DATA SHEET

U2040 X-Series Wide Dynamic Range Power Sensors

Accurately measure any modulated signal with the Keysight Technologies U2040 X-Series power sensors. With LAN connectivity, a first in the industry, and USB connectivity, the U2040 X-Series comes with the world's widest dynamic range in a power sensor, covering a range of -70 to +26 dBm. And because the U2049XA LAN power sensor is thermal vacuum qualified, you can get the same accuracy and performance even in thermal vacuum chambers.

U2040 X-Series Power Sensor Comparison Table

Model	Description	Frequency range / Power Range	Supported measurements	Connector type
U2041XA	USB wide dynamic range power sensor	10 MHz to 6 GHz -70 to +26 dBm	Average, time selectivity in average mode	N-type (male)
U2042XA	USB peak and average power sensor		Peak, average, peak-to-average power, time-gated and free run mode, pulse	
U2043XA	USB wide dynamic range power sensor	10 MHz to 18 GHz -70 to +26 dBm	Average, time selectivity in average mode	N-type (male)
U2044XA	USB peak and average power sensor		Peak, average, peak-to-average power, time-gated and free run mode, pulse parameters analysis, pulse profiling	
U2049XA	LAN peak and average power sensor	10 MHz to 33 GHz -70 to +20 dBm	Peak, average, peak-to-average power, time-gated and free run mode, pulse parameters analysis, pulse profiling	3.5 mm (male)
U2049XA (Option TVA)	LAN peak and average power sensor with thermal vacuum compliant option			

U2040 X-Series selection guide

<table>
<tr><th>Measurement types</th><th>U2041/43XA</th><th>U2042/44/49XA</th></tr>
<tr><td>CW power</td><td colspan="2">Yes</td></tr>
<tr><td>Wideband average power (example: 100 MHz bandwidth)</td><td colspan="2">Yes</td></tr>
<tr><td>Time selectivity in average mode</td><td colspan="2">Yes</td></tr>
<tr><td>Time gated average power</td><td>No</td><td>Yes</td></tr>
<tr><td>Peak power or peak-to-average power up to 5 MHz bandwidth</td><td>No</td><td>Yes</td></tr>
<tr><td>Peak power or peak-to-average power above 5 MHz bandwidth</td><td colspan="2">No</td></tr>
<tr><td>Pulse parameter analysis ≥ 100 ns rise time (example: rise/fall time, duty cycle, pulse width, etc.)</td><td>No</td><td>Yes</td></tr>
<tr><td>Pulse parameter analysis < 100 ns rise time (example: rise/fall time, duty cycle, pulse width, etc.)</td><td colspan="2">No</td></tr>
<tr><td>Pulse profiling (power vs time display)</td><td>No</td><td>Yes</td></tr>
</table>

U2040 X-Series Key Features

Widest dynamic range power sensor

The U2040 X-Series are power sensors with the widest dynamic range of 96 dB (-70 dBm to +26 dBm). The 96 dB dynamic range enables accurate power measurements of very low signal levels for a broad range of applications such as wireless chipset, power amplifier and module manufacturing, satellite payload testing, test system or instrument calibration, and radar pulse parameter measurements. The U2042/44/49XA can support up to 4 pairs of gate power measurements.

Super-fast measurement speed

The U2040 X-Series takes up to 50,000 super-fast readings per second (in fast/buffer mode/average mode), a ten times improvement over Keysight’s previous sensor offerings, allowing test engineers to increase test throughput capacity and reduce cost of test especially in high volume manufacturing environments such as mobile chipset manufacturing.

This measurement speed is fast enough to measure every continuous pulse without leaving time gaps in between measurement acquisitions. While conventional sensors only provide a snapshot of continuous pulses, leaving dead time where a glitch could slip by unnoticed, the U2040 X-Series measures continuously in real time and keeps pace with very fast pulses, up to 10 kHz PRF. Users are also able to fully control which portion of the signal is measured and what throughput they can expect because the aperture duration precisely defines the maximum measurement speed as 1/aperture duration. For example, setting the aperture duration to 20 µs offers 20 µs of measurement time per reading, equaling a measurement speed of 50,000 readings per second.

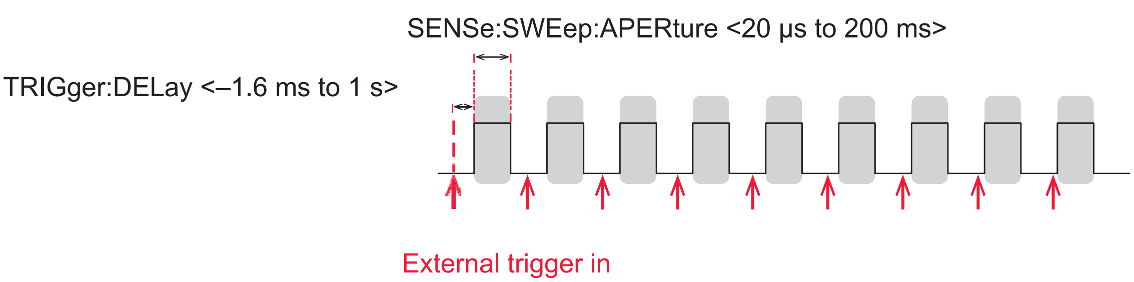


Figure 1. The U2040 X-Series offers real time measurement by measuring every consecutive pulse without dead time.

Broadband coverage for any modulated signal formats

The U2040 X-Series makes accurate average or time-selective average power measurements of any modulated signal, and covers all common wireless signals such as LTE, LTE-Advanced with 100 MHz bandwidth, and WLAN 802.11ac with 80/160 MHz bandwidth. A 4-path diode stack design with parallel data acquisition paths offers seamless range transition with high accuracy and repeatability. This design enables all the diodes to operate in their square law region, allowing the U2040 X-Series to function like thermocouple power sensors to provide accurate average or RMS power for broadband modulated signals.

Time selectivity in average mode with variable aperture duration

The U2040 X-series offers a new feature called average mode time selectivity, whereby users can configure the aperture duration of measurement capture with reference to immediate trigger or external trigger. The aperture duration can be set from 20 µs to 200 ms with a resolution of 100 ns, a resolution low enough to cover any radio format.

This new feature allows users to control which portions of the waveform to be measured, giving the same results as time-gated power measurements made in the conventional normal/peak mode. The key benefits of this feature is that it enables the sensor to measure both average and time-selective average power measurements across the full 96 dB dynamic range, and offers real time measurements of up to 50,000 readings per second. This is a significant improvement when compared to conventional power sensors; a conventional sensor’s time gated power dynamic ranges are typically clipped at around 50 dB with maximum speed of 1000 readings per second.

Internal zero and calibration

Save time and reduce measurement uncertainty with the internal zero and calibration function. Each U2040 X-Series sensor comes with technology that integrates a DC reference source and switching circuits into the body of the sensor so you can calibrate the sensor while it is connected to a device-under-test. This feature removes the need for connection and disconnection from an external calibration source, speeding up testing and reducing connector wear and tear.

This internal zero and calibration function allows continuous long distance and remote measurements by maintaining the accuracy of the sensor and is useful in manufacturing and automated test environments where each second and each connection counts.

Built-in trigger in and out

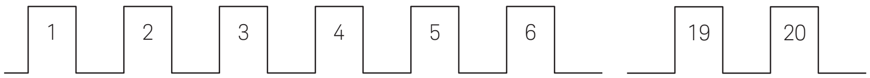
An external trigger enables accurate triggering of low-level signals close to the sensor’s noise floor. The U2040 X-series power sensors come with built-in trigger in/out connection, allowing you to connect an external trigger signal from a signal source or the device-under-test in order to achieve precise triggering timing. Once the trigger output is enabled, a TTL trigger output signal will be generated on every triggered measurement. The built-in trigger in and out is particularly useful when users need to synchronize the measurement acquisition of a series of daisy-chain power sensors.

Figure 2. The external trigger input and output ports on the U2044XA.

20 automatic pulse parameter measurements

The U2040 X-Series offers simultaneous pulse parameter characterization of up to 20 pulses within a single capture. Individual pulse duration, period, duty cycle, rise time, fall time and other pulse parameters can be queried through the following SCPI codes:
TRACe:MEASurement:PULSe[1-20]
TRACe:MEASurement:TRANsition[1-20]

Together with a system's rise time and fall time of 100 ns and video bandwidth of 5 MHz, the U2040 X-Series enables a minimum measurable pulse width of 250 ns with its sampling interval of 50 ns. Users can quickly and accurately measure the output power and pulse parameters of pulses for radar pulse component design or manufacturing.



Pulse parameter	SCPI command
Duty cycle	TRAC:MEAS:PULS[1-20]:DCYC?
Pulse duration	TRAC:MEAS:PULS[1-20]:DUR?
Pulse period	TRAC:MEAS:PULS[1-20]:PER?
Pulse separation	TRAC:MEAS:PULS[1-20]:SEP?
Negative transition duration (fall time)	TRAC:MEAS:TRAN[1-20]:NEG:DUR?
Occurrence of a negative transition relative to trigger instant	TRAC:MEAS:TRAN[1-20]:NEG:OCC?
Positive transition duration (rise time)	TRAC:MEAS:TRAN[1-20]:POS:DUR?
Occurrence of a positive transition relative to trigger instant	TRAC:MEAS:TRAN[1-20]:POS:OCC?

Figure 3. The U2040 X-Series offers simultaneous analysis of up to 20 pulses within a single capture.

Auto burst detection

Auto burst detection helps the measurement setup of the trace of gate positions and sizes. This feature also helps set up triggering parameters on a large variety of complex modulated signals by synchronizing to the RF bursts. After a successful auto-scaling, the triggering parameters, such as trigger level, delay and hold-off, are automatically adjusted for optimum operation. The trace settings are also adjusted to align the RF burst to the center of the trace display.

Built-in radar and wireless presets

Begin testing faster; the U2040 X-Series comes with built-in radar and wireless presets for common signals such as DME, GSM, EDGE, WCDMA, WLAN and LTE.

Gamma correction

In an ideal measurement scenario, the reference impedance of the power sensor and device-under-test (DUT) impedance should equal the reference impedance (Z0); however, this is rarely the case in practice. The mismatch in impedance values results in a portion of the signal voltage being reflected, and this reflection is quantified by the reflection coefficient, gamma.

Using the gamma correction function, users can simply input the DUT’s gamma into the USB power sensor using SCPI commands or the Keysight BenchVue software. This will remove the mismatch error, yielding more accurate measurements.

S-parameter correction

Additional errors are often caused by components that are inserted between the DUT and the power sensor, such as in base station testing where a high power attenuator is connected between the sensor and base station to reduce the output power to the measurable power range of the sensor. The S-parameters of these components can be obtained with a vector network analyzer in the touchstone format and inputted into the sensor using SCPI commands or through the Keysight BenchVue software. This error can now be corrected using the U2040 X-Series’s S-parameter correction function. The sensor will behave as though it is connected directly to the DUT, giving users highly accurate power measurements.

Compact and portable form factor

The U2040 X-Series are standalone sensors that operate without the need of a power meter or an external power supply. The sensors draw power from a USB port and do not need additional triggering modules to operate, making them portable and lightweight solutions for field applications such as base station testing. Simply plug the sensor to the USB port of your PC or laptop with Keysight BenchVue software’s BV0007B Power Meter/Power Sensor Control and Analysis app and start your power measurements.

U2049XA: The Ideal Solution for Remote Monitoring of Satellite Systems

Get the same accuracy and performance in thermal vacuum (TVAC) chambers with the world's first TVAC qualified power sensor. With best-in-class long term drift performance, a frequency range of 10 MHz to 33 GHz and a dynamic range spanning 90 dB, the U2049XA LAN power sensor is ideal for fault detection and monitoring of satellite systems. And with LAN/power over Ethernet (PoE) connectivity, a first in the industry, you can perform long distance, remote monitoring of satellite systems with ease and confidence.

Figure 4. U2049XA Option 100

LAN/Power over ethernet connectivity

Overcome the cable length limitations associated with USB connectivity. With Power over Ethernet (PoE)/LAN connectivity, the LAN power sensor is able to perform remote monitoring over a single span of up to 100 meters. The PoE connectivity is also compliant to the IEEE 802.3af or 802.3at Type 1 standards.

Note that the typical LAN port found on a PC or Keysight instruments will not be able to power up the LAN power sensor. A typical LAN port is only used for data transfer and communication. The LAN power sensor must connect to a PoE port, which can be used to supply the DC power required to power up the sensor and to transfer data.

Figure 5. U2049XA Option TVA

Broad frequency coverage

With a broad frequency coverage of 10 MHz to 33 GHz, the U2049XA is optimized for satellite and aerospace/defense applications. Together with internal zero and calibration and excellent lon- term drift performance, the U2049XA enables automated performance monitoring without needing human intervention.

Thermal vacuum option

The U2049XA LAN power sensor comes with a thermal vacuum option (Option TVA) for use within a thermal vacuum chamber. This option has been meticulously designed by selecting components with minimum outgassing properties. Each of the sensors is also subject to temperature cycling in a vacuum chamber to stabilize the materials and to remove outgassing particles.

Performance Specifications

Specification definitions

There are two types of product specifications:

- Warranted specifications are specifications which are covered by the product warranty and apply over a range of
  0 to 55 °C unless otherwise noted. Warranted specifications include measurement uncertainty calculated with a 95% confidence.
- Characteristic specifications are specifications that are not warranted. They describe product performance that is useful in the application of the product. These characteristics are shown in italics.

Characteristic information is representative of the product. In many cases, it may also be supplemental to a warranted specification. Characteristics specifications are not verified on all units. These are several types of characteristic specifications. They can be divided into two groups:

One group of characteristic types describes ‘attributes’ common to all products of a given model or option. Examples of characteristics that describe ‘attributes’ are the product weight and ‘50-ohm input Type-N connector’. In these examples, product weight is an ‘approximate’ value and a 50-ohm input is ‘nominal’. These two terms are most widely used when describing a product’s ‘attribute’.

The second group describes ‘statistically’ the aggregate performance of the population of products. These characteristics describe the expected behavior of the population of products. They do not guarantee the performance of any individual product. No measurement uncertainty value is accounted for in the specification. These specifications are referred to as ‘typical’.

The power sensor will meet its specifications when:

- Stored for a minimum of two hours at a stable temperature within the operating temperature range, and turned on for at least 30 minutes
- The power sensor is within its recommended calibration period, and
- Used in accordance to the information provided in the User’s Guide
- For power measurements below -60 dBm, it is recommended to turn on the power sensor for 1.5 hours (with the X-Series power sensor connected to the device-under-test)

Specifications

Key specifications

	U2041/43XA USB average power sensor	U2042/44XA USB peak and average power sensor	U2049XA LAN peak and average power sensor
Average mode power range (Average only mode)	*-70 dBm to +26 dBm*	*-70 dBm to +26 dBm*	*-70 dBm to +20 dBm*
Normal mode power range (Peak mode)	N/A	*Off: -40 to +26 dBm*	*Off: -40 to +20 dBm*
		High/5 MHz: -40 to +26 dBm	*High/5 MHz: -40 to +20 dBm*
		Medium/1.5 MHz: -45 to +26 dBm	*Medium/1.5 MHz: -45 to +20 dBm*
		Low/300 kHz: -45 to +26 dBm	*Low/300 kHz: -45 to +20 dBm*
Maximum power (Damage level)	Average: +29 dBm	Average: +29 dBm	Average: +29 dBm
	Peak: +32 dBm for < 10 µs duration	Peak: +32 dBm for < 10 µs duration	Peak: +32 dBm for < 10 µs duration
	Voltage: ≤ 20 VDC	Voltage: ≤ 20 VDC	Voltage: ≤ 20 VDC
Zero and calibration	Internal zero and calibration supported	Internal zero and calibration supported	Internal zero and calibration Supported
Rise/fall time [3]	≤ 100 ns	≤ 100 ns	≤ 100 ns
Maximum sampling rate	*20 Msamples/second continuous sampling*	*20 Msamples/second continuous sampling*	*20 Msamples/second continuous Sampling*
Power linearity at 5 dB step [1]	*Average mode: < 1.0%*	*Average mode: < 1.0%*	*Average mode: < 1.0%*
		Normal mode: < 1.3%	*Normal mode: < 1.0%*
Basic accuracy of average power measurement	≤ ± 0.21 dB or ± 4.7% for < 30 MHz	≤ ± 0.21 dB or ± 4.7% for < 30 MHz	≤ ± 0.30 dB or ± 6.6% for < 30 MHz
	≤ ± 0.18 dB or ± 4.1% for ≥ 30 MHz to ≤ 10 GHz	≤ ± 0.18 dB or ± 4.1% for ≥ 30 MHz to ≤ 10 GHz	≤ ± 0.23 dB or ± 5.2% for ≥ 30 MHz to ≤ 26.5 GHz
	≤ ± 0.19 dB or ± 4.3% for > 10 GHz to 18 GHz	≤ ± 0.19 dB or ± 4.3% for > 10 GHz to 18 GHz	≤ ± 0.27 dB or ± 5.9% for > 26.5 GHz to ≤ 33 GHz
Signal bandwidth	*Wideband average power*	*VBW for peak power: ≤ 5 MHz [4]*	*VBW for peak power: ≤ 5 MHz [4]*
		Wideband average power	*Wideband average power*
Single shot bandwidth	NA	*5 MHz*	*5 MHz*
Minimum pulse width	NA	*250 ns*	*250 ns*
Maximum capture length	NA	*1 s (decimated)*	*1 s (decimated)*
		6.5 ms (at full sampling rate)	*6.5 ms (at full sampling rate)*
Maximum pulse repetition rate	NA	*2 MHz (based on 10 samples/period)*	*2 MHz (based on 10 samples/period)*

1. Any relative power measurement of up to 5 dB will have <1% error, excluding zero set, zero drift and noise effects. With default aperture and averaging, for power levels above -50 dBm, zero set, zero drift and noise effects can be disregarded.
2. For U2041/42/43/44XA, specification is valid over a range of -45 to +26 dBm, DUT Max SWR < 1.2.For U2049XA, specification is valid over a range of–45 to +20 dBm, DUT Max SWR < 1.2.For all models, averaging set to 32, in Free Run mode. For power levels below –45 dBm, the effect of zero drift, zero set and measurement noise must be considered separately base on the uncertainty calculation method shown in Appendix A.
3. With video bandwidth OFF setting and carrier frequency ≥ 300 MHz.
4. Five MHz video bandwidth is applicable for carrier frequency ≥ 300 MHz. For carrier frequency < 300 MHz, video bandwidth of LOW/MED is 90 kHz, video bandwidth of HIGH/OFF is 240 kHz. Refer to Characteristic peak flatness section for details.

Noise and drift

Mode	VBW setting	Zero set [1]		Zero drift [2]	Measurement noise	Noise per sample
		External zero	Internal zero			
Normal [3]	LOW/MED	± 16 nW	± 23 nW	*± 10 nW*	*± 10 nW* [4]	*± 0.15 µW*
	HIGH/OFF	± 50 nW	± 60 nW	*± 15 nW*	*± 32 nW* [4]	*± 0.8 µW*
Average	–	± 100 pW for < 300 MHz	± 1 nW	*± 25 pW*	*± 80 pW* [5]	—
		± 70 pW for >= 300MHz				

1. After 1 hour of warm up and at a constant temperature.
2. After 1 hour of warm up and at a constant temperature, measurements taken over a period of 4 hours after zeroing. Drift is calculated based on the average difference of any two measurements 1 hour apart.
3. Only applicable to U2042/44/49XA.
4. Noise defined for 1 average at free run mode.
5. Noise defined for 16 averages at 50 ms aperture.

Noise multipliers

The measurement noise for the U2040 X-Series power sensor is dependent on the measurement mode and the time for the measurement. In general, average only mode is lower noise than normal mode, and the longer a measurement takes the lower the noise is. We will define three measurement modes and how the noise can be adjusted.

Average-only mode

The measurement noise due to the U2040 X-Series power sensor is dependent on the measurement time. In general, the longer a measurement takes the lower the noise is. The measurement noise specification is defined for 16 averages with an aperture of 50 ms, or a total time of 800 ms. Noise will reduce or increase with the square root ratio of the measurement time to the specification measurement time. Thus, a noise multiplier factor can be derived for any combination of averaging and aperture: $N_{mult} = \sqrt{\frac{0.8}{N_{ave} \times t_a}}$

Increasing measurement time will reduce noise at this rate until around 3 seconds. As the measurement time increases beyond 3.2 seconds the noise reduction exponent changes from 0.5 to 0.2.

$$N_{mult} = 0.89 \times \left(\frac{1}{N_{ave} \times t_a} \right)^{0.5}, \text{ for } N_{ave} \times t_a \leq 3.2$$

$$N_{mult} = 0.63 \times \left(\frac{1}{N_{ave} \times t_a} \right)^{0.2}, \text{ for } N_{ave} \times t_a \leq 3.2$$

$$Noise_{actual} = N_{mult} \times Noise_{spec}$$

Where $N_{ave} \stackrel{def}{=}$ number of averages and $t_a \stackrel{def}{=}$ aperture in seconds.

Free-run normal mode

The measurement noise specification is defined for average of 1. Although the noise will reduce with increased averaging, it will not have a significant impact on the measurement uncertainty, and the figure of 32 nW (High/Off VBW) or 10 nW (Low/Med VBW) without any multiplier should be used in the uncertainty calculations. (Refer to the measurement noise in the noise and drift table above.)

Gated-average normal mode

The measurement noise on a time-gated average power measurement in normal mode will depend on the time gate length. 20 averages are carried out every 1 µs of gate length. The noise-per-sample contribution in this mode can be reduced by approximately $\sqrt{\frac{\text{gate length}}{50\ \text{ns}}}$ to a limit of 32 nW. (Refer to the noise and drift table above for the noise-per-sample.)

Maximum SWR

	U2041/42XA		U2043/44XA	
Frequency band	-70 to +15 dBm	+15 to +26 dBm	-70 to +15 dBm	+15 to +26 dBm
10 MHz to 6 GHz	< 1.2	< 1.29	< 1.20	< 1.29
> 6 GHz to 18 GHz			< 1.26	< 1.30

	U2049XA	
Frequency band	-70 to +15 dBm	+15 to +20 dBm
10 MHz to 30 MHz	< 2.18	< 2.21
> 30 MHz to 50 MHz	< 1.35	< 1.37
> 50 MHz to 100 MHz	< 1.22	< 1.24
> 100 MHz to 11.5 GHz	< 1.17	< 1.21
> 11.5 GHz to 30 GHz	< 1.29	< 1.33
> 30 GHz to 33 GHz	< 1.33	< 1.36

Calibration uncertainty

Definition: Uncertainty resulting from non-linearity in the U2040 X-Series detection and correction process. This can be considered as a combination of traditional linearity, calibration factor and temperature specifications and the uncertainty associated with the internal calibration process.

Average mode

Frequency band	U2041/42XA	U2043/44XA	U2049XA
10 MHz to 30 MHz	4.4%	4.4%	4.5%
> 30 MHz to 500 MHz	3.7%	3.7%	3.9%
> 500 MHz to 1 GHz	3.7%	3.7%	3.8%
> 1 GHz to 6 GHz	3.7%	3.7%	4.0%
> 6 GHz to 10 GHz	–	3.7%	4.0%
> 10 GHz to 18 GHz	–	4.0%	4.2%
> 18 GHz to 26.5 GHz	–	–	4.9%
> 26.5 GHz to 33 GHz	–	–	5.6%

Normal mode

Frequency band	VBW OFF/HIGH [1]			VBW MED/LOW		
	U2042XA	U2044XA	U2049XA	U2042XA	U2044XA	U2049XA
10 MHz to 30 MHz	5.7%	5.7%	4.5%	4.4%	4.4%	4.5%
> 30 MHz to 500 MHz	5.2%	5.2%	4.1%	3.7%	3.7%	3.9%
> 500 MHz to 1 GHz	5.2%	5.2%	3.9%	3.7%	3.7%	3.9%
> 1 GHz to 6 GHz	5.3%	5.3%	4.0%	3.7%	3.7%	4.0%
> 6 GHz to 10 GHz	—	5.3%	4.1%	—	3.7%	4.1%
> 10 GHz to 18 GHz	—	5.4%	4.3%	—	4.0%	4.2%
> 18 GHz to 26.5 GHz	—	—	5.0%	—	—	4.9%
> 26.5 GHz to 33 GHz	—	—	5.7%	—	—	5.6%

1. Specification valid for environment up to 70% relative humidity. Additional 1.6% to be included for environment up to 95% relative humidity.

Timebase and Trigger Specifications

Timebase	
Range	*2 ns to 100 ms/div*
Accuracy	*± 25 ppm*
Jitter	*≤ 1 ns*
Trigger	
Internal trigger	
Range	*U2042/44XA: -25 to +26 dBm*
	U2049XA: -25 to +20 dBm
Resolution	*0.1 dB*
Level accuracy	*± 0.5 dB*
Latency	*1.5 µs ± 50 ns*
Jitter	*≤ 5 ns rms*
External TTL trigger input	
High	*> 2.4 V*
Low	*< 0.7 V*
Latency	*500 ns ± 50 ns*
Minimum trigger pulse width	*150 ns (average mode)*
	50 ns (normal mode) [1]
Minimum trigger repetition period	*300 ns (average mode)*
	100 ns (normal mode) [1]
Maximum trigger voltage input	*5 V EMF from 50 Ω DC (current < 100 mA) or*
	5 V EMF from 50 Ω pulse width < 1 s (current < 100 mA)
Impedance	*100 kΩ (default), 50 Ω*
Jitter	*≤ 15 ns rms*
External TTL trigger output	
High	*> 2.4 V*
Low	*< 0.7 V*
Latency	*500 ns ± 50 ns*
Impedance	*50 Ω*
Jitter	*≤ 15 ns rms*
Trigger delay	
Range	*Normal mode:* [1] *± 1.0 s*
	Average only mode: –1.6 ms to +1 s
Resolution	*1% of delay setting, 50 ns minimum*
Trigger hold off	
Range	*1 µs to 400 ms*
Resolution	*1% of selected value (to a minimum of 50 ns)*
Trigger level threshold hysteresis	
Range	*± 3 dB*
Resolution	*0.05 dB*

General Specifications

Inputs/Outputs	
Current requirement	U2041/42/43/44XA: Approximately < 500 mA
	U2049XA: 3W, 802.3af or 802.3at Type 1 standard
Trigger input	Input has TTL compatible logic levels and uses a SMB connector
Trigger output	Output provides TTL compatible logic levels and uses a SMB connector
Remote programming	
Interface	U2041/42/43/44XA: USB 2.0 interface USB-TMC compliance
	U2049XA: 10/100 Mbps RJ-45 Power Over Ethernet port, transfers data and power on one single cable, 802.3af or 802.3 at Type 1 compliant
Command language	SCPI standard interface commands, IVI-COM, IVI-C drivers
Maximum measurement speed (Applicable for USB & LAN socket connectivity)	
Free run trigger measurement	*25,000 readings per second* [1]
External trigger time-gated measurement	*20,000 readings per second* [2]
Average mode real time measurement	*50,000 readings per second* [3]

1. Tested under normal mode and fast mode, with buffer mode trigger count of 100, output in binary format, unit in watt, auto-zeroing, auto-calibration, and step detect disabled.
2. Tested under normal mode and fast mode, with buffer mode trigger count of 100, pulsed signal with PRF of 20 kHz, and pulse width at 15 µs.
3. Tested under average only mode and fast mode, with buffer mode trigger count of 200, aperture duration of 20 µs, data format set to real, external trigger or immediate trigger setting.

Mechanical Characteristic

Mechanical characteristics such as center conductor protrusion and pin depth are not performance specifications. They are, however, important supplemental characteristics related to electrical performance. At no time should the pin depth of the connector be protruding.

Environmental compliance		
Temperature	All models except U2049XA Option TVA:	
	– Operating condition: 0 to 55 °C	
	– Storage condition: -40 to 70 °C	
	For U2049XA-TVA:	
	– Operating Condition: 0 to 55 °C. This operating condition is applicable for both standard Atmospheric environment and thermal vacuum environment.	
	– Storage condition: –40 to 100 °C (U2049XA Option TVA)	
Humidity	Operating condition: Maximum 95% at 40 °C (non-condensing)	
	Storage condition: Up to 90% at 65 °C (non-condensing)	
Altitude	Operating condition: Up to 3,000 m (9,840 ft)	
	Storage condition: Up to 15,420 m (50,000 ft)	
Regulatory compliance		
The X-Series complies with the following safety and EMC requirements	IEC 61010-1:2001/EN61010-1:2001 (2nd edition)	
	IEC 61326:2002/EN 61326:1997 + A1:1998 +A3:2003	
	Canada: ICES-001:2004	
	Australia/New Zealand: AS/NZS CISPR11:2004	
	Canada: ICES-001:2004	
	Australia/New Zealand: AS/NZS CISPR11:2004	
Others	**U2041/42/43/44XA**	**U2049XA**
Dimensions (Length x Width x Height)	168 mm x 46 mm x 35 mm	197 mm x 40 mm x 24 mm
Weight	Net weight: ≤ 0.3 kg	Net weight: ≤ 0.37 kg
	Shipping weight: ≤ 1.3 kg	Shipping weight: ≤ 1.4 kg
Recommended calibration interval	1 year	1 year

Additional Specifications for U2042/44XA USB Peak and Average Power Sensor

Measured rise time percentage error versus signal-under-test rise time

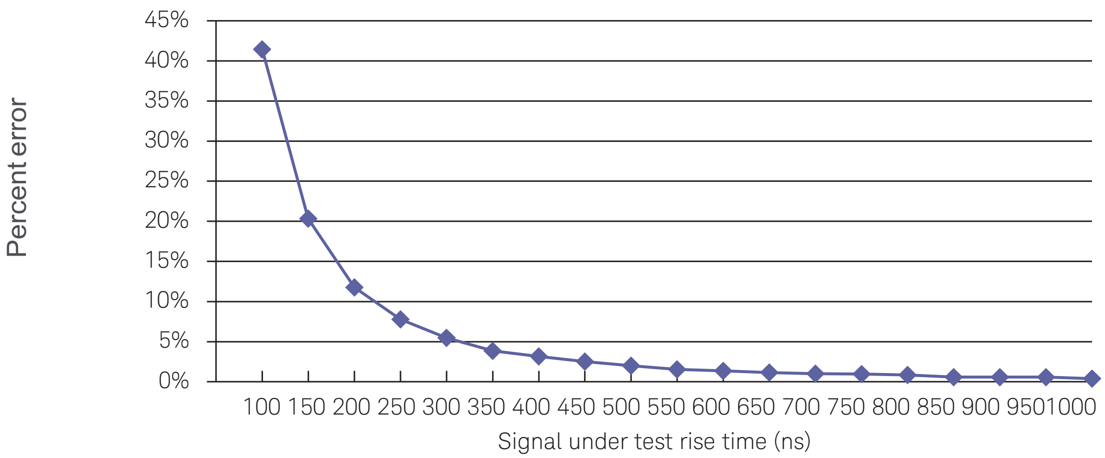


Figure 6. Measured rise time percentage error versus signal under test rise time.

Although the rise time specification is ≤ 100 ns, this does not mean that the U2040 X-Series can accurately measure a signal with a known rise time of 100 ns. The measured rise time is the root sum squares (RSS) of the signal-under-test (SUT) rise time and the system rise time:

$$\textit{Measured rise time} = \sqrt{\left[(\textit{SUT rise time})^2 + (\textit{system rise time})^2\right]}$$

And the % error is:

$$\%\ \text{error} = \left[\frac{\textit{measured rise time - SUT rise time}}{\textit{SUT rise time}}\right] \times 100$$

Video bandwidth

The video bandwidth in the normal mode of the U2042/44XA can be set to High, Medium, Low, and Off. The video bandwidths stated below are not the 3 dB bandwidths, as the video bandwidths are corrected for optimal flatness (except the Off filter). Refer to Figure 5, “Characteristic peak flatness,” for information on the flatness response. The Off video bandwidth setting provides the warranted rise time and fall time specifications and is the recommended setting for minimizing overshoot on pulse signals.

Video bandwidth setting (Normal mode)		LOW	MED	HIGH	OFF
Rise/fall time	< 300 MHz	*6.9 μs*	*6.9 μs*	*2.0 μs*	*2.0 μs*
	≥ 300 MHz	*0.6 μs*	*0.3 μs*	*0.1 μs*	*0.1 μs*
Overshoot [1]	< 300 MHz	*2%*	*2%*	*3%*	*4%*
	≥ 300 MHz	*12%*	*15%*	*9%*	*5%*

The average mode of the X-Series peak and average power sensor provide accurate average power measurements for broadband modulated signals like a thermocouple sensor. This is due to the X-Series power sensor’ four path diode design, which enables all the diodes to operate in their square-law region.

1. Specification is based on pulse signal with ≥ 80 ns rise time.

Characteristic peak flatness

The peak flatness is the flatness of a peak-to-average ratio measurement for various tone separations of an equal two-tone RF input. Figure 5 below refers to the relative error in peak-to-average ratio measurements as the tone separation is varied. The measurements were performed at –10 dBm and applicable for carrier frequency ≥ 300 MHz.

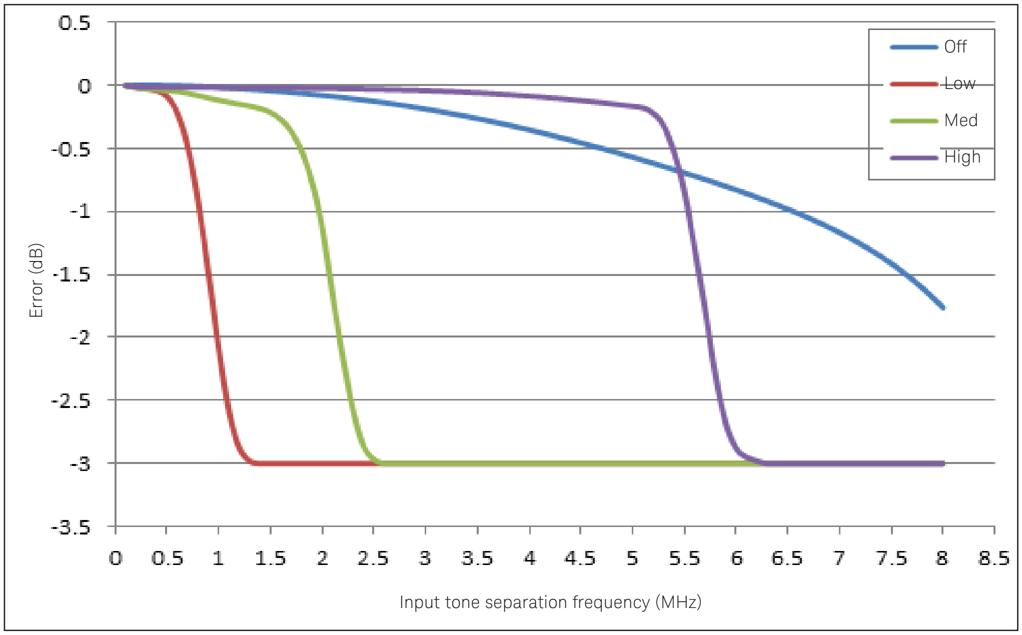


Figure 7. U2042/44/49XA error in peak-to-average ratio measurements for a two-tone input (High, Medium, Low and Off video bandwidth settings).

Using the U2040 X-Series with the BenchVue Software

Keysight BenchVue software for the PC accelerates testing by providing intuitive, multiple instrument measurement visibility and data capture with no programming necessary. You can derive answers faster than ever by easily viewing, capturing and exporting measurement data and screen shots. The U2040 X-Series is supported by the Keysight BenchVue software and BV0007B power meter/sensor control and analysis app. Once you plug the USB power sensor into a PC and run the software you can see measurement results in a wide array of display formats and log data without any programming. BenchVue software license (BV0007B) is now included with your instrument

For more information, www.keysight.com/find/BenchVue

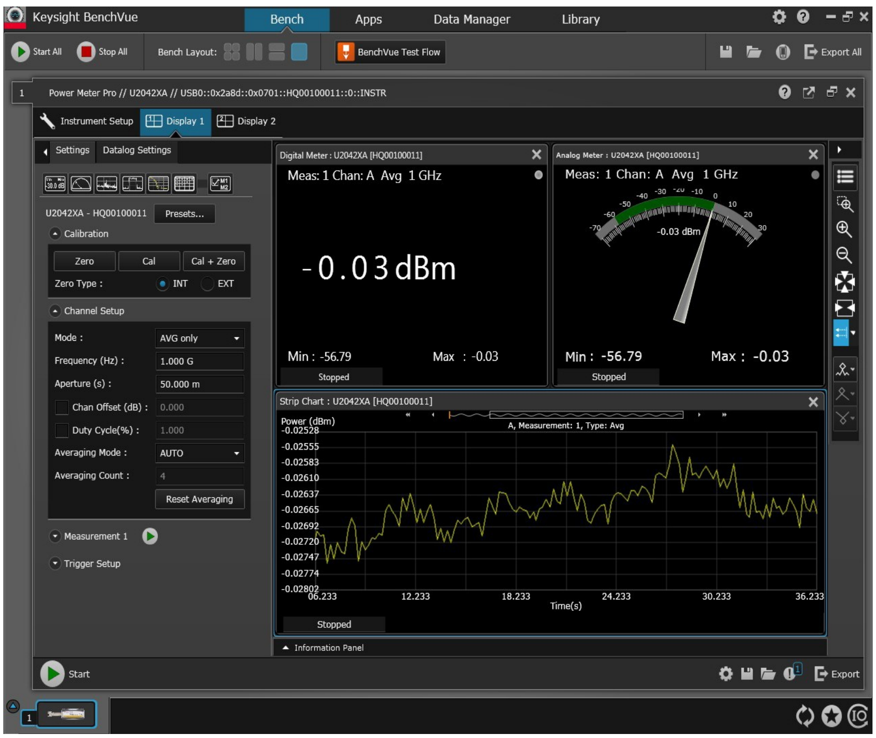


Figure 8. Digital meter, analog meter and datalog view.

Figure 9. Multi-channel trace display with 4-pairs of gates and automatic pulse parameters measurement (sample screen shot with two U2042XA).

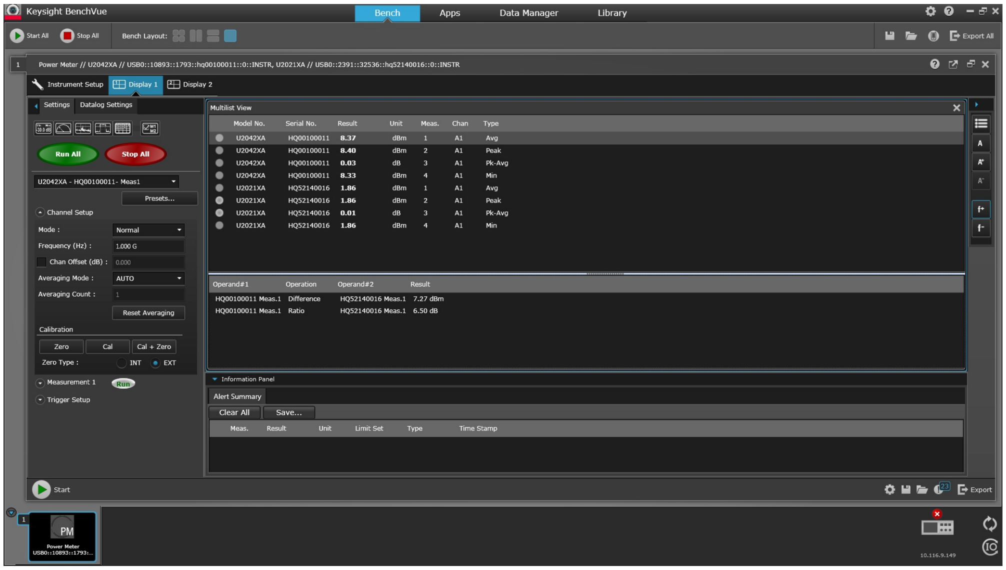


Figure 10. Multi-list view with ratio/difference function.

Supported functionality	
Measurement displays	Digital meter
	Analog meter
	Data log view
	Trace view (up to 4 channels or traces on one graph)
	Multilist with ratio/delta function
	Compact mode display
Graph functions	Single marker (up to 5 markers per graph)
	Dual marker (up to 2 sets of markers per graph)
	Graph autoscaling
	Graph zooming
	Gate measurement analysis (up to 4-pair of gates)
Pulse characterization functions	17-point automatic pulse parameters characterization
Instrument settings	Save and recall instrument state including graph settings
	Instrument preset settings (DME, GSM, WCDMA, WLAN, LTE, etc.)
	FDO tables
	Gamma and S-parameters tables
	Full instrumentation control includes frequency/average/trigger settings, zero and calibration, etc.
Limit and alert function	Sensors Limit and alert notification
	Alert summary
Export data or screen shots	Data logging (HDF5/MATLAB/Microsoft Excel/Microsoft Word/CSV)
	Save screen capture (PNG/JPEG/BMP)

System and Installation Requirements

PC operating system	
Windows 10, 8 and 7	Windows 10 32-bit and 64-bit (Professional, Enterprise, Education, Home versions)
	Windows 8 32-bit and 64-bit (Core, Professional, Enterprise)
	Windows 7 SP1 and later 32-bit and 64-bit (Professional, Enterprise, Ultimate)
Computer hardware	Processor: 1 GHz or faster (2 GHz or greater recommended)
	RAM: 1 GB (32-bit) or 2 GB (64-bit) (3 GB or greater recommended)
Windows XP SP3 32-bit (Professional)	Processor: 600 MHz or faster (1 GHz or greater recommended)
	RAM: 1 GB (2 GB or greater recommended)
Interfaces	USB, LAN
Display resolution	1024 x 768 minimum for single instrument view (higher resolutions are recommended for multiple instrument view)

Additional requirements

Software: BenchVue requires a VISA (Keysight or National Instruments) when used to connect to physical instruments. Keysight IO Libraries, which contains the necessary VISA, will be installed automatically when BenchVue is installed. IO Libraries information is available at: www.keysight.com/find/iosuite.

Ordering Information

Model	Description
U2041XA	USB wide dynamic range average power sensor, 10 MHz to 6 GHz
U2042XA	USB peak and average power sensor, 10 MHz to 6 GHz
U2043XA	USB wide dynamic range average power sensor, 10 MHz to 18 GHz
U2044XA	USB peak and average power sensor, 10 MHz to 18 GHz
U2049XA, Option 100	LAN peak and average power sensor, 10 MHz to 33 GHz
U2049XA, Option TVA	LAN peak and average power sensor, 10 MHz to 33 GHz, thermal vacuum option
Standard shipped items	
U2041/42/43/44XA USB power sensor	USB cable 5 ft (1.5 m), default cable length
	BNC male to SMB female trigger cable, 50 Ω, 1.5 m (Quantity: 2)
	Certificate of calibration
U2049XA LAN power sensor	LAN cable 5 ft (1.5 m), default cable length (for Option 100)
	BNC male to SMB female trigger cable, 50 Ω, 1.5 m (Quantity: 2)
	Certificate of calibration
	TVAC LAN cable (5 ft (1.5 m), default cable length (for Option TVA)
	TVAC sensor bracket (for Option TVA)
	Thermal interface material (for Option TVA)

U2041/42/43/44XA USB power sensor options

Options	Description
Accessories	
U2000A-201	Transit case
U2000A-202	Soft carrying case
U2000A-203	Holster
U2000A-204	Soft carrying pouch
Cables (selectable during sensor purchase)	
U2000A-301	USB cable 5 ft (1.5 m) – default selection
U2000A-302	USB cable 10 ft (3 m)
U2000A-303	USB cable 16.4 ft (5 m)
Cables (ordered standalone)	
U2031A	USB cable 5 ft (1.5 m)
U2031B	USB cable 10 ft (3 m)
U2031C	USB cable 16.4 ft (5 m)

U2049XA LAN power sensor options [1]

Options	Description
Accessories	
U2034A	U2049XA sensor casing (for Options 100)
U2034B	TVAC sensor bracket (for Option TVA only)
Standard LAN cables (selectable during sensor purchase and orderable standalone)	
U2034A	LAN cable 5 ft (1.5 m) – default selection Options 100
U2034B	LAN cable 10 ft (3 m)
U2034C	LAN cable 16.4 ft (5 m)
U2034D	LAN cable 50 ft (15.2 m)
U2034E	LAN cable 100 ft (30.5 m)
U2034F	LAN cable 200 ft (61 m)
TVAC LAN cables (selectable during sensor purchase and orderable standalone)	
U2034A	LAN cable 5 ft (1.5 m) – default selection for Option TVA
U2034B	LAN cable 10 ft (3 m)
U2034C	LAN cable 16.4 ft (5 m)
U2034D	LAN cable 50 ft (15.2 m)
U2034E	LAN cable 100 ft (30.5 m)
U2034F	LAN cable 200 ft (61 m)

1. PoE injector is not included. A commercially available 802.3at or 802.3af compliant PoE injector can be used with the LAN power sensors

U2040 X-Series power sensors options

Trigger cable	
U2032A	Standard trigger cable BNC Male to SMB female, 50 Ω, 1.5 m
U2033A	TVAC trigger cable BNC Male to SMB female, 50 Ω, 1.5 m (for U2049XA Option TVA only)
Documentation	
Option OB1	English language Operating and Service Guide
Option OBF	English language Programming Guide
Option OBN	English language Service Guide
Option ABJ	Japanese language Operating and Service Guide
U2041XA-CD	Documentation Optical Disk (consists of documentation CD-ROM and Keysight Instruments Control DVD)
Software	
BV0007B	BenchVue power meter/sensor control and analysis app license
Calibration	
UK6	Commercial calibration with test data
A6J	ANSI Z540 compliant calibration and test data
1A7	ISO 17025 compliant calibration and test data

Appendix A

Uncertainty calculations for a power measurement (settled, average power)

(Specification values from this document are in ***bold italic***, values calculated on this page are <u>underlined</u>.)

Process

1. Measured power level .... W
2. Frequency of measured signal (use to get calibration uncertainty and SWR) .... Hz
3. Calculate sensor uncertainty:
   Calculate noise contribution (from page 11)
   - Average-only mode: <u>Noise</u> = ***Measurement noise*** x average-only-mode noise multiplier
   - Free-run normal mode: <u>Noise</u> = ***Measurement noise*** for video bandwidth setting
   - Gated-average normal mode (Trigger normal mode), Noise = ***Noise-per-sample*** x noise-per-sample multiplier

   Convert noise contribution to a relative term[1] = Noise/Power .... %

   Convert zero drift to relative term = ***Drift***/Power = ... %

   RSS of above terms = ... %
4. Zero uncertainty

   (Mode and frequency dependent) = ***Zero set***/Power = ... %
5. ***Sensor calibration uncertainty*** (from page 12) ....

   (Sensor, measurement mode, frequency, and humidity dependent) = ... %
6. System contribution, coverage factor of 2 ≥ sys_{rss} = ... %

   (RSS three terms from steps 3, 4 and 5)
7. Standard uncertainty of mismatch

   Max SWR (frequency dependent) = ...

   Convert to reflection coefficient, | ρ_{Sensor} | = (SWR–1)/(SWR+1) = ...

   Max DUT SWR (frequency dependent) = ...

   Convert to reflection coefficient, | ρ_{DUT} | = (SWR–1)/(SWR+1) = ...
8. Combined measurement uncertainty @ k = 1

   $$U_c=\sqrt{\left(\frac{Max(\rho_{DUT})\bullet Max(\rho_{Sensor})}{\sqrt{2}}\right)^2+\left(\frac{sys_{rss}}{2}\right)^2}$$ .... %

   Expanded uncertainty, k = 2, = UC • 2 = ... %

1. The noise to power ratio for average only mode is capped at 0.01% for MU calculation purposes.

Worked Example for U2041XA

Uncertainty calculations for a power measurement (settled, average power)

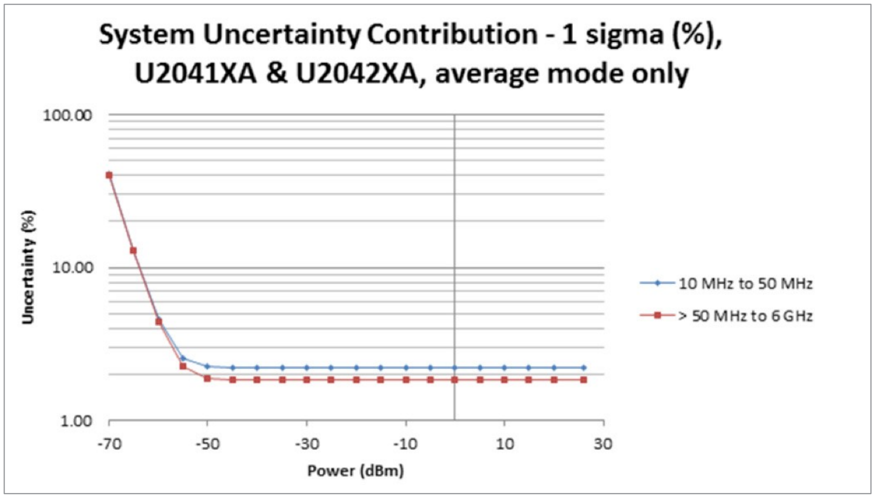
(Specification values from this document are in ***bold italic***, values calculated on this page are underlined.)

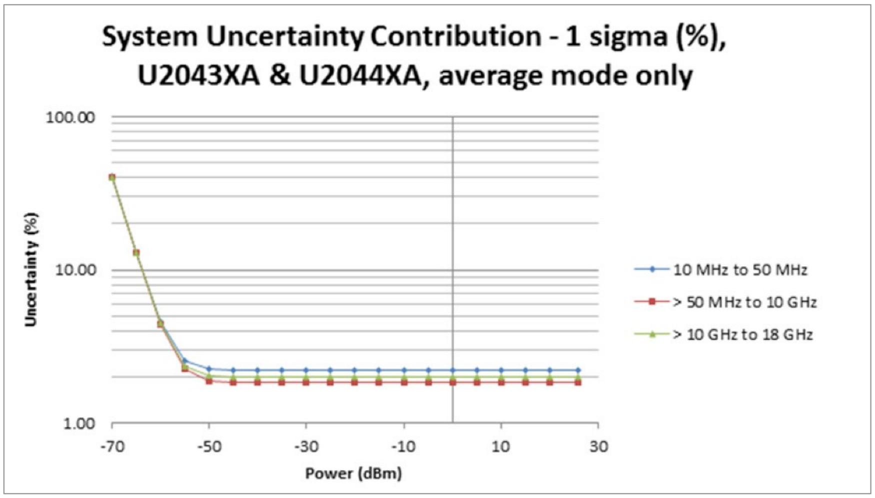
Process	
1. Measured power level	1 mW
2. Frequency of measured signal (use to get calibration uncertainty and SWR)	1 GHz
3. Calculate sensor uncertainty: In Free Run, auto zero mode average = 1 Calculate noise contribution, assuming 50 ms aperture (default) (from page 11) a. Average-only mode: Noise = ***Measurement noise*** x average-only-mode noise multiplier = 80 pW x 4.0 = 0.32 nW b. Free-run normal mode: Noise = ***Measurement noise*** for video bandwidth setting c. Gated-average normal mode (Trigger normal mode), Noise = ***Noise-per-sample*** x noise-per-sample multiplier	
Convert noise contribution to a relative term 1 = Noise/Power = 0.32 nW/1 mW = 0.000032%, value clipped to 0.01% =	0.01%
Convert zero drift to relative term = ***Drift***/Power = 25 pW/1 mW	0.0000025%
RSS of above terms = ...	0.01%
4. Zero uncertainty	
(Mode and frequency dependent) = ***Zero set***/Power = 70 pW/1 mW..	0.000007%
5. ***Sensor calibration uncertainty*** (from page 12)	
(Sensor, measurement mode, frequency, and humidity dependent) = ...	3.7%
6. System contribution, coverage factor of 2 ≥ sys_{rss} = ...	3.7%
(RSS three terms from steps 3, 4 and 5)	
7. Standard uncertainty of mismatch	
Max SWR (frequency dependent) = ...	1.20
Convert to reflection coefficient, $\lvert \rho_{Sensor} \rvert$ = (SWR–1)/(SWR+1) = ...	0.091
Max DUT SWR (frequency dependent) = ...	1.26
Convert to reflection coefficient, $\lvert \rho_{DUT} \rvert$ = (SWR–1)/(SWR+1) = ...	0.115
8. Combined measurement uncertainty @ k = 1	
$U_c = \sqrt{\left(\frac{Max(\rho_{DUT})\cdot Max(\rho_{Sensor})}{\sqrt{2}}\right)^2 + \left(\frac{sys_{rss}}{2}\right)^2}$ $U_c = \sqrt{\left(\frac{0.091\cdot 0.155}{\sqrt{2}}\right)^2 + \left(\frac{0.037}{2}\right)^2}$	1.99%
Expanded uncertainty, k = 2, = UC • 2 = ...	3.98%

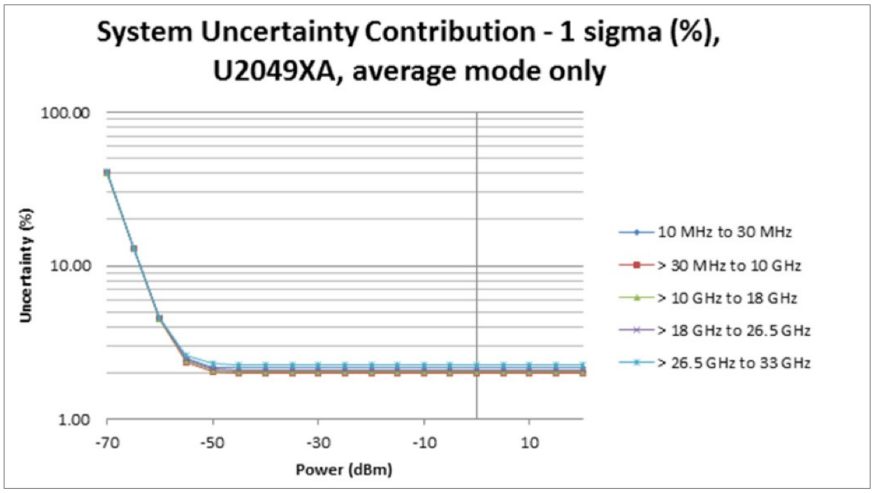
1. The noise to power ratio for average only mode is capped at 0.01% for measurement uncertainty calculation purpose

Graphical Example

A. System contribution to measurement uncertainty versus power level (equates to step 6 result/2)

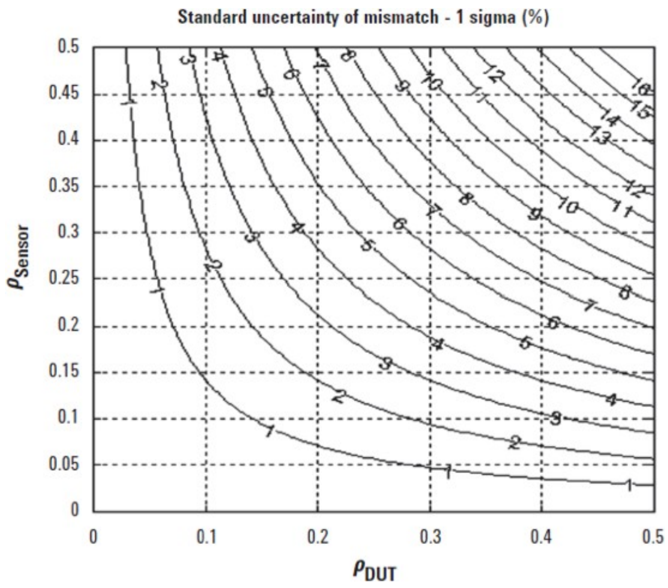






Note: The above graph is valid for conditions of free-run operation, with a signal within the video bandwidth setting on the system. Humidity < 70 %.

B. Standard uncertainty of mismatch



SWR	r	SWR	r
1.0	0.00	1.80	0.29
1.05	0.02	1.90	0.31
1.10	0.05	2.00	0.33
1.15	0.07	2.10	0.35
1.20	0.09	2.20	0.38
1.25	0.11	2.30	0.39
1.30	0.13	2.40	0.41
1.35	0.15	2.50	0.43
1.40	0.17	2.60	0.44
1.45	0.18	2.70	046
1.50	0.20	2.80	0.47
1.60	0.23	2.90	0.49
1.70	0.26	3.00	0.50

Note: The above graph shows the Standard Uncertainty of Mismatch = ρDUT. ρSensor / √2, rather than the Mismatch Uncertainly Limits. This term assumes that both the Source and Load have uniform magnitude and uniform phase probability distributions.

C. Combine A and B

$$U_c = \sqrt{(\text{Value from Graph A})^2 + (\text{Value from Graph B})^2}$$

Expanded uncertainty, k = 2, = $U_C \cdot 2$ = ... ± %

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