APPLICATION NOTE

Compatibility of USB Power Sensors with Keysight Instruments

Use USB Power Sensors as a Keysight Instruments Accessory

In many of today's power measurement applications there is a need to make power measurements and use other instruments such as a spectrum analyzer, vector network analyzer or signal generator. Traditional power-measurement methodologies require a power meter and a power sensor. This situation increases the costs of a test system significantly. Alternatively, Keysight Technologies, Inc. USB power sensors can be used as an accessory with other Keysight instruments, allowing the power measurement to be done via Keysight instruments, and perform other specific power measurement applications without the need for a PC/laptop.

This application note explains how the Keysight USB power sensor performs source power calibration with the N5222B PNA microwave network analyzer, and scalar analysis of a frequency converter with the E5071C/80A ENA vector network analyzer. The USB power sensors are able to augment the FieldFox handheld analyzer, N934xB/C HSA handheld spectrum analyzer, and X-Series signal generator with a power meter function. Keysight USB sensor are also able to provide user flatness correction (UFC) with external leveling and automatically level RF power amplifier output as well as USB pass through commands using the X-Series signal generator.

KEYSIGHT TECHNOLOGIES

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Keysight USB Power Sensors

Making an accurate power measurement requires both a power meter and power sensor. The power sensor converts the RF signal and microwave signal into analog signals. Subsequently, the power meter performs the statistical processing and displays the result in decimal/trace format. Today, the combination of a power meter and power sensor makes the USB power sensor a standalone instrument that provides an affordable solution for power measurement. Results of the power measurement can be retrieved and shown on the BenchVue software, BV0007B Power Meters/Sensors Control and Analysis App on the PC via a USB cable or SCPI commands. The SCPI-based command set provides a user-friendly programming environment and allows the use of the same method of communication for both the power sensor and the power meter.

Keysight offers four families of USB power sensors compatible with other Keysight instruments such as the network analyzer, spectrum analyzer, signal generator, cable and antenna tester, and FieldFox handheld analyzer:

- U2000A Series USB average power sensors
- U2020 X-Series USB peak and average power sensors
- U8480 Series USB thermocouple power sensors
- U2040 X-Series wide dynamic range peak and average power sensors

When USB power sensors are connected to these instruments without the need of PC/laptop, they can be powered-up to perform the specific application.

USB Power Sensor's Compatibility with Keysight Instruments

Keysight instruments such as vector network analyzers, spectrum analyzers, signal generators, cable and antenna testers, and FieldFox RF analyzers are now compatible with the Keysight USB power sensors (see Table 1 and Figure 2). Each compatible instrument has built-in firmware to support the USB power sensor, unless it specifically requires the BV0007B, BenchVue Power Meter App software.

Vector network analyzer

- Performs the source power calibration for providing accurate output power levels
- Plot the power sensor's power measurement on the VNA's display (Power Meter As Receiver function, available on PNA-X, PNA, PNA-L and E5071C, PXI-VNA and E5080A)

X-Series signal generator (EXG and MXG)

- Performs user flatness correction (UFC) with external leveling. Also turns the instrument into a power meter. Displays power measurement with its built-in user interface (UI), which integrates the display of USB power sensor measurements
- Supports and displays two USB power sensor measurements on a signal generator display. Automatically levels RF power amplifier output with power servo feature. Uses USB pass through commands to remotely control and program the power sensor.

Table 1. Keysight USB power sensors compatible with Keysight instruments

Keysight instruments	Model number	Keysight USB/LAN power sensors				
		U2000 Series	U2020 X-Series	U8480 Series	U2041-44XA USB Sensor	U2049XA LAN sensor
Vector network analyzer	PNA: E836xA/B/C[3]	Yes	No	No	No	No
	PNA: N522xA/B	Yes	Yes	Yes	Yes[2]	Yes[2]
	PNA-X: N524xA/B/ N5264A/B	Yes	Yes	Yes	Yes[2]	Yes[2]
	PNA-L: N5230A/C[3]	Yes	No	No	No	No
	PNA-L: N523xA/B	Yes	Yes	Yes	Yes[2]	Yes[2]
	ENA: E506xA/B[3]	No	No	No	No	No
	ENA: E5071C	Yes	Yes	Yes	Yes	No
	ENA: E5072A	Yes	No	No	No	No
	ENA: E5080A	Yes	Yes	Yes	Yes	Yes
	PXI: M937xA/M9485A	Yes	Yes	Yes	Yes	Yes
Spectrum analyzer/ signal analyzer	N9340B	Yes	No	No	No	No
	Handheld SA: N9342/43/44C	Yes	Yes	No	Yes	No
	N9320B	Yes	No	No	No	No
	BSA: N9322C	Yes	Yes	Yes	Yes	No
	CXA: N9000A	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]
	MXA: N9020A	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]
	EXA: N9010A	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]
	PXA: N9030A	Yes[1]	Yes[1]	Yes[1]	Yes[1]	Yes[1]
Signal generator	EXG: N517xB	Yes	Yes	Yes	Yes	No
	MXG: N518xA/B and N516xA	Yes	Yes	Yes	Yes	No
	UXG: N5193A	Yes	Yes	Yes	Yes	No
Fieldfox handheld analyzer	N991xA/5xA microwave combination analyzer	Yes	Yes	Yes	Yes	Yes
	N992xA microwave vector network analyzer	Yes	Yes	Yes	Yes	Yes
	N993xA/6xA microwave spectrum analyzer	Yes	Yes	Yes	Yes	Yes

1. Required installation of BV0007B BenchVue Power Meters/Sensors Control and Analysis app. Refer to the BenchVue Software Data Sheet (5991-3850EN) for PC hardware requirements.
2. Supported by instruments installed with Window 7 only.
3. Discontinued models

Handheld/RF spectrum analyzer and cable and antenna tester

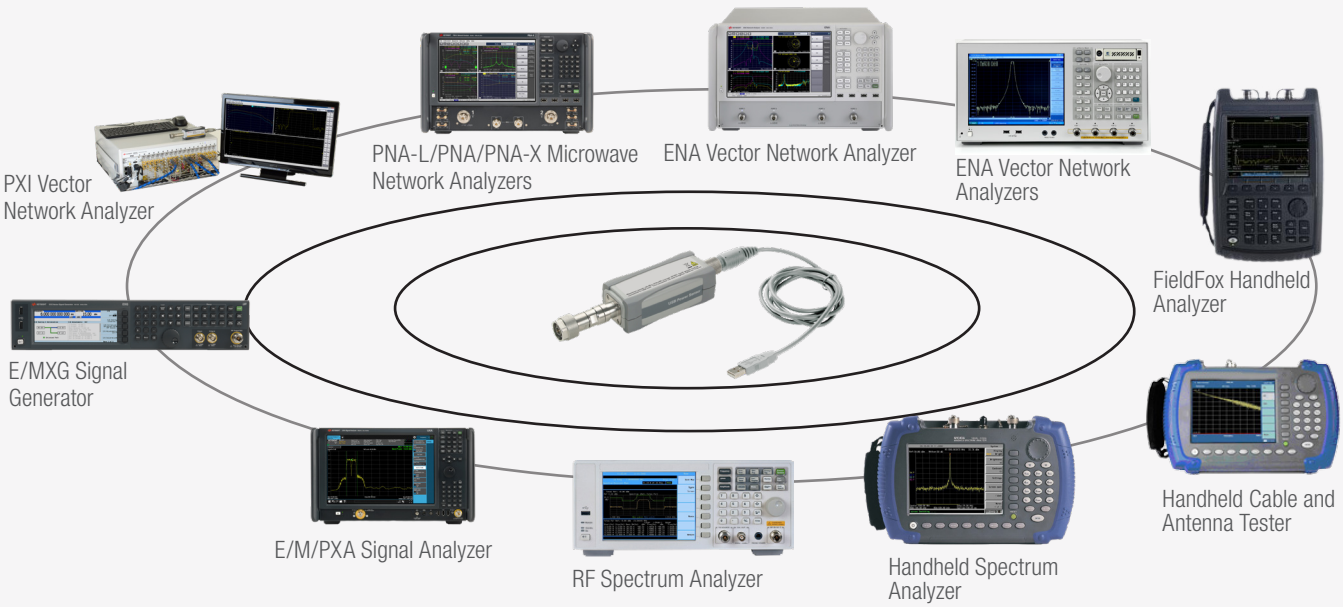
Turns the instrument into a power meter. Displays power measurement with its built-in UI, which integrates the display of USB power sensor measurements.

FieldFox handheld analyzer

Turns the instrument into a power meter. Displays power measurement with its built-in UI. Supports average and peak power measurements under Free Run mode, as well as pulse measurement under Continuous mode.

Spectrum analyzer (X-series signal anlayzers)

To display the power measurement on spectrum analyzer with the N1918A Power Analysis Manager or BenchVue Power Meter App software.



Note: Each compatible instrument comes with built-in firmware to support the USB power sensor, unless specified BenchVue software, BV0007B Power Meters/Sensors Control and Analysis App or VBA wizard is required.

Figure 2. USB power sensors' compatibility with Keysight instruments

How Does It Work?

PNA Family microwave network analyzer

Performs the source power calibration to provide the output power in order to measure the gain compression, inter-modulation distortion, and other parameters of active devices accurately.

The source power calibration allows you to calibrate the source power within the range of the uncertainty of the USB power sensor across the specified measurement frequency range.

As shown in Figure 3, a USB power sensor can be connected to a USB port on the PNA directly. Once the PNA detects the sensor, you can run the SmartCal (guided calibration) function, which guides you to perform the S-parameter calibration, the, match-corrected source power calibration and the receiver power calibration.

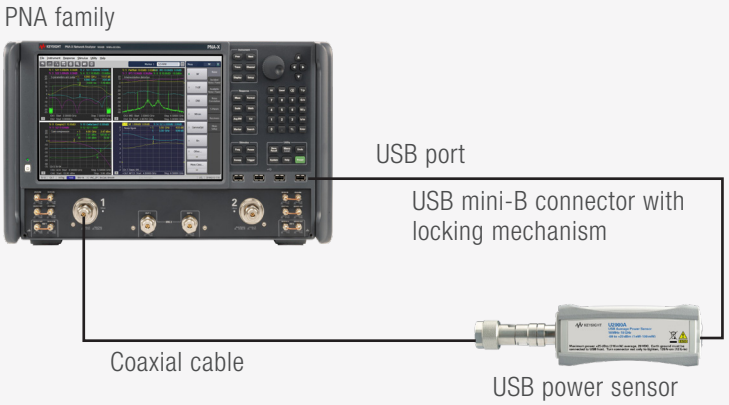


Figure 3. USB power sensor connecting directly to a PNA USB port through a USB mini-B connector.

If you have a classic configuration: a power meter and a power sensor, you can do the source power calibration by connecting the power meter to the PNA via GPIB (Figure 4).

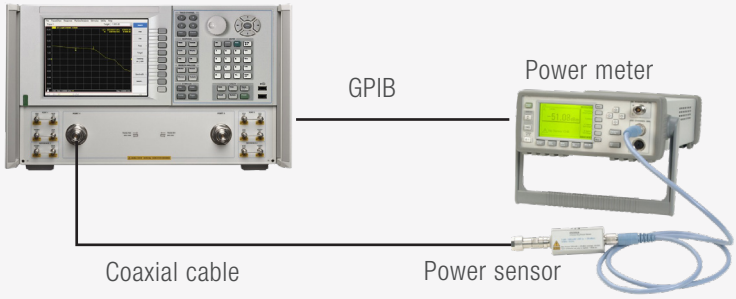


Figure 4. Source Power Cal using both a power meter and power sensor connected to a PNA through a GPIB connection.

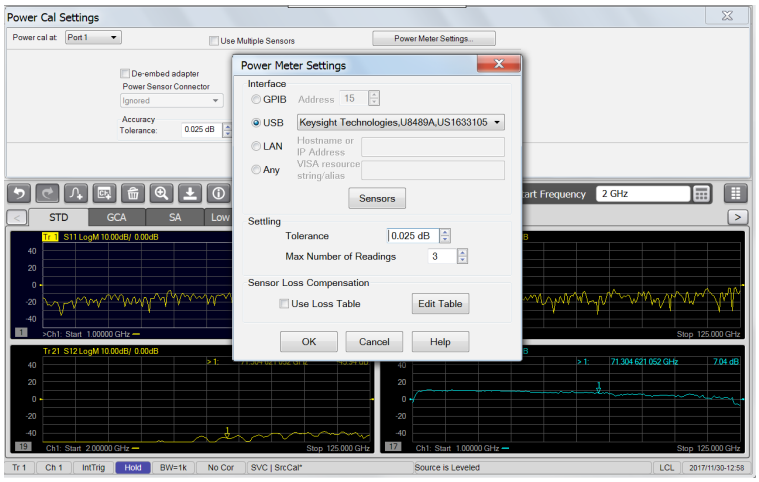


Figure 5. PNA's power meter setting for configuring USB sensor via a USB connectivity

Figure 6 show the results of source power calibration for USB power sensors. The PNA source is stepped through the specified range (in this example, stepped from 1 to 6 GHz), and power (at 0 dBm) is measured with the USB power sensor. At each data point, the source power is adjusted until the measured power is within the specified accuracy level.

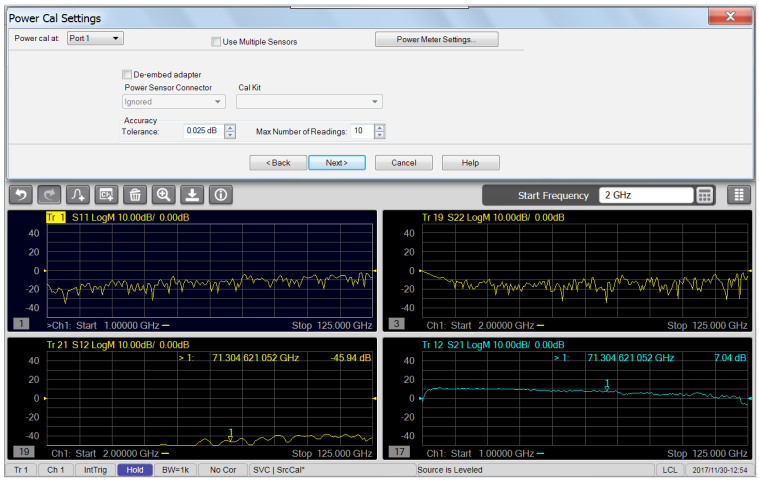


Figure 6. Source power calibration result with a USB power sensor

Note:

For details about the source power calibration procedure, please refer to the Keysight Web site's PNA Source Power Cal procedure online help file (Power Calibration, under the Calibrating a Measurement section). You can readily obtain the procedure from Network Analyzer's Help menu.

E5071C / E5080A ENA network analyzers

Some vector network analyzers such as the E5071C or E5080A ENA Series can measure mixers or frequency converters accurately.

The frequency offset mode (FOM) function of the S96082A Scalar Mixer/Converter Measurements software tunes the E5080A ENA's receivers to different frequencies from the signal source and controls an external signal generator as a LO signal source, and that enables to measure the conversion loss of mixers/converters. The software provides a scalar mixer calibration (SMC) function to achieve the highest accuracy for scalar conversion-loss/gain measurements.

The basic procedure of the SMC:

1. Connect a USB power sensor to one of the network analyzer's ports.
2. Measure the input match of the power sensor and the source power of the ENA.
3. Perform two sets of full 2-port calibration – one over the input frequencies and the other one over the output frequencies of the mixer under test. This SMC removes mismatch errors of the power sensor, and thus provides accurate measurements of the converter's loss.

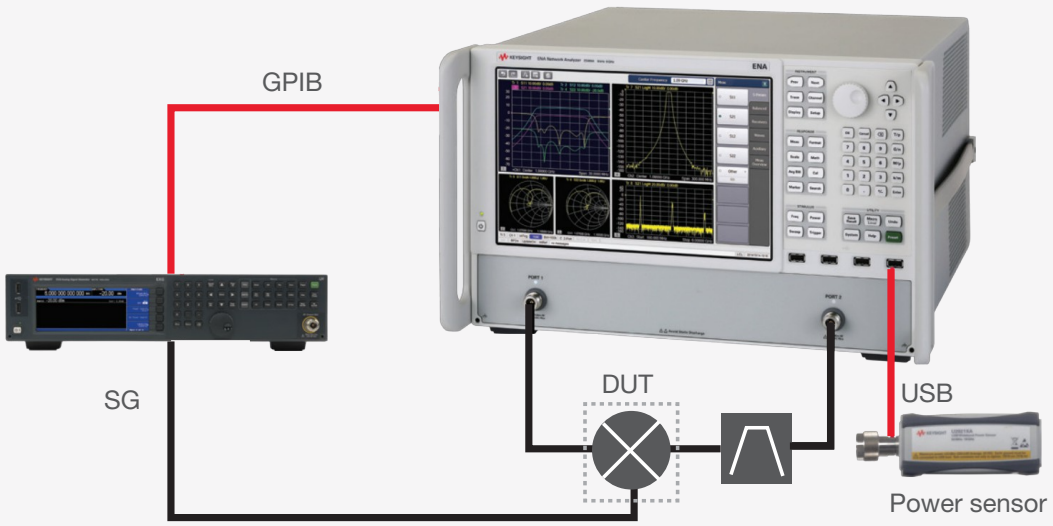


Figure 7. Scalar Mixer Calibration (SMC) setup using a USB power sensor

N9340B handheld spectrum analyzer (HSA)

- Turns the handheld spectrum analyzer into a power meter.
- Displays power measurement with its built-in UI, which integrates the display of USB power sensor measurements.

Keystrokes surrounded by [ ] represent front-panel hardkeys of the instruments, while keystrokes surrounded by { } represent softkeys.

Instructions

Power up the N9340B. Connect the USB power sensor to the USB port of the N9340B (see Figure 13).

Figure 13. N9340B HSA connect with USB power sensor

Press [Mode], use [↑] or [↓] to select {Power Meter} then press [ENTER] (see Figure 14).

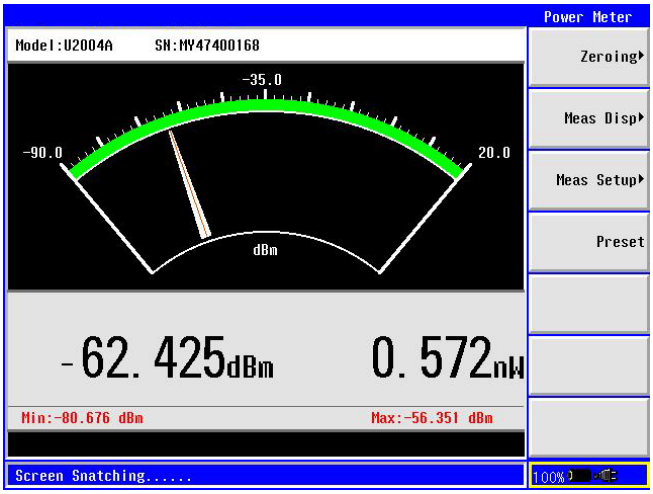


Figure 14. N9340B HSA HHSA turns into a power-meter measurement

Power meter menu

- Zeroing: Access to zeroing and calibration menu.
- Meas Disp: Access to measurement display menu and to configure the displayed measurement resolution and format.
- Meas Setup: Set up the relative measurement or set display offsets.
- Preset: Preset the USB power sensor.

Instructions

3. Press {Zeroing ▶} to perform the internal or external zeroing if necessary (see Figure 15).

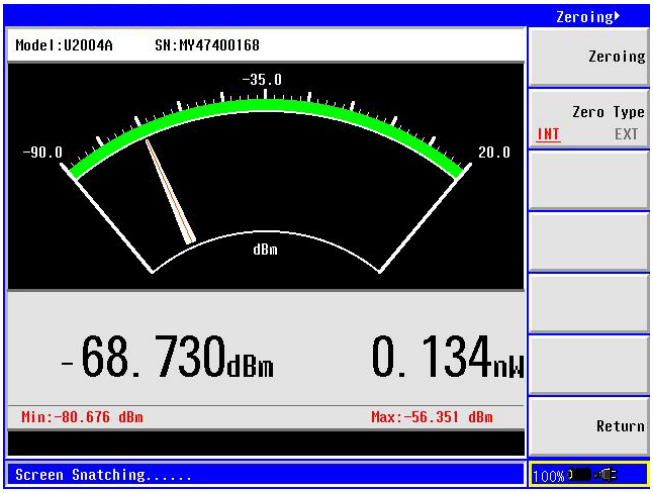


Figure 15. External and internal zeroing are performed to reduce the zero offset and noise impact in order to measure power accurately

Internal zeroing

Internal zeroing uses an electronic switch to isolate the power sensor bulkhead from the internal measurement circuitry during the procedure, allowing the sensor to be physically connected to an active RF source when internally zeroing. Therefore, you do not need to disconnect the RF source or power off the external source during an internal zeroing procedure. This feature makes internal zeroing more convenient, but you may only use internal zeroing if zero set (Internal) is within the application requirements.

External zeroing (applicable to the U2000 Series USB average power sensor only)

In external zeroing, the sensor does not use the electronic switch to isolate the measurement circuitry from the bulkhead. In this case, the RF power must be removed from the bulkhead either by turning the source off or physically removing it from the sensor during the external zeroing procedure. External zeroing generally has better zero set performance. The INT or EXT zeroing selection should be made based on the measurement needs.

By default, internal zeroing is performed by the firmware when the USB sensor is connected to the N9340B HHSA.

Instructions

4. Press {Return} > {Meas Disp ▶} (see Figure 16).

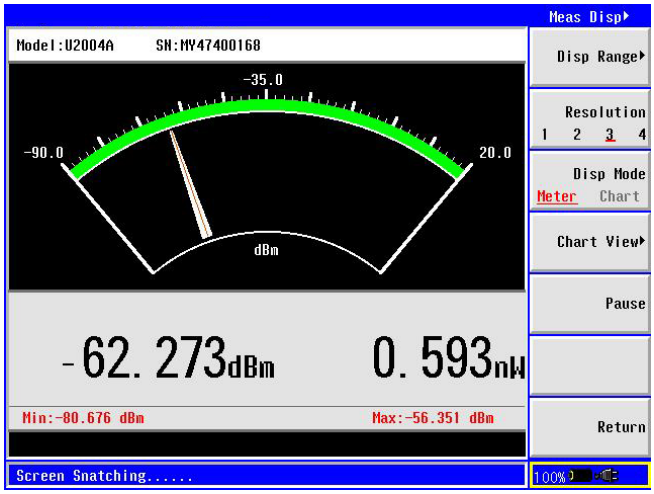


Figure 16. Meas Disp menu allows you to configure the display measurement and resolution

The Meas Disp (Measurement Display) menu allows you to configure the measurement display as follows:

- Disp Range: Indicates the top and bottom range of display measurement.
- Resolution: Indicates the measurement resolution's numeric type in four different levels (1, 2, 3, or 4). The default Resolution is 3.
- Disp Mode: You can configure the measurement display either in meter or chart format. The default Disp Mode is Meter.
- Chart View: Switches the measurement display to chart view.
- Pause: Pauses or continues the measurements.

To view the measurement in chart or graph format, press {Disp Mode} > {Chart} (see Figure 17).

Figure 17. Measurement display in chart format

Instructions

5. Press {Return} > {Meas Setup} (see Figure 18).

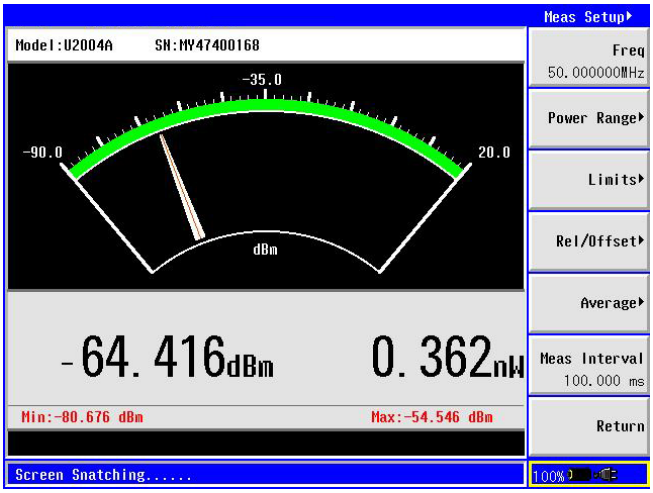


Figure 18. Measurement Setup menu with meter-view display measurement

Meas Setup (Measurement Setup) menu allows you to set up the relative measurement or set display offsets.

- Freq: Allows the frequency of the RF signal that you are measuring to be set. It optimizes the accuracy and minimizes measurement uncertainty, especially when making comparative measurements between signals.
- Power Range: Allows you to set the power range to Auto or Manual. Using Auto range is encouraged when there is uncertainty about the power level to be measured.
  In Manual range, there are two manual setting: Lower and Upper. Lower range covers the power from –60 to –10 dBm. Upper range covers the power from –10 to +20 dBm.
- Limits: Indicates if the measurement result is beyond the configured upper or lower limit.
- Rel/Offset: Rel (Relative) mode enables a comparison of a measurement result to a reference value. The relative reading, or difference, can be displayed in either dB or %. The offset setting can be configured to compensate for signal loss or gain (in dB) in the test setup.
- Averaging: Allows the measurement averaging to be set in Auto or Manual mode, to average power readings.
  The purpose of averaging is to reduce noise, obtain the desired resolution, and reduce the jitter in the measurement results. Increasing the value of the measurement average reduces measurement noise, but the measurement time increases. The default of Averaging is Auto.
- Step Detect: Reduces the filter settling time after a significant step in the measured power.
  The filter can be set to re-initialize upon detection of a step increase or decrease in the measured power.
- Meas Interval: Allows you to set the time (in s or ms) to capture the new power measurement continuously.

X-Series signal generator

- Performs user flatness correction (UFC) with external leveling to improve power accuracy and flatness.
- Provides dual display measurement of two USB power sensors.
- Automatically levels RF power amplifiers output with power meter servo feature.
- Uses the USB pass through commands to remotely program the USB power sensor using USB pass through.

User flatness correction (UFC)

User flatness correction (UFC) with external leveling provides the ability to have extremely flat output power at the testing interface beyond the signal generator's RF output connector. If an external device (such as amplifier, attenuator, coupler, detector, divider, or long cable) is placed between the RF output connector and the testing interface, it will introduce additional gain or loss as well as frequency response mismatch to the whole system. Therefore, it is necessary to perform the UFC with external leveling to remove this type of influence. In this case, the USB power sensor integrated with the MXG offers a solution. The USB power sensor directly connects to the MXG's front panel USB port (see Figure 19), providing a remote programming function. The MXG's built-in UFC personality allows you to configure the calibration array, start and stop frequency, and number of the frequency points to be corrected. The setup function will observe the difference between measured power and calibrated power.

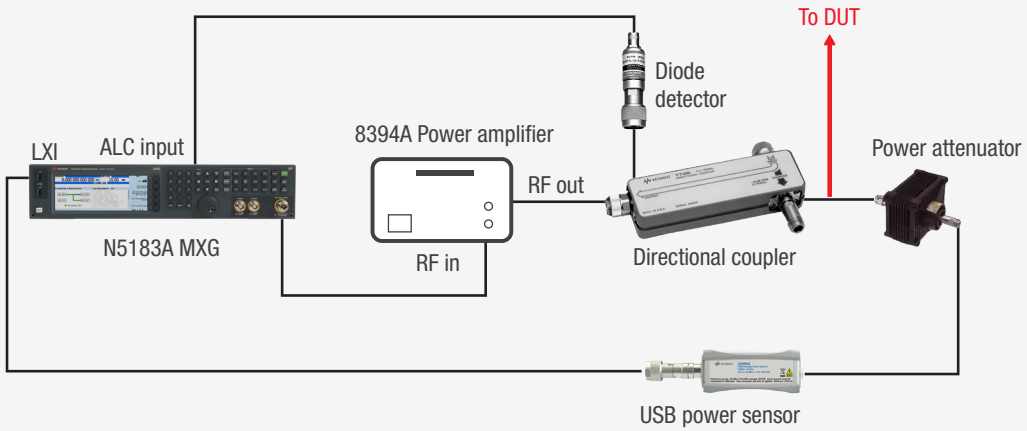


Figure 19. Power meter servo configuration

The correction factors of the UFC process are shown in Figure 20. For details on the operation and procedure on UFC with external level use of the measurement, please refer to *Keysight How to Utilize User Flatness Correction with External Leveling Using USB Power Sensor on MXG Signal Generator,* Application Note and *Keysight X-Series Signal Generators*, User's Guide.

Figure 20. Correction factors automatically performed and displayed on the MXG

Dual power meter display function

The dual power meter display function can be used to display the current frequency and average power of either one or two power sensors. For each channel, you can control the settings for On/Off, channel frequency, channel offset, averaging and measurement units, and the dual power meter display feature.

To use two USB power sensors with the MXG N518xA or N516xA, a USB hub (with power supply) can be connected to the MXG's front panel USB port (see Figure 21).

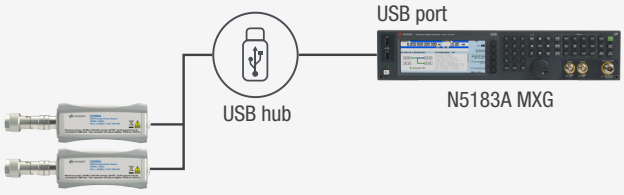


Figure 21. Connection diagram of two USB power sensors on MXG via external USB hub

Alternatively, the MXG B version, N518xB, and EXG N517xB signal generators come with two USB ports on the front panel. Without the need for an external USB hub, two USB power sensors can be connected directly, providing the generator with two-channel power measurement and the ability to make measurements simultaneously.

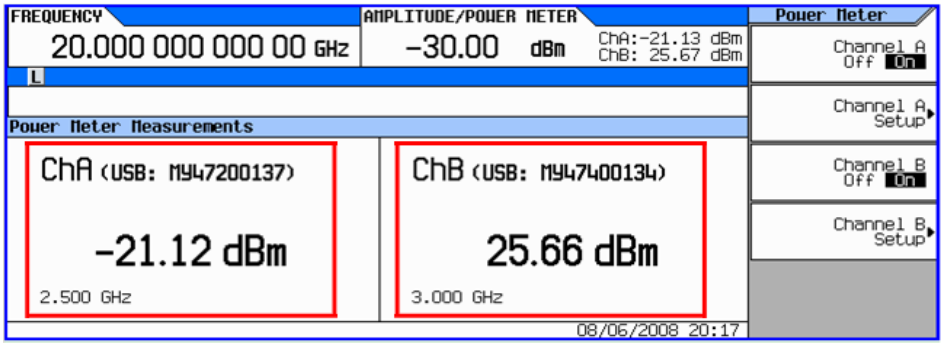


Figure 22. Dual power meter display function on MXG signal generator

To automatically level RF power amplifier output with power meter servo feature.

- Automatically levels amplifier output with USB power sensor accuracy using the X-Series signal generator's power meter servo feature

The power meter servo feature uses USB power sensor readings to adjust the output power of the source while maintaining a constant DUT output power. The power meter servo loop measures the output power of the DUT, compares it to the user-provided reference power, and adjusts the output of the source to achieve the user-provided power level within the settling error. This feature enables the automatic levelling of the RF power amplifier, which is especially useful for measurements of EVM, ACLR, LTE, or W-CDMA signals with a high peak-to-average ratio.

The power meter servo feature offers two types of RF levelling modes:

- Once Leveling: Power Meter Once performs the adjustment only at the end of any transition (amplitude or frequency change). After the adjustment is performed and the power is corrected, no further adjustments are performed until the next transition.
- Continuous Leveling: Power Meter Continuous performs the adjustment as in Power Meter Once mode, and continues to adjust the power periodically if the value differs by more than the specified settling error.

Figure 23 shows an example of a power meter servo configuration with USB power sensor and signal generator. This example emphasizes the importance of setting the amplitude offset as it protects the amplifier (DUT) from being exposed to too much power.

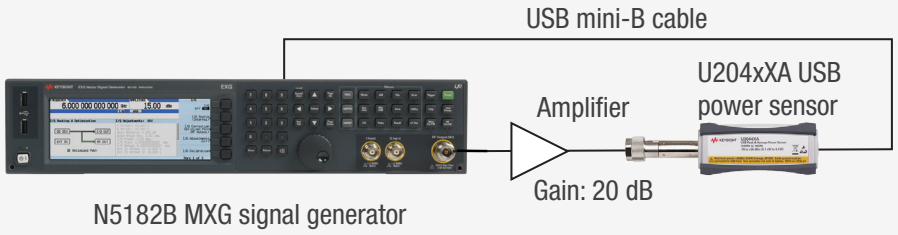


Figure 23. Power meter servo configuration

For this example, the source amplitude offset is 20 dB and the source amplitude is programmed to 25 dBm. The offset is subtracted from the programmed level, making the actual source output power 5 dBm. If the USB power sensor measures 24.5 dBm, for example, the output power will be adjusted by 0.5 dBm since the power measurement is 0.5 dBm lower than the desired 25 dBm. The new source output power is 5.5 dBm. If the USB power sensor then measures 24.97 dBm, no further adjustments will be made since the measured value is within half of the settling error of 0.2 dB.

If the amplitude offset remained at the default of 0 dB, the output power set to 25 dBm results in a power measurement of 40 dBm (assuming the amplifier already went into compression). The algorithm would have reduced the source power by 15 dB, thus outputting 10 dBm and resulting in a measurement of around 29.5 dBm. The additional reduction of another 4.5 dB would have led to the same outcome as with the 20 dB amplitude offset (source output power of 5.5 dBm). However, in-between, the DUT could possibly be stressed past its specified operating range.

For more information on the operation of the power meter servo feature, please refer to *Keysight X-Series Signal Generator*, User's Guide.

USB pass through SCPI commands

- Programs the USB power sensor test setup with USB pass through SCPI commands using an EXG/MXG signal generator

Users typically program USB power sensors by connecting the sensor to a PC and remotely controlling it through the PC. In additional to the dual power meter display, the EXG/MXG signal generator now offer an SCPI pass through method of accessing an attached USB power sensor (see Figure 24). In this mode, the signal generator exposes commands that encapsulate USB power sensor commands, allowing commands and query responses to pass through the signal generator.

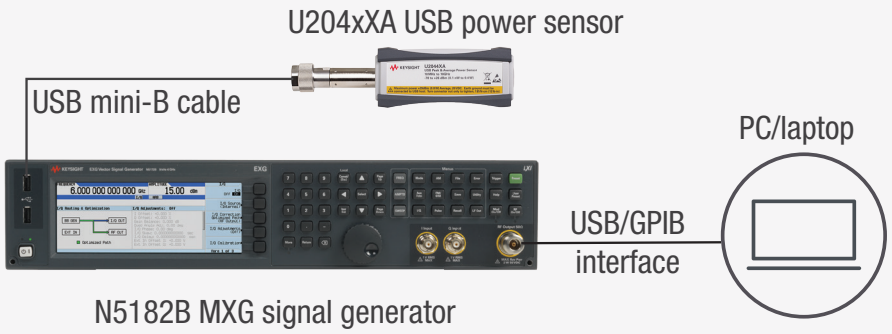


Figure 24. Connection diagram showing a USB power sensor connected to the N5182B MXG signal generator's USB port

Figure 25 shows an example of Keysight VEE software that was written to program the USB power sensor using the USB pass through SCPI commands. For more information on the USB pass through commands feature, please refer to the *Keysight X-Series Signal Generator,* User's Guide.

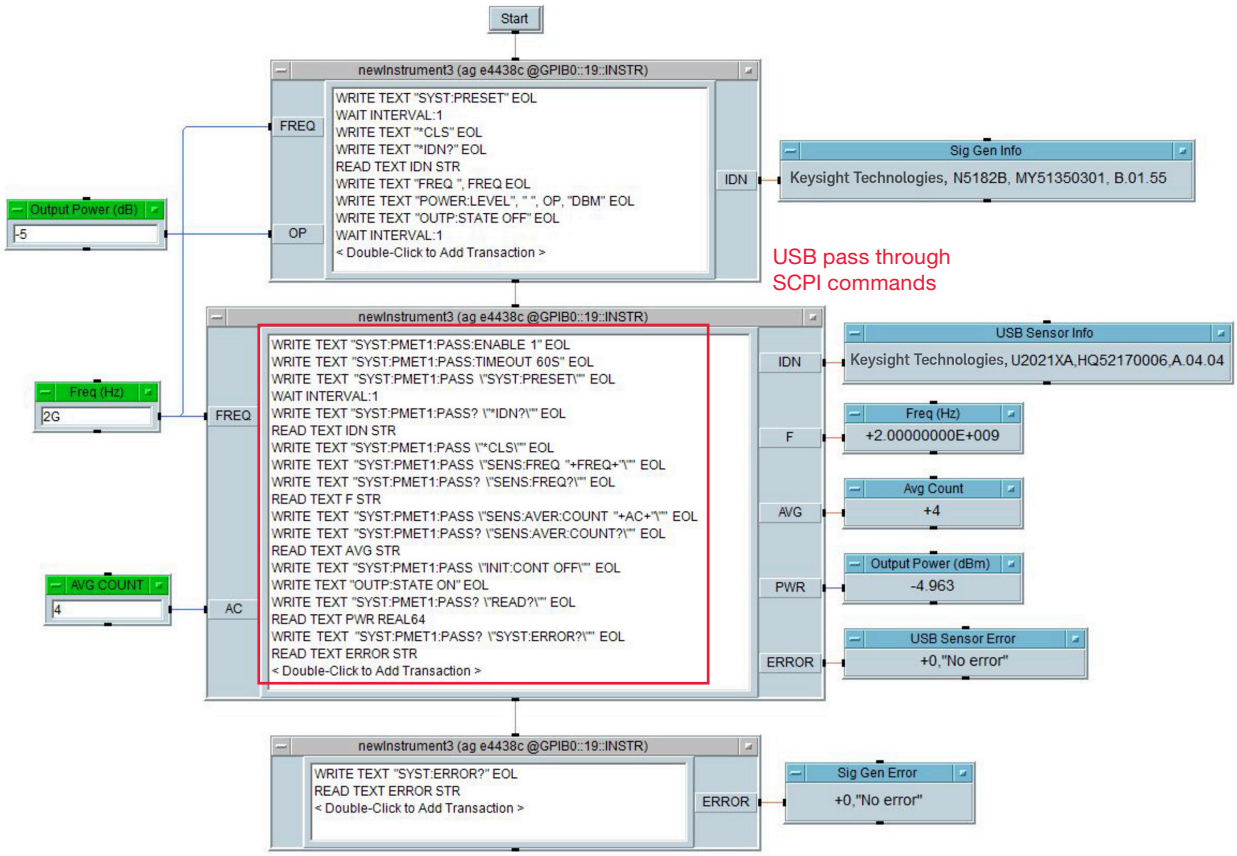


Figure 25. USB pass through SCPI commands (highlighted in red box) using the X-Series signal generator

FieldFox handheld analyzer

- Displays power measurement with its built-in user interface (UI), which integrates the display of USB power sensor measurements

Once the USB power sensors are connected to FieldFox, the user can switch the FieldFox to Power Meter mode and power readings will display on the FieldFox screen. The UI of power meter measurement provides the minimum configuration of power measurement such as frequency, averaging, single/continuous measurement, detection mode, zeroing, and display units measurement. Average and peak power measurement can be done via FieldFox depending on the USB power sensors.

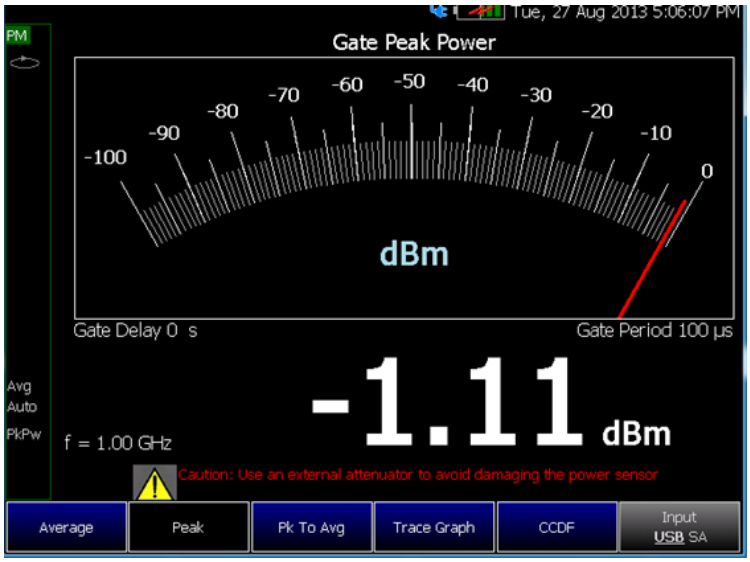


Figure 26. The FieldFox power meter measurement UI

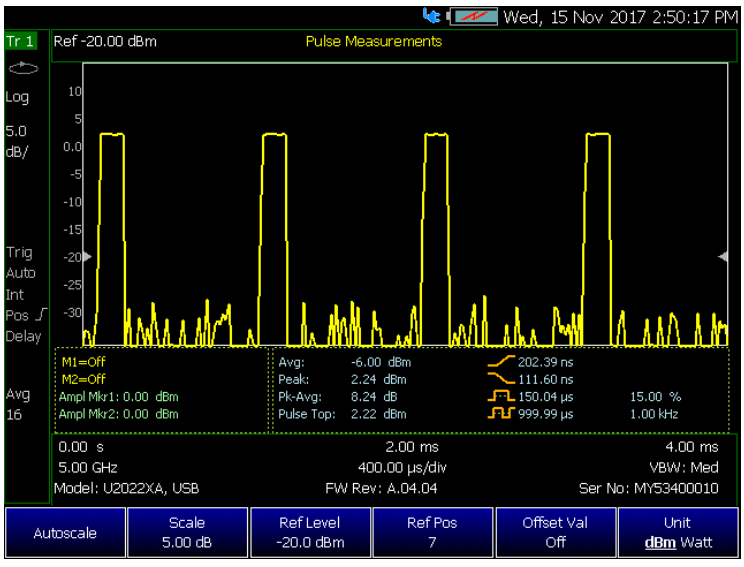


Figure 27. Pulse Measurement mode requires U2020 X-Series USB peak and average power sensors to measure the RF pulse signal

Power measurement on a UXA signal analyzer for power level verification

Once you install the BenchVue software, BV0007B Power Meters/Sensors Control and Analysis App on the UXA and connect a USB power sensor, you can check the power of the signal measured with the signal analyzer by changing the connection of the test cable from the signal analyzer to the USB power sensor.

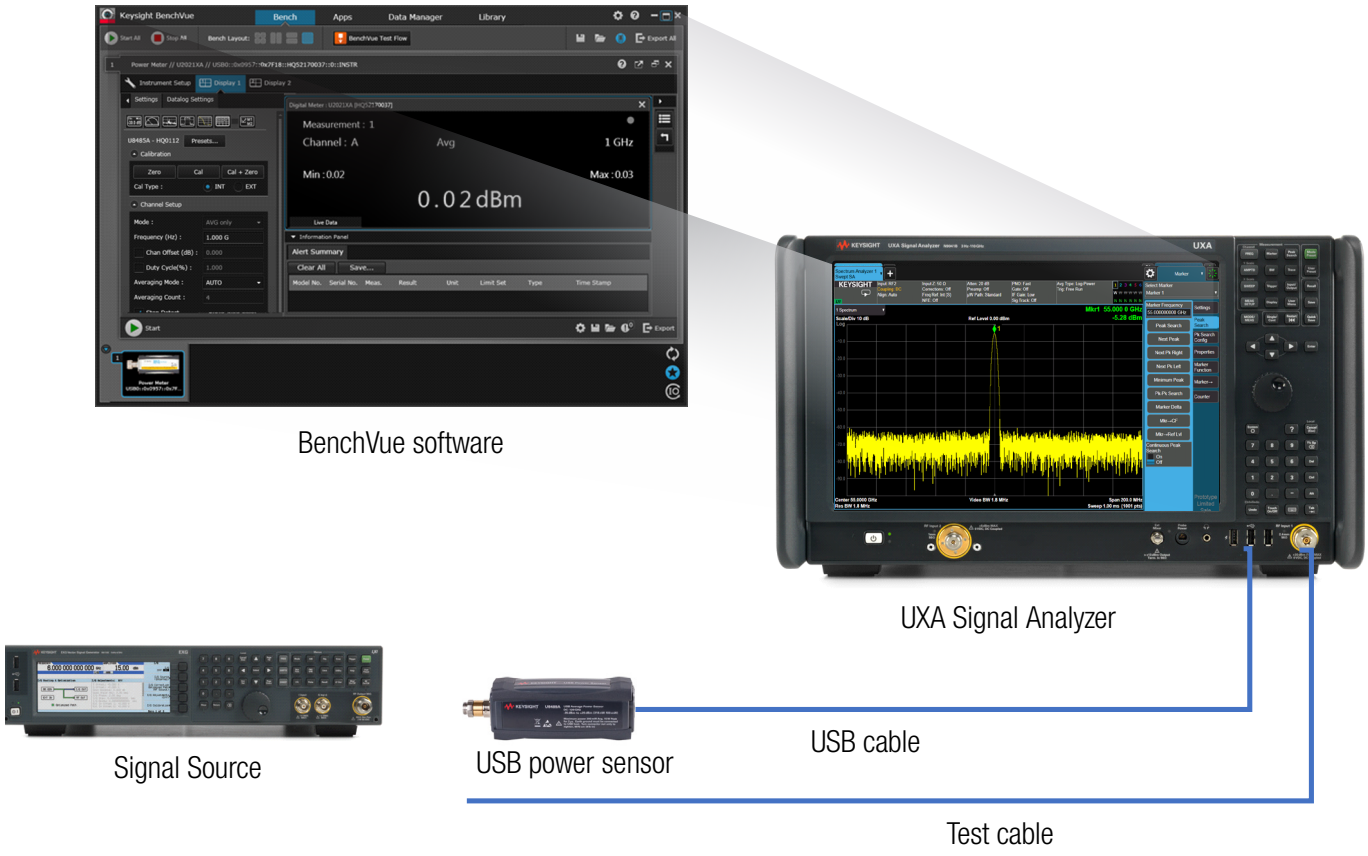


Figure 28. Power measurement with the USB power sensor and BenchVue software running on the UXA

Conclusion

The USB power sensors are compact and portable, easy to use, and cost effective for you as they provide the following benefits:

- Compatibility with other Keysight instruments such as vector network analyzer, spectrum analyzer, signal generators, cable and antenna testers, and FieldFox handheld analyzers.
- Portability for field applications. The smaller size and light weight of the USB power sensors allows you to carry them to the site for field applications.
- Simplified measurement setup with USB power, plug&play connectivity, and built-in triggering circuit
- Lower cost without compromising on performance or quality. Standalone USB power sensors do not need a power meter to provide accurate power measurement via PC/laptop or other Keysight instrument.

Related Literature

Keysight U2000 Series USB Power Sensors, Technical Overview, literature number 5989-6279EN

Keysight N9340B, N9342C, N9343C, N9344C Handheld Spectrum Analyzer, Brochure, literature number 5990-8024EN

Keysight Simple Scalar Network Analysis of Frequency Converter Devices Using the U2000 USB Power Sensor Series with the ENA Network Analyzer, Application Note, literature number 5989-8689EN

Product Web Site

For most up-to-date and complete application and product information, visit Keysight Web site at the following URL: www.keysight.com/find/usbsensor

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