurement.</li><li>3. If there appears to be too little or no change between the measured frequency values (Intervals 1, 2, and 3 <math>\approx 0</math>) then :<ul style="list-style-type: none"><li>• Check the Tune Voltage cable connections.</li><li>• Verify that the VCO's tuning is enabled.</li><li>• Perform the <i>Estimating the Tuning Constant</i> procedure provided in Chapter 3 of this manual to verify the tuning response of the VCO and check that the entered VCO Tuning Constant is within a factor of 2 of the actual value.</li><li>• Refer to the HP 3048A Reference Manual <i>Instrument Parameters</i> in Chapter 2, Measurement Definitions for Tuning Constant linearity requirements.</li><li>• Verify that the beatnote is tuned to within the Capture Range for the measurement.</li></ul></li></ol>
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Table 3-25. Numbered Error Messages (10 of 17)

<p><b>7</b> (cont'd)</p>	<p>4. If the Frequency Intervals vary greatly and are considerably larger than expected for the tuning range of the the VCO, then:</p> <ul style="list-style-type: none"> <li>• 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.)</li> </ul> <p>5. If all four measured frequencies are 0 Hz, then:</p> <ul style="list-style-type: none"> <li>• Check for injection locking. Refer to <i>Minimizing Injection Locking</i> in Chapter 3 of this manual for further information.</li> </ul>
<p><b>8</b></p>	<p><b>Unable to find a beatnote.</b> System was not able to detect a beatnote above <math>-24</math> dBm (20 mVpk) between 0.1 Hz and 40 MHz.</p> <p><b>Action:</b> 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 this manual.) If you are making a Phase lock loop measurement, be sure the VCO Tuning Constant value entered for the measurement is within a factor of 2 of the actual value. Refer to the HP 3048A Reference Manual <i>Calibration Process</i> in Chapter 2, Measurement Definitions for information about the beatnote calibration technique.</p>
<p><b>9</b></p>	<p><b>The calibration spur could not be found.</b> The system was unable to detect a spur within a factor of 2 of the entered spur frequency.</p> <p><b>Action:</b></p> <ol style="list-style-type: none"> <li>1. Check that the correct spur frequency was entered.</li> <li>2. Verify the output signal from the spur source.</li> <li>3. Increase the spur level up to but not exceeding a maximum of <math>-20</math> dBc.</li> </ol> <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;"><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></p>
<p><b>10</b></p>	<p><b>Waveform departs too drastically from sinusoidal to be used in calculation of the Phase Detector Constant.</b> The 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.</p> <p><b>Action:</b> Check the harmonic content of the two input signals to the Phase Detector. All even harmonics must be below <math>-20</math> dBc to guarantee good symmetry of the beatnote waveform. If possible, increase the PTR to <math>&gt;10</math> kHz so that the beatnote is <math>&gt;1</math> kHz. Then the HP 3048A will measure the fundamental and its harmonics. (<math>&lt;1</math> kHz beatnote system measures slope of sinusoid.)</p>

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

11	<p><b>DC offset too large. Waveform does not cross 0 volts.</b> This error occurs when the system is measuring the Phase Detector Calibration Constant and one of the following conditions exist.</p> <ol style="list-style-type: none"> <li>1. The dc offset is greater than the peak beatnote voltage due to a large dc offset or a low beatnote level.</li> <li>2. The beatnote frequency is much lower than expected and only the top or bottom portion of a sine wave peak is actually measured.</li> </ol>										
	<p><b>Action:</b></p> <ol style="list-style-type: none"> <li>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.</li> </ol>										
	<table border="1" style="margin: auto;"> <caption>Data points from Figure 3-36</caption> <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>.02</td> </tr> <tr> <td>-5</td> <td>.1</td> </tr> <tr> <td>+5</td> <td>.2</td> </tr> <tr> <td>+15</td> <td>.6</td> </tr> </tbody> </table>	R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)	-15	.02	-5	.1	+5	.2	+15	.6
R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)										
-15	.02										
-5	.1										
+5	.2										
+15	.6										
	<p><b>Figure 3-36. Beatnote Level Relative to the Signal Level at the R Port.</b></p> <ol style="list-style-type: none"> <li>2. Verify that the phase detector DC offset is <math>&lt; 30</math> mV (<math>&lt; 50</math> mV if you are using the 1.2 to 1.8 GHz Phase Detector).</li> <li>3. If the HP 3048A was not configured to measure the VCO Tuning Constant, verify that the entered value is within a factor of 2 of the VCO's actual Tuning Constant. A procedure for verifying the VCO's Tuning Constant is contained in <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</li> <li>4. When the 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.</li> </ol>										

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

<p><b>12</b></p>	<p><b>Insufficient span. Less than one waveform found.</b> A minimum of four zero crossings is necessary across the HP 3561A's display. This error occurs when the system is measuring the Phase Detector Constant and the expected beatnote is &lt; 1 kHz.</p> <p><b>Action:</b> When the 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. A procedure for evaluating the tuning sensitivity of the VCO is provided in <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</p>															
<p><b>13</b></p>	<p><b>The (File) does not exist in the current (Directory) and has not been loaded.</b> This error occurs when the HP 3048A attempts to load a file and the disc containing that file is not present in the designated mass storage device.</p> <p><b>Action:</b> Insert the disc containing the required file and proceed.</p>															
<p><b>14</b></p>	<p><b>DC offset from mixer &gt; 1/2 peak voltage.</b> The dc offset of the Phase Detector is determined and then used to adjust the Phase Detector calibration constant for true slope at the zero voltage point.</p> <p><b>Action:</b> Observe the beatnote on the HP 3561A display or with an oscilloscope connected to the AUX MONITOR port on the HP 11848A.</p> <p>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.</p> <div data-bbox="482 1171 1136 1612" data-label="Figure"> <table border="1"> <caption>Data points from Figure 3-37</caption> <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>.02</td> </tr> <tr> <td>-5</td> <td>-27</td> <td>.05</td> </tr> <tr> <td>+5</td> <td>-17</td> <td>.1</td> </tr> <tr> <td>+15</td> <td>-7</td> <td>.2</td> </tr> </tbody> </table> </div> <p><b>Figure 3-37. Beatnote Level Relative to the Signal Level at the R Port.</b></p>	R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL ON HP3561A (dBv)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)	-15	-37	.02	-5	-27	.05	+5	-17	.1	+15	-7	.2
R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL ON HP3561A (dBv)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)														
-15	-37	.02														
-5	-27	.05														
+5	-17	.1														
+15	-7	.2														

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

<p><b>14</b> (cont'd)</p>	<p>2. Verify that the Phase Detector DC offset is <math>&lt; 30</math> mV (<math>&lt; 50</math> mV for the 1.2 to 1.8 GHz Phase Detector). If the dc offset is within this limit and the beatnote level is <math>&lt; -23</math> dBV (<math>&lt; 0.1</math> 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.</p>															
<p><b>15</b></p>	<p><b>Detector Constant <math>&lt; 0.02</math> V/Rad.</b> The measured Phase Detector Constant was below the system's 20 mV limit.</p> <p><b>Action:</b> 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 <math>\geq +15</math> dBm (<math>\geq +7</math> dBm for the 1.2 GHz to 18 GHz Phase Detector).</p> <div data-bbox="574 1081 1214 1533" data-label="Figure"> <table border="1"> <caption>Data points from Figure 3-38</caption> <thead> <tr> <th>R PORT SIGNAL LEVEL (dBm)</th> <th>BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)</th> <th>BEATNOTE LEVEL ON HP3561A (dBv)</th> </tr> </thead> <tbody> <tr> <td>-15</td> <td>0.02</td> <td>-37</td> </tr> <tr> <td>-5</td> <td>0.05</td> <td>-27</td> </tr> <tr> <td>+5</td> <td>0.2</td> <td>-17</td> </tr> <tr> <td>+15</td> <td>0.6</td> <td>-7</td> </tr> </tbody> </table> </div> <p><b>Figure 3-38. Beatnote Level Relative to the Signal Level at the R Port.</b></p>	R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)	BEATNOTE LEVEL ON HP3561A (dBv)	-15	0.02	-37	-5	0.05	-27	+5	0.2	-17	+15	0.6	-7
R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)	BEATNOTE LEVEL ON HP3561A (dBv)														
-15	0.02	-37														
-5	0.05	-27														
+5	0.2	-17														
+15	0.6	-7														



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

<b>16</b>	<p><b>Detector Constant &gt; 10 V/Rad.</b> The measured Phase Detector Constant exceeded the system's 10 V limit.</p> <p><b>Action:</b> 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 3-39 shows the relationship between the beatnote level and the level at the R port. If necessary, decrease the signal level at the R port.</p> <div style="text-align: center;"> <table border="1" style="margin: 10px auto;"> <caption>Data points for Figure 3-39</caption> <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>.02</td> </tr> <tr> <td>-5</td> <td>-27</td> <td>.05</td> </tr> <tr> <td>+5</td> <td>-17</td> <td>.1</td> </tr> <tr> <td>+15</td> <td>-7</td> <td>.2</td> </tr> </tbody> </table> </div> <p><b>Figure 3-39. Beatnote Level Relative to the Signal Level at the R Port.</b></p>	R Port Signal Level (dBm)	Beatnote Level on HP3561A (dBV)	Beatnote Level at AUX Monitor Port (Vpk)	-15	-37	.02	-5	-27	.05	+5	-17	.1	+15	-7	.2
R Port Signal Level (dBm)	Beatnote Level on HP3561A (dBV)	Beatnote Level at AUX Monitor Port (Vpk)														
-15	-37	.02														
-5	-27	.05														
+5	-17	.1														
+15	-7	.2														
<b>17</b>	<p><b>Measured Tuning Range of VCO is less than 0.2 Hz.</b> The system was probably unable to cause a beatnote.</p> <p>The Tuning Range of the VCO is measured in this case as:  <math>2 \times \text{Entered Voltage Range of VCO} \times \text{Measured VCO Tuning Constant}</math></p> <p><b>Action:</b> If the <i>expected</i> tuning range of the VCO source is much larger than 0.2 Hz:</p> <ol style="list-style-type: none"> <li>1. Check the Tune Voltage cable connection.</li> <li>2. Verify that the VCO source's tuning capability is enabled.</li> <li>3. Verify the VCO's tuning response by performing the procedure provided in <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</li> <li>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 this manual.</li> </ol> <p>If the <i>expected</i> tuning range of the VCO source is near 0.2 Hz:</p> <ol style="list-style-type: none"> <li>1. Increase the tuning range, if possible, by increasing the Voltage Tune Range value entered for the measurement.</li> </ol>															

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

<p><b>18</b></p>	<p><b>The system perceives that the signals from the two sources differ by more than 15% of the VCO Tuning Range. The sources may be retuned to reduce the beatnote frequency, or the VCO Tuning Range may be adjusted.</b></p> <p>Once the HP 3048A has measured the VCO Tuning Constant, it is able to predict the tune voltage necessary to phase lock the loop. If the tuning range required for lock is &gt; 15% of the Peak Tuning Range (PTR), The system may not be able to pull the sources into lock, and will have very little tuning range (&lt; 5% of PTR) left for drift tracking.</p> <hr/> <p><b>Action:</b></p> <ol style="list-style-type: none"> <li>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 press the <b>Span</b> softkey to 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 this manual.)</li> <li>2. If necessary, change the Center Voltage value entered for the VCO to reduce the initial beatnote frequency, or increase the Tuning Voltage Range entered for the 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 this manual.)</li> </ol>
<p><b>19</b></p>	<p><b>There is no HP 3585A in the configuration table.</b> This task requires that an HP 3585A Spectrum Analyzer is configured into the HP 3048A system.</p> <hr/> <p><b>Action:</b> Enter an HP 3585A into the System Configuration Table.</p>
<p><b>20</b></p>	<p><b>Unable to detect presence of HP 3561A noise source. Check cabling and HP 3516A Noise Source Function.</b></p> <hr/> <p><b>Action:</b> Verify that the HP 3561A rear-panel "Source Out" port is connected to the HP 11848A rear-panel "Noise Input" port.</p>
<p><b>21</b></p>	<p><b>User tone not within +/-500 Hz of 55 KHz. Press re-try if you wish to re-adjust and continue. The frequency of the tone generator is not close enough to the required limits.</b></p> <hr/> <p><b>Action:</b> Adjust tone generator if possible. If the tone generator cannot meet this requirement, replace it with one that can.</p>

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

<b>22</b>	<b>User tone not within <math>\pm 5</math> dB of <math>-60</math> dBc. Press re-try if you wish to re-adjust and continue. The level from the tone generator is not close enough to the required limits.</b>
	<b>Action:</b> Adjust tone generator if possible. If the tone generator cannot meet this requirement, replace it with one that can to perform this test.
<b>23</b>	<b>Warning. Measurement has not been calibrated. 'New Msrmnt' should be requested.</b> Repeat Measurement or Noise Monitor was selected.
	<b>Action:</b> Select New Measurement or New Noise Monitor to allow the system to calibrate the measurement.
<b>24</b>	<b>No printer found in system configuration, Performance Tests cannot be initiated.</b> The Performance Tests require a printer to be connected to the system and entered in the System Configuration Table.
	<b>Action:</b> Connect a printer and enter the appropriate information into the System Configuration Table.
<b>25</b>	<b>Printer is not responding. Performance test cannot be initiated. Correct problem and Press 'Retry'.</b> The system cannot find the printer as addressed in the System Configuration Table.
	<b>Action:</b> Be sure the printer is connected on the system HP-IB bus. Verify that the printer is turned on and is set to the same address as is listed in the System Configuration Table.
<b>26</b>	<b>The system attempted to set (instrument) to (-) MHz.</b> The source was not able to respond to the frequency setting defined (or computed) for the measurement.
	<b>Action:</b> Verify that the Instrument Parameters defined for the measurement are correct and that the source's frequency range is adequate.
<b>27</b>	<b>The entered carrier frequency cannot be measured.</b> The HP 11729C cannot generate an intermediate frequency between 4.9 MHz and 1280 MHz for this carrier frequency.
	<b>Action:</b> Verify the carrier frequency. If the frequency is correct, verify the HP 11729C filter table in the System Configuration Table.

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

<b>28</b>	<b>Unable to disable PLL integrator by setting out-of-lock flip-flop. Test 03 results may be invalid. Fix the problem and try again. Test 03 will be aborted upon pressing 'Proceed' or 'Abort'.</b>
	<b>Action:</b> Troubleshoot and repair the HP 11848A Phase Noise Interface. Refer to the HP 11848A Service Manual for Troubleshooting information.
<b>29</b>	<b>Unable to disable PLL integrator by setting out-of-lock flip-flop. Test 09 results may be invalid. Fix the problem and try again. Test 09 will be aborted upon pressing 'Proceed' or 'Abort'.</b>
	<b>Action:</b> Troubleshoot and repair the HP 11848A Phase Noise Interface. Refer to the HP 11848A Service Manual for Troubleshooting information.
<b>30</b>	<b>Unable to disable PLL integrator by setting out-of-lock flip-flop. Test 10 results may be invalid. Fix the problem and try again. Test 10 will be aborted upon pressing 'Proceed' or 'Abort'.</b>
	<b>Action:</b> Troubleshoot and repair the HP 11848A Phase Noise Interface. Refer to the HP 11848A Service Manual for Troubleshooting information.
<b>110</b>	<b>Random noise obscures waveform.</b> The system is unable to measure the Detector Constant due to an erratic waveform. This error occurs during the Phase Detector Constant calibration.
	<b>Action:</b> Observe spectrum of beatnote and evaluate with respect to small angle criterion for expected PLL BW.

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

<p><b>Bad segment definitions.</b> The defined segments do not include the 100 kHz offset data point when accessing the Noise Monitor and New Noise Monitor.</p> <p><b>Action:</b> Define the Segment Table to include 100 kHz.</p>
<p><b>Cannot use the specified Tuning Constant.</b> The Tuning Constant was set to zero because the last New Measurement was aborted.</p> <p><b>Action:</b> Define a method for determining the VCO Tuning Constant other than use the current Tuning Constant. Then select <input type="text" value="New Msrmnt"/>.</p>
<p><b>External Timebase not allowed with Internal Source.</b></p> <p><b>Action:</b> Redefine the timebase in the Source Control display.</p>
<p><b>Files not created using identical segments.</b> The 2 Oscillator Comparison or the 3 Oscillator Comparison can only be performed using data acquired from identical segments and measurement spans.</p> <p><b>Action:</b> Remeasure the devices. Do not change any Segment Table entries between measurements or measurement definitions.</p>
<p><b>ILLEGAL DATA TYPE.</b> The system expected a numeric value to be entered.</p> <p><b>Action:</b> Enter numeric value only.</p>
<p><b>Insufficient data files for 3 Oscillator Comparison.</b> Less than three Result Files were found in the specified Mass Storage Media.</p> <p><b>Action:</b> Store a Result File for each of the three measurements to be compared on the same Mass Storage Media.</p>
<p><b>Insufficient data files for 2 Oscillator Comparison.</b> Less than two Result Files were found in the specified Mass Storage Media.</p> <p><b>Action:</b> Store a Result File for each of the two measurements to be compared on the same Mass Storage Media. (Note that these files cannot be identical, they must be distinct measurements).</p>
<p><b>Internal sources may not be used to drive the high frequency detector.</b> The HP 11848A internal oscillators can not be used as the input for the 1.2 to 1.8 GHz phase detector.</p> <p><b>Action:</b> Define a different source or phase detector.</p>
<p><b>No test-instruments defined.</b> Measurement initiated with an empty Configuration Table.</p> <p><b>Action:</b> Define the equipment being used in the System Configuration Table.</p>

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

<p><b>'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.</b></p> <p><b>Action:</b> Redefine the source selections on the Source Control Diagram.</p>
<p><b>3561A Noise Source not functioning or not connected to 11848A.</b> The HP 11848A can not detect the required noise source for this setup.</p> <p><b>Action:</b> 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.</p>
<p><b>Peak tuning range exceeds Hz.</b> The maximum Peak Tuning Range is 500 kHz (or 200 MHz when using a configured RF Analyzer).</p> <p><b>Action:</b> Reduce the Peak Tuning Range by reducing the Tuning Voltage or Tuning Constant value defined for the VCO source in the Instrument Parameters display.</p>
<p><b>Plot range is not within span range.</b> A Plotted Range has been defined that is not within the Measurement Range specified in the segment tables.</p> <p><b>Action:</b> Define each of the Plotted Ranges in the Segment Table so they are each within the Measurement Ranges defined in the table.</p>
<p><b>Range limits must be in ascending order.</b> A segment has been defined with a lower limit greater than the upper limit.</p> <p><b>Action:</b> Redefine the segment range so that the upper limit is greater than the lower limit.</p>
<p><b>Source specification is invalid and must be corrected.</b> The system has detected an error in the Source Control definition.</p> <p><b>Action:</b> Check the Source Control Diagram for accuracy and compatibility with other parameters defined for the measurement.</p>
<p><b>The currently defined measurement has not been properly calibrated. Select 'New Msrmt' or 'New Noise Monitor' to calibrate.</b> The Phase Detector Constant or VCO Tuning Constant has not been calibrated.</p> <p><b>Action:</b> Check that the appropriate calibration method has been defined in the Calibration Process display. Select <input type="button" value="New Msrmt"/> or a <input type="button" value="New Noise Monitor"/> to initiate calibration.</p>
<p><b>The frequency of the Internal 400 MHz Osc. cannot be tuned.</b> The system cannot obtain quadrature since the HP 11848A internal 400 MHz oscillator cannot be tuned.</p> <p><b>Action:</b> Use a tunable source or manually adjust quadrature using a phase shifter or line stretcher.</p>

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

<p><b>Tune line improperly connected.</b> The Tune Line is connected to a non-tunable source in the Source Control Diagram. A VCO source is required for Phase Lock Loop Measurements.</p> <p><b>Action:</b> Connect the Tune Line to a VCO source in the Source Control Diagram.</p>
<p><b>'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.</b></p> <p><b>Action:</b> Redefine the source selections on the Source Control Diagram.</p>
<p><b>3561A Noise Source not functioning or not connected to 11848A.</b> The HP 11848A can not detect the required noise source for this setup.</p> <p><b>Action:</b> 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.</p>

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

<b>1</b>	<p><b>Establish quadrature manually.</b></p> <p><b>Action:</b> Manually adjust the source frequency or the phase shifter to attain quadrature (within <math>\pm 1</math> 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.</p>
<b>2</b>	<p><b>The FM Deviation on the (source) will be changed from ___ to ___ Hz.</b> 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 Tuning Constant (deviation) will result in a narrower Peak Tuning Range (PTR) for the measurement.</p> <p><b>Action:</b> 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.</p> <p>If your VCO source is an HP 8642A/B and the carrier frequency for the measurement is <math>&lt; 123</math> MHz, the following steps will enable you to increase the tuning range of the HP 8642A/B.</p> <ol style="list-style-type: none"> <li>1. Configure the HP 3048A Source Control block diagram for manual control of the HP 8642A/B.</li> <li>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.</li> </ol>



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

<b>3</b>	<p><b>Cause FIRST calibration PEAK voltage at mixer input.</b></p> <p><b>Action:</b> 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 <span style="border: 1px solid black; padding: 2px;">Proceed</span> .</p> <p>When you are prompted to cause the second calibration peak, adjust to a maximum peak of the opposite polarity using the same technique.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><i>For this calibration technique to be most accurate, the two signal paths to the HP 11848A Phase Detector should be well matched (&gt;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></p>
<b>4</b>	<p><b>Apply modulation to carrier.</b> Either a double-sided spur or modulation of the same type as is being measured.</p> <p><b>Action:</b> 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.</p> <ul style="list-style-type: none"> <li>• Double-sided spur &lt; -20 dB</li> <li>• AM &lt; 10% (-26 dB)</li> </ul> <p>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 system).</p>
<b>5</b>	<p><b>Apply calibration spur to carrier.</b> A single-sided spur is expected.</p> <p><b>Action:</b> The spur is typically generated by combining a signal near the frequency of the device-under-test (DUT) with the DUT output. This can be done using a power splitter or a directional coupler.</p> <p>Turn on the spur signal source and note the amplitude of the spur signal relative to the amplitude of the DUT. The spur level should be high enough to be readily observable above the noise of the DUT on a spectrum analyzer. The spur level should not exceed -20 dBc relative to the DUT amplitude.</p>

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

<p><b>6</b></p>	<p><b>Remove the calibration spur.</b> If the spur signal is not removed, it will appear in the measurement and could affect the measurement results.</p>
	<p><b>Action:</b> Disconnect or turn off the spur source without disturbing the frequency or amplitude settings of the source.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><i>If you wish 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 system from having the full dynamic range necessary to make a valid noise measurement.</i></p>
<p><b>7</b></p>	<p><b>Offset the source and reference signals by at least 1 Hz and not more than 20 MHz.</b> The 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:</p> <p>With RF Spectrum Analyzer in System..... Offset Range: 1 Hz to 20 MHz          Without RF Spectrum Analyzer in System..... Offset Range: 1 Hz to 50 kHz</p>
	<p><b>Action:</b> Adjust the frequency of the device-under-test (DUT) to offset it from the reference source frequency.</p> <p>If the DUT cannot be adjusted to create a frequency offset that is within the offset range specified above, substitute a different source for the DUT. Adjust the substitute source for the same power level as the DUT source it is replacing. Terminate any ports in 50Ω that are not connected during the substitution. Reconnect the DUT source after the calibration is completed.</p>
<p><b>8</b></p>	<p><b>Remove the beatnote and connect the system for noise measurement.</b></p>
	<p><b>Action:</b> Readjust the device-under-test (DUT) to the frequency of the reference source or reconnect DUT.</p>
<p><b>9</b></p>	<p><b>Phase lock has been lost.</b> This message can be caused by any one of the following conditions.</p> <ol style="list-style-type: none"> <li>1. Frequency drift &gt; 25% of the Peak Tuning Range.</li> <li>2. A phase transient &gt; 0.25 radians.</li> <li>3. Out-of-Lock detector set by search oscillator.</li> </ol>

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

<p><b>9</b> (cont'd)</p>	<p><b>Action:</b> Press the <b>Proceed</b> key to cause the HP 3048A to attempt to relock the loop and re-measure the frequency segment. If the HP 3048A 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.)</p>
<p><b>10</b></p>	<p><b>The LNA is currently IN/OUT. This may be changed via the 'Toggle LNA' key.</b> This message only appears if the PULSED Carrier Type 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 system.</p> <p>If the system 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 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 system's noise floor) this degradation may affect the measurement results.</p> <p><b>Action:</b> Under most condition it is recommended that you proceed with the decision made by the system. 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.</p> <p>There are certain conditions when you may want to toggle the LNA OUT, however.</p> <ol style="list-style-type: none"> <li>1. When Pulse Mode is enabled. If the Phase Detector dc offset is <math>&gt; 5</math> mVdc, the system may not detect that the noise level is high enough to overload the LNA.</li> <li>2. To duplicate the exact conditions that existed for a previous measurement where the LNA was switched out.</li> <li>3. When you are performing the System Noise Floor Test and you wish to evaluate the system's noise floor without the LNA in the measurement path.</li> </ol> <p>If the system has decided to switch OUT the LNA and you are concerned about measurement sensitivity, you may wish 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 <math>-0.5V</math> or <math>+1V</math>, 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.</p>

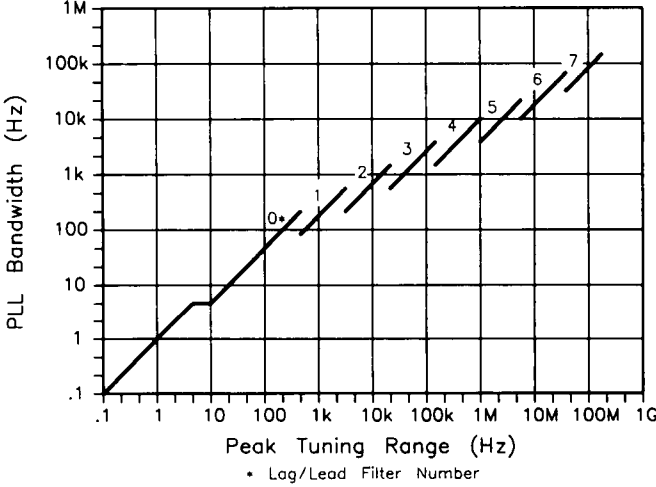
Table 3-26. Reference Messages (5 of 7)

<p><b>11</b></p>	<p><b>The LNA of the HP 11848A has been bypassed. This will result in a degradation of the system noise floor.</b> 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 system.</p> <p>If the system 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 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 system's noise floor) this degradation may affect the measurement results.</p> <p><b>Action:</b> 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:</p> <ol style="list-style-type: none"> <li>1. A large spur (&gt; -40 dBc) on one of the input signals.</li> <li>2. A high noise pedestal on one of the sources.</li> <li>3. Spurs at the output of the Phase Detector.</li> </ol> <p>To determine whether bypassing the LNA has affected your noise measurement results, compare your results to the noise floor provided by the system when the LNA is OUT. Use the Phase Detector Constant value measured by the HP 3048A to determine the system's noise floor with the LNA OUT from Detector Sensitivity graph (Figure 4-7). If it appears that your measurement may have been limited by the 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.</p> <ol style="list-style-type: none"> <li>1. Reduce the Phase Detector Calibration Constant by reducing the signal level into the R port of the Phase Detector. Then reinitiate a New Measurement.</li> <li>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 this manual.</li> </ol> <p>If you wish to further evaluate the LNA decision, abort the measurement and access the Special Functions display. Select the PULSED Carrier Type and then initiate 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.</p>
<p><b>12</b></p>	<p><b>A comparison of theoretical and actual PLL suppression indicates a degradation of the accuracy specified for the HP 11848A.</b> 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 &gt; 1 dB.</p>

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

<b>12</b> (cont'd)	<p><b>Action:</b></p> <ol style="list-style-type: none"><li>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 Tuning Constant. Abort the measurement and verify that these calibration constants are accurate.<ol style="list-style-type: none"><li>a. Verify that the VCO Tuning 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 this manual.)</li><li>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 system.</li></ol></li><li>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 this manual.<ol style="list-style-type: none"><li>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 <math>&gt; +15</math> dBm).</li><li>b. Verify that all even harmonics are <math>\leq -30</math> dBc on the beatnote and <math>\leq -20</math> dBc on the input signals.</li><li>c. Check for injection locking.</li><li>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 this manual for a procedure.)</li></ol></li><li>3. If the beatnote signal meets the preceding tests, proceed with a New Measurement. If this same message is displayed again, press the <b>Suppr. Plot</b> key to access a plot of the PLL suppression curve.<ol style="list-style-type: none"><li>a. If the measured curve does not match the theoretical because it is noisy, press <b>Proceed Theor</b> 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.</li><li>b. If the measured curve does not match the theoretical because it has high peaks and the Accuracy Spec. Degradation is <math>\leq 2</math> dB, press <b>Proceed w/Adj</b> 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 the HP3048A Reference Manual, Chapter 2, Measurement Definitions for further information about the PTR.)</li></ol></li></ol>
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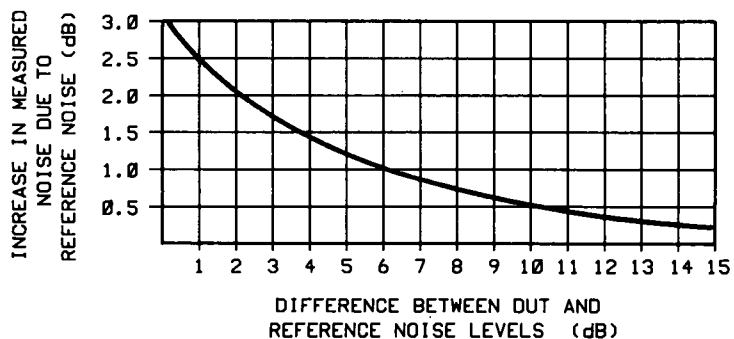
**Table 3-26. Reference Messages (7 of 7)**

<p><b>12</b> (cont'd)</p>	<p>c. If the Acc. Spec. Deg. is &gt;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 Acc. Spec. Deg. is still &gt;2 dB, press Proceed W/Adj to get an approximate noise measurement for use in further troubleshooting the problem.</p>  <p><b>Figure 3-40. Phase Lock Loop Bandwidth Relative to the Peak Tuning Range.</b></p>
<p><b>13</b></p>	<p><b>Establish a beatnote less than or equal to ( ) Hz.</b> 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 zerobeat.</p> <p><b>Action:</b> 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.</p>
<p><b>102</b></p>	<p><b>'CALDATAHI' and 'CALDATALO' will be restored from disc files.</b> Cal data in memory is in a unknown state. System will restore cal data from the mass storage media file.</p>
<p><b>103</b></p>	<p><b>NO PRINTER FOUND IN SYSTEM CONFIGURATION.</b> Functional Checks require a printer be configured in the system.</p> <p><b>Action:</b> Connect a printer to the system, and enter it in the System Configuration Table.</p>

## 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 device-under-test (DUT). In general, the lower the reference source's noise level is below the expected noise level of the DUT 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 DUT.)

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



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

### **Using a Similar Device**

The system performs best when you are able to use a device similar to the DUT as the reference source for your PLL measurement. Of course one of the devices must be capable of being voltage tuned by the HP 3048A 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 DUT. 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 DUT. (Refer to your HP 3048A Reference Manual for details on performing the *Three Source Comparison* procedure.)

If only one device is available in addition to the DUT, 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 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 device-under-test (DUT) 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 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	Required Tuning Constant Accuracy
Use the current Tuning Constant	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 HP 3048A 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.)

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 system).
2. **Note the frequency of the beatnote signal.** If the beatnote frequency is too low to resolve, decrease the span setting on the HP 3561A by pressing the **3561A Span** key on the HP 3048A or the **Define Span** softkey on the HP 3561A. Continue decreasing the span setting until the beatnote frequency can be easily read.
3. **Notice the Center Volt.: label shown in the top right corner of the HP 3048A display.** The value displayed is the Center Voltage of the VCO Tuning Curve specified in the Instr. Params menu. This is the voltage level that the HP 11848A TUNE VOLTAGE OUTPUT is currently set to.
4. **Press the **Center Voltage** softkey on the HP 3048A.** Notice that the center voltage value is incremented by 2% of the entered Voltage Tuning Range (shown in top right corner) each time this key is pressed. (The value can also be decremented by pressing the **Shift** key on the keyboard and the **Center Voltage** key at the same time.) The voltage level at the TUNE VOLTAGE OUTPUT is also incremented each time this key is pressed.
5. **Continue to 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.** 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 HP 3084A'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 quadrature, the HP 3048A will inform you by placing a message in its display. If the beatnote drifts beyond the Drift Tracking Range during the measurement, the HP 3048A will stop the measurement and inform you that it 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 HP 3048A 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 Voltage Tuning Range entered for the VCO and the VCO's Tuning Constant. (If the HP 3048A has been configured 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 its 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.

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### The Tuning Qualifications

Changing the PTR is accomplished by changing the VCO Voltage Tuning Range 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 Voltage Tuning Range of the VCO source.

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#### Caution

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

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**Note**

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

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**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 have the HP 3048A measure the new Tuning Constant. (Note that increasing the deviation setting often increases the source's noise level as well. Refer to your HP 3048A 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 its own reference signal.

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 HP 3048A will inform 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 device-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.

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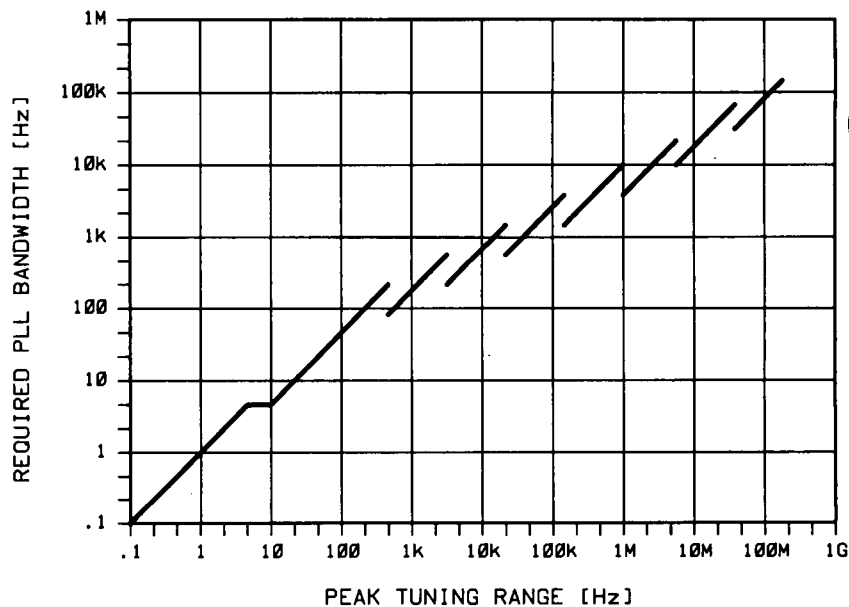
**Note**

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 HP 3048A 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.)

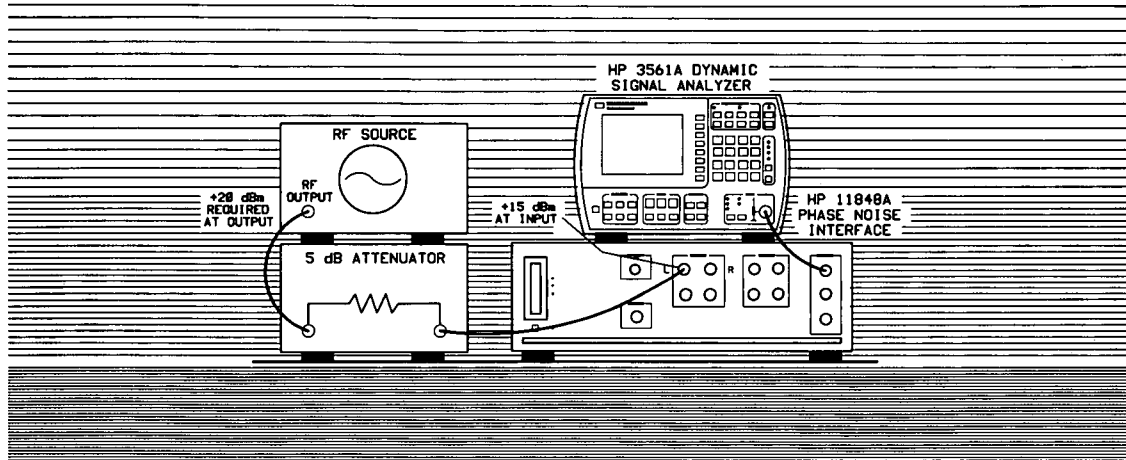


**Figure 3-42. Peak Tuning Range (PTR) Required by Injection Locking.**

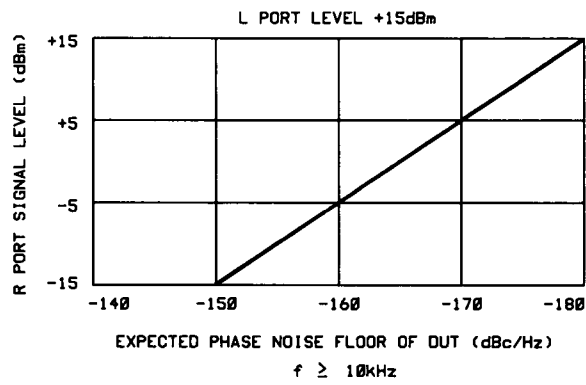
### Inserting a Device An Attenuator

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 device-under-test (DUT) 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 DUT.

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.**

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### An Amplifier

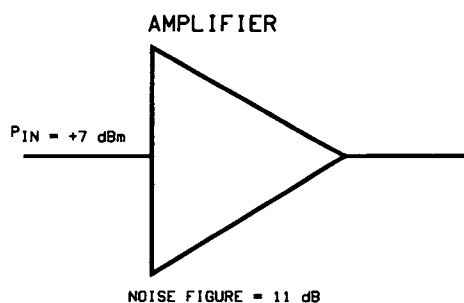
If a source is not able to provide a sufficient output level, or if additional isolation is needed at the output, it may be necessary to insert a low noise amplifier at the output of the source.

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

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

**For Example,**



$$\mathcal{L}(f) \text{ out} = -174 + 11 - 7 - 3 = \frac{-173 \text{ dBc}}{\text{Hz}}$$

---

### 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 HP 3048A from attaining phase lock.

The following procedure allows you to evaluate the beatnote created between the two sources being measured by the HP 3048A. The intent is to verify that the PLL bandwidth is adequate to prevent the noise on the two sources from causing the HP 3048A to lose lock.

If the HP 3048A 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 Voltage Tuning Range 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,**

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

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.

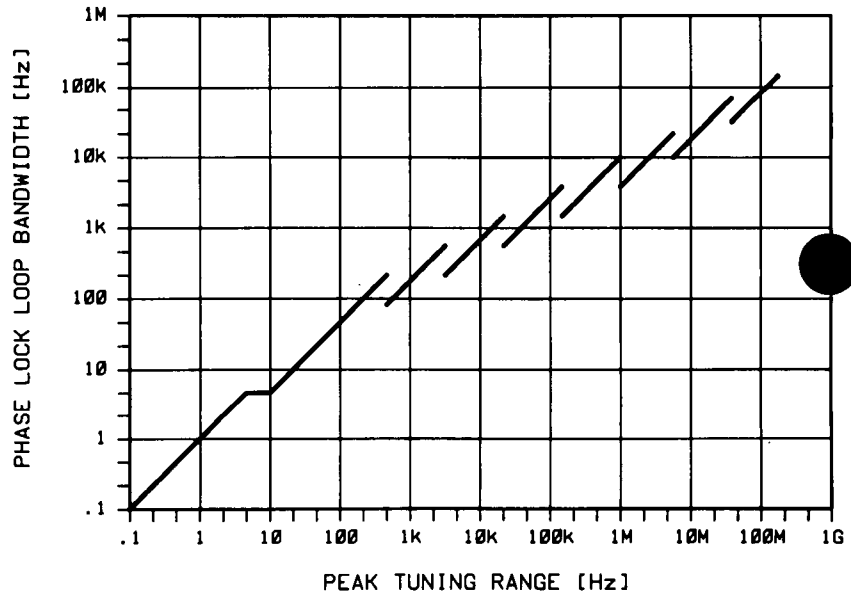


Figure 3-45. Graph of Phase Lock Loop Bandwidth Provided by the Peak Tuning Range



- 
1. Once the beatnote is being 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 to Peak**.
  4. Press **REL MKR**, and **MKR REF**.
  5. Press the **DEFINE TRACE** and the **MATH FUNCTION** keys.

6. Using the Right Arrow 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.)

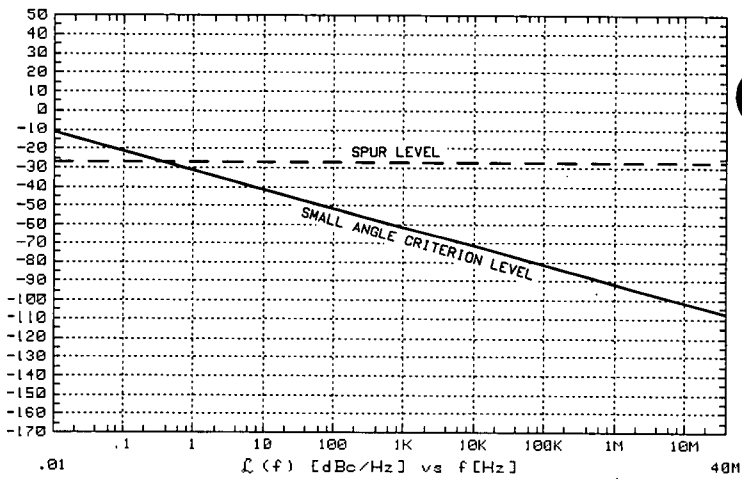
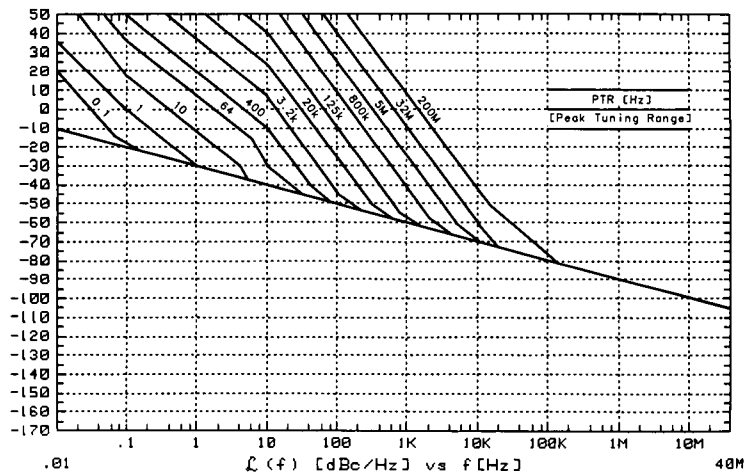


Figure 3-46. Graph of Small Angle Line and Spur Limit

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 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  $\Phi$ 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.

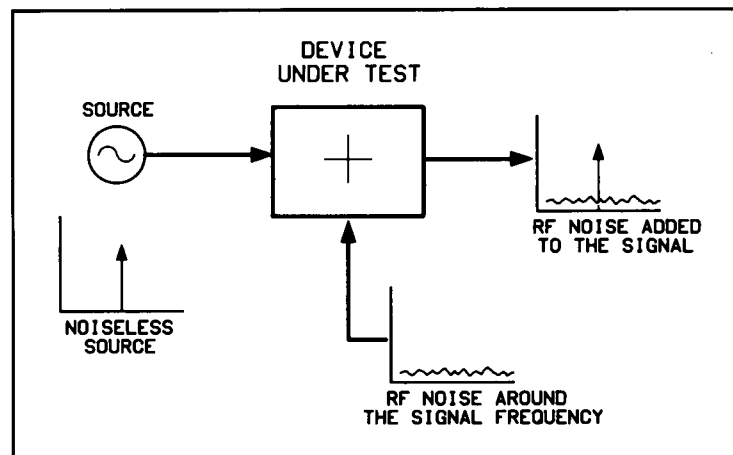


Figure 4-1. Additive Noise Components

2. **Multiplicative noise:** This noise has two known causes. The first, is an intrinsic, direct, phase modulation with a  $1/f$  spectral density, 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.

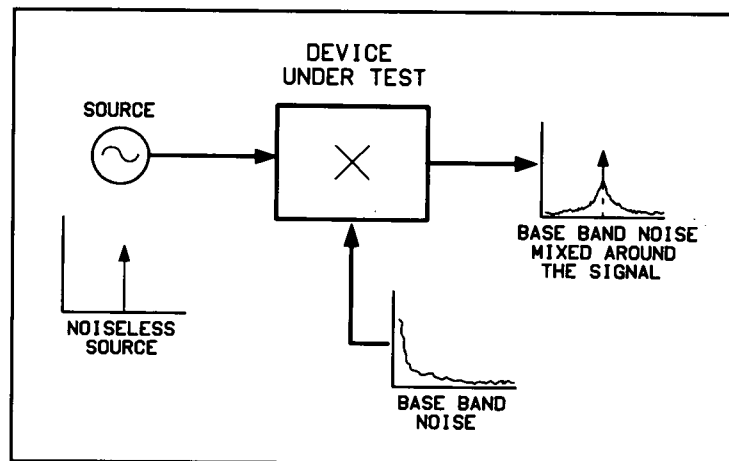


Figure 4-2. Multiplicative Noise Components

## 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  $\Phi$ M 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  $\Phi$ M noise conversion. This AM noise can contribute to the residual phase noise. This includes AM noise in phase detectors.



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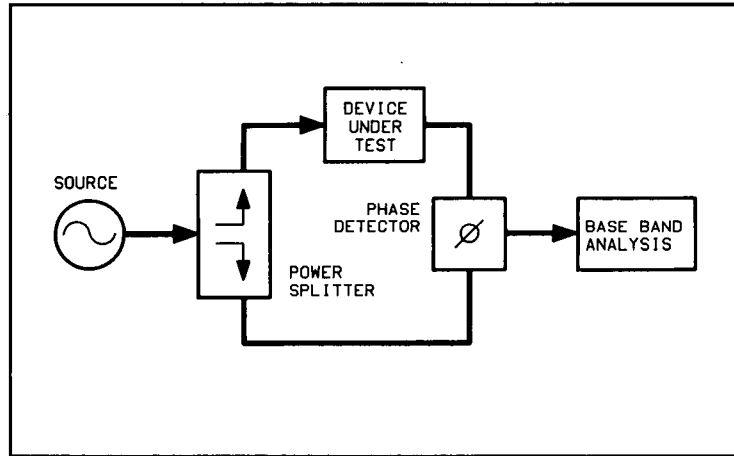
## Basic Assumptions Regarding Residual Phase Noise Measurements

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 DUT.
- **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 DUT 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 device-under-test (DUT) 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 DUT will be measured.



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

## Frequency Translation Devices

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

If the DUT's are identical, a possible (but not recommended) assumption is that the noise of each DUT is half the measured result, or 3 dB less. In lieu of this assumption, all that can be concluded is that the noise level of one of the DUT's is at least 3 dB lower than the measured result.

If a more precise determination is required at any particular offset frequency, a third DUT must also be measured against the other two DUT'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 DUT's.

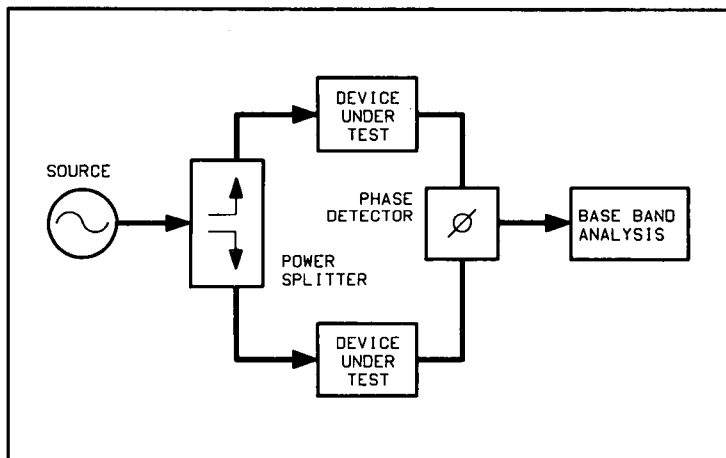


Figure 4-4. Measurement Setup for Two Similar DUTs

## Calibrating the Measurement

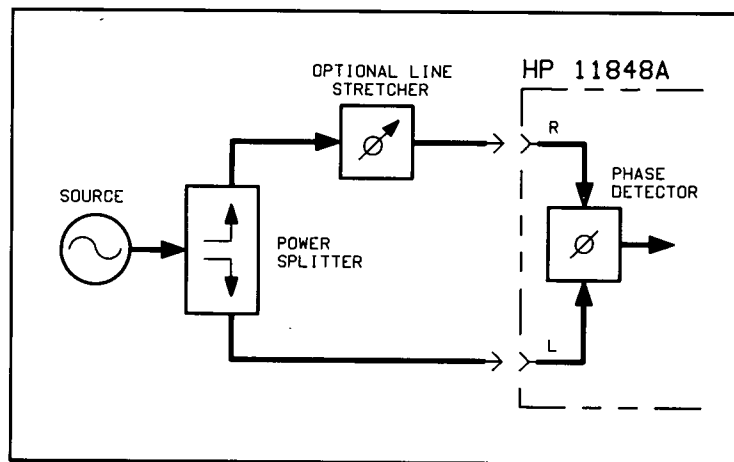
In the HP 3048A system, residual phase noise measurements are made by selecting "Phase Noise Measurement without Phase-Lock Loop" because no phase locking is required.

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  $\Phi$ 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,  $\tau$  will be small. The attenuation of the source noise is a function of the carrier offset frequency, and the delay time ( $\tau$ ) and is equal to:

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

where

$f$  = carrier offset frequency  
 $\pi = 3.14159$   
 $\tau$  = 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  $\Phi$ M conversion in the DUT.
    - b. Mixer-type phase detectors only provide about 20 to 30 dB of rejection to AM noise in a  $\Phi$ 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 DUT 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 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 DUT 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:**

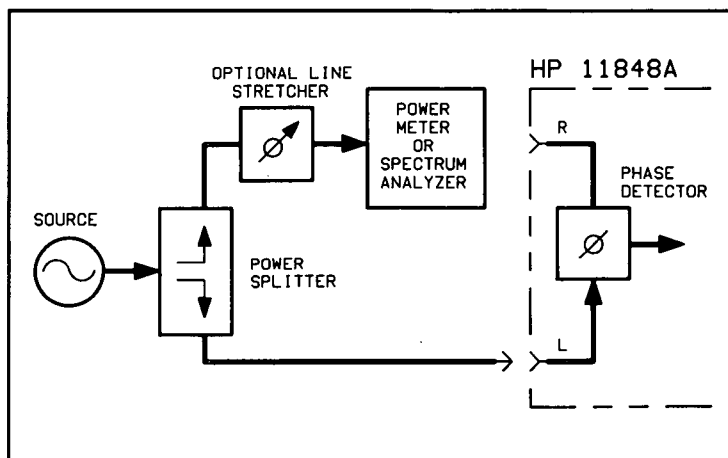
The user entry of the phase detector constant is the least accurate of all the calibration methods.

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**

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 +10 dBm

3. 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.)

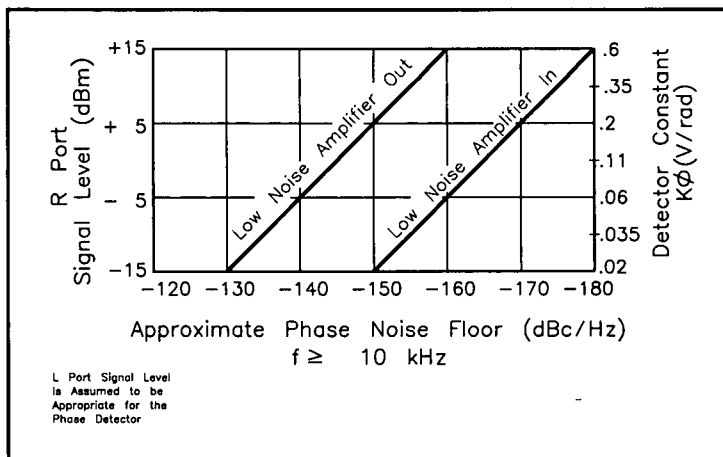
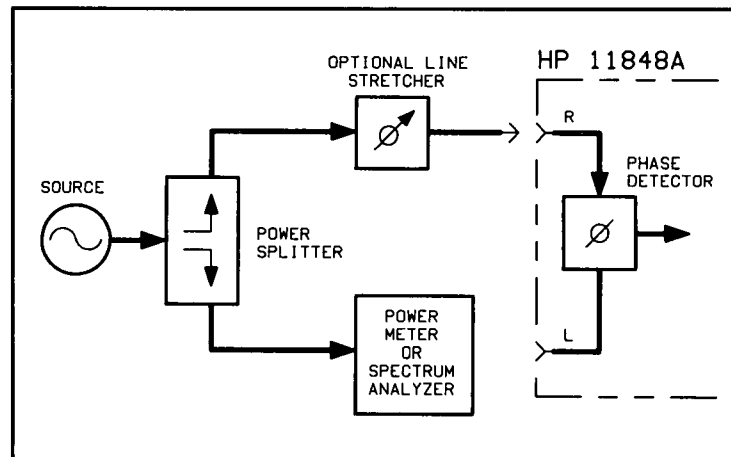


Figure 4-7. Phase Detector Sensitivity

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 HP 3048A 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 +/-  
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.

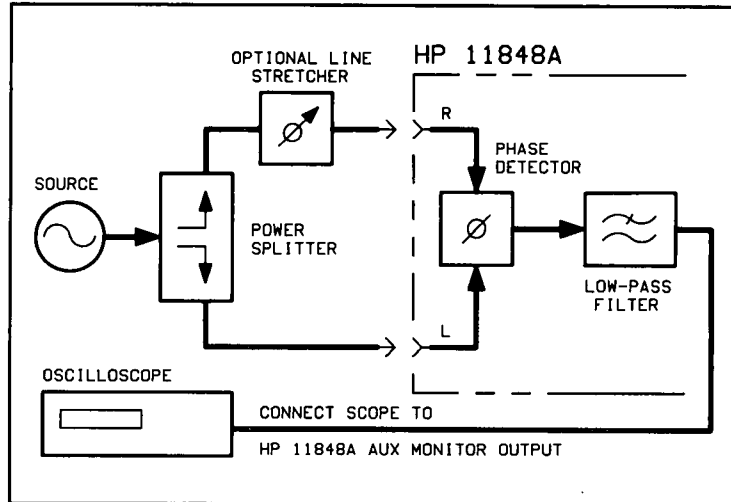
Does not take into account the amount of phase detector harmonic distortion relative to the measured phase detector gain, hence the phase detector must operate in its linear region.

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	-5 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +10 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	$1 \text{ Hz} < f_B < 1 \text{ MHz}$
> 95 MHz	$1 \text{ Hz} < f_B < 20 \text{ MHz}$

### Advantages:

Does not require an RF spectrum analyzer

Simple method of calibration.

### Disadvantages:

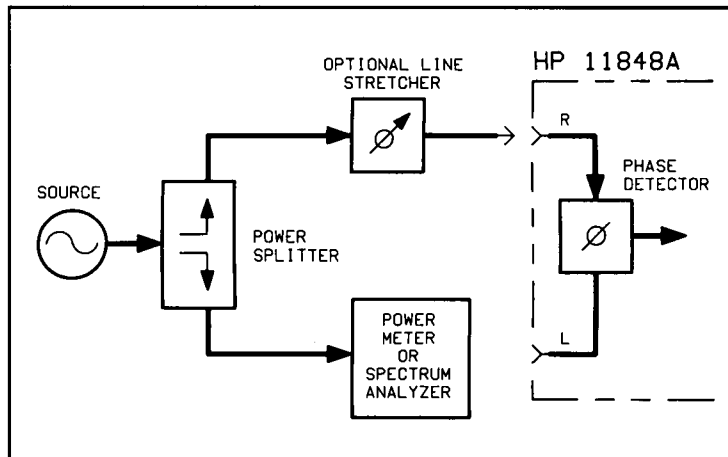
It does not take into account the harmonics of the phase detector and all non-linearities thereof, when using the HP 3048A.

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	-5 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +10 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.

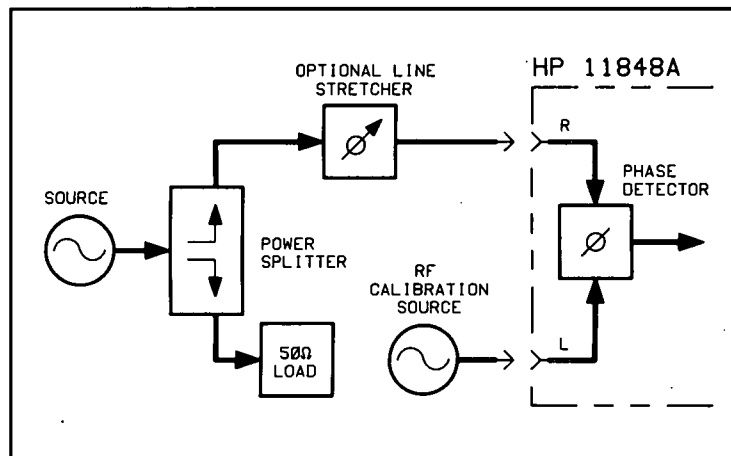


5. Adjust the output frequency such that the beatnote frequency is between 1 Hz and 100 kHz, or to between 1 Hz and 20 MHz if an RF spectrum analyzer is included in the system. (Note that the beatnote frequency may be measured on the system spectrum analyzers.)
6. The system can now measure the calibration 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  $\Phi$ 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.

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### Disadvantages:

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

Requires audio calibration source.

Requires RF spectrum analyzer for manual measurement of  $\Phi$ M sidebands

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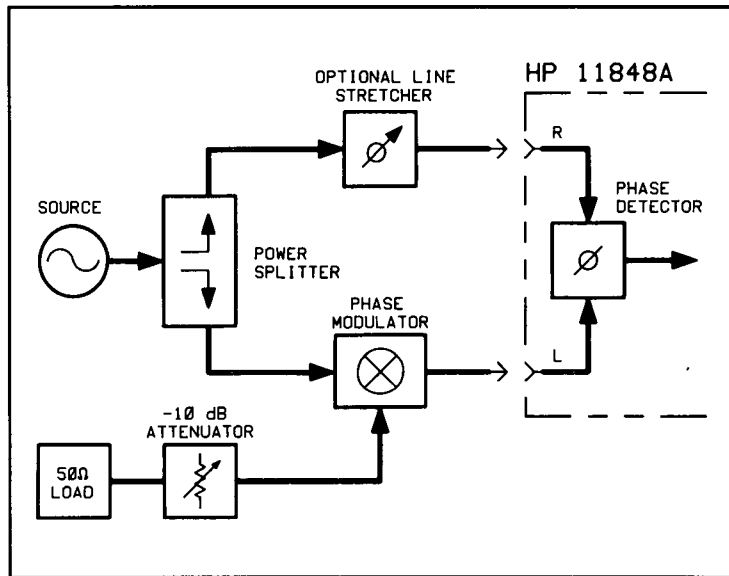
### Note

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

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**Procedure**

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

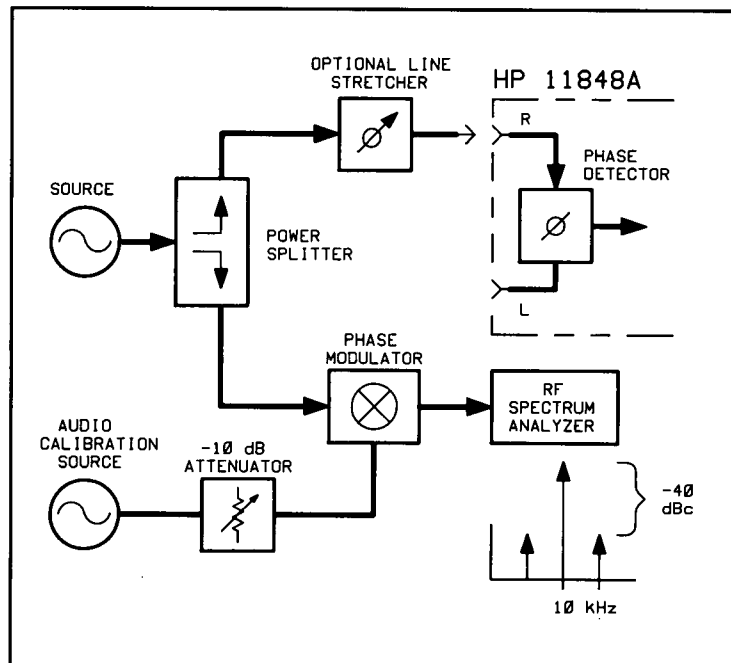


**Figure 4-12. Calibration Setup**

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.

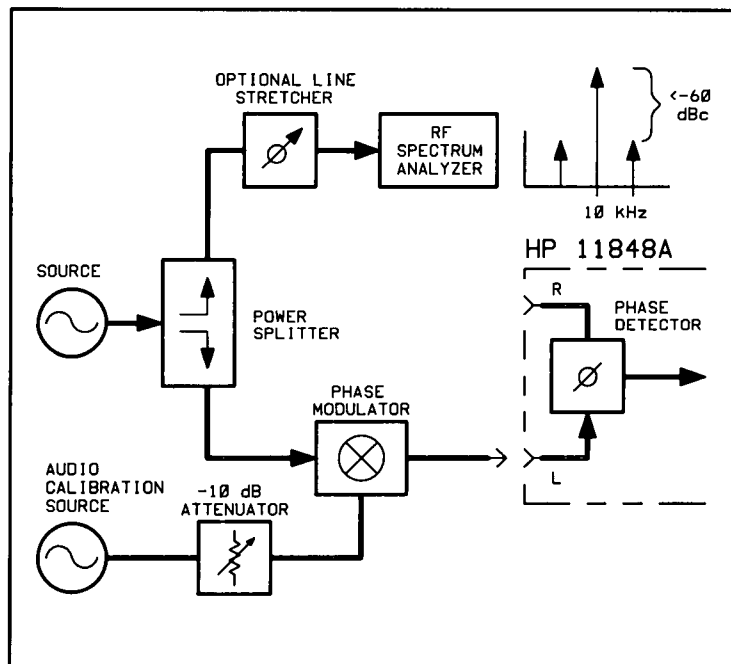
Phase Detector			
5 MHz to 1.6 GHz		1.2 GHz to 18 GHz	
L Port	R Port	L Port	R Port
+15 dBm to +23 dBm	-5 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +10 dBm

- 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.
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. At the Connect Diagram access the Calibration Process display by pressing the **Calib Process** softkey.
  8. Enter the sideband amplitude and offset frequency.
  9. Press **Done** to return to the Connect Diagram.
  10. Check quadrature and measure the phase detector constant by pressing **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.

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Broadband couplers with good directivity are available, at reasonable cost, to couple in the calibration spur.

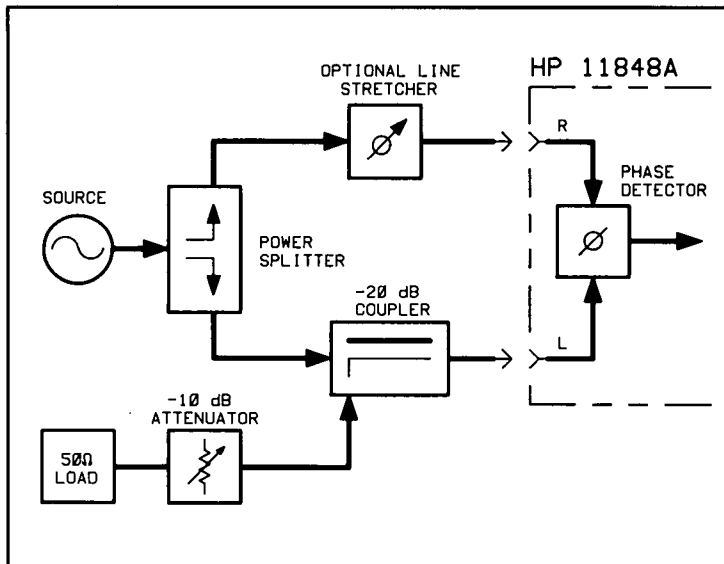
### Disadvantages:

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	-5 dBm to +23 dBm	+7 dBm to +10 dBm	0 dBm to +10 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).

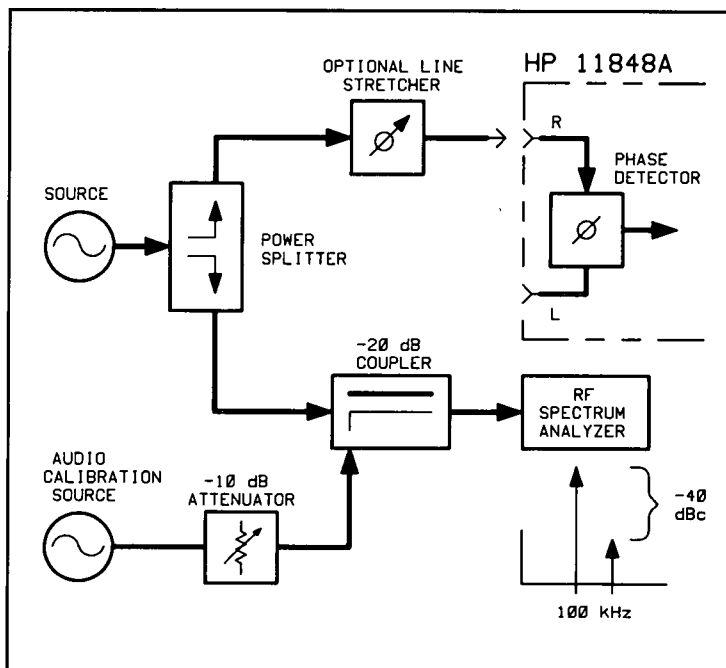


Figure 4-16. Carrier-to-spur Ratio of Modulated Signal

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.

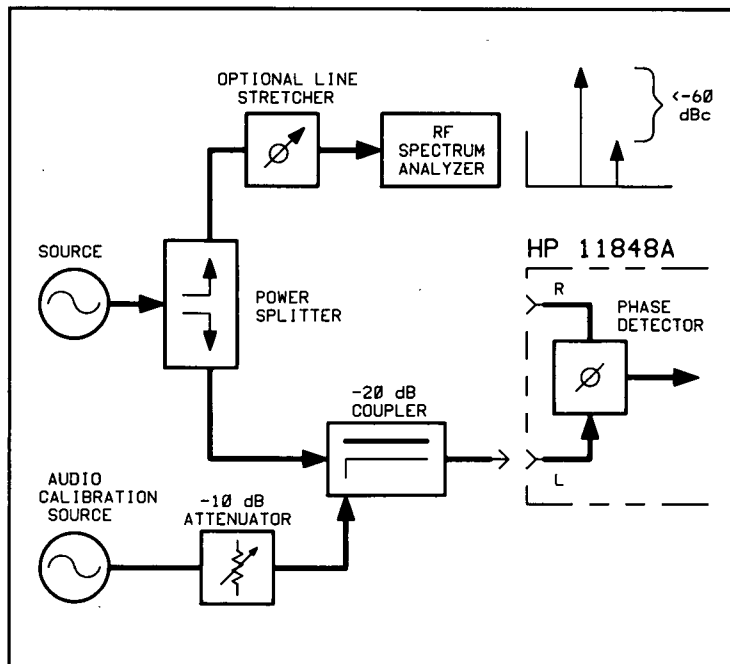


Figure 4-17. Carrier-to-spur Ratio of Non-modulated Signal

- 
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.

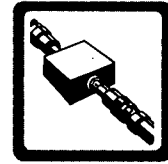
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7. Enter sideband level and offset.
8. Check quadrature and measure the phase detector constant.
9. Remove audio source.
10. Reset quadrature and measure phase noise data.



# 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 device-under-test (DUT).

**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 DUT.
Attenuators	2	Two 10 dB attenuators or one 20 dB attenuator. The attenuators are used to negate the gain of the DUT so the DUT and the internal HP 11848A circuitry will not be over-driven.

---

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

---

### Defining the Measurement

1. Press the **Define Msrmnt** softkey available at the Main Software Level on the HP 3048A.
2. Press the **Test Files** softkey.
3. Move the cursor down until it is positioned at the file labeled "HP EXAMPLE TWO-PORT AMPLIFIER". 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.)
4. Press the **Load File** softkey.

---

**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** parameter menu. This will allow you to see the entire range of the HP 3048A.

---

5. After the system has completed the file loading sequence, press the **Done** softkey. Parameter entry is now completed for this measurement example. (Table 5-2 lists the parameter data that has been entered for this measurement example.)
6. Press **Done** to return to the Main Software Level.

**Table 5-2. Parameter Data for the HP 8447E Amplifier Measurement Example**

Step	Parameters	Data
1	<b>Measurement Type</b> <b>Frequency Range</b> Start Freq. Stop Freq. Averages	Phase Noise without Using a PPL  1 Hz 100 E + 3 Hz 4
2	<b>Instrument Parameters</b> Carrier Frequency Detector/Discr. Input Frequency  Internal Phase Detector	435 E + 6 Hz 435 E + 6 Hz  5 MHz to 1600 MHz
3	<b>Calibration Technique</b> Phase Detector Constant	Derive From Measured +/- DC Peak
4	<b>Source Control</b>	
5	<b>Define Graph</b> Title Minimum X Maximum X Minimum Y Maximum Y  Graph Type	HP 8447E NOISE FLOOR USING AN 8642B 1 Hz 100 E + 3 Hz -170 0  Single Sideband Phase Noise (dBc/Hz)

## Beginning the Measurement

1. Press the **New Msrmt** softkey.
2. Press **Yes, Proceed**. The HP 3048A 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 via a displayed warning and 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 HP 3048A's System Configuration table.)
3. When the Connect Diagram appears on the HP 3048A's display, connect the signal paths as shown in Figure 5-1. Figure 5-1 differs from the Connect Diagram shown on the HP 3048A's display. (The setup considerations provided in Table 5-3 will help you ensure that your measurement results are valid.)

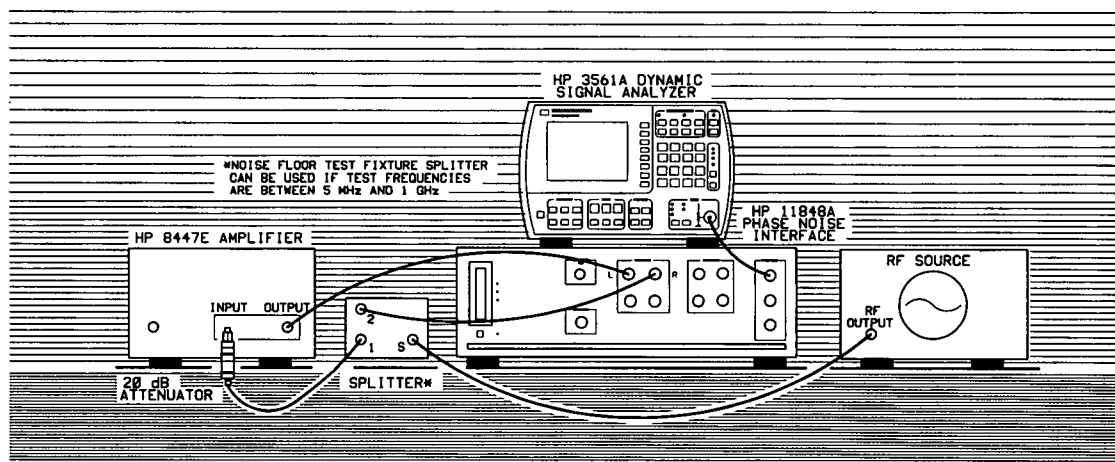


Figure 5-1. Setup diagram for the HP 8447E Amplifier Measurement Example.



### Calibrating the Measurement

4. After the connections have been made and checked, press the **Proceed** softkey.

Since the "Derive From Measured +/- 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 the HP 3048A prompts 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 the **Proceed** softkey.

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:  <ol style="list-style-type: none"><li>1. Filtering on power supply lines</li><li>2. Protection from microphonics</li><li>3. Shielding from air currents may be necessary.</li></ol>

---

**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 the HP 3048A prompts 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 the **Proceed** softkey.

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 ( $\pm 1$  division) on the meter scale.

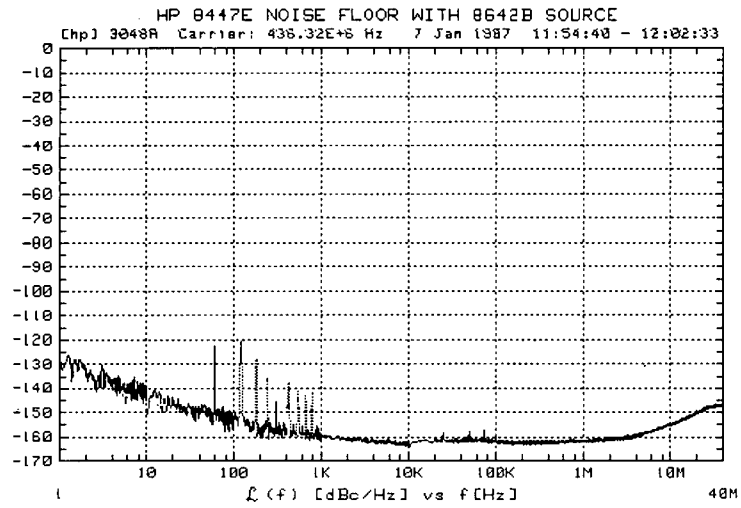
The system can now run the measurement. The segment data will be displayed on the computer screen as the data is taken until all segments have been taken over the entire range you specified in the **Type/Range** entry.

---

### 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 5-2 shows a typical phase noise curve for an HP 8447E Amplifier. This plot was generated by the HP 3048A.



**Figure 5-2. Typical Phase Noise Curve for an HP 8447E Amplifier.**

**Problem Solving**

## **Interpreting Display Messages**

The following are lists of the HP 3048A'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 by the HP 3048A, the number of the Error message appears ahead of the message.

### **Reference Messages**

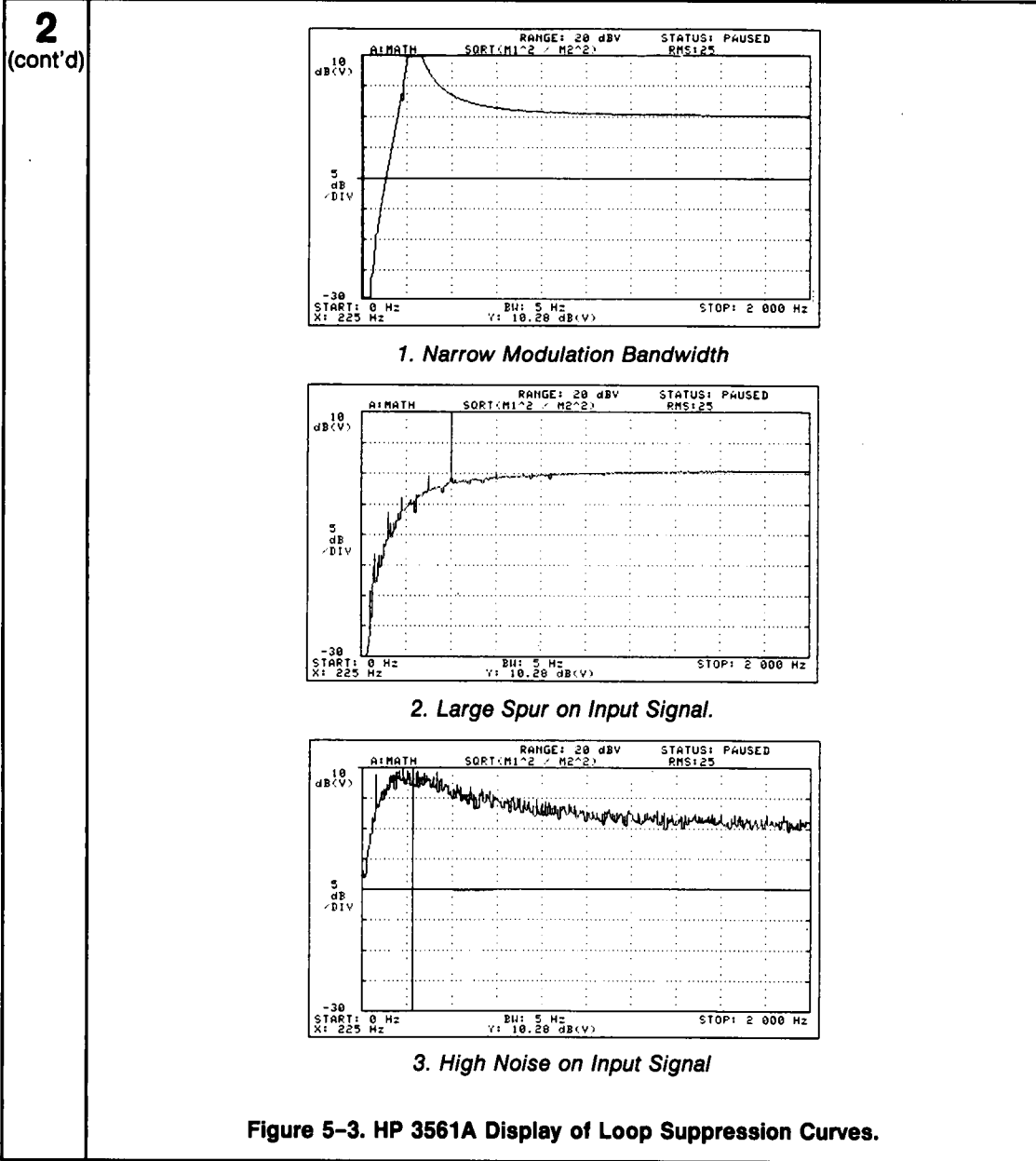
The reference message list begins after the Error message list. The HP 3048A designates a Reference message by placing the reference number at the end of the message.

A complete listing of all messages, warning, and, prompts can be found in the Messages section of the HP 3048A Reference Manual.

Table 5-4. Numbered Error Messages (1 of 17)

<p><b>1</b></p>	<p><b>The Signal level entering the NOISE INPUT port of the HP 11848A exceeds 1 volt peak.</b></p> <hr/> <p><b>Action:</b> Press the <b>[Retry]</b> key. If the overload condition was transient, the system will proceed with the measurement. If Error 1 occurs again, reduce the signal level at the NOISE INPUT port on the HP 11848A.</p> <p>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.</p>
<p><b>2</b></p>	<p><b>The loop suppression peak exceeds 10 dB.</b> 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.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><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. If these ports are not connected, connect them now, press the <b>[Retry]</b> softkey.</i></p> <p>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 system has completed the loop suppression characterization. Figure 5-3 illustrates the typical curve response for each of the three conditions.</p> <hr/> <p><b>Action:</b> 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 5-3 that most closely resembles the curve displayed on your HP 3561A.</p>

Table 5-4. Numbered Error Messages (2 of 17)



**Table 5-4. Numbered Error Messages (3 of 17)**

<p><b>2</b> (cont'd)</p>	<p><b>1. Narrow Modulation Bandwidth</b></p> <p>A noise hump 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 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 5-4. (The PTR for the measurement is determined by multiplying the VCO's Tuning Constant by its Voltage Tuning Range.)</p> <div style="text-align: center; margin: 20px 0;"> </div> <p style="text-align: center;">* Log/Lead Filter Number</p>
	<p><b>Figure 5-4. Phase Lock Loop Bandwidth as a Function of the Peak Tuning Range of the Measurement.</b></p>



Table 5-4. Numbered Error Messages (4 of 17)

<p><b>2</b> (cont'd)</p>	<p>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.</p> <ul style="list-style-type: none"><li>• 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.</li><li>• Use a different VCO source with greater modulation bandwidth.</li><li>• Decrease the PLL bandwidth to 1/10 the VCO's modulation bandwidth by decreasing the Peak Tuning Range (PTR) for the measurement. Use Figure 5-4 to determine the PTR required. The PTR can be reduced by decreasing the Tuning Voltage Range value entered. Divide the required PTR by the VCO's Tuning Constant to determine the appropriate Voltage Tuning Range to enter. (Keep in mind that reducing the PTR limits the HP 3048A'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 this manual.) 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.<ol style="list-style-type: none"><li>a. Connect a tracking generator output (such as the HP 3585A) to the tuning input port on your VCO.</li><li>b. Set the tracking generator output to sweep the audio spectrum.</li><li>c. Connect the RF output from your VCO to a modulation analyzer (such as an HP 8901A).</li><li>d. Set the modulation analyzer to measure FM.</li><li>e. Connect an audio spectrum analyzer to the MODULATION OUTPUT on the HP 8901A.</li><li>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 <math>\geq</math> ten times the PLL bandwidth for the measurement.</li></ol></li></ul> <p>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.</p>
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Table 5-4. Numbered Error Messages (5 of 17)

<p><b>2</b> (cont'd)</p>	<p><b>2. Large Spur on Input Signal</b></p> <p>A sharp peak on an otherwise correct loop suppression curve is evidence of a large spur (typically &gt; -40 dBc) near the phase lock loop (PLL) bandwidth of the measurement (within a factor of two). Press <b>Proceed</b> 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> provides information that will help you isolate the spur source).</p> <p>If you are not able to reduce the spur level to &lt; -40 dBc, it may be possible to make an accurate noise measurement by changing the PLL bandwidth. Measurement accuracy is only affected by spurs &gt; -40 dBc that are within a factor of 2 of the PLL bandwidth.</p> <p>The PLL bandwidth is shown as a function of Peak Tuning Range (PTR) in Figure 5-4. (The PTR for the measurement is determined by multiplying the VCO's Tuning Constant by the VCO's Voltage Tuning Range entered for the measurement. For further information about changing the PTR, refer to <i>Changing the PTR</i> in Chapter 3 of this manual.</p> <p><b>3. High Noise on Input Signal</b></p> <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;"><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. If these ports are not connected, connect them now, press the <b>Retry</b> softkey.</i></p> <p>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 <i>Evaluating Noise Above the Small Angle Line</i> in Chapter 3 of this manual.</p>
<p><b>3</b></p>	<p><b>Unable to detect the presence of a beatnote.</b></p> <p><b>Action:</b></p> <ol style="list-style-type: none"> <li>1. Check to be sure that the correct Phase Detector is selected in the Inst. Params menu.</li> <li>2. Check sources to verify the frequency of each output signal.</li> <li>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 this manual. An oscilloscope connected to the HP 11848A AUX MONITOR port can be helpful for monitoring and zeroing the beatnote.)</li> </ol>

Table 5-4. Numbered Error Messages (6 of 17)

<b>4</b>	<p><b>Unable to close the Phase Lock Loop.</b></p> <p><b>Action:</b> There are several possible conditions that can prevent the HP 3048A 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.</p> <ol style="list-style-type: none"><li>1. The system is not able to tune the beatnote to within the Capture Range set for the measurement. This possibility can be minimized by carefully following the <i>Checking the Beatnote</i> procedure provided in each measurement example in Chapter 3 of this manual. 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 in the HP 3048A's 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 system attempts to adjust it to 0 Hz can provide clues about tuning problems that may exist.</li><li>2. The beatnote drifted beyond the system's Capture Range before the HP 3048A was able to acquire lock. For further information on verifying the frequency stability of the beatnote, refer to <i>Tracking Frequency Drift</i> in Chapter 3 of this manual.</li><li>3. The VCO Tuning Constant entered for the measurement was not within a factor of 2 of the actual Tuning Constant, and the HP 3048A was not configured to <i>measure</i> the Tuning Constant for verification. For details on verifying the Tuning Constant of your VCO, refer to <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</li><li>4. The Peak Tuning Range set for the measurement is <math>&gt; 10</math> MHz and is causing the loop dynamics to be non-linear. When this condition exists, the non-linear response of the beatnote as the 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.</li><li>5. One of the sources is being injection locked as the HP 3048A is tuning the beatnote to 0 Hz. (Refer to <i>Minimizing Injection Locking</i> in Chapter 3 of this manual for recommended actions.)</li><li>6. The modulation bandwidth of the VCO source's tuning port is not wide enough to provide adequate phase margin for the 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 5-5. (The PTR for the measurement is determined by multiplying the VCO's Tuning Constant by its Voltage Tuning Range.)</li></ol>
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Table 5-4. Numbered Error Messages (7 of 17)

4  
(cont'd)

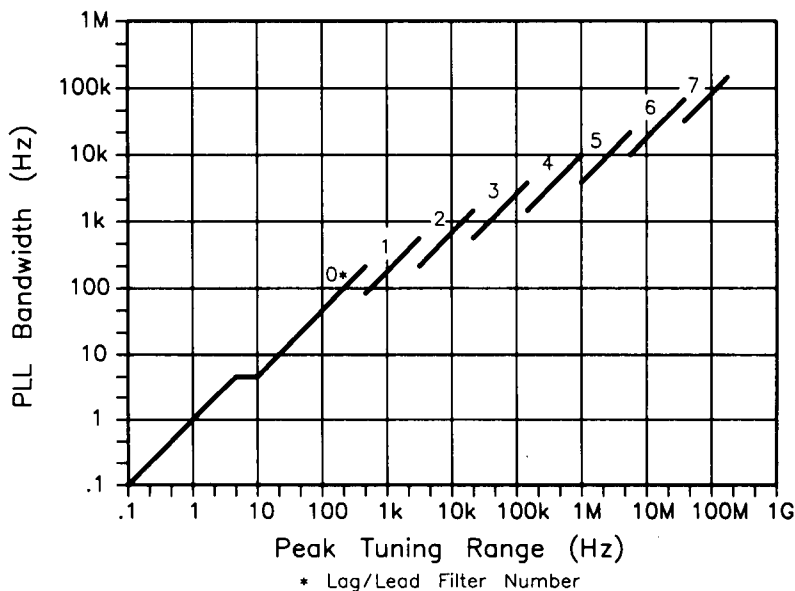


Figure 5-5. Phase Lock Loop Bandwidth as a Function of the Peak Tuning Range of the Measurement.

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 5-6 to determine the PTR required. The PTR can be reduced by decreasing the Tuning Voltage Range value entered. Divide the required PTR by the VCO's Tuning Constant to determine the appropriate Voltage Tuning Range to enter. (Keep in mind that reducing the PTR limits the HP 3048A's Frequency Drift Tracking Range for the measurement. For further information about changing the PTR, refer to *Changing the PTR* in Chapter 3 of this manual.)

Table 5-4. Numbered Error Messages (8 of 17)

<p><b>4</b> (cont'd)</p>	<p>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.</p> <ol style="list-style-type: none"> <li>a. Connect a tracking generator output (such as the HP 3585A) to the tuning input port on your VCO.</li> <li>b. Set the tracking generator output to sweep the audio spectrum.</li> <li>c. Connect the RF output from your VCO to a modulation analyzer (such as an HP 8901A).</li> <li>d. Set the modulation analyzer to measure FM.</li> <li>e. Connect an audio spectrum analyzer to the MODULATION OUTPUT on the HP 8901A.</li> <li>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 <math>\geq</math> ten times the PLL bandwidth for the measurement.</li> </ol> <p>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.</p> <p>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 <i>Evaluating Noise Above the Small Angle Line</i> in Chapter 3 of this manual. For information about measuring sources with high close-in noise, refer to Ignore Out of Lock in the Test Mode Section of Chapter 5 of the HP 3048A Reference Manual.</p>
<p><b>5</b></p>	<p><b>Measured VCO peak tuning range exceeds 500 kHz (or 200 MHz.)</b> The Peak Tuning Range limit for the system is 500 kHz (or 200 MHz if an RF analyzer is configured in the system). The Peak Tuning Range is the product of the VCO Tuning Constant multiplied by the Voltage Tuning Range of the VCO. (If the system <i>measures</i> the VCO's Tuning Constant, it will use the measured value to compute the Peak Tuning Range for the measurement.)</p> <p><b>Action:</b> Reduce the Voltage Tuning Range entered for the VCO source you are using, or select a VCO source with a lower Tuning Constant.</p>
<p><b>6</b></p>	<p><b>Unable to establish quadrature.</b> Occurs when source is under system control and system is unable to acquire quadrature. The 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.</p> <p><b>Action:</b> 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.</p>

Table 5-4. Numbered Error Messages (9 of 17)

<b>7</b>	<p><b>Measured beatnotes depict non-linear VCO Tuning Constant.</b> (Error 7 only occurs when the HP 3048A has been configured to <i>Measure the VCO Tuning Constant</i>.)</p> <p>The values shown on the display represent the measured beatnote frequencies for four tune voltage settings. The tune voltage settings are each derived as a percentage of the entered Voltage Tuning Range of the VCO (-45%, -15%, +15%, +45%) relative to the entered Center Voltage of the VCO Tuning Curve. For Example:</p> <p style="padding-left: 40px;">Voltage Tuning Range of VCO = <math>\pm 10V</math> Center Voltage of VCO Tuning Curve = <math>0V</math> Tune Voltage Settings = <math>-4.5V, -1.5V, +1.5V, +4.5V</math>.</p> <p>Refer to the HP 3048A Reference Manual <i>Instrument Parameters</i> in Chapter 2, Measurement Definitions for system requirements for VCO linearity.</p> <p>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.)</p> <p><b>Action:</b></p> <ol style="list-style-type: none"><li>1. This error will occur if a Tuning Voltage Range of <math>\pm 10</math> volts has been defined for a source with calibrated DC FM, and the HP 3048A is configured to <i>Measure the VCO Tuning Constant</i> rather than to <i>Compute</i> it. Refer to the HP 3048A Reference Manual "Enhanced Tuning" in the <i>Instrument Parameters</i> section of Chapter 2, Measurement Definitions for details on extending the Tuning Voltage Range of calibrated DC FM.</li><li>2. If Interval 2 (described above) <math>\gg 1</math>, and Interval 2 <math>\gg 3</math>, then: Reduce the value entered for the Voltage Tuning Range of the VCO and then initiate a New Measurement.</li><li>3. If there appears to be too little or no change between the measured frequency values (Intervals 1, 2, and 3 <math>\approx 0</math>) then :<ul style="list-style-type: none"><li>• Check the Tune Voltage cable connections.</li><li>• Verify that the VCO's tuning is enabled.</li><li>• Perform the <i>Estimating the Tuning Constant</i> procedure provided in Chapter 3 of this manual to verify the tuning response of the VCO and check that the entered VCO Tuning Constant is within a factor of 2 of the actual value.</li><li>• Refer to the HP 3048A Reference Manual <i>Instrument Parameters</i> in Chapter 2, Measurement Definitions for Tuning Constant linearity requirements.</li><li>• Verify that the beatnote is tuned to within the Capture Range for the measurement.</li></ul></li></ol>
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Table 5-4. Numbered Error Messages (10 of 17)

<p><b>7</b> (cont'd)</p>	<p>4. If the Frequency Intervals vary greatly and are considerably larger than expected for the tuning range of the the VCO, then:</p> <ul style="list-style-type: none"> <li>• 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.)</li> </ul> <p>5. If all four measured frequencies are 0 Hz, then:</p> <ul style="list-style-type: none"> <li>• Check for injection locking. Refer to <i>Minimizing Injection Locking</i> in Chapter 3 of this manual for further information.</li> </ul>
<p><b>8</b></p>	<p><b>Unable to find a beatnote.</b> System was not able to detect a beatnote above <math>-24</math> dBm (20 mVpk) between 0.1 Hz and 40 MHz.</p> <p><b>Action:</b> 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 this manual.) If you are making a Phase lock loop measurement, be sure the VCO Tuning Constant value entered for the measurement is within a factor of 2 of the actual value. Refer to the HP 3048A Reference Manual <i>Calibration Process</i> in Chapter 2, Measurement Definitions for information about the beatnote calibration technique.</p>
<p><b>9</b></p>	<p><b>The calibration spur could not be found.</b> The system was unable to detect a spur within a factor of 2 of the entered spur frequency.</p> <p><b>Action:</b></p> <ol style="list-style-type: none"> <li>1. Check that the correct spur frequency was entered.</li> <li>2. Verify the output signal from the spur source.</li> <li>3. Increase the spur level up to but not exceeding a maximum of <math>-20</math> dBc.</li> </ol> <p style="text-align: center;"><b>NOTE</b></p> <p style="text-align: center;"><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></p>
<p><b>10</b></p>	<p><b>Waveform departs too drastically from sinusoidal to be used in calculation of the Phase Detector Constant.</b> The 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.</p> <p><b>Action:</b> Check the harmonic content of the two input signals to the Phase Detector. All even harmonics must be below <math>-20</math> dBc to guarantee good symmetry of the beatnote waveform. If possible, increase the PTR to <math>&gt;10</math> kHz so that the beatnote is <math>&gt;1</math> kHz. Then the HP 3048A will measure the fundamental and its harmonics. (<math>&lt;1</math> kHz beatnote system measures slope of sinusoid.)</p>

Table 5-4. Numbered Error Messages (11 of 17)

11

**DC offset too large. Waveform does not cross 0 volts.** This error occurs when the system is measuring the Phase Detector Calibration 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 5-6 shows the relationship between the beatnote level and the level at the R input port.

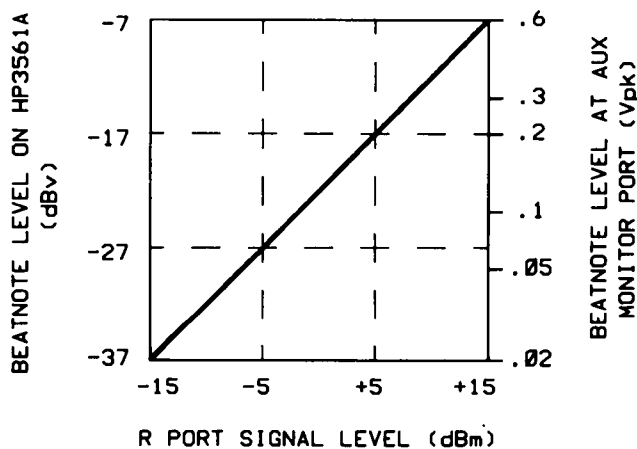


Figure 5-6. Beatnote Level Relative to the Signal Level at the R Port.

2. Verify that the phase detector DC offset is  $< 30$  mV ( $< 50$  mV if you are using the 1.2 to 1.8 GHz Phase Detector).
3. If the HP 3048A was not configured to measure the VCO Tuning Constant, verify that the entered value is within a factor of 2 of the VCO's actual Tuning Constant. A procedure for verifying the VCO's Tuning Constant is contained in *Estimating the Tuning Constant* in Chapter 3 of this manual.
4. When the 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 5-4. Numbered Error Messages (12 of 17)

<p><b>12</b></p>	<p><b>Insufficient span. Less than one waveform found.</b> A minimum of four zero crossings is necessary across the HP 3561A's display. This error occurs when the system is measuring the Phase Detector Constant and the expected beatnote is &lt; 1 kHz.</p> <p><b>Action:</b> When the 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. A procedure for evaluating the tuning sensitivity of the VCO is provided in <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</p>															
<p><b>13</b></p>	<p><b>The (File) does not exist in the current (Directory) and has not been loaded.</b> This error occurs when the HP 3048A attempts to load a file and the disc containing that file is not present in the designated mass storage device.</p> <p><b>Action:</b> Insert the disc containing the required file and proceed.</p>															
<p><b>14</b></p>	<p><b>DC offset from mixer &gt; 1/2 peak voltage.</b> The dc offset of the Phase Detector is determined and then used to adjust the Phase Detector calibration constant for true slope at the zero voltage point.</p> <p><b>Action:</b> Observe the beatnote on the HP 3561A display or with an oscilloscope connected to the AUX MONITOR port on the HP 11848A.</p> <ol style="list-style-type: none"> <li>1. Verify that the beatnote amplitude is correct for the signal level at the R input port on the HP 11848A. Figure 5-7 shows the relationship between the beatnote level and the level at the R port.</li> </ol> <div data-bbox="578 1155 1222 1596" data-label="Figure"> <table border="1"> <caption>Data points for Figure 5-7</caption> <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>.02</td> </tr> <tr> <td>-5</td> <td>-27</td> <td>.05</td> </tr> <tr> <td>+5</td> <td>-17</td> <td>.1</td> </tr> <tr> <td>+15</td> <td>-7</td> <td>.2</td> </tr> </tbody> </table> </div> <p><b>Figure 5-7. Beatnote Level Relative to the Signal Level at the R Port.</b></p>	R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL ON HP3561A (dBv)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)	-15	-37	.02	-5	-27	.05	+5	-17	.1	+15	-7	.2
R PORT SIGNAL LEVEL (dBm)	BEATNOTE LEVEL ON HP3561A (dBv)	BEATNOTE LEVEL AT AUX MONITOR PORT (Vpk)														
-15	-37	.02														
-5	-27	.05														
+5	-17	.1														
+15	-7	.2														

Table 5-4. Numbered Error Messages (13 of 17)

<p><b>14</b> (cont'd)</p>	<p>2. Verify that the Phase Detector DC offset is <math>&lt; 30</math> mV (<math>&lt; 50</math> mV for the 1.2 to 1.8 GHz Phase Detector). If the dc offset is within this limit and the beatnote level is <math>&lt; -23</math> dBV (<math>&lt; 0.1</math> 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.</p>															
<p><b>15</b></p>	<p><b>Detector Constant <math>&lt; 0.02</math> V/Rad.</b> The measured Phase Detector Constant was below the system's 20 mV limit.</p> <p><b>Action:</b> 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 5-8 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 <math>\geq +15</math> dBm (<math>\geq +7</math> dBm for the 1.2 GHz to 18 GHz Phase Detector).</p> <div data-bbox="490 1081 1131 1528" data-label="Figure"> <table border="1"> <caption>Data points from Figure 5-8</caption> <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> </div> <p><b>Figure 5-8. Beatnote Level Relative to the Signal Level at the R Port.</b></p>	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 5-4. Numbered Error Messages (14 of 17)

<p><b>16</b></p>	<p><b>Detector Constant &gt; 10 V/Rad.</b> The measured Phase Detector Constant exceeded the system's 10 V limit.</p> <p><b>Action:</b> 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 5-9 shows the relationship between the beatnote level and the level at the R port. If necessary, decrease the signal level at the R port.</p> <div data-bbox="578 693 1222 1155" data-label="Figure"> <table border="1"> <caption>Data points for Figure 5-9</caption> <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> </div> <p>Figure 5-9. Beatnote Level Relative to the Signal Level at the R Port.</p>	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														
<p><b>17</b></p>	<p><b>Measured Tuning Range of VCO is less than 0.2 Hz.</b> The system was probably unable to cause a beatnote.</p> <p>The Tuning Range of the VCO is measured in this case as:  <math>2 \times \text{Entered Voltage Range of VCO} \times \text{Measured VCO Tuning Constant}</math></p> <p><b>Action:</b> If the <i>expected</i> tuning range of the VCO source is much larger than 0.2 Hz:</p> <ol style="list-style-type: none"> <li>1. Check the Tune Voltage cable connection.</li> <li>2. Verify that the VCO source's tuning capability is enabled.</li> <li>3. Verify the VCO's tuning response by performing the procedure provided in <i>Estimating the Tuning Constant</i> in Chapter 3 of this manual.</li> <li>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 this manual.</li> </ol> <p>If the <i>expected</i> tuning range of the VCO source is near 0.2 Hz:</p> <ol style="list-style-type: none"> <li>1. Increase the tuning range, if possible, by increasing the Voltage Tune Range value entered for the measurement.</li> </ol>															

Table 5-4. Numbered Error Messages (15 of 17)

<p><b>18</b></p>	<p><b>The system perceives that the signals from the two sources differ by more than 15% of the VCO Tuning Range. The sources may be retuned to reduce the beatnote frequency, or the VCO Tuning Range may be adjusted.</b></p> <p>Once the HP 3048A has measured the VCO Tuning Constant, it is able to predict the tune voltage necessary to phase lock the loop. If the tuning range required for lock is &gt; 15% of the Peak Tuning Range (PTR), The system may not be able to pull the sources into lock, and will have very little tuning range (&lt; 5% of PTR) left for drift tracking.</p>
	<p><b>Action:</b></p> <ol style="list-style-type: none"> <li>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 press the <b>Span</b> softkey to 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 this manual.)</li> <li>2. If necessary, change the Center Voltage value entered for the VCO to reduce the initial beatnote frequency, or increase the Tuning Voltage Range entered for the 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 this manual.)</li> </ol>
<p><b>19</b></p>	<p><b>There is no HP 3585A in the configuration table.</b> This task requires that an HP 3585A Spectrum Analyzer is configured into the HP 3048A system.</p> <p><b>Action:</b> Enter an HP 3585A into the System Configuration Table.</p>
<p><b>20</b></p>	<p><b>Unable to detect presence of HP 3561A noise source. Check cabling and HP 3516A Noise Source Function.</b></p> <p><b>Action:</b> Verify that the HP 3561A rear-panel "Source Out" port is connected to the HP 11848A rear-panel "Noise Input" port.</p>
<p><b>21</b></p>	<p><b>User tone not within <math>\pm 500</math> Hz of 55 KHz. Press re-try if you wish to re-adjust and continue. The frequency of the tone generator is not close enough to the required limits.</b></p> <p><b>Action:</b> Adjust tone generator if possible. If the tone generator cannot meet this requirement, replace it with one that can.</p>

Table 5-4. Numbered Error Messages (16 of 17)

<b>22</b>	<b>User tone not within <math>\pm 5</math> dB of <math>-60</math> dBc. Press re-try if you wish to re-adjust and continue. The level from the tone generator is not close enough to the required limits.</b>
	<b>Action:</b> Adjust tone generator if possible. If the tone generator cannot meet this requirement, replace it with one that can to perform this test.
<b>23</b>	<b>Warning. Measurement has not been calibrated. 'New Msrmnt' should be requested.</b> Repeat Measurement or Noise Monitor was selected.
	<b>Action:</b> Select New Measurement or New Noise Monitor to allow the system to calibrate the measurement.
<b>24</b>	<b>No printer found in system configuration, Performance Tests cannot be initiated.</b> The Performance Tests require a printer to be connected to the system and entered in the System Configuration Table.
	<b>Action:</b> Connect a printer and enter the appropriate information into the System Configuration Table.
<b>25</b>	<b>Printer is not responding. Performance test cannot be initiated. Correct problem and Press 'Retry'.</b> The system cannot find the printer as addressed in the System Configuration Table.
	<b>Action:</b> Be sure the printer is connected on the system HP-IB bus. Verify that the printer is turned on and is set to the same address as is listed in the System Configuration Table.
<b>26</b>	<b>The system attempted to set (instrument) to (-) MHz.</b> The source was not able to respond to the frequency setting defined (or computed) for the measurement.
	<b>Action:</b> Verify that the Instrument Parameters defined for the measurement are correct and that the source's frequency range is adequate.
<b>27</b>	<b>The entered carrier frequency cannot be measured.</b> The HP 11729C cannot generate an intermediate frequency between 4.9 MHz and 1280 MHz for this carrier frequency.
	<b>Action:</b> Verify the carrier frequency. If the frequency is correct, verify the HP 11729C filter table in the System Configuration Table.

Table 5-4. Numbered Error Messages (17 of 17)

<b>28</b>	<b>Unable to disable PLL integrator by setting out-of-lock flip-flop. Test 03 results may be invalid. Fix the problem and try again. Test 03 will be aborted upon pressing 'Proceed' or 'Abort'.</b>
	<b>Action:</b> Troubleshoot and repair the HP 11848A Phase Noise Interface. Refer to the HP 11848A Service Manual for Troubleshooting information.
<b>29</b>	<b>Unable to disable PLL integrator by setting out-of-lock flip-flop. Test 09 results may be invalid. Fix the problem and try again. Test 09 will be aborted upon pressing 'Proceed' or 'Abort'.</b>
	<b>Action:</b> Troubleshoot and repair the HP 11848A Phase Noise Interface. Refer to the HP 11848A Service Manual for Troubleshooting information.
<b>30</b>	<b>Unable to disable PLL integrator by setting out-of-lock flip-flop. Test 10 results may be invalid. Fix the problem and try again. Test 10 will be aborted upon pressing 'Proceed' or 'Abort'.</b>
	<b>Action:</b> Troubleshoot and repair the HP 11848A Phase Noise Interface. Refer to the HP 11848A Service Manual for Troubleshooting information.
<b>110</b>	<b>Random noise obscures waveform.</b> The system is unable to measure the Detector Constant due to an erratic waveform. This error occurs during the Phase Detector Constant calibration.
	<b>Action:</b> Observe spectrum of beatnote and evaluate with respect to small angle criterion for expected PLL BW.

**Table 5-5. Reference Messages (1 of 7)**

<b>1</b>	<p><b>Establish quadrature manually.</b></p>
	<p><b>Action:</b> Manually adjust the source frequency or the phase shifter to attain quadrature (within <math>\pm 1</math> 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.</p>
<b>2</b>	<p><b>The FM Deviation on the (source) will be changed from ___ to ___ Hz.</b> 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 Tuning Constant (deviation) will result in a narrower Peak Tuning Range (PTR) for the measurement.</p>
	<p><b>Action:</b> 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.</p> <p>If your VCO source is an HP 8642A/B and the carrier frequency for the measurement is <math>&lt; 123</math> MHz, the following steps will enable you to increase the tuning range of the HP 8642A/B.</p> <ol style="list-style-type: none"> <li>1. Configure the HP 3048A Source Control block diagram for manual control of the HP 8642A/B.</li> <li>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.</li> </ol>

Table 5-5. Reference Messages (2 of 7)

<b>3</b>	<p><b>Cause FIRST calibration PEAK voltage at mixer input.</b></p> <p><b>Action:</b> 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 <b>Proceed</b>. When you are prompted to cause the second calibration peak, adjust to a maximum peak of the opposite polarity using the same technique.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><i>For this calibration technique to be most accurate, the two signal paths to the HP 11848A Phase Detector should be well matched (&gt;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></p>
<b>4</b>	<p><b>Apply modulation to carrier.</b> Either a double-sided spur or modulation of the same type as is being measured.</p> <p><b>Action:</b> 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.</p> <ul style="list-style-type: none"> <li>• Double-sided spur &lt; -20 dB</li> <li>• AM &lt; 10% (-26 dB)</li> </ul> <p>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 system).</p>
<b>5</b>	<p><b>Apply calibration spur to carrier.</b> A single-sided spur is expected.</p> <p><b>Action:</b> The spur is typically generated by combining a signal near the frequency of the device-under-test (DUT) with the DUT 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 DUT. The spur level should be high enough to be readily observable above the noise of the DUT on a spectrum analyzer. The spur level should not exceed -20 dBc relative to the DUT amplitude.</p>



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

<p><b>6</b></p>	<p><b>Remove the calibration spur.</b> If the spur signal is not removed, it will appear in the measurement and could affect the measurement results.</p>
	<p><b>Action:</b> Disconnect or turn off the spur source without disturbing the frequency or amplitude settings of the source.</p> <p style="text-align: center;"><b>NOTE</b></p> <p><i>If you wish 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 system from having the full dynamic range necessary to make a valid noise measurement.</i></p>
<p><b>7</b></p>	<p><b>Offset the source and reference signals by at least 1 Hz and not more than 20 MHz.</b> The 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:</p> <p>With RF Spectrum Analyzer in System . . . . . Offset Range: 1 Hz to 20 MHz  Without RF Spectrum Analyzer in System . . . . . Offset Range: 1 Hz to 50 kHz</p>
	<p><b>Action:</b> Adjust the frequency of the device-under-test (DUT) to offset it from the reference source frequency.</p> <p>If the DUT cannot be adjusted to create a frequency offset that is within the offset range specified above, substitute a different source for the DUT. Adjust the substitute source for the same power level as the DUT source it is replacing. Terminate any ports in 50Ω that are not connected during the substitution. Reconnect the DUT source after the calibration is completed.</p>
<p><b>8</b></p>	<p><b>Remove the beatnote and connect the system for noise measurement.</b></p>
	<p><b>Action:</b> Readjust the device-under-test (DUT) to the frequency of the reference source or reconnect DUT.</p>
<p><b>9</b></p>	<p><b>Phase lock has been lost.</b> This message can be caused by any one of the following conditions.</p> <ol style="list-style-type: none"> <li>1. Frequency drift &gt; 25% of the Peak Tuning Range.</li> <li>2. A phase transient &gt; 0.25 radians.</li> <li>3. Out-of-Lock detector set by search oscillator.</li> </ol>

Table 5-5. Reference Messages (4 of 7)

<p><b>9</b> (cont'd)</p>	<p><b>Action:</b> Press the <b>Proceed</b> key to cause the HP 3048A to attempt to relock the loop and re-measure the frequency segment. If the HP 3048A 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.)</p>
<p><b>10</b></p>	<p><b>The LNA is currently IN/OUT. This may be changed via the 'Toggle LNA' key.</b> This message only appears if the PULSED Carrier Type 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 system.</p> <p>If the system 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 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 system's noise floor) this degradation may affect the measurement results.</p> <p><b>Action:</b> Under most condition it is recommended that you proceed with the decision made by the system. 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.</p> <p>There are certain conditions when you may want to toggle the LNA OUT, however.</p> <ol style="list-style-type: none"> <li>1. When Pulse Mode is enabled. If the Phase Detector dc offset is <math>&gt; 5</math> mVdc, the system may not detect that the noise level is high enough to overload the LNA.</li> <li>2. To duplicate the exact conditions that existed for a previous measurement where the LNA was switched out.</li> <li>3. When you are performing the System Noise Floor Test and you wish to evaluate the system's noise floor without the LNA in the measurement path.</li> </ol> <p>If the system has decided to switch OUT the LNA and you are concerned about measurement sensitivity, you may wish 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 <math>-0.5V</math> or <math>+1V</math>, 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.</p>

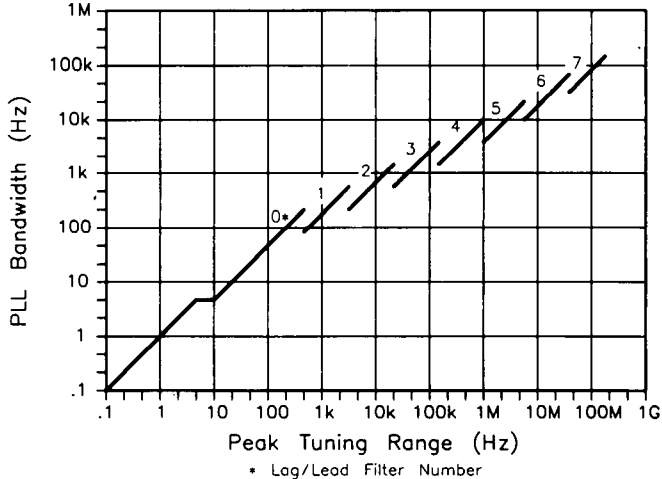
Table 5-5. Reference Messages (5 of 7)

<p><b>11</b></p>	<p><b>The LNA of the HP 11848A has been bypassed. This will result in a degradation of the system noise floor.</b> 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 system.</p> <p>If the system 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 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 system's noise floor) this degradation may affect the measurement results.</p> <p><b>Action:</b> 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:</p> <ol style="list-style-type: none"> <li>1. A large spur (&gt; -40 dBc) on one of the input signals.</li> <li>2. A high noise pedestal on one of the sources.</li> <li>3. Spurs at the output of the Phase Detector.</li> </ol> <p>To determine whether bypassing the LNA has affected your noise measurement results, compare your results to the noise floor provided by the system when the LNA is OUT. Use the Phase Detector Constant value measured by the HP 3048A to determine the system's noise floor with the LNA OUT from the Detector Sensitivity graph (Figure 4-7). If it appears that your measurement may have been limited by the 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.</p> <ol style="list-style-type: none"> <li>1. Reduce the Phase Detector Calibration Constant by reducing the signal level into the R port of the Phase Detector. Then reinitiate a New Measurement.</li> <li>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 this manual.</li> </ol> <p>If you wish to further evaluate the LNA decision, abort the measurement and access the Special Functions display. Select the PULSED Carrier Type and then initiate 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.</p>
<p><b>12</b></p>	<p><b>A comparison of theoretical and actual PLL suppression indicates a degradation of the accuracy specified for the HP 11848A.</b> 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 &gt; 1 dB.</p>

Table 5-5. Reference Messages (6 of 7)

<p><b>12</b> (cont'd)</p>	<p><b>Action:</b></p> <ol style="list-style-type: none"><li>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 Tuning Constant. Abort the measurement and verify that these calibration constants are accurate.<ol style="list-style-type: none"><li>a. Verify that the VCO Tuning 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 this manual.)</li><li>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 system.</li></ol></li><li>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 this manual.<ol style="list-style-type: none"><li>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 <math>&gt; +15</math> dBm).</li><li>b. Verify that all even harmonics are <math>\leq -30</math> dBc on the beatnote and <math>\leq -20</math> dBc on the input signals.</li><li>c. Check for injection locking.</li><li>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 this manual for a procedure.)</li></ol></li><li>3. If the beatnote signal meets the preceding tests, proceed with a New Measurement. If this same message is displayed again, press the <b>Suppr. Plot</b> key to access a plot of the PLL suppression curve.<ol style="list-style-type: none"><li>a. If the measured curve does not match the theoretical because it is noisy, press <b>Proceed Theor</b> 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.</li><li>b. If the measured curve does not match the theoretical because it has high peaks and the Accuracy Spec. Degradation is <math>\leq 2</math> dB, press <b>Proceed w/Adj</b> 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 5-10 shows PLL bandwidth relative to the Peak Tuning Range (PTR) set by the VCO source. (Refer to the HP3048A Reference Manual, Chapter 2, Measurement Definitions for further information about the PTR.)</li></ol></li></ol>
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**Table 5-5. Reference Messages (7 of 7)**

<p><b>12</b> (cont'd)</p>	<p>c. If the Acc. Spec. Deg. is &gt;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 Acc. Spec. Deg. is still &gt;2 dB, press Proceed W/Adj to get an approximate noise measurement for use in further troubleshooting the problem.</p>  <p style="text-align: center;">* Lag/Lead Filter Number</p>
<p><b>13</b></p>	<p><b>Establish a beatnote less than or equal to ( ) Hz.</b> 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.</p> <p><b>Action:</b> 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.</p>
<p><b>102</b></p>	<p><b>'CALDATAHI' and 'CALDATALO' will be restored from disc files.</b> Cal data in memory is in a unknown state. System will restore cal data from the mass storage media file.</p>
<p><b>103</b></p>	<p><b>NO PRINTER FOUND IN SYSTEM CONFIGURATION.</b> Functional Checks require a printer be configured in the system.</p> <p><b>Action:</b> Connect a printer to the system, and enter it in the System Configuration Table.</p>

## 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. 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 5-11). The signal level required for the measurement depends on the noise floor level needed to measure the DUT.

Figure 5-12 shows the relationship between the signal level at the R port and the measurement noise floor.

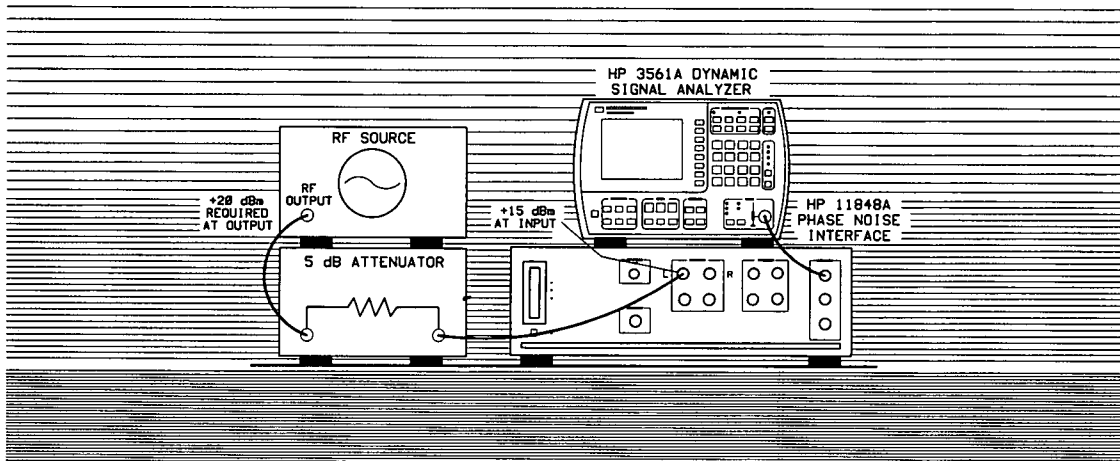
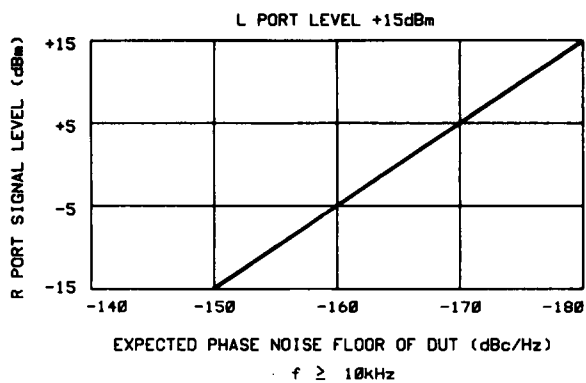


Figure 5-11. Output Level Required From Signal Source with In-line Attenuator.



**Figure 5-12. Measurement Noise Floor Relative to R Port Signal Level.**

### **An Amplifier**

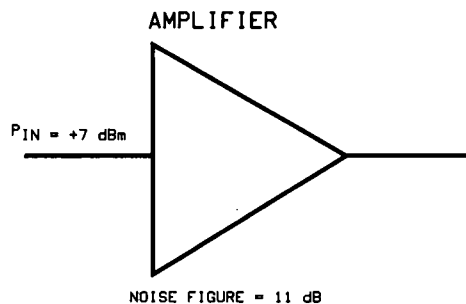
If a source is not able to provide a sufficient output level, or if additional isolation is needed at the output, it may be necessary to insert a low noise amplifier at the output of the source.

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

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

**For Example,**



$$\mathcal{L}(f) \text{ out} = -174 + 11 - 7 - 3 = \frac{-173 \text{ dBc}}{\text{Hz}}$$



**6** Evaluating  
Measurement Results



# 6

## Evaluating the Measurement Results



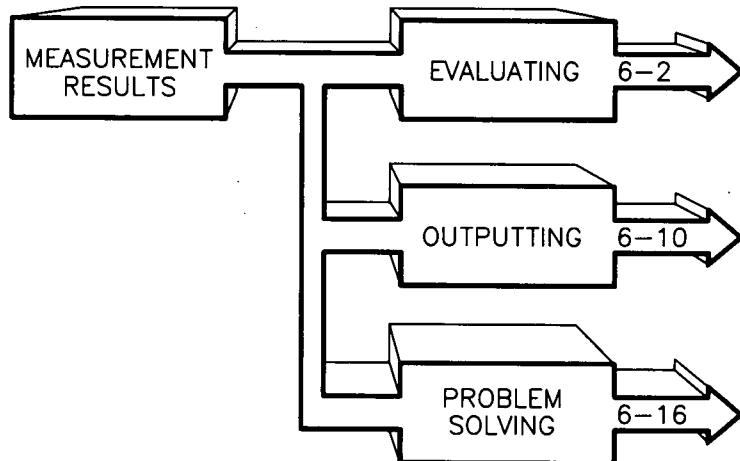
### In This Chapter

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 HP 3048A should be displaying a graph of its measurement results. Storing the measurement results in the Result File is recommended for each measurement.

### The Directory

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.
- **Outputting the Results** – Refer here for information about the graphics and hard copy functions.
- **Problem Solving** – Refer here for help in solving specific problems on the noise graph.



## 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 device-under-test (DUT). 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 DUT.

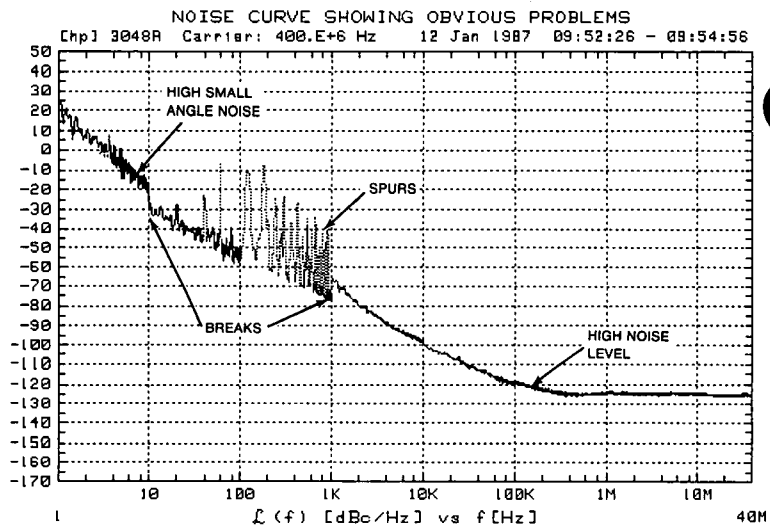


Figure 6-1. Noise Plot Showing Obvious Problems

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## Looking For Obvious Problems

Obvious problems on a graph are such things as:

- 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 this chapter 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 *device-under-test*
- The noise floor and accuracy specifications of the *HP 3048A*
- The noise characteristics of the signal source used as the *reference source*

### The Device-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 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.

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## The HP 3048A

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 device-under-test may have similar or lower noise floor specifications than the HP 3048A. 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 device-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 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*.

1. The same source that you used to measure your device-under-test should be used for the *Noise Floor Test*.
2. 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).

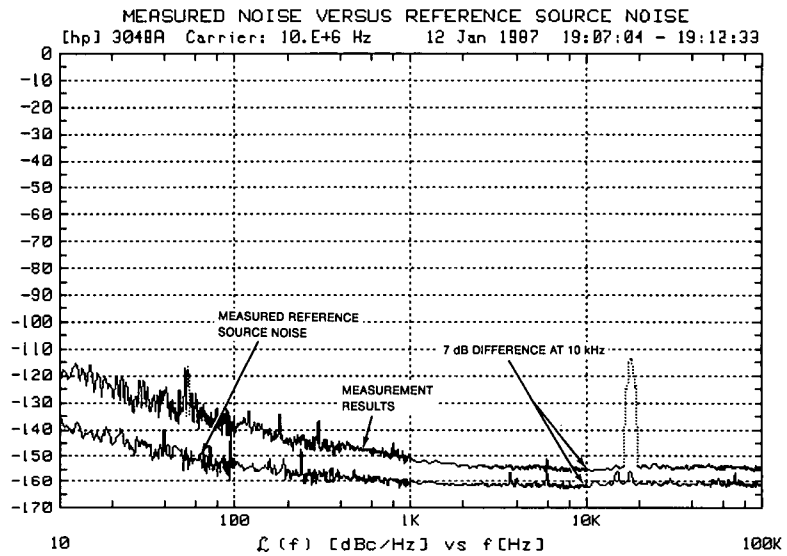
When you have obtained a noise floor curve for the system, compare it against the measurement results for your DUT. Check for areas on the DUT graph that are at or near the system noise level.

## The Reference Source

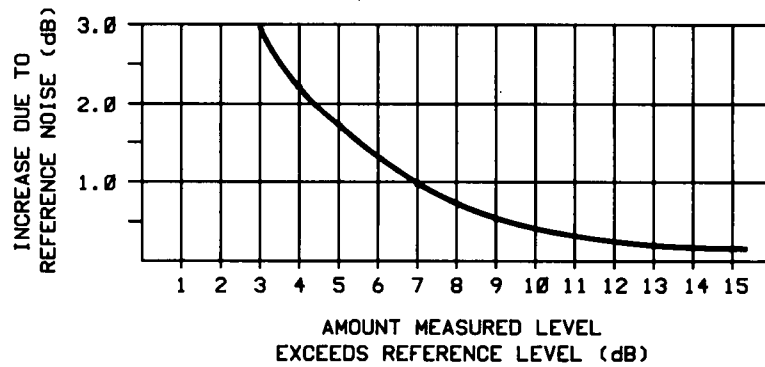
It is important that you know the noise and spur characteristics of your reference source when you are making phase noise measurements. (The noise measurement results provided when using this technique reflect the sum of all contributing noise sources in the system.)

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 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 DUT.



**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.**

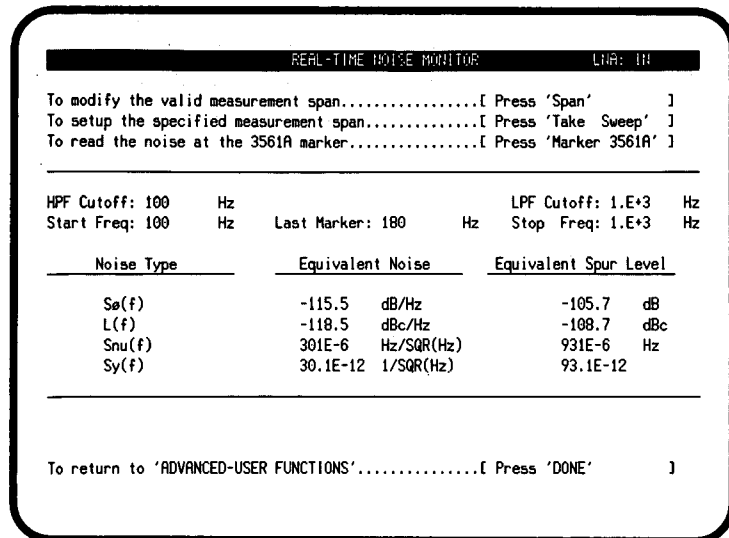
For example, applying the 7 dB difference in noise levels, shown in Figure 6-2 at 10 kHz, to the graph, reveals that the measured results should be decreased by about 1 dB at 10 kHz to reflect the actual noise of the DUT.

## Gathering More Data Using the Noise Monitor Mode

The HP 3048A's Noise Monitor Mode allows you to gather specific information about the noise level directly from the spectrum analyzer. In the Noise Monitor Mode, you can monitor the noise level being measured as you make changes to the setup or device-under-test. This allows you to use the HP 3048A as a phase noise, troubleshooting tool.

To access the Noise Monitor Mode:

1. Press the **Spcl. Funct'n** key available at the Main Software Level.
2. Press the **Noise Monitor** key to access the Real-Time Noise Monitor menu.



3. Press the **Span** softkey to step through the sweep-segments ("Start Freq:", "Stop Freq:" on the display). Select the segment that will place the phenomenon you wish to evaluate nearest to the center of the HP 3561A display.



4. After you have selected the appropriate segment, press the **Take Sweep** key on the HP 3561A to initiate a measurement of the selected segment. Notice that the HP 3561A is displaying a measurement trace that has been captured. Whenever you wish to recapture a new trace, press the **Take Sweep** key.
5. Use the marker arrow keys on the HP 3561A to position its marker at the point you are interested in.
6. Press the **Marker 3561A** key to update the marker data shown on the HP 3048A's menu. Note that the level of the marker is shown normalized to a 1 Hz bandwidth (Equivalent Noise) and unnormalized (Equivalent Spur Level) for each of the different measurement types.

The cutoff frequencies shown on the menu for the high-pass (HPF) and low-pass (LPF) filters can be changed using the corresponding softkeys. The frequency range between the cutoff frequencies is the bandwidth over which noise is viewed on the HP 3561A display.

### **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.

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### **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 device-under-test or data sheets for components used in the device) can often provide insights into the expected performance of the device-under-test.

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## Outputting the Results

This section describes the HP 3048A's capabilities for generating a printed or plotted hardcopy of your measurement results.

**Note** Whenever you generate a hardcopy of the noise graph for your records, we recommend that you also generate a copy of the Parameter Summary as well. (The Parameter summary is generated along with the noise graph by pressing the **Shift** **Hardcopy** softkey.)

### External Printer

If an external printer is connected to the HP 3048A, a hard copy of the HP 3048A graphics display can be printed by pressing the **Hardcopy** softkey. The external printer must be listed in the HP 3048A's System Configuration table. (Refer to Appendix A for details on configuring the HP 3048A to operate an external printer.)

### External Plotter

To plot a copy of the results graph using an external plotter, press the **SHIFT** key on the keyboard and the **Redraw Graph** key on the display at the same time. The **SHIFT** key, plotter function can also be used in conjunction with other graphics keys to produce many of the graph variations described in Table 6-1.

The plotter must be listed in the HP 3048A's System Configuration table. (Refer to Appendix A for details about adding instruments to the System Configuration table.) After you have added the plotter to the System Configuration table, you can press the **Plotter Pens** key, which will appear below the table, to assign pen selection for the different portions of the graph (grid, label, trace, and spurs).

### Graphics Functions

Table 6-1 lists each of the graphics functions provided by the HP 3048A. Following the table is a brief procedure that demonstrates the operation of many of the graphics functions.

**Table 6-1. List of Graphics Key Functions**

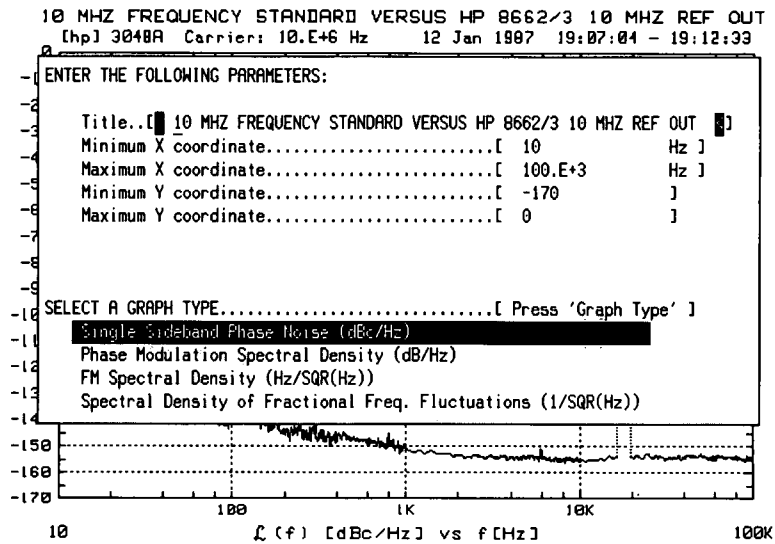
<b>Key Name</b>	<b>Description</b>
<b>Hard Copy</b>	Sends contents of displayed screen to the external printer listed in the System Configuration table.
<b>Results Files</b>	Accesses the capabilities for Storing and Recalling measurement results.
<b>Define Graph</b>	Opens a window for changing the graph parameters. (Press Redraw Graph to create a new graph using the new graph parameters.)
<b>Marker ON/OFF</b>	Enables the function for placing a marker on the noise graph.
<b>Other Keys</b>	Accesses the second set of graphics function keys.
<b>Redraw Graph</b>	Redraws the noise graph on the display.
<b>Plot Data</b>	Plots the noise data on the display without drawing the graticule.
<b>Redraw Graticule</b>	Redraws the graph without the noise plot.
<b>Param Summary</b>	Accesses the list of measurement setup and calibration data for the current noise graph displayed.
<b>Computed Outputs</b>	Accesses additional formats of the test results including: Sigma vs. Tau, Integrated Noise, Residual FM, and a listing of the measured spurs.
<b>Plot w/o Spurs</b>	Plots the normalized noise only, without including the unnormalized spurs.
<b>Slope Lines</b>	Accesses the function for placing slope lines on the noise graph.

## Graphics Demonstration

The following demonstration will help you become familiar with operating the graphics functions. To perform the demonstration, you will need to have the noise curve from your measurement displayed on the HP 3048A.

### Changing the Graph

1. Press the **Define Graph** key.

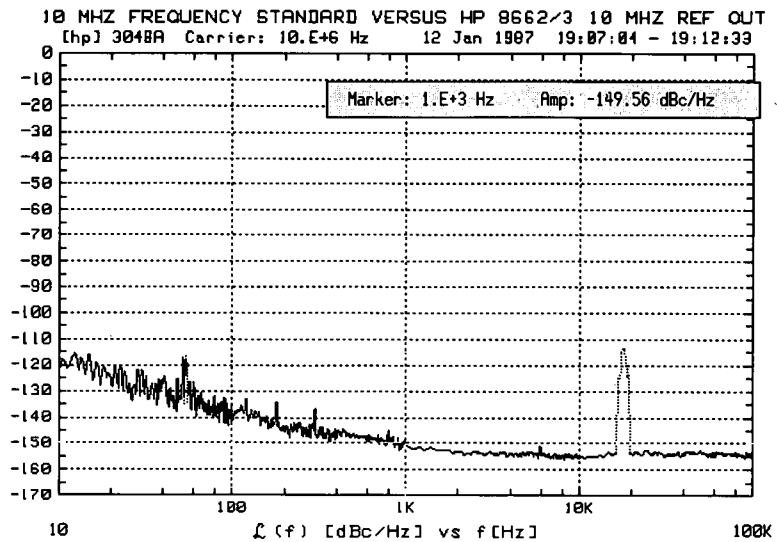


This key opens a window to the graph parameters. Changing these parameters allows you to redefine the *axis* on the graph or select a different *graph type*.

2. Press the **Define Graph** key again to close the window.

## Reading the Level at a Single Point

1. Press the **Marker ON/OFF** key.

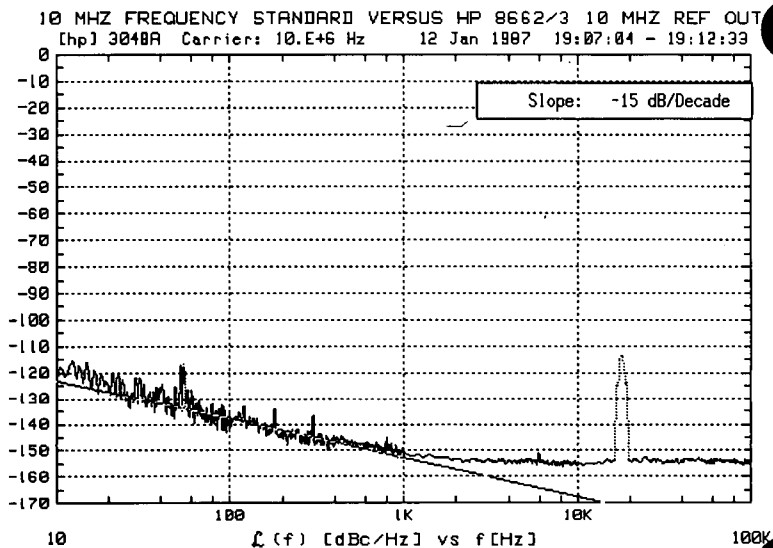


This key activates the marker function. The right and left arrow keys, or the knob, on your keyboard will enable you to position the marker anywhere along your noise curve. The marker window indicates the level and offset frequency at the marker position.

2. Press the **Marker ON/OFF** key again to turn off the marker function.
3. Now press **Other Keys** to access more graphics functions.

## Reading the Slope of the Noise Curve

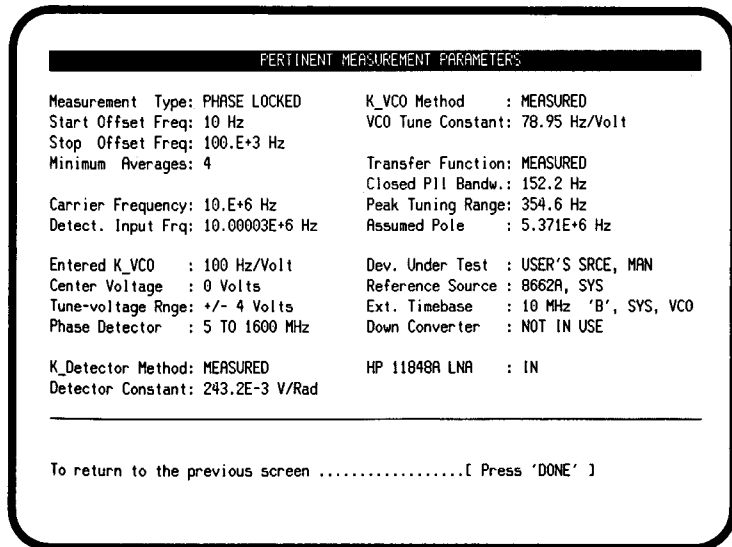
1. Press the **Slope Lines** key.



2. Use the down arrow key or the knob on your keyboard, to move the cursor down from the center of the graph until it is positioned on the noise curve at 1 kHz.
3. Press **New Line**.
4. Now press the cursor positioning (arrow) keys, or turn the knob, to rotate the slope line until it lies along the average curve of the plot. You can now read the average slope of the noise curve directly from the slope window shown on the graph.
5. Notice the **Hard Copy** key. If you have a printer connected to the HP 3048A via its HP-IB connection and the printer's address has been entered into the System Configuration table, you can press this key to generate a print out of the displayed graph including the slope line.
6. Press **Done** to exit the slope lines function.

## Reviewing the Measurement Parameters

1. Press the **Params Summary** key.



This key 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 HP 3048A. We recommend that you include a hard copy of this menu with any copies of the measurement results that you create for your records.

2. Press **Done** to exit the parameter summary menu.

You have completed the graphics demonstration. The remaining graphics functions operate similarly to the functions you have just used.



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## Problem Solving

<i>If you need to know:</i>	<i>Refer to:</i>
• <i>What to do about breaks in the noise graph .....</i>	<b>Discontinuity In the Graph (6-17)</b>
• <i>How to verify a noise level that is higher than expected .....</i>	<b>High Noise Level (6-19)</b>
• <i>How to verify unexpected spurs on the graph .....</i>	<b>Spurs on the Graph (6-22)</b>
• <i>How to interpret noise above the small angle line.....</i>	<b>Small Angle Line (6-26)</b>

## 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.

The following table 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
<p>Break between segments where closely spaced spurs are resolved in one segment but not in the next.</p>	<p>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.</p>	<p>Use the Noise Monitor Mode to evaluate the noise spectrum at the break frequency on the graph. (Refer to <i>Gathering More Data</i> in the <i>Evaluating the Results</i> section of this chapter for details on using the Noise Monitor Mode.)</p> <p>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.</p>
<p>Erratic Noise: One or more segments out of line with the rest of the graph.</p>	<p>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.</p>	<p>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. You can also use the Noise Monitor Mode to set up the HP 3561A and then manually set the HP 3561A to display the noise in the time domain. (Refer to <i>Gathering More Data</i> in the <i>Evaluating the Results</i> section of this chapter for details on using the Noise Monitor Mode.)</p>

Table 6-2. Potential Causes of Discontinuity in the Graph (2 of 2)

Circumstance	Description	Recommended Action
<p>Break at the beginning of the segment following <math>\text{PLL Bandwidth} \div 4</math></p>	<p>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:</p> <ol style="list-style-type: none"> <li>1) An inaccurate Tuning or Phase Detector Constant,</li> <li>2) Injection locking, or</li> <li>3) Noise near or above the small angle line at an offset equal to the PLL Bandwidth for the measurement.</li> </ol>	<p>Check the Parameter Summary list provided for your results graph to see if any accuracy degradation was noted.</p> <p>If the Tuning constant and Phase Detector were not <i>measured</i> by the HP 3048A, verify their accuracy by selecting the "Measured" calibration method and then initiating a New Measurement.</p> <p>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.</p>
<p>Small Break at 100 kHz, 10 kHz, or 1 kHz</p>	<p>May occur when the HP 11848A calibration data sent from the factory is not being used.</p>	<p>Check to be sure that the serial number on the data disc matches the serial number on the HP 11848A you are using.</p> <p>Try reloading the calibration data using the following procedure:</p> <ol style="list-style-type: none"> <li>1. Insert disc 5.</li> <li>2. Press <span style="border: 1px solid black; padding: 2px;">Spcl Funct'n</span></li> <li>3. Press <span style="border: 1px solid black; padding: 2px;">3048A Sys Chk</span></li> <li>4. Press <span style="border: 1px solid black; padding: 2px;">Manage Cal Data</span></li> <li>5. Press <span style="border: 1px solid black; padding: 2px;">Load Cal Data</span>.</li> </ol>

## High Noise Level

The noise level measured by the HP 3048A 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																												
<p><b>Reference Source</b></p>	<p>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 DUT.</p> <div data-bbox="591 940 1361 1297" data-label="Figure"> <table border="1"> <caption>Data points for the graph in Table 6-3</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>2.2</td></tr> <tr><td>5</td><td>1.8</td></tr> <tr><td>6</td><td>1.5</td></tr> <tr><td>7</td><td>1.3</td></tr> <tr><td>8</td><td>1.1</td></tr> <tr><td>9</td><td>1.0</td></tr> <tr><td>10</td><td>0.9</td></tr> <tr><td>11</td><td>0.8</td></tr> <tr><td>12</td><td>0.75</td></tr> <tr><td>13</td><td>0.7</td></tr> <tr><td>14</td><td>0.65</td></tr> <tr><td>15</td><td>0.6</td></tr> </tbody> </table> </div> <p>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 <i>Three Source Comparison</i> technique (described in the Reference Manual) to determine the absolute noise level of each source.</p>	Amount Measured Level Exceeds Reference Level (dB)	Increase Due to Reference Noise (dB)	3	3.0	4	2.2	5	1.8	6	1.5	7	1.3	8	1.1	9	1.0	10	0.9	11	0.8	12	0.75	13	0.7	14	0.65	15	0.6
Amount Measured Level Exceeds Reference Level (dB)	Increase Due to Reference Noise (dB)																												
3	3.0																												
4	2.2																												
5	1.8																												
6	1.5																												
7	1.3																												
8	1.1																												
9	1.0																												
10	0.9																												
11	0.8																												
12	0.75																												
13	0.7																												
14	0.65																												
15	0.6																												

**Table 6-3. Potential Causes of a Higher than Expected Noise Floor (2 of 3)**

Cause	Recommended Action										
<p><b>HP 3048A</b></p>	<p>Refer to Chapter 1 for the noise and accuracy specifications of the HP 3048A. If you suspect that the HP 3048A is not meeting its noise level specifications, run the Noise Floor Test. Refer to the HP 3048A Calibration Manual for the Noise Floor Test Procedure.</p> <p>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 DUT.</p> <div data-bbox="657 934 1252 1297" data-label="Figure"> <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> </div>	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 6-3. Potential Causes of a Higher than Expected Noise Floor (3 of 3)**

Cause	Recommended Action
<b>Device-Under-Test</b>	<p>Sometimes the device-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. The HP 3048A's Noise Monitor Mode can provide an effective tool for troubleshooting the phase noise of your DUT. (Refer to <i>Gathering More Data</i> in the <i>Evaluating the Results</i> section of this chapter for details on using the Noise Monitor Mode.)</p>
<b>Environment</b>	<p>The lower the noise level of the device-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.</p> <ol style="list-style-type: none"> <li>1. Filtering on power supply lines.</li> <li>2. Protection from microphonics.</li> <li>3. Protection from external noise sources on unshielded oscillators.</li> <li>4. Shorter coax cable lengths or semi-rigid cable (particularly for the Tune Voltage Output).</li> <li>5. Shielding from air currents may even be necessary for very low noise devices.</li> </ol>
<b>Inserted Amplifier</b>	<p>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 (<math>\mathcal{L}_{(f)out}</math>) with the added noise of the amplifier.</p> $\mathcal{L}_{(f)out} = -174 \text{ dB} + \text{Amplifier Noise Figure} - \text{Power into the Amplifier} - 3 \text{ dB}$
<b>AM Noise</b>	<p>To ensure that a high phase noise level is not due to high AM noise, measure the AM noise of the device-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.</p>

---

## 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) across 3 or 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
	$\geq 4$	17
	$\geq 8$	12
	$\geq 30$	6
> 100 kHz	Any	4

### To List the Marked Spurs

1. Press the **Cmpud Outputs** softkey. (If this key does not appear on the display below your noise graph, press **Other Keys**.)
2. Press the **Spur List** key.

The screenshot shows a device display titled "SPUR LIST". At the top, it shows "Start Frequency (Hz): 1" and "Stop Frequency (Hz): 40.E+6". To the right, it says "Acceptable Values: 1 TO 40.E+6". Below this is a table with two columns: "Spur Freq. (Hz)" and "Spur Ampl. (dBc)". The table lists several spurs with their frequencies and amplitudes. At the bottom of the display, it says "To return to 'COMPUTED RESULTS' ..... [ Press 'DONE' ]".

Spur Freq. (Hz)	Spur Ampl. (dBc)
60	-75.8
120	-88.52
157	-102.4
170	-104.2
180	-84.88
240	-104.9
253	-109.2
300	-103.6
360	-106.6

3. Enter the start and stop frequencies of the range over which you wish to list the spurs that were marked during your noise measurement.
4. Press **List Spurs** to generate the spur list.
5. Press **Hard Copy** to output a printed copy of the spur list.



### 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 device-under-test wiring, etc. A breadboarded or prototype circuit should be well shielded from *external* RF fields when phase noise measurements are being made.

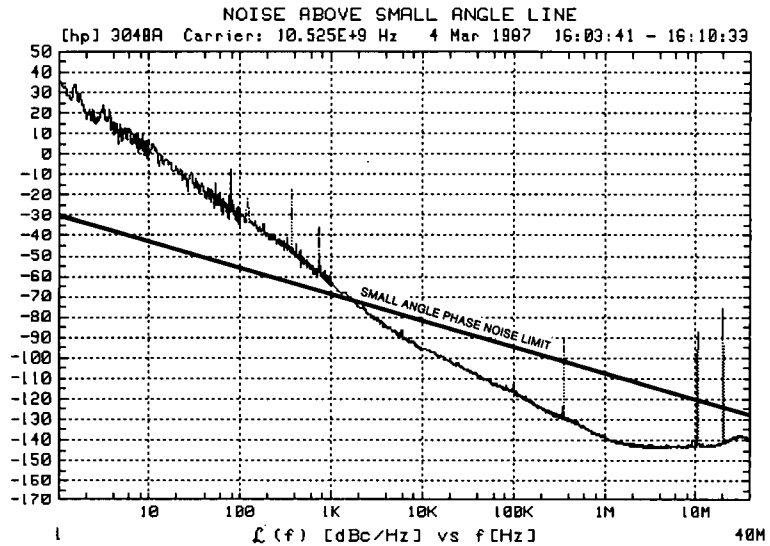
**Table 6-4. Potential Spur Sources (1 of 2)**

Spur Sources	Description	Recommended Action
<b>Internal</b>	Potential spur sources within the measurement system include the HP 3048A System, the device-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 Appendix B. If you suspect that the device-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.
<b>External</b>	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
<b>Electrical</b>	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.	<p>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 HP 3048A's spur listing function.</p> <p>The best high frequency resolution is obtained by using the Noise Monitor Mode function. The Noise Monitor Mode allows you to observe the spur on the system's spectrum analyzers. The resolution available in Noise Monitor Mode is 0.01 Hz below 100 kHz and 0.1 Hz above 100 kHz (when using an HP 3585A). Using this mode to observe the spur as you make changes to your circuitry or measurement setup can provide an effective way to troubleshoot and isolate the spur source. (Refer to <i>Gathering More Data</i> in the <i>Evaluating the Results</i> section of this chapter for a procedure for using the Noise Monitor Mode.)</p>
<b>Mechanical</b>	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.  $\mathcal{L}(f)$  Is Only Valid for Noise Levels Below the Small Angle Line**

Caution must be exercised when  $\mathcal{L}(f)$  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  $\mathcal{L}(f)$  is correct; above the line,  $\mathcal{L}(f)$  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  $\mathcal{L}(f)$  is still valid.



# A

## Installation



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### Setting Up the System

This appendix is intended to help you set up your HP 3048A Phase Noise Measurement System.

The topics covered in this section include:

- Preparing the Site
- Unpacking the System
- Setting Up the System Hardware
- Loading the System Software
- Setting Up the HP-IB Addresses
- Verifying Operation

After you set up your system, return to Chapter 1 for details about making noise measurements with the HP 3048A.

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### Preparing the Site

In preparing the site for your system, consider:

1. Environmental limitations of the system,
2. System placement,
3. HP-IB cable length limitations, and
4. 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.

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**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, *Unpacking, Storing, and Shipping Considerations*, also gives guidelines to consider when storing or shipping the system.

---

**Caution**

When opening boxes, do not use long-bladed knives, screwdrivers, or instruments 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 Calibration Manual System for more detailed information about accessing calibration and performance tests.)

---

**Table A-1. Site Preparation Considerations**

<p><b>Environmental Limits</b></p> <p>Temperature:</p> <p>Relative humidity:</p> <p>Altitude:</p> <p>Magnetic field strength:</p> <p>Adding Equipment:</p> <p>Avoid these characteristics:</p>	<p>For the standard system or Option 201            0°C to +55°C (Recalibration (option 1) is required for a temperature change greater than ±10°C.)</p> <p>&lt; 95% (maximum wet bulb temperature = 40°C)</p> <p>&lt; 4600 meters (15 000 ft)</p> <p>&lt; 0.04 gauss p-p</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.</p> <p>Mechanical vibration            Low frequency magnetic fields            Electromagnetic interference (EMI)</p>
<p><b>System Placement</b></p> <p>Instrument table:</p> <p>Air Flow:</p> <p>Area:</p>	<p>Review the installation documentation for each instrument</p> <p>Choose a table that can handle the weight of the system: from 31 to 275 kg (68 to 603 lbs) depending on options ordered.</p> <p>Provide at least 10 cm (4 in.) of space behind each instrument to allow adequate air flow to internal circuitry.</p> <p>Allow enough clearance around the system and the device under test so they will not be accidentally bumped during a measurement.</p>
<p><b>HP-IB Requirements</b></p> <p>Total cable length:</p>	<p>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.)</p>
<p><b>Power Requirements</b></p> <p>Maximum power consumption:</p> <p>Power source required:</p> <p>Grounding:</p> <p>Minimum Interference:</p>	<p>Between 190 and 900 VA depending on the options included.</p> <p>Either 100, 120, 220, 240 VAC (at +5%, -10%, 48 to 66 Hz single phase).</p> <p>AC power cords for the instruments and service outlets are the three-conductor type (which include a safety earth-ground conductor).</p> <p>Safe operation of the system requires that the (mains) power cord be connected only to an outlet with a protective earth contact.</p> <p>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.</p>

**Table A-2. Unpacking, Storing, and Shipping Considerations**

<p><b>Initial Inspection</b> Inspect for damage:</p>	<p>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.</p>
<p><b>Unpacking</b> Procedure for each box:</p>	<ol style="list-style-type: none"> <li>1) Carefully cut the reinforced tape sealing the top box flaps.</li> <li>2) Remove foam or Polystyrene from the top of the instrument.</li> <li>3) Lift the instrument from the box.</li> <li>4) Remove all miscellaneous items from the box.</li> </ol>
<p><b>Checking the Contents</b> For completeness:  For electrical defect:  If problems exist:</p>	<p>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.</p>
<p><b>Warranty Information</b></p>	<p>Warranty information for each instrument is available inside the front cover of the instrument manual.</p>
<p><b>Storing the System</b> General: Temperature: Relative Humidity: Altitude:</p>	<p>The following environmental limits apply to both storage and shipment. Store in a clean, dry environment. -55°C to +75°C &lt;95% relative; maximum wet bulb temperature = 40°C &lt;15 000 meters (50 000 feet).</p>
<p><b>Shipping the System</b> Packaging instructions:        If shipping to HP:   Corresponding about the package:</p>	<p>Use the original packaging material or:</p> <ol style="list-style-type: none"> <li>1) Wrap the instrument in heavy paper or plastic.</li> <li>2) Use a strong shipping container: A double-wall carton made of 2.4 mPa (350 psi) test material is adequate.</li> <li>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.</li> <li>4) Seal the shipping container securely.</li> <li>5) Mark the shipping container "FRAGILE" to ensure careful handling.</li> </ol> <p>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.</p> <p>In any correspondence, refer to the instrument by model number and full serial number.</p>



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## Setting Up the System Hardware

In order to set up the system hardware, you need to install the computer and its peripheral devices (described below in *Installing the Computer*) as well as make the interconnections between instruments (described in *Interconnecting Instruments* which begins on page A-9).

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**Note** If the configuration you are using is different than the examples provided, refer to the computer installation manuals you received with your system.

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### Installing the Computer

This section briefly describes how to install a new computer.

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**Note** Check the amount of available Random Access Memory (RAM) in the computer. This value must be 3 MBytes of RAM memory to operate the HP 3048A software.

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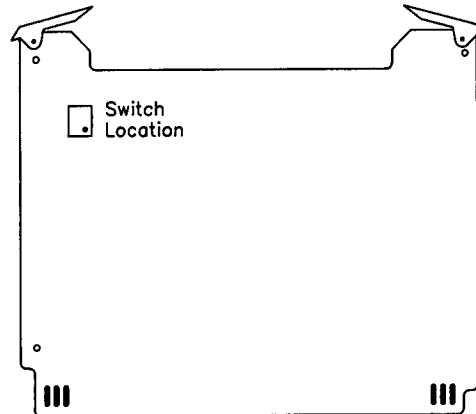
#### Computer Memory Cards

Before turning on the computer, you need to install the memory and I/O cards (such as RS-232, SRM, etc.). The number of actual memory cards installed will depend on the computer since some Series 200/300 computers have built-in memory and some do not.

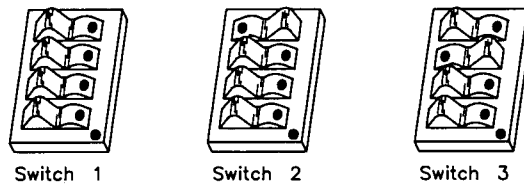
If you are using the HP 98580A Option 008 or the HP 9836S Option 001, the information about installing memory cards (in Figure A-1) will help you get your system up and running. If you are using any other computer, refer to the computer manuals shipped with your computer for detailed information on configuring memory and I/O cards.

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For the HP 98580A and the HP 9836S, RAM memory is contained on HP 98257A cards (similar to the one shown below) that plug into the rear of the controller.



The switches on these cards set the card address so the processor can access the RAM memory. When you order either the HP 98580A Option 008 or the HP 9836A Option 001, you receive a card, already installed in the computer, that provides 1 Mbyte of memory. The addition of the two separately ordered HP 98257A 1-Mbyte RAM cards provides another 2 Mbytes of RAM memory. The switches should be set as shown below:



- Switch 1:** Switch settings on the first card (which is currently installed in the computer).
- Switch 2:** Switch settings on the second card.
- Switch 3:** Switch settings on the third card.

**Figure A-1. Memory Cards in the HP 98580 Opt. 008 or HP 98368 Opt. 001**

---

## Peripheral Devices: Disc Drives, Plotters, and Printers

To integrate these devices into the system, connect HP-IB cables to them and enter their addresses (as explained in *Setting Up the HP-IB Addresses* on page A-11.)

### Additional Information

- **Disc Drives**  
The HP 9122 3<sup>1</sup>/<sub>2</sub>-inch Drive, the HP 9153 10-Mbyte Winchester 3<sup>1</sup>/<sub>2</sub>-inch Drive, or equivalent is required for system operation.
- **Plotters**  
Set up the pens for the different portions of the graph to be plotted (trace, graticule, spurs, and labels) from the **System Config** menu.

### Device Interconnections

Your computer manual provides the details of computer installation. However, the brief instructions here for installing either the HP 98580A Option 008 or the HP 9836S Option 001 may be enough to enable you to get your system up and running. If you run into any problems, refer to your computer installation manual.

### Caution

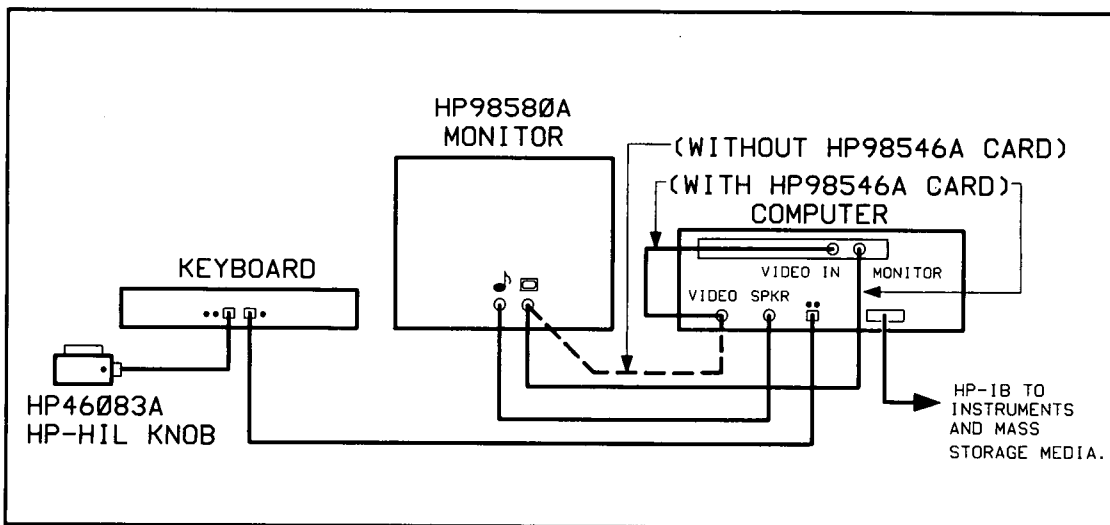
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BEFORE PLUGGING ANY INSTRUMENTS into the Mains (line) voltage, be sure the correct voltage and fuse have been selected for each instrument. Refer to each instrument's installation manual if you need fuse size and power connection information.

---

**Table A-3. Interconnecting System Instruments**

Using HP 9836S Option 001	Using HP 98580A Option 008
<ol style="list-style-type: none"> <li>1) Connect the cable between the mainframe and the display of the computer.</li> <li>2) Connect the power cords to the computer and peripherals.</li> <li>3) Connect the HP-IB cables to the computer and each instrument and peripheral device. (Instructions on HP-IB cable interconnections are provided in the section <i>Interconnecting Instruments</i> on the next page.)</li> </ol>	<ol style="list-style-type: none"> <li>1) Make the connections shown in Figure A-2.</li> <li>2) Connect the power cords to the computer and peripherals</li> <li>3) Connect the HP-IB cables to the computer and each instrument and peripheral device. (Instructions on HP-IB cable interconnections are provided in the section <i>Interconnecting Instruments</i> on the next page.)</li> </ol>



**Figure A-2. Computer Interconnections**

## Interconnecting Instruments

The following diagrams are examples of interconnections between instruments in the system.

### Rear-Panel Interconnections

Figure A-3 shows an example of rear-panel interconnections for the HP 3048A. If you add other allowed instruments, connect the HP-IB cables to those instruments as well.

### Front-Panel Interconnections

Connect the instruments as shown in Figure A-4.

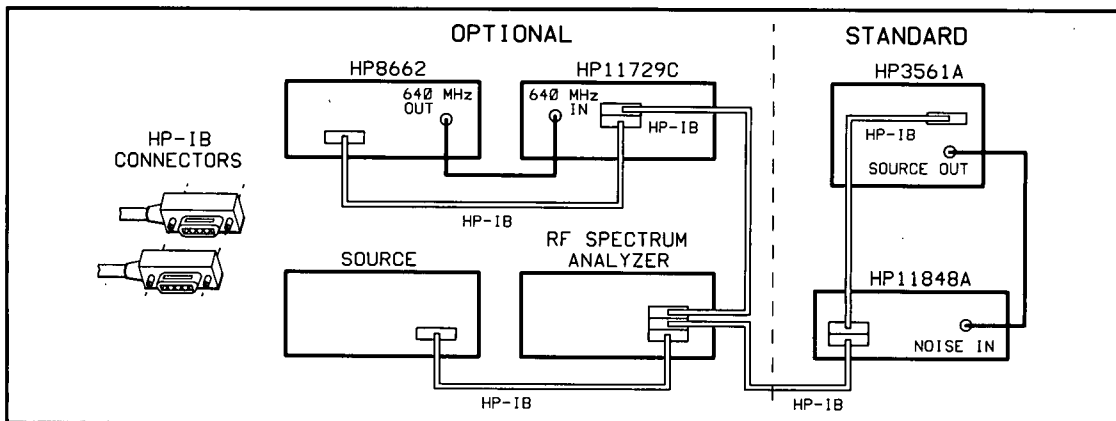


Figure A-3. Example of Instrument Rear-Panel Interconnections

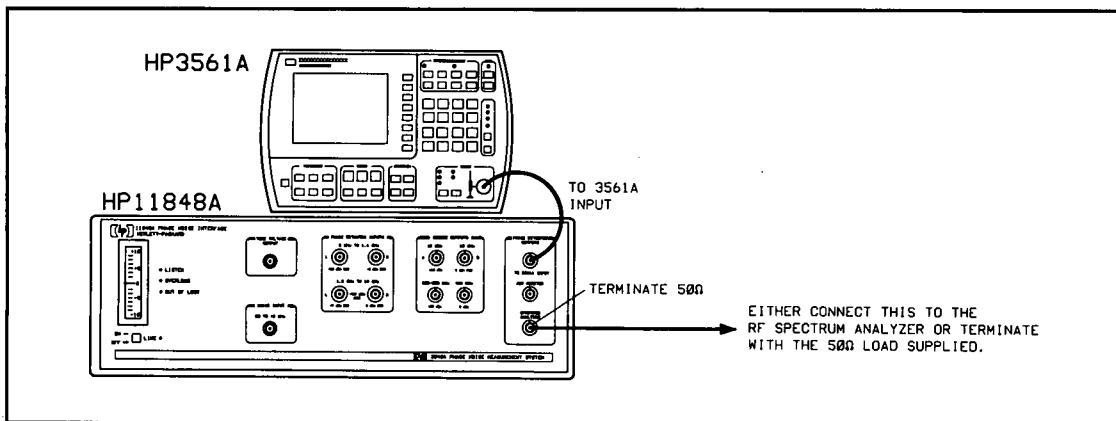


Figure A-4. Front-Panel Interconnections for the HP 3048A

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## Loading the System Software



The HP 3048A Phase Noise Measurement System software is distributed on six discs that require the 5.0 BASIC OPERATING SYSTEM. The six discs are labeled as follows:

- "PHASE"(contains the system program files)
- "PHASE\_SUBS"(contains system sub programs)
- "SYS\_TESTS"(contains system sub programs)
- SYSTEM DATA (contains all data files necessary for operation of the software)
- UTILITIES (contains the following utility programs:  
"EXT\_DEMO" an example program to remotely control the HP 3048A, and  
"FILE\_UTIL" a utility program for managing disc files)
- DIAGNOSTIC (contains diagnostic program for the HP 11848A)

### Loading Each Disc To Load the 3048A System Disc

1. Turn the computer power off.
2. Turn the disc drive and monitor power on.
3. Insert 5.0 BASIC SYSTEM DISC, into a flexible disc drive. (The drive you select will be the "default drive".)
4. Turn the computer power on.

---

**Caution** Removing the disc while the program is loading could cause damage to the disc.

---

- 
5. The light next to the drive will light while the program is loading. When the flexible disc access light goes out, remove the disc.
  6. The computer will prompt you to insert the appropriate disc to install the BASIC Operating System. The BASIC HFS utilities are not required for the HP 3048A Phase Noise Measurement System software.
  7. After BASIC is loaded insert the disc labeled "PHASE" into the disc drive.
  8. Load the HP 3048A System software by typing **LOAD "PHASE",1** then pressing ENTER. This loads and starts the PHASE program.
  9. The system will now prompt you to insert the appropriate disc at the proper time until the HP 3048A is fully loaded and running.

---

### **Copying the Discs Into a Winchester Disc Drive**

If you are using a Winchester Disc Drive, refer to the Disc Drive Operating Manual to initialize the fixed disc and to copy the system files onto the fixed disc. The Utilities Disc included with the HP 3048A software provides routines and instructions for copying software files.

### **Making Back-Up Copies**

It is strongly recommended that you make back-up copies of all your system discs. Refer to the Disc Drive Operating Manual to copy the system files onto another set of discs. After copying the discs, test them by loading and running the operating system, main program, and diagnostic program.

---

### **Setting Up the HP-IB Addresses**

The computer can address the instruments in the system after the system software is loaded. You need to specify the HP-IB address for each instrument that you have connected via HP-IB.

1. After loading the software and pressing the **RUN** key, press the **System Config** softkey available at the Main Software Level. (If you are not already at the Main Software Level, press the **Done** or **Abort** key until you are, then press **System Config**.)
2. Press the **HELP** softkey for the list of valid instrument names and models supported by the HP 3048A. Use the **Next Page** softkey to see the complete list. Press the **DONE** softkey to get back to the System Config menu.
3. Edit the configuration table to list each instrument in your setup that will be a part of the system.



---

**Note** List only the instruments connected via HP-IB.

---

Example

NAME	MODEL	ADDR
FFT ANALYZER	HP 3561A	711
INTERFACE	HP 11848A	720
RF SOURCE	HP 8662A	719
PRINTER	HP 2671G	701

Use the **TAB** key to move from left to right through the fields in the table. Use the **SHIFT TAB** keys to move from right to left. You can also use the  $\uparrow\downarrow\rightarrow\leftarrow$  keys and the Knob.

Use **Delete Instr** to remove an instrument from the list.

When entering instrument and address information into the table, a noticeable time delay will occur as the cursor moves from the Model field to the Address field. This delay is normal; the screen is being refreshed with the addition of a new device.

4. Whenever you make a valid entry into one of the fields and exit that field, the entry will be stored in volatile memory. Volatile memory storage keeps the edits until you turn off the computer.
5. Use **Store Config** to store the instrument addresses on the SYSTEM DATA DISC.
6. Use **Load Config** to load the instrument addresses from a disc.
7. You may want to verify that the addresses you have entered in the computer correspond to the actual instrument addresses. Refer to the procedure on the next page, *Verifying Instrument Addresses*.
8. Press the **DONE** key when you have completed this operation.

---

### **The System's Response to Address Entry**

When you move the editing cursor from a completed address field or when entering The System Config display screen, the HP 3048A polls the HP-IB address entered for that field. If no response is received at the address specified, the HP 3048A places a blinking asterisk (\*) next to the address. Note that at this time the system only checks for that response at the entered address, it does not verify that the appropriate instrument has responded.

### **Verifying Instrument Addresses**

The computer checks for an 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 711. The computer will check to see if an instrument is responding at address 711, but it cannot verify whether that instrument is the FFT analyzer.

You can verify that the correct instrument is responding by turning its power off and checking whether the program can tell that it is no longer responding. (Refer to the following example.)

#### Example of Address Verification

To check whether 711 is really the FFT analyzer, you could use the following procedure:

1. Turn off the FFT Analyzer.
2. Position the editing cursor at the address entry field for the FFT Analyzer.
3. Now move the editing cursor to a different entry field. (The computer will check for a response at address 711 as it leaves the FFT analyzer's address entry field.)
4. Check to see that a blinking asterisk (\*) appears next to the address of the FFT analyzer you turned off.

---

## 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 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.

---

## 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.

### Note

The performance tests in the HP 3048A 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 (a test described in the HP 3048A Calibration Manual.)

1. Press the **System Preset** softkey. This softkey appears at the Main Software Level menu.
2. Press **New Measurement**.
3. Press **Yes, Proceed**. The HP 3048A now addresses each instrument listed in its System Configuration Table. If an instrument does not respond to the HP-IB address listed for it in the table, the HP 3048A will inform you with a message in its display. (For details on adding an instrument to the system configuration table or verifying an HP-IB address, refer to *Setting Up the HP-IB Addresses* on page A-11.)
4. Connect the two 10 MHz source outputs to the Phase Detector inputs on the HP 11848A as shown in the connect diagram on the computer display.
5. Press **Proceed**.
6. If the measurement proceeds without any error messages and the measured noise is within 10 dB of that in Figure A-5, the HP 3048A system is functioning properly.

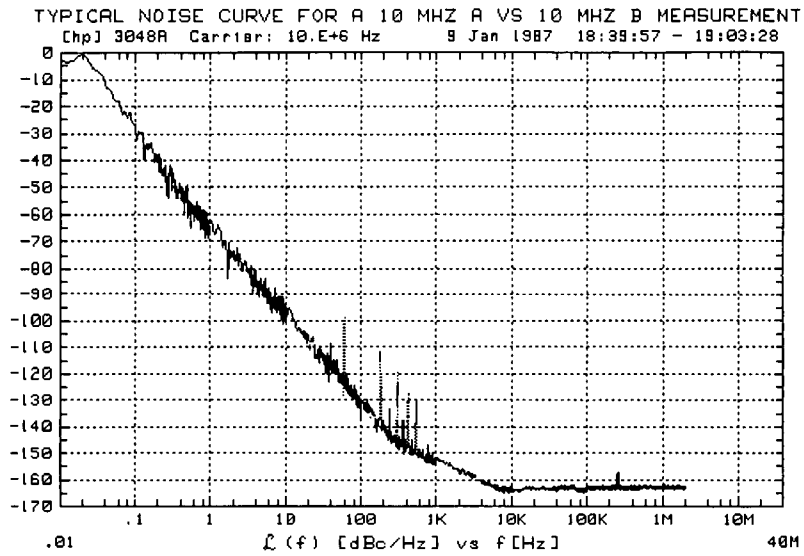


Figure A-5. Typical Noise Curve Obtained by System Verification



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S E R V I C E N O T E

SUPERSEDES: None

**HP 3048A Phase Noise Measurement System  
(HP 11848A Phase Noise Interface)**

**Serial Numbers:**

0000A00000 / 2637A99999 (3048A)  
0000A00000 / 2938A99999 (11848A)

**External HP-IB Filter Assembly Replacement**

**Duplicate Service Notes:**

3047A-02  
3048MS-01  
11740A-01

**Parts Required:**

11848-60114 HP-IB Connector/Filter Assembly

**Situation:**

External HP-IB Filter assembly 9135-0159 is obsolete and not available for replacement. This assembly is used to reduce the effect of Controller/HP-IB generated spurs on system measurement results. It is normally located on the rear-panel HP-IB connector of the HP 11848A Phase Noise Interface.

If it becomes necessary to replace this external filter assembly, an internally-mounted PC assembly with equivalent low-pass filters is available. It replaces existing PC assembly 35601-66562 in the HP 11848A and is drop-in compatible. Re-calibration is not required.

*Continued*

DATE: 25 June 1993

ADMINISTRATIVE INFORMATION

SERVICE NOTE CLASSIFICATION:		
<b>INFORMATION ONLY</b>		
AUTHOR:	ENTITY:	ADDITIONAL INFORMATION:
LHL	1000	

S E R V I C E N O T E

SUPERSEDES: None

**HP 3048MS Phase Noise Measurement System  
(HP 11848A Phase Noise Interface)**

**Serial Numbers:**

0000A00000 / 3039A99999 (3048MS)  
0000A00000 / 2938A99999 (11848A)

**External HP-IB Filter Assembly Replacement**

**Duplicate Service Notes:**

3047A-02  
3048A-01  
11740A-01

**Parts Required:**

11848-60114 HP-IB Connector/Filter Assembly

**Situation:**

External HP-IB Filter assembly 9135-0159 is obsolete and not available for replacement. This assembly is used to reduce the effect of Controller/HP-IB generated spurs on system measurement results. It is normally located on the rear-panel HP-IB connector of the HP 11848A Phase Noise Interface.

If it becomes necessary to replace this external filter assembly, an internally-mounted PC assembly with equivalent low-pass filters is available. It replaces existing PC assembly 35601-66562 in the HP 11848A and is drop-in compatible. Re-calibration is not required.

*Continued*

DATE: 25 June 1993

**ADMINISTRATIVE INFORMATION**

SERVICE NOTE CLASSIFICATION:		
<b>INFORMATION ONLY</b>		
AUTHOR:	ENTITY:	ADDITIONAL INFORMATION:
LHL	1000	

S E R V I C E N O T E

SUPERSEDES: None

**HP 3048A Phase Noise Interface**

Serial Numbers: 3138A00888 / 9999A99999

**Clarification of functional and diagnostic test failures due to an 11848A PC board modification (A3 board).**

Duplicate Service Notes: 11848A-03  
3048MS-02

**Situation:**

In some applications using an unmodified 11848A, where the peak tuning range is typically greater than 50 MHz, the phase lock loop (PLL) may not lock up. If it does lock up, there may be an otherwise unexplained noise peak displayed in the plot of phase noise for the device under test (DUT). This noise peak may have the appearance of a wide spurious signal several dB above the average noise floor, and typically shows up at an offset from the carrier of about 500 KHz to 2 MHz.

Starting in November 1992, the A3 board (p/n 11848-60203) in new 11848As was modified by cutting a trace. This eliminated a feedback path that was either generating noise or preventing lockup of the phase lock loop. While this modification did not affect the application measurement software for the 3048A, it did impact some test programs.

The 3048A Functional test #4 (Lag-Lead Transfer Functions Test) may fail depending upon what software revision is being used (see below).

*Continued*

DATE: August 1994

**ADMINISTRATIVE INFORMATION**

SERVICE NOTE CLASSIFICATION:		
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KD	5340	



11848A Diagnostic Software Tests will always fail since they attempt to test a circuit that uses the cut trace, and this diagnostic software (now obsolete) was never revised.

On the A3 board (p/n 11848-60203), the trace was cut between U25 (15) and U30 (2) on the component side of the board. All boards shipped in 11848As, serial numbers 3138A00888 and up, weremodified. In addition, all exchange assemblies (p/n 11848-69103) are being modified as they go through the repair process at the factory. Therefore, a user could send in a failed (unmodified) board for a different reason and receive a working modified one (cut trace) in return. Tests that did not fail previously may now fail.

**Solution/Action:**

This service note provides information on acceptable performance for the 11848A under certain known situations where some specific tests may fail but the 11848A is functioning normally. The user may either disregard test failures where the cause is known and the 3048A system is otherwise performing normally, or if that is unacceptable, the user may upgrade his 3048A software to the latest version.

Performance specifications and functionality of the 11848A are not affected by the cut trace since it was part of an unused circuit designed in for future enhancements of the 11848A that were never implemented. However, testing of that circuit was designed into the test software so some tests can fail.

For the 11848A Diagnostic program (now obsolete), some tests will always fail when the trace is cut since there was only one version of the program and it expects the trace to be a valid circuit path. The diagnostic program was only intended to be used as an aid for isolating failures uncovered by other means and not as a verification of system or instrument operational status. If the system checks in the 3048A software (as described in the 3048A System Calibration manual) all pass, and the system makes valid phase noise measurements, the results of the diagnostic tests can be ignored.

For Functional Test #4 (Lag-lead test), the test results are determined by the 3048A software revision as follows:

**3048A RMB Software Rev A.02.0x and a cut trace on A3:**

Functional Test #4 fails. However, if the 10 MHz A vs B test (Quick Check) passes, there is a very high confidence level ( 90% ) that the lag-lead circuits are OK so the test is not really needed.

**3048A RMB Software Rev A.03.00:**

Functional Test #4 (under investigation) was removed from the software so as not to hold up release of this revision. Therefore a cut trace on A3 will not cause a functional test failure with this revision.

**3048A RMB Software Rev A.03.0x and a cut trace:**

Functional Test #4 (modified) was put back in the software at Rev A.03.01 & up, but now it does not test the path where the trace was cut so it should pass as long as nothing else is wrong with the instrument.

**3048A DOS Software (Option 301) Rev A.00.02:**

Same as for RMB software Rev A.02.0x.

**3048A DOS Software (Option 301) Rev A.01.0x:**

Same as for RMB software Rev A.03.0x.

**CAUTION:**

Customers and HP personnel should not automatically assume that an uncut trace on an unmodified 11848A is causing a problem they may be seeing. Only the specific symptoms noted above have a high confidence level of being corrected by cutting the subject trace.

Cutting the trace, if it does not fix the problem, may disrupt test continuity and, in some cases, service traceability. The new test failures may also then mask valid failures later on. It is recommended that the factory be contacted first and the problem discussed before cutting the trace. It may be that an invalid application is contributing to the problem or that a software upgrade may be a wiser solution. The 3048A software system checks described in the 3048A Calibration manual should run to verify system operation. HP customers can receive needed technical support through their closest HP Sales or Service office.