DEMO GUIDE

N9069A and W9069A Noise Figure X-Series Measurement Application

KEYSIGHT TECHNOLOGIES

Introduction

Measuring the noise figure of a device requires knowledge of the measurement system. Once the noise figure of the measurement instrument is known and the gain of the device under test (DUT) is known, then the noise figure of the DUT can be calculated, after which the overall noise figure is measured. This guide demonstrates how using the Keysight Technologies, Inc. N/W9069A noise figure X-Series measurement application will allow you to make noise figure measurements quickly and efficiently.

The demonstrations included in this guide are:

- Entering the ENR table for SNS Series noise sources
- Entering the ENR table for 346 Series noise sources
- Calibration for the noise figure measurement
- Noise figure and gain measurements
- Using the display features
- Markers
- Noise figure uncertainty calculator with SNS N40002A
- Noise figure measurement using an amplifier as the DUT

Demonstration Preparation

All demonstrations use an X-Series signal analyzer or MXE EMI receiver with the noise figure measurement application and a noise source. Keystrokes surrounded by [ ] indicate front-panel keys; keystrokes surrounded by { } indicate softkeys located on the right edge of the display.

Minimum equipment configuration requirements

Product type	Model number	Required options
For X-Series signal analyzers, firmware revision A.06.xx or later For MXE EMI receiver, firmware revision A.10.xx or later	N9030A PXA	503, 508, 513, 526, 543, 544, or 550
	N9020A MXA	503, 508, 513, or 526
	N9010A EXA	503, 507, 513, or 526
	N9000A CXA	503 or 507
	N9038A MXE	508 or 526
Preamplifier	N9030A PXA or N9020A MXA	P03, P08, P13, P26, P43, P44, or P50
	N9010A EXA	P03
	N9038A MXE	Preamplifiers are standard
	N9000A CXA	P03 or P07
Noise figure measurement application	N9030A PXA N9020A MXA N9010A EXA N9038A MXE	N9069A
	N9000A CXA	W9069A

Noise source- one required
Notes:

- Any noise source listed below will work with any configuration of signal analyzers listed above.
- For the 346 Series noise sources, you will need a cable and matching connectors to connect these noise sources to the instrument.
- For the SNS Series noise sources, you will need an 11730A cable to connect these noise sources to the instrument.

	Frequency range	ENR-typical
346A	10 MHz to 18 GHz	5 to 7 dB
346B	10 MHz to 18 GHz	14 to 16 dB
346C	10 MHz to 26 GHz	12 to 17 dB
Q347B	33 GHz to 50 GHz	6 to 13 dB
R347B	26.5 GHz to 40 GHz	10 to 13 dB
N4000A	10 MHz to 18 GHz	4.6 to 6.5 dB
N4001A	10 MHz to 18 GHz	14 to 16 dB
N4002A	10 MHz to 26 GHz	12 to 17 dB

Helpful tip:

Update your instrument firmware and software to the latest version, available at

www.keysight.com/find/x-series
www.keysight.com/find/x-series_apps

Demonstrations

To begin using the noise figure measurement application with any of the X-Series signal analyzers or N9038A EMI receiver, enter the keystrokes: **[Mode] (More 1 of 2 if necessary) {Noise Figure}.** On N9038A use input 1 only.

Demonstration 1:

Entering the ENR table for SNS Series noise source

The SNS Series noise sources simplify the process of entering ENR data into your instrument. They save time by automatically downloading the ENR table when connected to an X-Series signal analyzer. Simply connect the SNS to the X-Series instrument via an 11730A cable to automatically transfer the ENR data to the signal analyzer.

Instructions	Keystrokes
Automatic upload of ENR data from the SNS noise source.	**[Meas Setup] {ENR} {SNS Setup} {Noise Source}** toggle to SNS(Auto) **{Auto Load ENR}** toggle to ON.
Connect one end of the 11730A cable to the rear panel of the instrument and the other to the SNS.	No key presses are required for this step.
Verify that the data has correctly transferred.	Look at the upper right hand corner of the screen to verify the ENR has turned to green for the ENR state.
Save the ENR table.	**[Save] {Data} {ENR Table}** to select **{ENR Table}** to enter menu **{Meas} (Common)** Table or **{Cal Table} {Save As}** enter name and desired location **[enter]** or click ok.

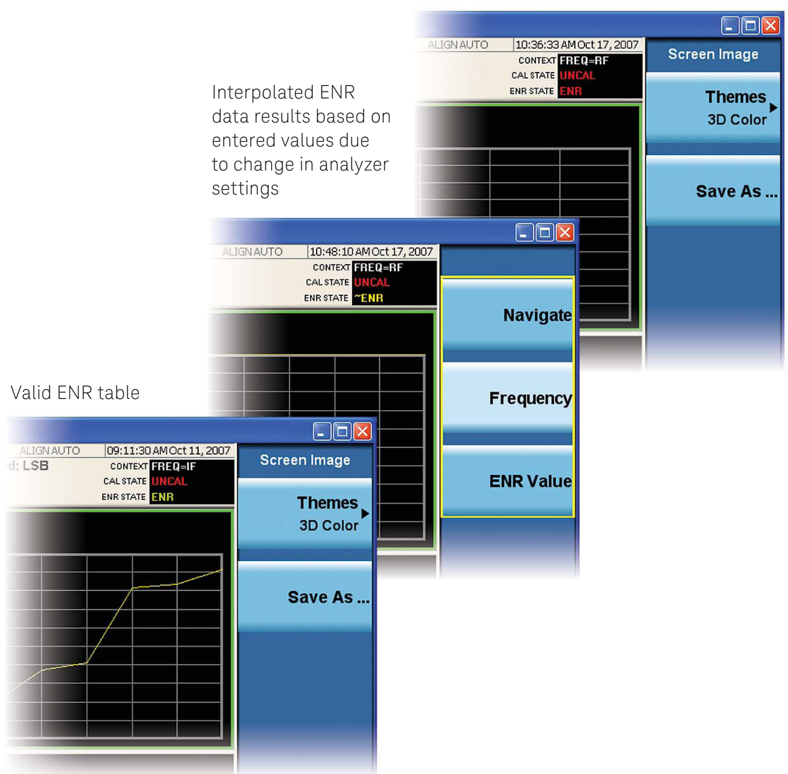
Helpful tip:

You can use the same ENR table for calibration and making measurements, or you can use separate measurement ENR and calibration ENR tables. You need separate measurement and calibrationtables when separate noise sources are used for DUT measurements than for calibration (for example, when you are using frequency converters and the calibration range is different than the measurement range). Otherwise, you can select common ENR tables to save time.

Invalid or empty ENR table

Interpolated ENR data results based on entered values due to change in analyzer settings

Valid ENR table



Demonstration 2:

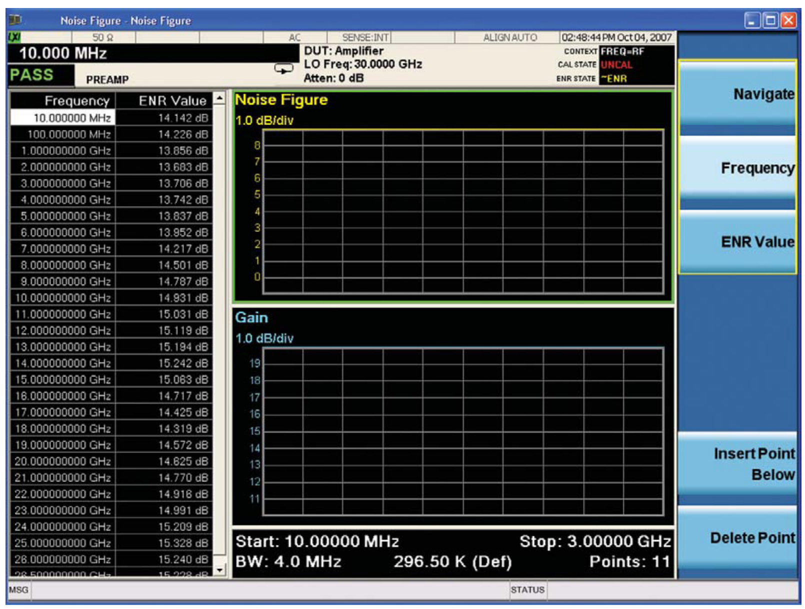
Entering the ENR table for 346 Series noise source

This series of broadband noise sources has been designed to cover the majority of measurement applications with a range of frequencies, excess noise ratio (ENR), and coaxial connector types.

Instructions	Keystrokes
Enter the noise source serial number.	**{Meas Setup} {ENR} {Meas Table} {Clear Table} {Serial #}** use the alpha editor from the soft keys or connected keyboard. **{Done}**
Enter the model ID of the noise source.	**{Model ID}** use the alpha editor from the soft keys or connected keyboard. **{Done}**
Enter the ENR Frequency.	**{Edit} {Frequency}** use a connected keyboard, or front panel numeric keypad to enter the value **{select appropriate units}.**
Enter the ENR value.	**{Edit} {ENR Value}** use a connected keyboard, or front panel numeric keypad to enter the value **{dB}.**
Continue to enter the ENR frequencies and values until all of the frequency points of your noise source are entered.	No key presses are required for this step.
Save the ENR table.	**[Save] {Data} {ENR Table}** to select **{ENR Table}** to enter menu **{Meas} (Common)** Table or **{Cal Table} {Save As}** enter name and desired location **[enter]** or click ok.

Helpful tip:

You can enter or load ENR data in four different ways: Manually enter the data shown above, load SNS data automatically as shown in the previous demonstration, load ENR data from a USB memory stick, or load ENR data from internal memory.



Common ENR table

Demonstration 3:

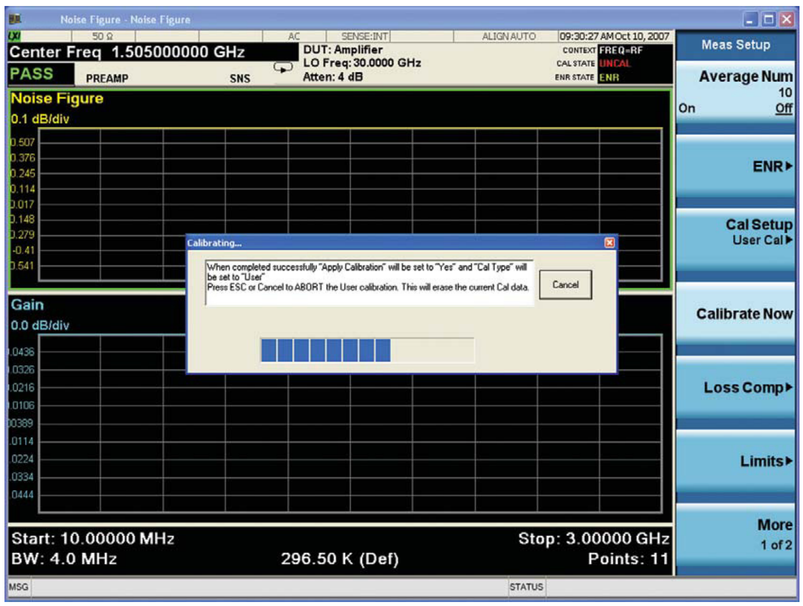
Calibration for the noise figure measurement

For accurate noise figure measurements, the measurement system must first be calibrated to identify and correct the system's inherent noise figure before a DUT can be measured. The measured instrument noise figure is then removed from the total noise figure measurement so that only the DUT noise figure and gain is displayed.

There are three simple steps to calibrate the X-Series signal analyzers:

1. Select the frequency range appropriate for the DUT
2. Set the number of points and averages
3. Turn on the built-in preamplifier before beginning calibration. Default setting is ON. To find the internal preamplifier go to **[AMPTD]{more} {Internal Preamp}**

Instructions	Keystrokes
Connect the noise source to the rear of the X-Series signal analyzers via BNC cable for 346 series or 11730A cable for SNS series noise sources.	No key presses are required for this step.
Set the start frequency.	**[Freq Channel] {Start Freq} [10] {MHz}**
Set the stop frequency.	**{Stop Freq} [3] {GHz}**
Set the number of points.	**{Points} [30] {Enter}**
Set the averaging function.	**[Meas Setup] {Average Num}**, toggle to ON **[15] {Enter}.**
Calibrate the N9069A.	**[Meas Setup] {Calibrate Now} [Enter]** (or click OK with attached mouse).



Calibration of the noise figure measurementA application

Helpful tip:

Use the {Optimize Preselector} under [meas setup] {more} in order to optimize your settings if the preselector drift is impacting your results and giving you higher errors than expected. When doingmeasurements above 3.6 GHz this saves time of running another calibration when you are making measurements over a period of time.

Did you know?

"User Cal" operates the same as "Calibrate" in the ESA, PSA, and NFA. No corrected results will be available until the measurement had been calibrated. Aborting the calibration will work in single and continuous mode.

Demonstration 4:

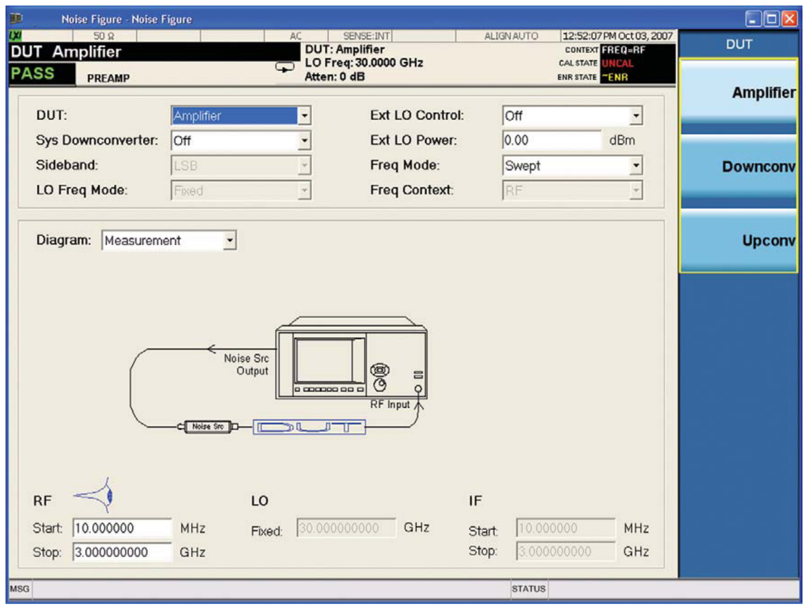
Noise figure and gain measurements

Now that the analyzer is calibrated with the noise source connected directly to the input, it is easy to make the noise figure and gain measurements on your device. Once the following steps are complete, the noise figure and gain of the DUT will be shown on the screen.

Instructions	Keystrokes
Use the visual setup guide to get started.	**[Mode Setup] {DUT Setup...} {Amplifier}** or select your DUT from the drop down menu with a mouse.
Disconnect the noise source from the input and connect the output of the DUT to the RF input of the signal analyzer. Connect the input of the DUT to the output of the noise source.	No key presses are required for this step.

Helpful tip:

Use the Auto Scaling feature to give the broadest view of the measured trace. The lowest point will be placed at the bottom of the graph and the highest value at the top of the graph. This feature can be found under the AMPTD hard key. Auto Scale's default state is ON.



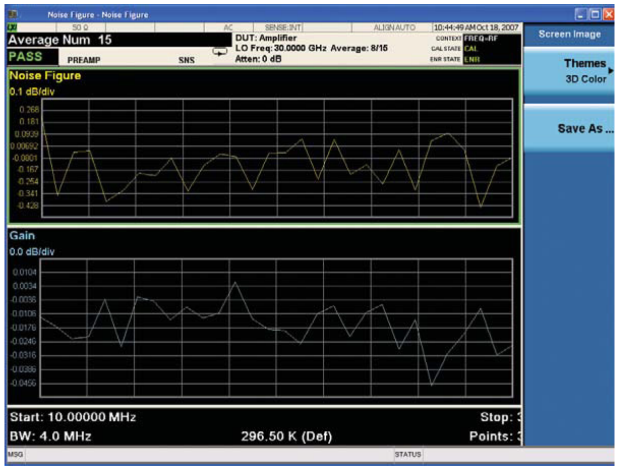
DUT set-up menu

Demonstration 5:

Using the display features

The noise figure measurement application allows you to select the format in which your measurement results are displayed. Choose from three different layouts: Graph, table, and meter display.

Instructions	Keystrokes
Change the display.	**[View/Display] {Layout}** to select your preferred method.



Graph display: The large screen of the X-Series signal analyzers allows for full viewing of the graph.

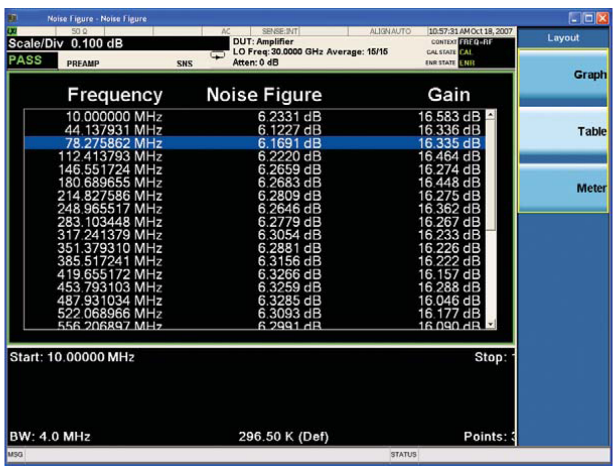
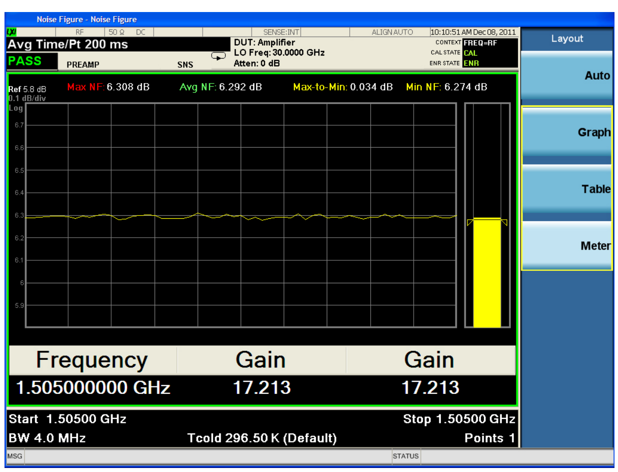


Table display: The table has a highlighted bar that follows the measurement in process. This allows you to see the point that is being measured at any particular moment.



Meter display: In addition to the more detailed graph and table displays, users familiar with the discontinued 8970 noise figure meter can continue to review results in the same format with the meter display view. Real-time interface allows users to easily view results while making adjustments or analyzing trends.

Helpful tip:

When viewing one of the six measurement results in graph view you can zoom in on either graph. By using the  button.

Note: Current owners check for upgrade Option N9069A-AFP.

Demonstration 6:

Markers

Markers can be used for searching a trace, and for displaying point data more accurately than with a trace alone. A total of four normal markers can be placed on the graphical display. Marker functions measure the frequency and measurement results by placing a diamond-shaped marker at a point on the trace.

Instructions	Keystrokes
Place a normal marker on the top graph.	**[Marker] {Normal}**
Create a delta marker.	**{Delta}**–Use the front panel knob to scroll the delta marker.
Create a delta marker from the top graph to the bottom graph.	**{Properties} {Marker Trace} {Trace 2}**–Use the front panel knob to scroll the delta marker.
Change delta marker 1 to marker 3.	**{Relative To} {Marker 3}**

Markers with marker table

Did you know?

While in graph view you can use delta markers between two traces and also show the marker table under the [marker] key.

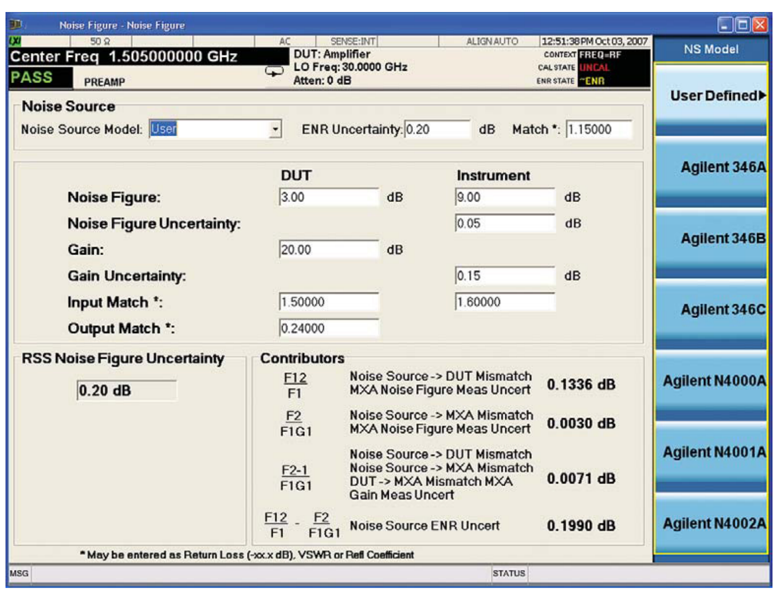
Demonstration 7:

Noise figure uncertainty calculator with SNS N40002A

To compute the total uncertainty for your noise figure measurement, you need to take into account other factors besides noise figure instrument uncertainty such as: DUT noise figure, gain and match, instrument noise figure, gain uncertainty and match, and noise source ENR uncertainty and match. The computations can be performed with the uncertainty calculator included in the noise figure measurement application. Similar calculators are also available on the Keysight web site, go to www.keysight.com/find/nfu.

The noise figure uncertainty calculator can be used in conjunction with either the 346 or SNS Series noise sources.

Instructions	Keystrokes
Find and use the uncertainty calculator.	**[Mode Setup] {Uncertainty Calculator}**
Choose your source.	Use the tab keys or mouse to highlight the "Noise Source Model" box and select "Keysight N40002A."
Enter DUT and instrument values.	Use the tab keys or mouse to highlight each box. Enter the following values using either an attached keyboard or the front panel key pad: 1. DUT a. Noise figure: 3.75 dB b. Gain: 19.40 dB c. Input match: 1.50 d. Output match: 1.50 2. Instrument a. Noise figure: 8.00 dB b. Noise figure uncertainty: i. PXA: 0.02 dB ii. MXA: 0.02 dB iii. EXA: 0.03 dB iv. CXA: 0.05 dB v. MXE: 0.02 dB c. Gain: .41 dB d. Gain uncertainty: i. PXA: 0.10 dB ii. MXA: 0.10 dB iii. EXA: 0.15 dB iv. CXA: 0.20 dB v. MXE: 0.10 dB e. 1.80 for frequencies up to 3.6 GHz The measurement uncertainty is then calculated and the results are displayed at the bottom of the form.



Uncertainty calculator display for above example

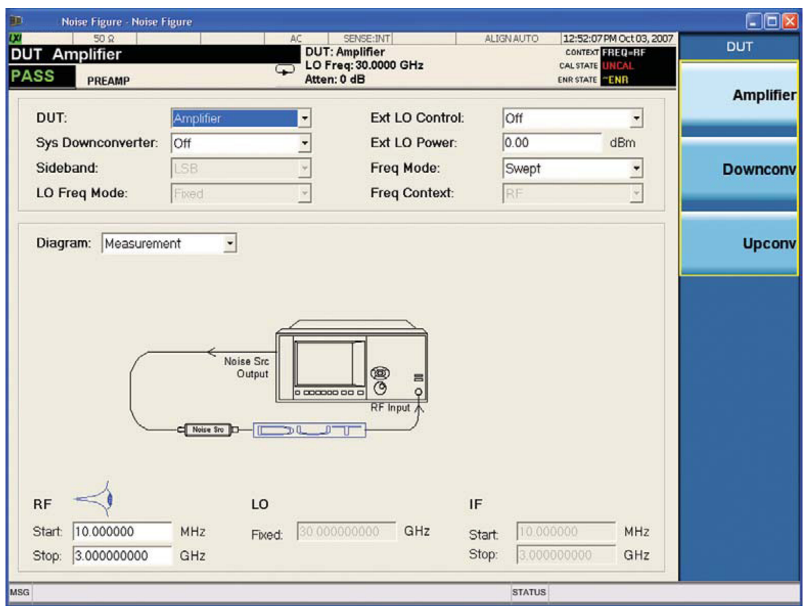
Demonstration 8:

Noise figure measurement using an amplifier as the DUT

Noise figure measurements are made by measuring the output power of the DUT for two different input noise power levels. The high and low power inputs come from a calibrated noise source. The noise source is switched on and off in rapid succession. High power input to the analyzer uses the noise power generated when the noise source is switched on, and low power input uses the noise power generated at ambient temperature when the noise source is switched off. This section uses a DUT to show how a basic noise figure measurement and various basic operations are performed. The purpose of this measurement is to verify that the amplifier is meeting the specifications in the table below. The example DUT specifications are as follows:

1. Frequency range: 20 MHz to 3 GHz
2. Typical gain: 20 dB
3. Minimum gain: 14 dB
4. Typical noise figure: 4.8 dB

Instructions	Keystrokes
Access the DUT setup menu.	**[Mode Setup] {DUT Setup} {Amplifier}** System downconverter: Off Frequency mode: Off RF start frequency: 10 MHz RF stop frequency: 3 GHz
Calibration setup.	**[Meas Setup] {Cal Setup} {User Cal}** Min Att = 0 dB default Max Att = 10 dB default Change attenuation up to a maximum of 40 dB based on calibration need.
Measurement attenuation.	**[Ampt] {Attenuation} [0] {dB}**
Calibration.	**[Meas Setup] {Calibrate} [Enter]**
Connect the preamplifier between the noise source and RF input of the signal analyzer.	No key presses required for this step.
View results on display.	**[Meas]**



Amplifier measurement setup

Did you know?

Base box alignments will be disabled between points of an NF measurement sweep as long as the full measurement sweep time is under a minute, otherwise, only enable alignments between points. Alignments will always be disabled between P cold and P hot readings for a single frequency point.

Result Types

When using the noise figure measurement application, there are seven different results that can be viewed. Brief descriptions of each of these result types are below.

Noise figure: The contribution by the device itself to thermal noise at its output. Typical noise figures range from .5 dB for very low noise devices, to 4 to 8 dB. In some systems (for example, heterodyne systems) total output noise power includes noise from other than thermal sources, such as spurious contributions from image-frequency transformation, however noise from these sources is not considered in determining the noise figure. Noise figure is expressed in dB.

Noise factor: The same description as above; however, noise factor is expressed using linear units rather than dB.

Gain: The amplification factor, also called gain, is the extent to which an analog amplifier boosts the strength of a signal. Amplification factors are usually expressed in terms of power. Gain is expressed in dB.

Y-factor: This method is very simple as it is a ratio of two noise power levels—one measured with the noise source ON and the other with the noise source OFF. These values are expressed in dB.

All types of random noise can be expressed as the equivalent amount of thermal noise that would be generated at a physical temperature (Te). Generally the word effective (or equivalent) is taken as understood, and the normal term is simply "noise temperature." These values are expressed in Kelvin.

P hot (Hot power density): This measurement is made with the noise source ON. The level of the noise floor observed on a signal analyzer depends, in part, on the selected bandwidth of the measurement. The wider the bandwidth the more noise is measured for each data point. If the instrument can display noise density, it has simply normalized the power measurements to a 1 Hz bandwidth and references it to kTB -173.88 dBm/Hz; the displayed function is equivalent to power spectral density referenced to kTB. For example, 15 dB would mean the power spectral density = -158.88 dBm/Hz. P hot is expressed in dB.

P cold (Cold power density): This measurement is the same as P hot, however, the noise source is OFF.

Additional Resources

Literature

N9069A and W9069A X-Series Measurement Application, Technical Overview, *literature number 5989-6536EN*

Web

Product pages:
www.keysight.com/find/N9069A
www.keysight.com/find/W9069A

X-Series signal analyzers:
www.keysight.com/find/X-Series

X-Series measurement applications:
www.keysight.com/find/X-Series_apps

Application page:
www.keysight.com/find/nf