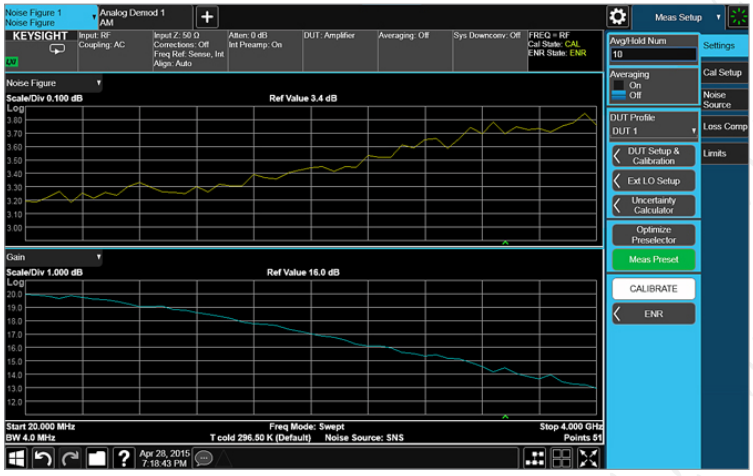
TECHNICAL OVERVIEW

Noise Figure
X-Series Measurement App, Multi-Touch UI N9069EM0E

- Characterize noise figure and gain of connectorized devices and system blocks with graph, meter, and table layouts and built-in uncertainty calculator
- Provide fully-specified measurements with optional internal preamp; improved specifications with external USB preamp
- Speed up multi-DUT measurements with multi-DUT calibration and measurement profiles
- Extend noise figure measurements to 110 GHz (Option 526 or greater required) with Keysight's K-Series block downconverters
- Use multi-touch front panel user interface or SCPI remote interface
- Flexible licensing provides the option of using perpetual or time based licenses with one or multiple signal analyzers



KEYSIGHT TECHNOLOGIES

Noise Figure Measurement Application

Noise figure is one of the fundamental parameters that differentiates one system, amplifier, or transistor from another. To minimize the problems resulting from noise generated in receiver systems, engineers can either make a weak signal stronger, or reduce the noise of that system or its individual components. The Keysight Technologies, Inc. N9069EM0E noise figure measurement application offers development engineers a simple tool to make accurate and repeatable noise figure measurements. The speed of this application also allows manufacturing engineers to rapidly measure any one of the following in their test racks:

- Noise figure/factor
- Gain
- Effective temperature
- Y-factor
- Hot/cold power density

The noise figure application utilizes the Y-factor method for calculating noise figure. By using a noise source, an X-Series signal analyzer can quickly determine the noise of the device under test. This method is very simple, as it utilizes a ratio of two noise power levels: one measured with the noise source ON and the other with the noise source OFF.

Preamps are available to reduce the uncertainty of Y-factor noise figure measurements. With an optional preamp installed in an X-Series signal analyzer or standard with N8973/N8974/N8975/N8976B NFA X-Series, you can obtain better noise figure measurements. NFA X-Series specifications are not included in this document. For those specifications, please visit www.keysight.com/find/NFA_X-series_specifications.

X-Series measurement applications increase the capability and functionality of Keysight signal analyzers to speed time to insight. They provide essential measurements for specific tasks in general-purpose, cellular communications, wireless connectivity and digital video applications, covering more than 40 standards or modulation types. Applications are supported on both benchtop and modular, with the only difference being the level of performance achieved by the hardware you select.

Make fast, accurate noise figure measurements with NFA

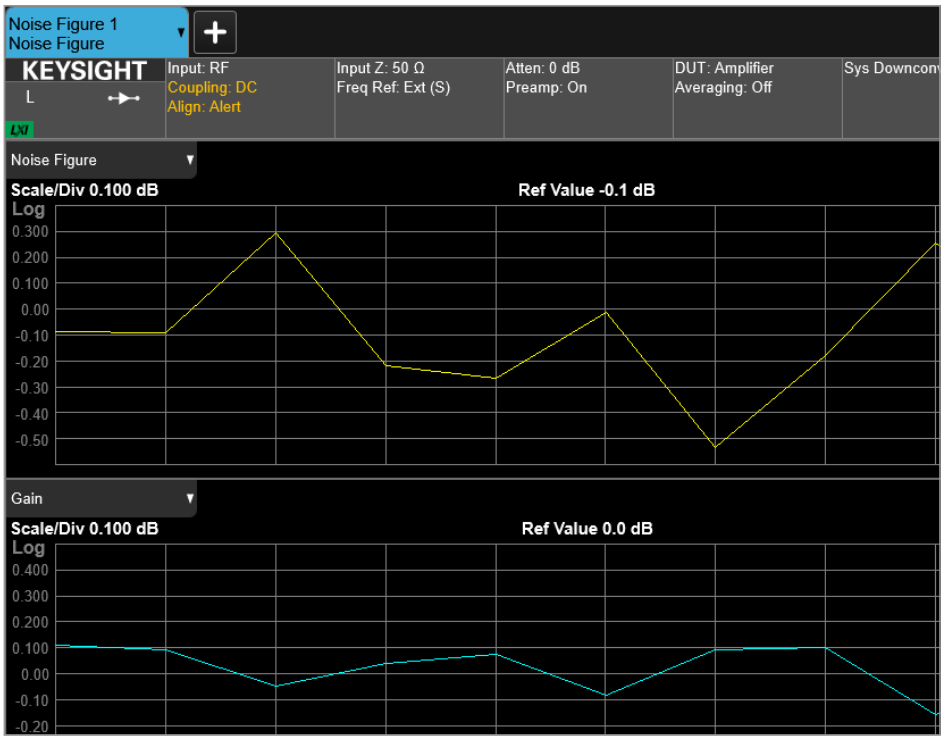
Performing accurate noise figure measurements start with a solid understanding of the uncertainty contributors - your components, subsystems and test equipment. The NFA X-Series noise figure analyzers are the simple way to make fast, accurate and repeatable noise figure measurements up to 40 GHz. With built-in expertise, ease of use features and a best-in-class USB preamplifier, our NFA's help you easily set up complex measurements - providing you with repeatable and reliable results while minimizing the overall uncertainty for your noise figure measurement challenges.

Learn more at:
www.keysight.com/find/nfa

Top Features

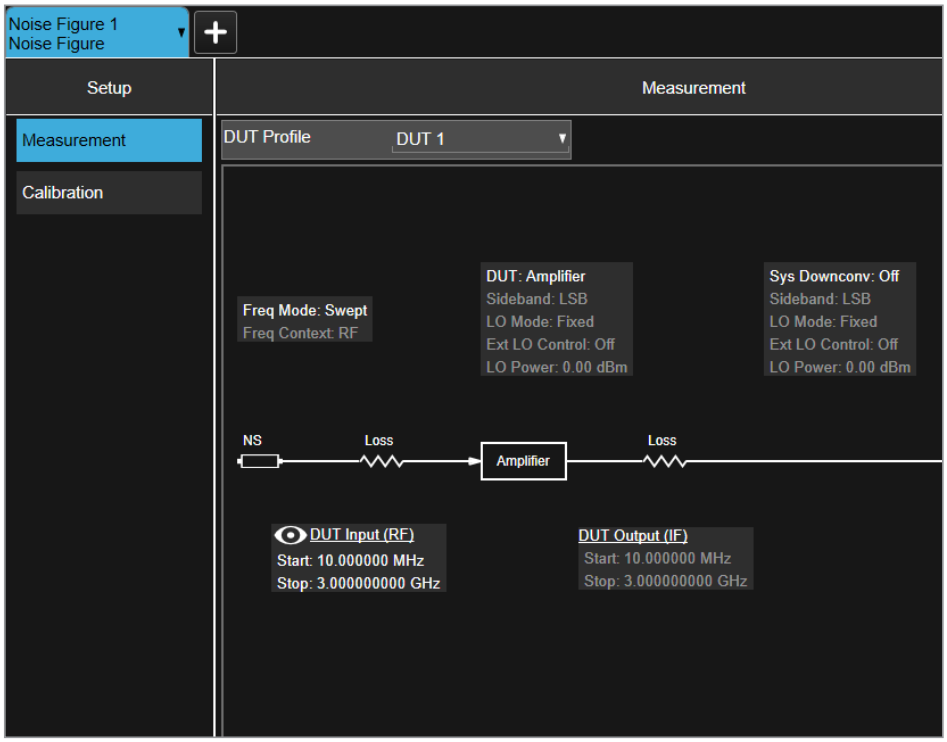
Noise figure and gain measurements for amplifier and converters

The N9069EM0E noise figure measurement application provides accurate noise figure and gain results for the DUT, which can be amplifiers or converters (including multi-stage converters). The noise figure and gain results are shown versus frequencies.



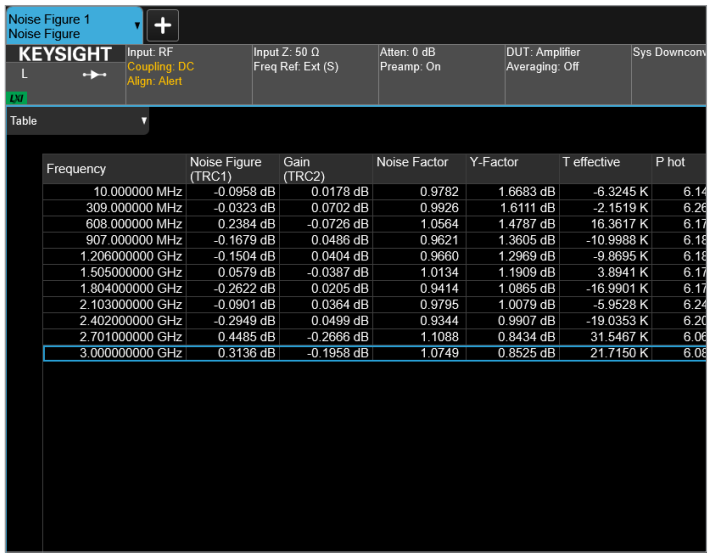
Multi-DUT calibration and measurement profiles

Use this feature to speed up your multi-DUT measurements. It enables you to set up measurement profiles for up to 12 DUTs, calibrate for each profile continuously, and make noise figure measurements on each DUT with the corresponding profile

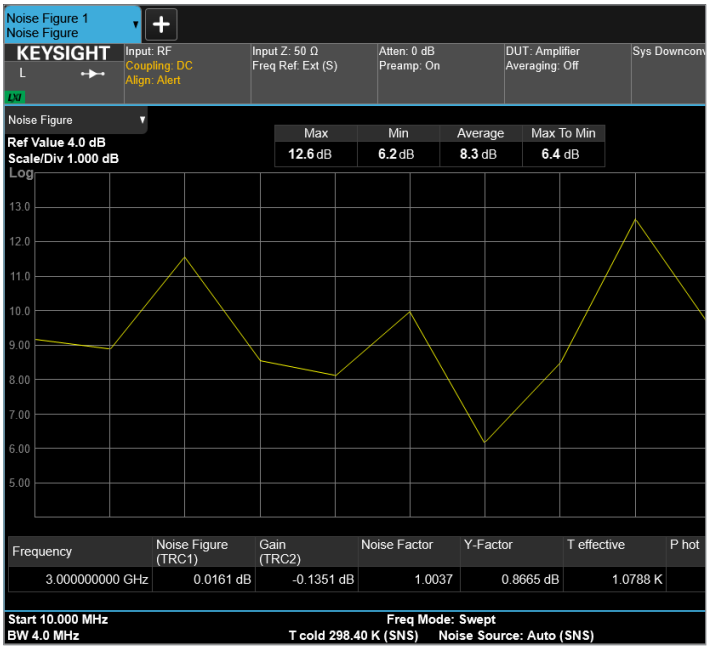


Simultaneous display of multi-results in table format or meter view

View multiple results of the DUT simultaneously in the table or meter layout. Results include noise figure, gain, noise factor, Y-Factor, T-Effective, P hot, and P cold.



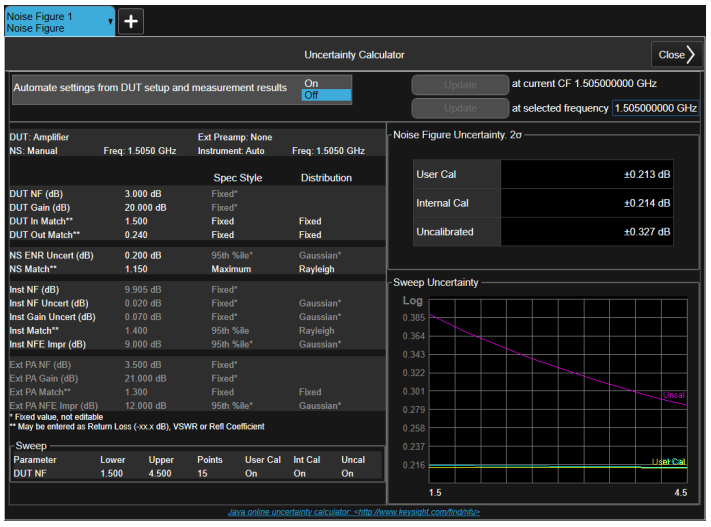
Frequency	Noise Figure (TRC1)	Gain (TRC2)	Noise Factor	Y-Factor	T effective	P hot
10.000000 MHz	-0.0958 dB	0.0178 dB	0.9782	1.6683 dB	-6.3245 K	6.14
309.000000 MHz	-0.0323 dB	0.0702 dB	0.9926	1.6111 dB	-2.1519 K	6.26
608.000000 MHz	0.2384 dB	-0.0726 dB	1.0564	1.4787 dB	16.3617 K	6.17
907.000000 MHz	-0.1679 dB	0.0486 dB	0.9621	1.3605 dB	-10.9988 K	6.19
1.206000000 GHz	-0.1504 dB	0.0404 dB	0.9660	1.2969 dB	-9.8695 K	6.19
1.505000000 GHz	0.0579 dB	-0.0387 dB	1.0134	1.1909 dB	3.8941 K	6.17
1.804000000 GHz	-0.2622 dB	0.0205 dB	0.9414	1.0865 dB	-16.9901 K	6.17
2.103000000 GHz	-0.0901 dB	0.0364 dB	0.9795	1.0079 dB	-5.9528 K	6.24
2.402000000 GHz	-0.2949 dB	0.0499 dB	0.9344	0.9907 dB	-19.0353 K	6.20
2.701000000 GHz	0.4485 dB	-0.2666 dB	1.1088	0.8434 dB	31.5467 K	6.06
3.000000000 GHz	0.3136 dB	-0.1958 dB	1.0749	0.8525 dB	21.7150 K	6.08



Frequency	Noise Figure (TRC1)	Gain (TRC2)	Noise Factor	Y-Factor	T effective	P hot
3.000000000 GHz	0.0161 dB	-0.1351 dB	1.0037	0.8665 dB	1.0788 K	

Built-in uncertainty calculator

Use the built-in uncertainty calculator to calculate the measurement uncertainty for the current measurement. It simplifies the process of calculating measurement uncertainty by importing the SNS ENR and the USB preamplifier data (if connected to the analyzer) as well as the instrument data automatically.



Key Specifications

Definitions

- Specifications describe the performance of parameters covered by the product warranty.
- 95th percentile values indicate the breadth of the population (≈2) of performance tolerances expected to be met in 95% of cases with a 95% confidence. These values are not covered by the product warranty.
- Typical values are designated with the abbreviation "typ." These are performance beyond specification that 80% of the units exhibit with a 95% confidence. These values are not covered by the product warranty.
- Nominal values are designated with the abbreviation "nom." These values indicate expected performance, or describe product performance that is useful in the application of the product, but is not covered by the product warranty.

Analyzer noise figure is computed from the specified DANL. See specifications on following pages for further explanation.

Noise figure for the combination of USB preamp and analyzer is

$$NF_{sys} = 10 * Log (F_{preamp} + (F_{analyzer} - 1)/G_{preamp})$$

The noise figure and gain of the preamp are specified and warranted.

Analyzer VSWR is characterized to the 95th percentile but not measured and warranted. USB preamp VSWR is measured and warranted and becomes the input VSWR of the measurement system when used.

Instrument uncertainty is defined for gain measurements as uncertainty due to relative amplitude uncertainties encountered in the analyzer when making the measurements required for the gain computation.

The noise figure measurement application is not specified for use below 10 MHz. Instrument uncertainty will nominally be the same as the 10 MHz to 3.6 GHz specifications; however, performance is not warranted. Instrument uncertainty for gain is characterized to the 95th percentile above 3.6 GHz.

These notes apply to the following specifications. For more information on configuring an X-Series signal analyzer for noise figure measurements, depending on the DUT noise figure and gain, see the Noise Figure Measurement Guide, literature number N9069-90001.

Performance specifications

The following table provides noise figure specification for the UXA. For specifications for other X-Series signal analyzers, please refer to the links at the end of this section.

UXA with U7227A preamplifier

Description		Specifications			Supplemental information
VSWR[1]	Frequency	UXA full range	UXA 26.5 GHz + U7227A preamp full range		
Band 0	10 to 100 MHz	1.45	3.57		
Band 0	0.1 to 2 GHz	1.45	1.54		
Band 0	2 to 3 GHz	1.45	1.73		
Band 0	3 to 3.6 GHz	1.45	1.93		
Band 1	3.5 to 4 GHz	1.54	1.93		
Band 1	4 to 8.4 GHz	1.54	–		
Band 2	8.3 to 13.6 GHz	1.57	–		
Band 3	13.5 to 17.1 GHz	1.48	–		
Band 4	17.0 to 26.5 GHz	1.54	–		
Noise figure[2, 3]		Internal preamp on	Internal preamp off + U7227A	Internal preamp on + U7227A	
	10 MHz to 100 MHz	12.25	9.46	5.96	
	0.1 to 2.1 GHz	12.25	9.49	5.45	
	2.1 to 3.6 GHz	14.25	11.35	5.65	
	3.5 to 4.0 GHz	14.25	12.88	5.63	
	4 to 6 GHz	14.25	–	–	
	6 to 8.4 GHz	14.25	–	–	
	8.3 to 13.6 GHz	15.25	–	–	
	13.5 to 16.9 GHz	17.25	–	–	
	16.9 to 18 GHz	19.25	–	–	
	18 to 20 GHz	19.25	–	–	
	20 to 26.5 GHz	23.25	–	–	
Instrument uncertainty for noise figure[4]					
10 MHz to 26.5 GHz					
Noise source ENR	Measurement range				
4 to 6.5 dB	0 to 20 dB	± 0.02 dB	± 0.02 dB	± 0.02 dB	Using the internal preamp and RBW 4 ≤ MHz
12 to 17 dB	0 to 30 dB	± 0.025 dB	± 0.025 dB	± 0.025 dB	
20 to 22 dB	0 to 35 dB	± 0.03 dB	± 0.03 dB	± 0.03 dB	
Instrument uncertainty for gain[5, 6]					
	10 MHz to 3.6 GHz	± 0.07 dB	± 0.07 dB	± 0.07 dB	DUT gain range = –20 to +40 dB
	> 3.6 GHz	± 0.13 dB	± 0.13 dB	± 0.13 dB	
Jitter		± 0.15 dB	± 0.15 dB	± 0.15 dB	

Performance specifications

UXA with U7227C preamplifier

Description		Specifications			Supplemental information
VSWR[1]	Frequency	UXA full range	UXA 26.5 GHz + U7227C preamp full range		
Band 0	10 to 100 MHz	1.45	–		
Band 0	0.1 to 3.6 GHz	1.45	1.43		
Band 1	3.5 to 4 GHz	1.54	1.43		
Band 1	4 to 8.4 GHz	1.54	2.32		
Band 2	8.3 to 13.6 GHz	1.57	2.32		
Band 3	13.5 to 17.1 GHz	1.48	2.32		
Band 4	17.0 to 26.5 GHz	1.54	2.32		
Noise figure[2, 3]		Internal preamp on	Internal preamp off + U7227A	Internal preamp on + U7227A	
	10 MHz to 100 MHz	12.25	–	–	
	0.1 to 2.1 GHz	12.25	9.88	6.36	
	2.1 to 3.6 GHz	14.25	11.60	6.52	
	3.5 to 4.0 GHz	14.25	13.06	6.51	
	4 to 6 GHz	14.25	11.64	5.56	
	6 to 8.4 GHz	14.25	10.94	4.61	
	8.3 to 13.6 GHz	15.25	10.66	4.57	
	13.5 to 16.9 GHz	17.25	13.30	4.74	
	16.9 to 18 GHz	19.25	15.77	5.06	
	18 to 20 GHz	19.25	15.37	5.77	
	20 to 26.5 GHz	23.25	20.39	6.25	
Instrument uncertainty for noise figure[4]					
10 MHz to 26.5 GHz					
Noise source ENR	Measurement range				
4 to 6.5 dB	0 to 20 dB	± 0.02 dB	± 0.02 dB	± 0.02 dB	Using the internal preamp and RBW 4 ≤ MHz
12 to 17 dB	0 to 30 dB	± 0.025 dB	± 0.025 dB	± 0.025 dB	
20 to 22 dB	0 to 35 dB	± 0.03 dB	± 0.03 dB	± 0.03 dB	
Instrument uncertainty for gain[5, 6]					
	10 MHz to 3.6 GHz	± 0.07	± 0.07	± 0.07	DUT gain range = –20 to +40 dB
	> 3.6 GHz	± 0.13 dB	± 0.13 dB	± 0.13 dB	
Jitter		± 0.15 dB	± 0.15 dB	± 0.15 dB	

1. Analyzer VSWR is characterized to the 95th percentile but not measured and warranted. The VSWR measurement is made on the PNA-X which is traceable. The reverse isolation of the USAB preamp is high enough that the system VSWR is insignificantly affected by the analyzer VSWR. So the system VSWR is the warranted VSWR of the USB preamp.
2. Analyzer noise figure is computed from the specified DANL using NF = D - (K - L + B) where D is the DANL (displayed average noise level), K is kTB (-173.98 dBm in a 1 Hz bandwidth at 290 K), L is 2.51 dB (the effect of log averaging used in DANL verifications), N is 0.24 dB (the ratio of the noise bandwidth of the RBW filter with which the DANL is specified to an ideal noise bandwidth), B is ten times the base-10 logarithm of the RBW (in hertz) in which the DANL is specified. B is 0 dB for the 1 Hz RBW. The actual NF will vary from the nominal due to frequency response errors. Frequency response errors help as often as they harm, so NF derived from the DANL is a very good approximation to the true NF. Any other uncertainties created by deriving the noise figure are small second-order uncertainties the GUM does not require.
3. Noise figure for the combination of USB preamp and analyzer is $NF_{sys} = 10*Log(F_{preamp} + (F_{analyzer} - 1)/G_{preamp})$. The noise figure and gain of the preamp are specified and warranted. The noise figure of the analyzer is derived and discussed in [2]. The uncertainty due to the noise figure of the analyzer is smaller than [2].
4. "Instrument Uncertainty" is defined for noise figure analysis as uncertainty due to relative amplitude uncertainties encountered in the analyzer when making the measurements required for a noise figure computation. The relative amplitude uncertainty depends on, but is not identical to, the relative display scale fidelity, also known as incremental log fidelity. The uncertainty of the analyzer is multiplied within the computation by an amount that depends on the Y factor to give the total uncertainty of the noise figure or gain measurement. See Agilent App Note 57-2, literature number 5952-3706E for details on the use of this specification. Jitter (amplitude variations) will also affect the accuracy of results. The standard deviation of the measured result decreases by a factor of the square root of the Resolution Bandwidth used and by the square root of the number of averages. This application uses the 4 MHz Resolution Bandwidth as default because this is the widest bandwidth with uncompromised accuracy.
5. "Instrument Uncertainty" is defined for gain measurements as uncertainty due to relative amplitude uncertainties encountered in the analyzer when making the measurements required for the gain computation. See Agilent App Note 57-2, literature number 5952-3706E for details on the use of this specification. Jitter (amplitude variations) will also affect the accuracy of results. The standard deviation of the measured result decreases by a factor of the square root of the Resolution Bandwidth used and by the square root of the number of averages. This application uses the 4 MHz Resolution Bandwidth as default since this is the widest bandwidth with uncompromised accuracy.
6. Instrument uncertainty for gain is characterized to the 95th percentile above 3.6 GHz.

Note: Data subject to change

For a complete list of specifications, refer to the appropriate specifications guide:
UXA: **www.keysight.com/find/uxa_specifications**
PXA: **www.keysight.com/find/pxa_specifications**
MXA: **www.keysight.com/find/mxa_specifications**
EXA: **www.keysight.com/find/exa_specifications**
CXA: **www.keysight.com/find/cxa_specifications**
NFA: **www.keysight.com/find/NFA_X-Series_specifications**

PXIe:
VSA up to 6 GHz: **www.keysight.com/find/m9391a**
VSA up to 50GHz: **www.keysight.com/find/m9393a**

Computing measurement uncertainty

Keysight provides three versions of noise figure uncertainty calculation, including

- Built-in noise figure uncertainty calculator (NFUC) enables you to calculate measurement uncertainty directly using the current measurement results.
- Spreadsheet version gives you the most freedom to enter DUT information and instrument specifications to get an accurate noise figure uncertainty. The spreadsheet version of the NFUC can be found at: www.keysight.com/find/nfu
- Online version enables you to sweep on almost all the relevant parameters to see their impact on measurement uncertainty. Access the online version of the NFUC through: www.keysight.com/find/nfuc

Ordering Information

Flexible licensing and configuration

- **Perpetual:** License can be used in perpetuity.
- **Time-based:** License is time limited to a defined period, such as 12-months.
- **Node-locked:** Allows you to use the license on one specified instrument/computer.
- **Transportable:** Allows you to use the license on one instrument/computer at a time. This license may be transferred to another instrument/computer using Keysight's online tool.
- **Floating:** Allows you to access the license on networked instruments/computers from a server, one at a time. For concurrent access, multiple licenses may be purchased.
- **USB portable:** Allows you to move the license from one instrument/computer to another by end-user only with certified USB dongle, purchased separately.
- **Software support subscription:** Allows the license holder access to Keysight technical support and all software upgrades

You Can Upgrade!

All of our X-Series application options are license-key upgradeable.

UP GRADE

Noise figure measurement application (N9069EM0E)

Software License Type	Software License	Support Subscription (12-month) [2]
Node-locked perpetual	R-Y5C-001-A[2]	R-Y6C-001-L[2]
Node-locked 12-month	R-Y4C-001-L[1]	Included
Transportable perpetual	R-Y5C-004-D[2]	R-Y6C-004-L[2]
Transportable 12-month	R-Y4C-004-L[1]	Included
Floating perpetual	R-Y5C-002-B[2]	R-Y6C-002-L[2]
Floating 12-month	R-Y4C-002-L[1]	Included
USB portable perpetual	R-Y5C-005-E[2]	R-Y6C-005-L[2]
USB portable 12-month	R-Y4C-005-L[1]	Included

One month software support subscription extensions [3]

Support Subscription	Description
R-Y6C-501[3]	1-month of software support subscription for node-locked license
R-Y6C-502[3]	1-month of software support subscription for floating license
R-Y6C-504[3]	1-month of software support subscription for transportable license
R-Y6C-505[3]	1-month of software support subscription for USB portable license

1. All time-based X-Series measurement application licenses includes a 12-month support contract which also includes the 12-month software support subscription as same duration.
2. Support contract must bundle software support subscription for all perpetual licenses in the first year. All software upgrades and Keysight support are provided for software licenses with valid support subscription.
3. After the first year, software support subscription may be extended with annual or monthly software support subscription extension.

Try Before You Buy!

Evaluate a full-featured version of our X-Series measurement application with our ***FREE*** trial. Redeem one 30-day trial license of each measurement application online at: www.keysight.com/find/X-Series_apps_trial

Hardware Configurations

To learn more about compatible platforms and required configurations, please visit: www.keysight.com/find/X-Series_apps_platform

Software Models & Options

To learn more about X-Series measurement application licensing, model numbers and options, please visit: www.keysight.com/find/X-Series_apps_model

Hardware configuration

For optimizing measurements on noise figure signals with the noise figure measurement application, Keysight recommends a minimum level of X-Series multi-touch instrument hardware functionality at each instrument performance point. Supported instruments include:

Benchtop:
- UXA N9040B
- PXA N9030B
- MXA N9020B
- EXA N9010B
- CXA N9000B

PXIe:
- VSA up to 6 GHz M9391A
- VSA up to 50 GHz M9393A

Capability	Instrument Option	Benefit
Precision Frequency Reference	-PFR	**Recommended**: For enhanced frequency accuracy and repeatability for lower measurement uncertainty
Electronic Attenuator	-EA3	**Recommended**: Fast and reliable attenuation changes ideal for manufacturing without the wear associated with mechanical attenuators up to 3.6 GHz in 1 dB steps
Pre-amplifier	3.6 GHz (-P03) or higher	**Recommended**: For maximizing the measurement sensitivity
Fine Resolution Step attenuator	-FSA	**Recommended**: Useful for maximizing useable dynamic range to see signals

M9391/93A PXIe VSA vector signal analyzer

Description	Model-Option	Additional information
Frequency range 3 or 6 GHz	M9391A-F03, or F06	One required for M9391A
Frequency range 8.4, 14, 18, or 27 GHz Frequency extension to 43.5 or 50 GHz	M9393A-F08, F14, F18, or F27 M9393A-FRZ or FRX	One required for M9393A Optional (requires M9393A-F27)
Analysis bandwidth 40, 100 or 160 MHz	M9391A/M9393A-B04, B10 or B16	One required
Memory 128, 512 or 1024 MSa	M9391A/M9393A-M01, M05 or M10	One required
Frequency reference 10 MHz and 100 MHz	M9391A/M9393A-300	One required

Noise source

346 Series noise sources work with the full range of Keysight noise figure solutions. They are categorized by frequency coverage as well as excess noise ratio (ENR). The SNS noise sources replicate the ENR output and frequency coverage of the 346 Series noise sources, however with the SNS Series, ENR data is stored in an EPROM and is automatically downloaded to the instrument, eliminating the need to manually enter the values into the calibration table at each cardinal frequency point. In addition, a thermistor is built into the sensor to continually update the analyzer with the correct temperature, delivering automatic temperature compensation/correction within the measurement's source.

The U7227A/C/F USB preamplifiers, used with an X-Series signal analyzer reduces uncertainty of Y-factor noise figure measurements up to 50 GHz.

Noise source	Frequency range	ENR
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
346CK01	1 GHz to 50 GHz	7 to 20 dB
346CK40	1 GHz to 40 GHz	3 to 14 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
U1831C	10 MHz to 26.5 GHz	12 to 17 dB

Note: If the DUT noise figure is beyond 30 dB, then the Keysight PNA-X Option 029 for noise figure measurements on a network analyzer may be more suitable than the Y-factor method.

USB preamplifiers

Specification	U7227A	U7227C	U7227F
Frequency	10 MHz to 4 GHz	100 MHz to 26.5 GHz	2 GHz to 50 GHz
Gain (dB)	10 to 100 MHz: > 16 100 MHz to 4 GHz: > 0.5F + 17	100 MHz to 26.5 GHz: > 16.1 + 0.26F	2 to 50 GHz: > 16.5 + 0.23F
Input return loss (Input SWR)	10 to 100 MHz: > 5 dB (3.57) 100 MHz to 2 GHz: > 13.5 dB (1.54) 2 to 3 GHz: > 11.5 dB (1.73) 3 to 4 GHz: > 10 dB (1.93)	100 MHz to 4 GHz: > 15 dB (1.43) 4 to 26.5 GHz: > 8 dB (2.32)	2 GHz to 40 GHz: > 8 dB (2.32) 40 to 44 GHz: > 6 dB (3.00) 44 to 50 GHz: > 5 dB (3.57)
Output return loss (Output SWR)	10 MHz to 4 GHz: > 18 dB (1.29)	100 MHz to 4 GHz: > 18 dB (1.29) 4 to 26.5 GHz: > 11 dB (1.78)	2 GHz to 4 GHz: > 18 dB (1.29) 4 to 40 GHz: > 11 dB (1.78) 40 to 50 GHz: > 8 dB (2.32)
Noise figure	10 to 100 MHz: < 5.5 dB 10 MHz to 4 GHz: < 5 dB	100 MHz to 4 GHz: < 6 dB 4 to 6 GHz: < 5 dB 6 to 18 GHz: < 4 dB 18 to 26.5 GHz: < 5 dB	2 to 4 GHz: < 10 dB 4 to 40 GHz: < 8 dB 40 to 44 GHz: < 9 dB 44 to 50 GHz: < 10 dB
Plug and play USB connection	Yes	Yes	Yes
Optimized gain slope for better spectrum analysis	Yes	Yes	Yes
Automatic gain compensation	Yes	Yes	Yes
Automatic temperature compensation	Yes	Yes	Yes

Related Literature

Fundamentals of RF and Microwave Noise Figure Measurements - Application Note, literature number 5952-8255EN

Noise Figure Measurement Accuracy – the Y-factor method - Application Note, literature number 5952-3706EN

10 Hints for Making Successful Noise Figure Measurements - Application Note, literature number 5980-0288E

Keysight N4000A, N4001A, N4002A SNS Series Noise Sources 10 MHz to 26.5 GHz - Technical Overview, literature number 5980-0288E

Keysight USB Preamplifiers U7227A/C/F - Technical Overview, literature number 5991-4246EN

Web

Noise figure X-Series measurement app, multi-touch UI product webpage:
www.keysight.com/find/N9069E

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

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

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

KEYSIGHT TECHNOLOGIES