DATA SHEET

# U2049XA (Option TVA) and U/L2050/60 X-Series USB/LAN Wide Dynamic Range Peak and Average Power

KEYSIGHT TECHNOLOGIES

Accurately measure most modulated signal with Keysight U2049XA (Option TVA) and U/L2050/60 X-Series USB/LAN wide dynamic range peak and average power sensors. The X-Series power sensors come with widest dynamic range covering a range of -70 to +26 dBm. U2049XA (Option TVA) and L2065XT TVAC LAN power sensors are thermal vacuum qualified, you can get the same accuracy and performance even in thermal vacuum chambers.

## X-Series Power Sensors Comparison Table

| USB model | LAN model | Description | Frequency range | Power range | Connector type |
|---|---|---|---|---|---|
| U2051XA | L2051XA | Wide dynamic range average power sensor | 10 MHz to 6 GHz | −70 to +26 dBm | N-type (male) |
| U2061XA | L2061XA | Wide dynamic range peak and average power sensor | | | |
| U2052XA | L2052XA | Wide dynamic range average power sensor | 10 MHz to 18 GHz | −70 to +26 dBm | N-type (male) |
| U2062XA | L2062XA | Wide dynamic range peak and average power sensor | | | |
| U2053XA | L2053XA | Wide dynamic range average power sensor | 10 MHz to 33 GHz | −70 to +26 dBm | 3.5 mm (male) |
| U2063XA | L2063XA | Wide dynamic range peak and average power sensor | | | |
| | U2049XA | Wide dynamic range peak and average power sensor | 10 MHz to 33 GHz | −70 to +20 dBm | 3.5 mm (male) |
| U2054XA | L2054XA | Wide dynamic range average power sensor | 10 MHz to 40 GHz | −70 to +20 dBm | 2.92 mm (male) |
| U2064XA | L2064XA | Wide dynamic range peak and average power sensor | | | |
| U2055XA | L2055XA | Wide dynamic range average power sensor | 10 MHz to 50 GHz<br>10 MHz to 53 GHz<br>(Option 053) | −70 to +20 dBm (10 MHz to 50 GHz)<br>−70 to 0 dBm (> 50 GHz to 53 GHz) [1] | 2.4 mm (male) |
| U2065XA | L2065XA | Wide dynamic range peak and average power sensor | | | |
| **Thermal Vacuum Compliance Power Sensor** | | | | | |
| | U2049XA (Option TVA) | Wide dynamic range peak and average power sensor with thermal vacuum option | 10 MHz to 33 GHz | −70 to +20 dBm | 3.5 mm (male) |
| | L2065XT | Wide dynamic range peak and average power sensor with thermal vacuum compliance | 10 MHz to 53 GHz | −70 to +20 dBm (10 MHz to 50 GHz)<br>−70 to 0 dBm (> 50 GHz to 53 GHz) | 2.4 mm (male) |

1. Applicable for Option 053 only.

## X-Series Power Sensors Selection Guide

| Measurement types | X-Series USB/LAN Wide Dynamic Range Average Power Sensors | X-Series USB/LAN Wide Dynamic Range Peak and Average Power Sensor |
|---|---|---|
| | U/L2051/52/53/54/55XA | U2049XA (Option TVA), U/L2061/62/63/64/65XA and L2065XT |
| CW power | Yes | |
| Wideband average power (Example: 100 MHz bandwidth) | | |
| Time selectivity in average mode | | |
| Time gated average power | No | Yes |
| Pulse profiling (Power vs time display) | | |
| Peak power or peak-to-average power < 5 MHz bandwidth | | |
| Pulse parameter analysis ≥ 100 ns rise time (Example: rise/fall time, duty cycle, pulse width, etc.) | | |

# X-Series Power Sensor Key Features

## Widest dynamic range power sensor

The X-Series power sensors 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 X-Series sensors are available with average only and peak and average feature sets, supporting frequency ranges to 53GHz. The average only versions have extensive features to help optimize the average power measurements, while the peak and average models add gated power measurements and pulse analysis.

## Super-fast measurement speed

The X-Series power sensor 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 X-Series power sensor 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.

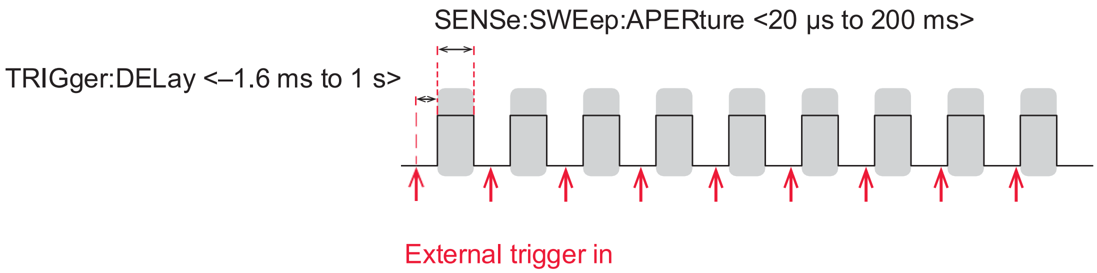



Figure 1. The X-Series power sensor offers real time measurement by measuring every consecutive pulse without dead time.

## Broadband coverage for any modulated signal formats

The X-Series power sensors 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 X-Series power sensors to function like thermocouple power sensors to provide accurate average power for broadband modulated signals.

## Time selectivity in average mode with variable aperture duration

The X-Series power sensors offer a new feature called average mode time selectivity, whereby users can configure the aperture duration of measurement capture with reference to immediate trigger, external trigger and internal 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 enables precise control of what portion of the signal waveform is measured in a similar manner to time-gated measurements in peak power sensors. The key benefit of this feature is that it enables the sensor to measure average power with time selectivity across the full dynamic range and provides real time measurements up to 50000 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 X-Series power sensors 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

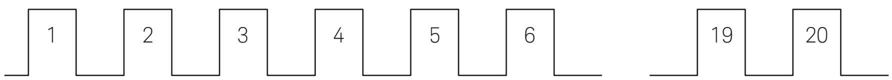
An external trigger enables accurate triggering of low-level signals close to the sensor's noise floor. The X-Series power sensors come with built-in trigger in/out connection, allowing you to connect an external trigger signal from a signal source or the device-under-test in order to achieve precise 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 X-Series power sensor.

## 20 automatic pulse parameter measurements

The U2049XA (Option TVA), U/L2060 X-Series and L2065XT peak and average power sensors offer 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], and 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 X-Series peak and average power sensor 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 X-Series peak and average power sensor 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 X-Series power sensors come 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 X-Series 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 X-Series power sensor'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 X-Series power sensors are standalone sensors that operate without the need of a power meter or an external power supply. The sensors draw power from a USB/LAN 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 or LAN port (using Power over Ethernet, POE connectivity) 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 (Option TVA), L2050/60XA and L2065XT X-Series LAN Power Sensors: 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, 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. L2050/60XA

## 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 can 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)

## Thermal vacuum compliance

The U2049XA Option TVA (thermal vacuum option) and L2065XT are LAN TVAC compliant power sensors that can be used within a thermal vacuum chamber. These sensors have been meticulously designed by selecting components with minimum outgassing properties. Each of these sensors are also subject to temperature cycling in a vacuum chamber to stabilize the materials and to remove outgassing particles.


Figure 6. U2065XT

# 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

## U/L2050 X-Series wide dynamic range average power sensors

| | U/L2051/52XA | U/L2053XA | U/L2054XA | U/L2055XA | |
|---|---|---|---|---|---|
| Frequency range | U/L2051XA: 10 MHz to 6 GHz<br>U/L2052XA: 10 MHz to 18 GHz | 10 MHz to 33 GHz | 10 MHz to 40 GHz | 10 MHz to 50 GHz | 10 MHz to 53 GHz (Option 053) |
| Average mode power range (Average only mode) | −70 to +26 dBm | | −70 to +20 dBm | −70 to +20 dBm<br>−70 to 0 dBm (> 50 GHz to 53 GHz) [3] | |
| Maximum power (Damage level) | Average: +29 dBm | | Average: +26 dBm | | |
| | Peak: +32 dBm for < 10 µs duration | | Peak: +29 dBm for < 10 µs duration | | |
| | Voltage: ≤ 10 VDC | | | | |
| Zero and calibration | Internal zero and calibration supported | | | | |
| Maximum sampling rate | *20 Msamples/second continuous sampling* | | | | |
| Power linearity at 5 dB step [1] | *Average mode: < 1.0%* | | | | |
| Basic accuracy of average power measurement [2] | *≤ ± 0.20 dB or ± 4.5% for < 30 MHz* | *≤ ± 0.20 dB or ± 4.6% for < 30 MHz* | *≤ ± 0.24 dB or ± 5.8% for < 30 MHz* | *≤ ± 0.23 dB or ± 5.5% for < 30 MHz* | *≤ ± 0.24 dB or ± 5.8% for < 30 MHz* |
| | *≤ ± 0.18 dB or ± 4.0% for ≥ 30 MHz to ≤ 10 GHz* | *≤ ± 0.22 dB or ± 5.0% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.19 dB or ± 4.5% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.20 dB or ± 4.6% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.20 dB or ± 4.7% for ≥ 30 MHz to ≤ 26.5 GHz* |
| | *≤ ± 0.18 dB or ± 4.1% for > 10 GHz to 18 GHz* | *≤ ± 0.26 dB or ± 5.8% for > 26.5 GHz to ≤ 33 GHz* | *≤ ± 0.24 dB or ± 5.8% for > 26.5 GHz to ≤ 40 GHz* | *≤ ± 0.23 dB or ± 5.5% for > 26.5 GHz to ≤ 50 GHz* | *≤ ± 0.28 dB or ± 6.6% for > 26.5 GHz to ≤ 53 GHz* |

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. Valid overpower range -45dBm to +26dBm for all power sensors with up to 33GHz frequency range (where the DUT max SWR is <1.2. For all other sensor's specification is valid over a power range of -45dBm to +20dBm where the DUT SWR is <1.2. For all models it is assumed the sensor operates with free run acquisition and averaging set to 32. Attention is drawn to Appendix A for the calculations required to understand the measurement uncertainty for conditions not covered in this definition.
3. Applicable for option 053.

# U2049XA (Option TVA), U/L2060 X-Series and L2065XT wide dynamic range peak and average power sensors

| | U2049XA (Option TVA) | U/L2061/62XA | U/L2063XA | U/L2064XA | U/L2065XA | U/L2065XA and L2065XT |
|---|---|---|---|---|---|---|
| Frequency range | 10 MHz to 33 GHz | U/L2061XA:<br>10 MHz to 6 GHz<br>U/L2062XA:<br>10 MHz to 18 GHz | 10 MHz to 33 GHz | 10 MHz to 40 GHz | 10 MHz to 50 GHz | 10 MHz to 53 GHz (Option 053) |
| Average mode power range (Average only mode) | –70 to +20 dBm | –70 to +26 dBm | −70 to +26 dBm | −70 to +20 dBm | −70 to +20 dBm<br>−70 to 0 dBm (> 50 GHz to 53 GHz) [5] | |
| Maximum power (Damage level) | Average: +29 dBm | | | Average: +26 dBm | | |
| | Peak: +32 dBm for < 10 µs duration | | | Peak: +29 dBm for < 10 µs duration | | |
| | Voltage: ≤ 20 VDC | Voltage: ≤ 10 VDC | | | | |
| Zero and calibration | Internal zero and calibration supported | | | | | |
| Maximum sampling rate | *20 Msamples/second continuous sampling* | | | | | |
| Power linearity at 5 dB step [1] | *Average mode: < 1.0%* | | | | | |
| | *Normal mode: < 1.0%* | *Normal mode: < 1.3%* | | | | |
| Basic accuracy of average power measurement [2] | *≤ ± 0.30 dB or ± 6.6% for < 30 MHz* | *≤ ± 0.20 dB or ± 4.5% for < 30 MHz* | *≤ ± 0.20 dB or ± 4.6% for < 30 MHz* | *≤ ± 0.24 dB or ± 5.8% for < 30 MHz* | *≤ ± 0.23 dB or ± 5.5% for < 30 MHz* | *≤ ± 0.24 dB or ± 5.8% for < 30 MHz* |
| | *≤ ± 0.23 dB or ± 5.2% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.18 or ± 4.0% for ≥ 30 MHz to ≤ 10 GHz* | *≤ ± 0.22 dB or ± 5.0% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.19 dB or ± 4.5% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.20 dB or ± 4.6% for ≥ 30 MHz to ≤ 26.5 GHz* | *≤ ± 0.20 dB or ± 4.7% for ≥ 30 MHz to ≤ 26.5 GHz* |
| | *≤ ± 0.27 dB or ± 5.9% for > 26.5 GHz to ≤ 33 GHz* | *≤ ± 0.18 dB or ± 4.1% for > 10 GHz to 18 GHz* | *≤ ± 0.26 dB or ± 5.8% for > 26.5 GHz to ≤ 33 GHz* | *≤ ± 0.24 dB or ± 5.6% for > 26.5 GHz to ≤ 40 GHz* | *≤ ± 0.23 dB or ± 5.5% for > 26.5 GHz to ≤ 50 GHz* | *≤ ± 0.28 dB or ± 6.6% for > 26.5 GHz to ≤ 53 GHz* |
| Normal mode power range (Peak mode) | *Off: –40 to +20 dBm* | *Off: –40 to +26 dBm* | *Off: –40 to +26 dBm* | *Off: –40 to +20 dBm* | *Off: –40 to +20 dBm* | *Off: –40 to +20 dBm* [6] |
| | *High/5 MHz: –40 to +20 dBm* | *High/5 MHz: –40 to +26 dBm* | *High/5 MHz: –40 to +26 dBm* | *High/5 MHz: –40 to +20 dBm* | *High/5 MHz: –40 to +20 dBm* | *High/5MHz: –40 to +20 dBm* [6] |
| | *Medium/1.5 MHz: –45 to +20 dBm* | *Medium/1.5 MHz: –45 to +26 dBm* | *Medium/1.5 MHz: –45 to +26 dBm* | *Medium/1.5 MHz: –45 to +20 dBm* | *Medium/1.5 MHz: –45 to +20 dBm* | *Medium/1.5 MHz: –45 to +20 dBm* [7] |
| | *Low/300 kHz: –45 to +20 dBm* | *Low/300 kHz: –45 to +26 dBm* | *Low/300 kHz: –45 to +26 dBm* | *Low/300 kHz: –45 to +20 dBm* | *Low/300 kHz: –45 to +20 dBm* | *Low/300 kHz: –45 to +20 dBm* [7] |
| Signal bandwidth | *VBW for peak power: ≤ 5 MHz* [4] | | | | | |
| | *Wideband average power* | | | | | |
| Single shot bandwidth | *5 MHz* | | | | | |
| Minimum pulse width | *250 ns* | | | | | |
| Rise/fall time [3] | ≤ 100 ns | | | | | |
| Maximum capture length | *1 s (decimated)* | | | | | |
| | *6.5 ms (at full sampling rate)* | | | | | |
| Maximum pulse repetition rate | *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. Valid overpower range -45dBm to +26dBm for all power sensors with up to 33GHz frequency range (except U2049XA Option TVA) where the DUT max SWR is <1.2. For all other sensor's specification is valid over a power range of -45dBm to +20dBm where the DUT SWR is <1.2. For all models it is assumed the sensor operates in average only mode, with free run acquisition and averaging set to 32. Attention is drawn to Appendix A for the calculations required to understand the measurement uncertainty for conditions not covered in this definition.
3. With video bandwidth OFF setting and carrier frequency ≥ 300 MHz.
4. 5 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.
5. Applicable for option 053.
6. Applicable for frequency ≤ 50 GHz only. –40 dBm to 0 dBm for frequency > 50 GHz.
7. Applicable for frequency ≤ 50 GHz only. –45 dBm to 0 dBm for frequency > 50 GHz.

## Noise and drift

### U2049XA (Option TVA) and L2065XT

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

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. Noise defined for 1 average in free run mode.
4. Noise defined for 16 averages with 50 ms aperture.

### U/L2050/60 X-Series

| Mode | VBW setting | Zero set [1] | | Zero drift [2] | Measurement noise | Noise per sample |
|---|---|---|---|---|---|---|
| | | External zero | Internal zero | | | |
| Normal [3] | LOW/MED | ± 12 nW | ± 15 nW | *± 10 nW* | *± 10 nW* [4] | *± 0.15 µW* |
| | HIGH/OFF | ± 27 nW | ± 30 nW | *± 15 nW* | *± 32 nW* [4] | *± 0.8 µW* |
| Average | – | ± 90 pW for < 300 MHz<br>± 70 pW for >= 300 MHz | ± 1 nW | *± 25 pW* | *± 80 pW* [5] | — |

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 U/L2060 X-Series.
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 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 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 $N_{ave} \stackrel{def}{=}$ is 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

| | U2049XA (Option TVA) | |
|---|---|---|
| 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 |

| | U/L2051/61XA | | U/L2052/62XA | |
|---|---|---|---|---|
| Frequency band | −70 to +15 dBm | +15 to +26 dBm | −70 to +15 dBm | +15 to +26 dBm |
| 10 MHz to 6 GHz | 1.15 | 1.24 | 1.15 | 1.24 |
| > 6 GHz to 18 GHz | — | — | 1.26 | 1.30 |

| | U/L2053/63XA | |
|---|---|---|
| Frequency band | −70 to +15 dBm | > +15 to +26 dBm |
| 10 MHz to 6 GHz | 1.16 | 1.24 |
| > 6 GHz to 16 GHz | 1.24 | 1.27 |
| > 16 GHz to 26.5 GHz | 1.33 | 1.40 |
| > 26.5 GHz to 33 GHz | 1.41 | 1.53 |

| | U/L2054/64XA | | U/L2055/65XA and L2065XT | |
|---|---|---|---|---|
| Frequency band | −70 to +10 dBm | > +10 to +20 dBm | −70 to +10 dBm | > +10 to +20 dBm |
| 10 MHz to 30 MHz | 1.60 | 1.60 | 1.60 | 1.60 |
| > 30 MHz to 50 MHz | 1.15 | 1.22 | 1.15 | 1.22 |
| > 50 MHz to 300 MHz | 1.13 | 1.21 | 1.13 | 1.21 |
| > 300 MHz to 4 GHz | 1.17 | 1.26 | 1.14 | 1.20 |
| > 4 GHz to 8 GHz | 1.21 | 1.22 | 1.16 | 1.20 |
| > 8 GHz to 14 GHz | 1.19 | 1.25 | 1.20 | 1.21 |
| > 14 GHz to 26.5 GHz | 1.28 | 1.31 | 1.29 | 1.29 |
| > 26.5 GHz to 40 GHz | 1.36 | 1.39 | 1.32 | 1.32 |
| > 40 GHz to 48 GHz | – | – | 1.40 | 1.40 |
| > 48 GHz to 50 GHz | – | – | 1.40 | 1.47 |
| > 50 GHz to 53 GHz [1] | – | – | 1.68 | – |

1. Applicable for option 053 and power dynamic range −70 to 0 dBm only.

## Calibration uncertainty

Definition: Relative expanded uncertainty resulting from non-linearity in the X-Series power sensors detection and correction processes. This can be considered as a combination of traditional linearity, calibration factor and temperature specifications and the uncertainty associated with the internal calibration process. See Appendix A for how to combine all uncertainty terms to provide the combined measurement uncertainty for power.

## Average mode, 0 to 55 °C (25 ± 5 °C where applicable)

| Frequency band | 0 to 55 °C (25 to ± 5 °C) | | | |
|---|---|---|---|---|
| | U2049XA (Option TVA) | U/L2051/61XA | U/L2052/62XA | U/L2053/63XA |
| 10 MHz to 30 MHz | 4.5% | 4.3% (3.2%) | 4.3% (3.2%) | 4.4% |
| > 30 MHz to 500 MHz | 3.9% | 3.5% (2.3%) | 3.5% (2.3%) | 3.9% |
| > 500 MHz to 1 GHz | 3.8% | 3.5% (2.3%) | 3.5% (2.3%) | 3.9% |
| > 1 GHz to 6 GHz | 4.0% | 3.5% (2.3%) | 3.5% (2.3%) | 3.9% |
| > 6 GHz to 10 GHz | 4.0% | – | 3.6% (2.8%) | 4.0% |
| > 10 GHz to 18 GHz | 4.2% | – | 3.7% (3.0%) | 4.2% |
| > 18 GHz to 26.5 GHz | 4.9% | – | – | 4.5% |
| > 26.5 GHz to 33 GHz | 5.6% | – | – | 5.1% |

| Frequency band | 0 to 55 °C | | |
|---|---|---|---|
| | U/L2054/64XA | U/L2055/65XA | U/L2055/65XA (Option 053) and L2065XT |
| 10 MHz to 30 MHz | 4.6% | 4.6% | 4.7% |
| > 30 MHz to 500 MHz | 3.6% | 3.6% | 3.8% |
| > 500 MHz to 6 GHz | 3.6% | 3.6% | 3.9% |
| > 6 GHz to 8 GHz | 3.7% | 3.7% | 3.9% |
| > 8 GHz to 12 GHz | 3.7% | 3.7% | 3.9% |
| > 12 GHz to 16 GHz | 3.9% | 3.9% | 3.9% |
| > 16 GHz to 26.5 GHz | 4.2% | 4.2% | 4.3% |
| > 26.5 GHz to 33 GHz | 4.3% | 4.3% | 4.9% |
| > 33 GHz to 40 GHz | 4.8% | 4.8% | 5.0% |
| > 40 GHz to 50 GHz | – | 5.0% | 5.6% |
| > 50 GHz to 53 GHz | – | – | 5.8% |

## Normal mode, 0 to 55 °C (25 ± 5 °C where applicable)

| Frequency band | 0 to 55 °C (25 to ± 5 °C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | VBW OFF/HIGH | | | | VBW MED/LOW | | | |
| | U2049XA (Option TVA) | U/L2061XA | U/L2062XA | U/L2063XA | U2049XA (Option TVA) | U/L2061XA | U/L2062XA | U/L2063XA |
| 10 MHz to 30 MHz | 4.5% | 4.3% (3.7%) | 4.3% (3.7%) | 4.4% | 4.5% | 4.5% (3.8%) | 4.5% (3.8%) | 4.3% |
| > 30 MHz to 500 MHz | 4.1% | 3.6% (2.8%) | 3.6% (2.8%) | 4.1% | 3.9% | 3.8% (2.8%) | 3.8% (2.8%) | 4.0% |
| > 500 MHz to 1 GHz | 3.9% | 3.6% (2.8%) | 3.6% (2.8%) | 4.1% | 3.9% | 3.8% (2.8%) | 3.8% (2.8%) | 4.0% |
| > 1 GHz to 6 GHz | 4.0% | 3.6% (2.8%) | 3.6% (2.8%) | 4.1% | 4.0% | 3.7% (2.9%) | 3.7% (2.9%) | 4.0% |
| > 6 GHz to 10 GHz | 4.1% | – | 3.6% (3.3%) | 4.1% | 4.1% | – | 3.7% (3.3%) | 4.1% |
| > 10 GHz to 18 GHz | 4.3% | – | 3.8% (3.4%) | 4.3% | 4.2% | – | 3.8% (3.5%) | 4.3% |
| > 18 GHz to 26.5 GHz | 5.0% | – | – | 4.6% | 4.9% | – | – | 4.5% |
| > 26.5 GHz to 33 GHz | 5.7% | – | – | 5.2% | 5.6% | – | – | 5.2% |

| Frequency band | 0 to 55 °C | | | | | |
|---|---|---|---|---|---|---|
| | VBW OFF/HIGH | | | VBW MED/LOW | | |
| | U/L2064XA | U/L2065XA | U/L2065XA (Option 053) and L2065XT | U/L2064XA | U/L2065XA | U/L2065XA (Option 053) and L2065XT |
| 10 MHz to 30 MHz | 4.7% | 4.7% | 4.6% | 4.4% | 4.4% | 4.7% |
| > 30 MHz to 500 MHz | 4.0% | 4.0% | 4.0% | 3.5% | 3.5% | 3.9% |
| > 500 MHz to 6 GHz | 4.0% | 4.0% | 4.0% | 3.5% | 3.5% | 4.0% |
| > 6 GHz to 8 GHz | 4.1% | 4.1% | 4.2% | 3.7% | 3.7% | 4.0% |
| > 8 GHz to 12 GHz | 4.1% | 4.1% | 4.2% | 3.7% | 3.7% | 4.0% |
| > 12 GHz to 16 GHz | 4.2% | 4.2% | 4.2% | 3.8% | 3.8% | 4.4% |
| > 16 GHz to 26.5 GHz | 4.6% | 4.6% | 4.5% | 4.0% | 4.0% | 5.0% |
| > 26.5 GHz to 33 GHz | 4.7% | 4.7% | 5.1% | 4.2% | 4.2% | 5.0% |
| > 33 GHz to 40 GHz | 5.3% | 5.3% | 5.1% | 4.7% | 4.7% | 5.0% |
| > 40 GHz to 50 GHz | – | 5.7% | 5.8% | – | 4.9% | 5.6% |
| > 50 GHz to 53 GHz | – | – | 5.9% | – | – | 5.8% |

# Timebase and Trigger Specifications

| Model | U2049XA (Option TVA) | U/L2060 X-Series | L2065XT | U/L2050 X-Series |
|---|---|---|---|---|
| **Timebase** | | | | |
| Range [3] | *2 ns to 100 ms/div* | | | |
| Accuracy | *± 25 ppm* | *± 2.0 ppm[1]* | *± 25 ppm* | |
| Jitter | *≤ 1 ns* | | | |
| **Trigger** | | | | |
| Minimum internal trigger level (Normal Mode) | *-25 dBm* | | | |
| Resolution | *0.1 dB* | | | |
| Level accuracy | *± 0.5 dB* | | | |
| Latency | *1.5 μs ± 50 ns* | *1.95 μs ± 50 ns [4]* | | |
| Jitter | *≤ 5 ns rms* | | | |
| | | | | |
| Minimum internal trigger level (Average Mode) | | *-40 dBm* | *-37 dBm* | *-40 dBm* |
| Resolution | | *0.1 dB* | | |
| Level accuracy | | *± 0.5 dB* | | |
| Latency | | *1.95 μs ± 50 ns* | | |
| Jitter | | *≤ 5 ns rms* | | |
| | | | | |
| **External TTL trigger input** | | | | |
| High | *> 2.4 V* | | | |
| Low | *< 0.7 V* | | | |
| Latency | *500 ns ± 50 ns* | *950 ns ± 50 ns* | *500 ns ± 50 ns* | *950 ns ± 50 ns* |
| Minimum trigger pulse width | *150 ns (average mode)* | | | |
| | *50 ns (normal mode)* | | | |
| Minimum trigger period | *300 ns (average mode)* | | | |
| | *100 ns (normal mode)* | | | |
| 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* | *950 ns ± 50 ns* | *500 ns ± 50 ns* | *950 ns ± 50 ns* |
| Impedance | *50 Ω* | | | |
| Jitter | *≤ 15 ns rms* | | | |
| **Trigger delay** | | | | |
| Range | *Normal mode: ± 1.0 s* | | | |
| | *Average only mode: -1.6 ms to +1 s* | | | |
| Resolution | *1% of delay setting, 50 ns minimum* | | | |
| **Trigger hold off (Normal Mode)** | | | | |
| Range | *1 μs to 400 ms* | | | |
| Resolution | *1% of selected value (to a minimum of 50 ns)* | | | |
| **Trigger hold off (Average Mode)** | | | | |
| Range | *1 μs to 400 ms* | | | |
| Resolution | *1% of selected value (to a minimum of 50 ns)* | | | |

| Model | U2049XA (Option TVA) | U/L2060 X-Series | L2065XT | U/L2050 X-Series |
|---|---|---|---|---|
| **Trigger level threshold hysteresis** | | | | |
| Range | *± 3 dB* | | | |
| Resolution | *0.05 dB* | | | |

1. ± 2.0 ppm for first year. Typically, ± 2.7 ppm after first year.
2. For frequency range > 50 GHz to 53 GHz.
3. Applicable only when use with Benchvue PM App software.
4. Except L2065XT. L2065XT refer to U2049XA (Option TVA) Latency's specification.

# General Specifications

| **Inputs/Outputs** | |
|---|---|
| Current requirement | **U2050/60 X-Series:** compatible with USB 2.0 (<500 mA) |
| | **U2049XA (Option TVA), L2050/60 X-Series and L2065XT:** compatible with 802.3af and 802.3at type 1 (≤3 W) |
| Trigger input | Input has TTL compatible logic levels and uses an SMB connector |
| Trigger output | Output provides TTL compatible logic levels and uses an SMB connector |
| **Remote programming** | |
| Interface | **U2050/60 X-Series:** USB 2.0 interface USB-TMC compliant |
| | **U2049XA (Option TVA), L2050/60 X-Series and L2065XT:** 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. For LAN socket connectivity, network traffic might affect the measurement speed intermediately. Direct LAN connection to computer via PoE injector would provide the fastest measurement speed.

# 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.

## General Specifications (continued)

| Environmental compliance | |
|---|---|
| Temperature | All models except U2049XA Option TVA and L2065XT:<br>– Operating condition: 0 to 55 °C<br>– Storage condition: –40 to 70 °C |
| | For U2049XA Option TVA and L2065XT:<br>– Operating Condition: 0 to 55 °C. This operating condition is applicable for both standard Atmospheric environment and thermal vacuum environment.<br>– Storage condition: –40 to 100 °C (U2049XA Option TVA and L2065XT) |
| Humidity | Operating condition: Maximum 95% at 40 °C (non-condensing)<br>Storage condition: Up to 90% at 65 °C (non-condensing) |
| Altitude | Operating condition: Up to 3,000 m (9,840 ft)<br>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)<br>IEC 61326:2002/EN 61326:1997 + A1:1998 +A3:2003<br>Canada: ICES-001:2004<br>Australia/New Zealand: AS/NZS CISPR11:2004<br>Canada: ICES-001:2004<br>Australia/New Zealand: AS/NZS CISPR11:2004 |

| Others | U2049XA (Option TVA) | U2051/52/61/62XA | L2051/52/61/62XA | U2053/63XA | L2053/63XA | U2054/55/64/65XA | L2054/55/64/65XA | L2065XT |
|---|---|---|---|---|---|---|---|---|
| Dimensions: Length x Width x Height (mm) | 197 x 40 x 24 | 159 x 44 x 35 | 180 x 46 x 36 | 148 x 44 x 35 | 169 x 46 x 36 | 133 x 44 x 35 | 155 x 46 x 36 | 172 x 40 x 24 |
| Net weight (kg) | ≤ 0.37 | ≤ 0.3 | | | | ≤ 0.24 | ≤ 0.26 | ≤ 0.26 |
| Shipping weight (kg) | ≤ 1.4 | ≤ 1.3 | | | | ≤ 1.24 | ≤ 1.26 | ≤ 1.26 |
| Recommended calibration interval | 1 year | | | | | | | |

# Additional Specifications for X-Series peak and average power sensors

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

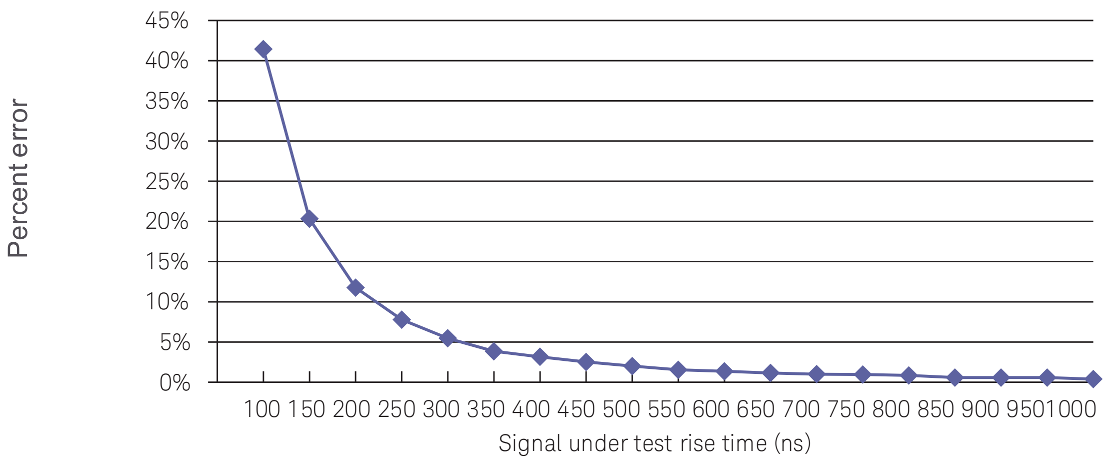



Figure 7. Measured rise time percentage error versus signal under test rise time.

Although the rise time specification is ≤ 100 ns, this does not mean that the X-Series peak and average power sensors 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 X-Series peak and average power sensors can be set to High (5 MHz), Medium (1.5 MHz), Low (300 KHz), 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 8 and Figure 9, "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

## U2049XA (Option TVA) and L2065XT

| 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%* |

## U/L2060 X-Series

| Video bandwidth setting (Normal mode) | | LOW | MED | HIGH | OFF |
|---|---|---|---|---|---|
| Rise/fall time [2] | < 300 MHz | *5.3 µs* | *5.4 µs* | *1.8 µs* | *1.8 µs* |
| | ≥ 300 MHz | *0.6 µs* | *0.64 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.
2. Specification is based on pulse signal with 5 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 8 and Figure 9 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.

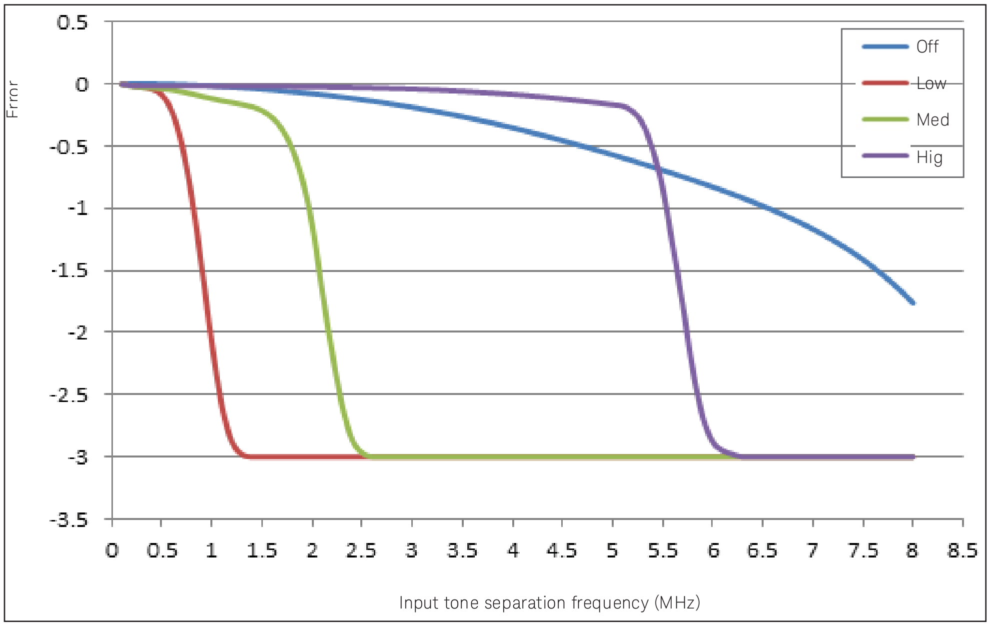



Figure 8. U2049XA (Option TVA) and L2065XT error in peak-to-average ratio measurements for a two-tone input (High, Medium, Low and Off video bandwidth settings).

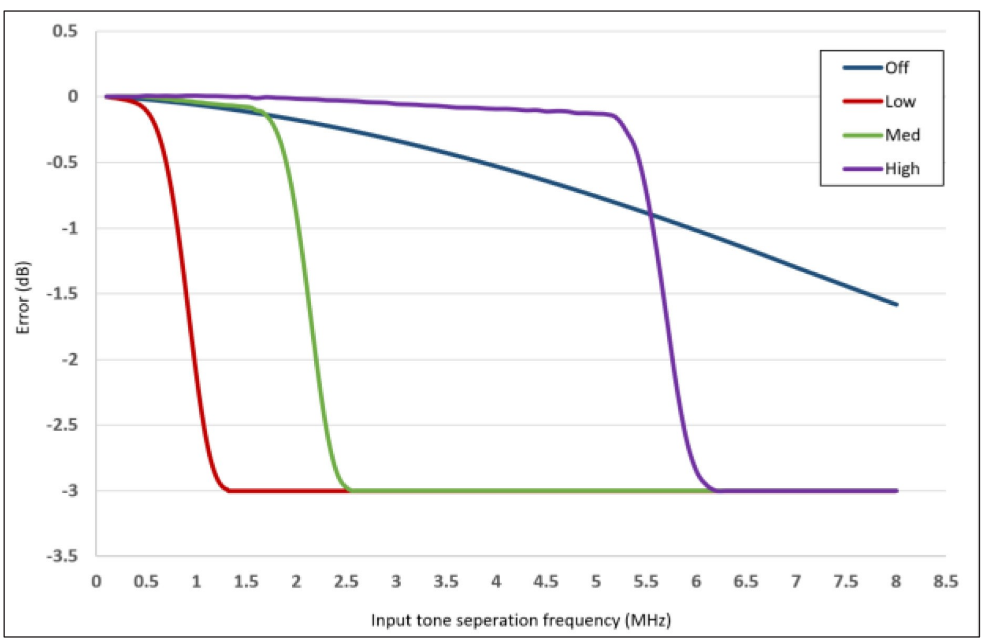



Figure 9. U/L2060 X-Series error in peak-to-average ratio measurements for a two-tone input (High, Medium, Low and Off video bandwidth settings).

# Using the X-Series Power Sensors 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 X-Series power sensors are supported by the Keysight BenchVue software and BV0007B power meter/sensor control and analysis app. Once you plug the X-Series power sensors 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

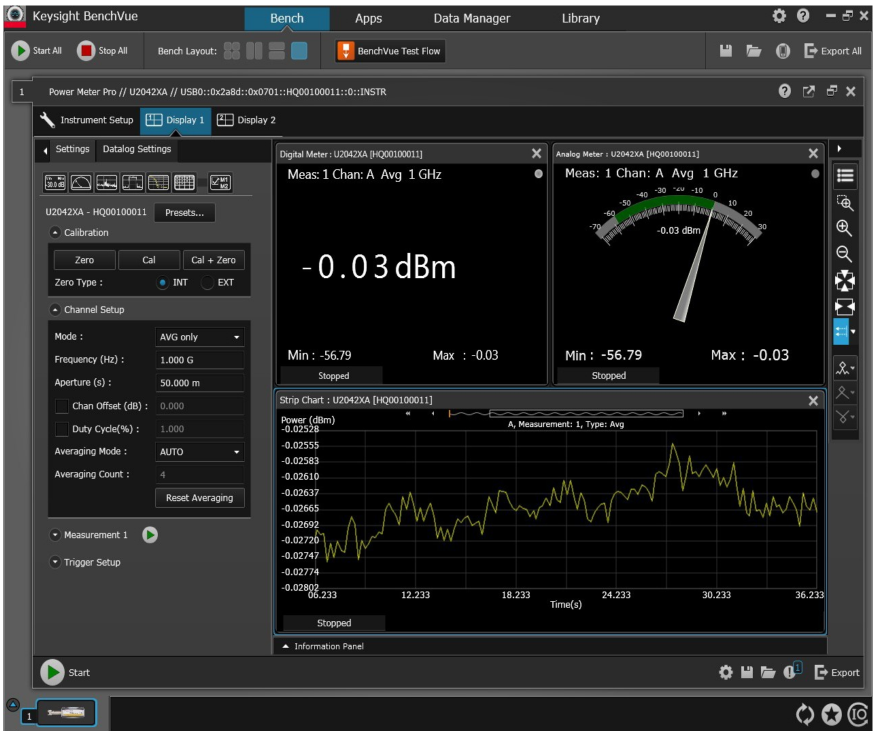



Figure 10. Digital meter, analog meter and datalog view.


Figure 11. Multi-channel trace display with 4-pairs of gates and automatic pulse parameters measurement (sample screen shot with two X-Series power sensors.

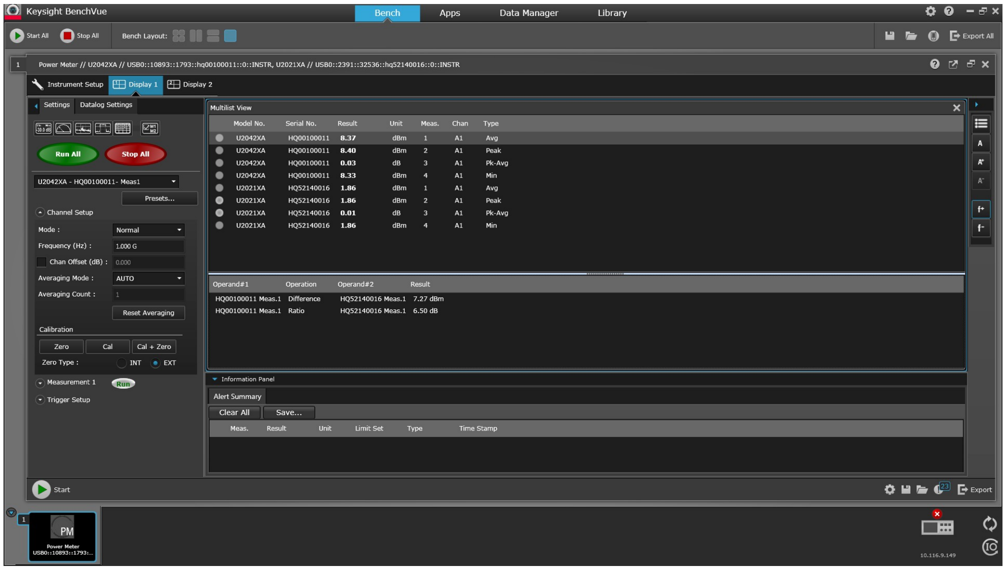


Figure 12. Multi-list view with ratio/difference function.

| Supported functionality | |
|---|---|
| Measurement displays | Digital meter<br>Analog meter<br>Data log view<br>Trace view (up to 4 channels or traces on one graph)<br>Multilist with ratio/delta function<br>Compact mode display |
| Graph functions | Single marker (up to 5 markers per graph)<br>Dual marker (up to 2 sets of markers per graph)<br>Graph autoscaling<br>Graph zooming<br>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<br>Instrument preset settings (DME, GSM, WCDMA, WLAN, LTE, etc.)<br>FDO tables<br>Gamma and S-parameters tables<br>Full instrumentation control includes frequency/average/trigger settings, zero and calibration, etc. |
| Limit and alert function | Sensors Limit and alert notification<br>Alert summary |
| Export data or screen shots | Data logging (HDF5/MATLAB/Microsoft Excel/Microsoft Word/CSV)<br>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)<br>Windows 8 32-bit and 64-bit (Core, Professional, Enterprise)<br>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)<br>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)<br>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 |
| --- | --- |
| U2049XA | 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 |
| U2051XA | USB wide dynamic range average power sensor, 10 MHz to 6 GHz |
| U2052XA | USB wide dynamic range average power sensor, 10 MHz to 18 GHz |
| U2053XA | USB wide dynamic range average power sensor, 10 MHz to 33 GHz |
| U2054XA | USB wide dynamic range average power sensor, 10 MHz to 40 GHz |
| U2055XA | USB wide dynamic range average power sensor, 10 MHz to 50 GHz |
| U2055XA, Option 053 | USB wide dynamic range average power sensor, 10 MHz to 53 GHz |
| U2061XA | USB wide dynamic range peak and average power sensor, 10 MHz to 6 GHz |
| U2062XA | USB wide dynamic range peak and average power sensor, 10 MHz to 18 GHz |
| U2063XA | USB wide dynamic range peak and average power sensor, 10 MHz to 33 GHz |
| U2064XA | USB wide dynamic range peak and average power sensor, 10 MHz to 40 GHz |
| U2065XA | USB wide dynamic range peak and average power sensor, 10 MHz to 50 GHz |
| U2065XA, Option 053 | USB wide dynamic range peak and average power sensor, 10 MHz to 53 GHz |
| L2051XA | LAN wide dynamic range average power sensor, 10 MHz to 6 GHz |
| L2052XA | LAN wide dynamic range average power sensor, 10 MHz to 18 GHz |
| L2053XA | LAN wide dynamic range average power sensor, 10 MHz to 33 GHz |
| L2054XA | LAN wide dynamic range average power sensor, 10 MHz to 40 GHz |
| L2055XA | LAN wide dynamic range average power sensor, 10 MHz to 50 GHz |
| L2055XA, Option 053 | LAN wide dynamic range average power sensor, 10 MHz to 53 GHz |
| L2061XA | LAN wide dynamic range peak and average power sensor, 10 MHz to 6 GHz |
| L2062XA | LAN wide dynamic range peak and average power sensor, 10 MHz to 18 GHz |
| L2063XA | LAN wide dynamic range peak and average power sensor, 10 MHz to 33 GHz |
| L2064XA | LAN wide dynamic range peak and average power sensor, 10 MHz to 40 GHz |
| L2065XA | LAN wide dynamic range peak and average power sensor, 10 MHz to 50 GHz |
| L2065XA, Option 053 | LAN wide dynamic range peak and average power sensor, 10 MHz to 53 GHz |
| L2065XT, Option 053 | LAN peak and average power sensor, 10 MHz to 53 GHz, thermal vacuum compliance |
| **Standard shipped items** | |
| U2050/60 X-Series USB power sensors | USB cable 5 ft (1.5 m), default cable length<br>BNC male to SMB female trigger cable, 50 Ω, 1.5 m (Quantity: 2)<br>Certificate of calibration |
| U2049XA & L2050/60 X-Series LAN power sensors | LAN cable 5 ft (1.5 m), default cable length<br>BNC male to SMB female trigger cable, 50 Ω, 1.5 m (Quantity: 2)<br>Certificate of calibration |
| U2049XA (Option TVA) and L2065XT<br>TVAC LAN power sensors | TVAC LAN cable 5 ft (1.5 m), default cable length<br>TVAC BNC male to SMB female trigger cable, 50 Ω, 1.5 m (Quantity: 2)<br>TVAC sensor bracket<br>Thermal interface material<br>Certificate of calibration |

## U2050/60 X-Series USB power sensors 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 (Option TVA), L2050/60 X-Series and L2065XT LAN power sensor options[1]

| Options | Description |
|---|---|
| **Standard LAN cables (selectable during sensor purchase and orderable standalone)** | |
| U2034A | LAN cable 5 ft (1.5 m) – default selection for LAN power sensors |
| 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) |
| U2037A | TVAC LAN cable, 5ft (1.5m) - default selection for TVAC LAN power sensor |
| U2037B | TVAC LAN cable, 10ft (3m) |
| U2037C | TVAC LAN cable, 16.4ft (5m) |
| U2037D | TVAC LAN cable, 50ft (15.2m) |
| U2037E | TVAC LAN cable, 100ft (30.5m) |
| U2037F | TVAC LAN cable, 200ft (61m) |

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.

## X-Series USB/LAN power sensors options

| | |
|---|---|
| **Trigger cable** | |
| U2032A | Standard trigger cable BNC Male to SMB female, 50 Ω, 1.5 m (For X-Series power sensors except U2049XA Option TVA and L2065XT) |
| U2033A | TVAC trigger cable BNC Male to SMB female, 50 Ω, 1.5 m (For U2049XA Option TVA and L2065XT 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-CD1 [1] | Documentation Optical Disk (consists of documentation CD-ROM and Keysight Instruments Control DVD) |
| U2053XA-CD1 [2] | 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 |

1. Available for U2049XA (Option TVA) only.
2. Available for U/L2050/60 X-Series and L2065XT only.

# 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:<br>Calculate noise contribution (from page 11)<br>• Average-only mode: <u>Noise</u> = ***Measurement noise*** x average-only-mode noise multiplier<br>• Free-run normal mode: <u>Noise</u> = ***Measurement noise*** for video bandwidth setting<br>• Gated-average normal mode (Trigger normal mode), Noise = ***Noise-per-sample*** x noise-per-sample multiplier | |
| | Convert noise contribution to a relative term 1 = <u>Noise</u>/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, $\vert \rho_{Sensor} \vert$ = (SWR–1)/(SWR+1) = ........................................ | |
| | Max DUT SWR (frequency dependent) = ........................................ | |
| | Convert to reflection coefficient, $\vert \rho_{DUT} \vert$ = (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

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

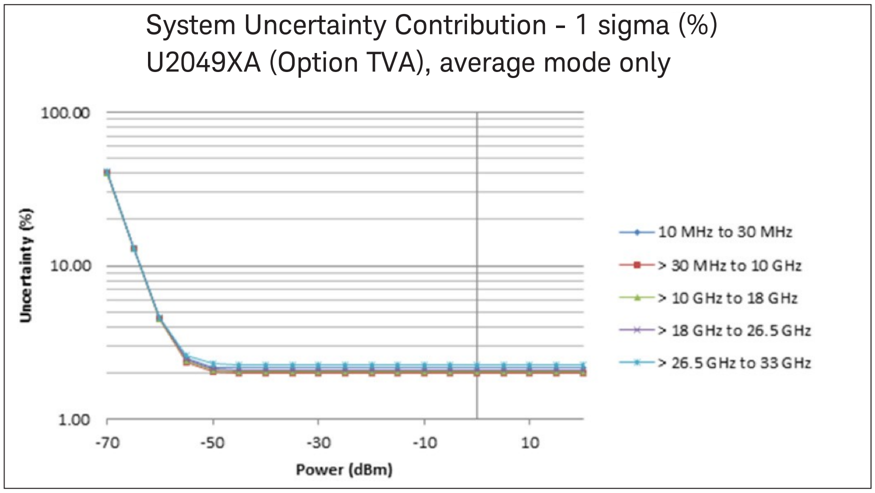
(Specification values from this document are in ***bold italic***, values calculated on this page are underlined.)

| 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<br>Calculate noise contribution, assuming 50 ms aperture (default) (from page 11)<br>• Average-only mode: Noise = ***Measurement noise*** x average-only-mode noise multiplier = 80 pW x 4.0 = 0.32 nW<br>• Free-run normal mode: Noise = ***Measurement noise*** for video bandwidth setting<br>• 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<br>(Mode and frequency dependent) = ***Zero set***/Power = 70 pW/1 mW........ | 0.000007% |
| 5. ***Sensor calibration uncertainty*** (from page 12) ........<br>(Sensor, measurement mode, frequency, and humidity dependent) = ........ | 3.7% |
| 6. System contribution, coverage factor of 2 ≥ $sys_{rss}$ = ........<br>(RSS three terms from steps 3, 4 and 5) | 3.7% |
| 7. Standard uncertainty of mismatch<br>***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<br>$U_c=\sqrt{\left(\frac{Max(\rho_{DUT})\bullet Max(\rho_{Sensor})}{\sqrt{2}}\right)^2+\left(\frac{sys_{rss}}{2}\right)^2}$ $U_c=\sqrt{\left(\frac{0.091\bullet 0.155}{\sqrt{2}}\right)^2+\left(\frac{0.037}{2}\right)^2}$ ........ | 1.99% |
| Expanded uncertainty, k = 2, = UC • 2 = ........ | 3.98% |

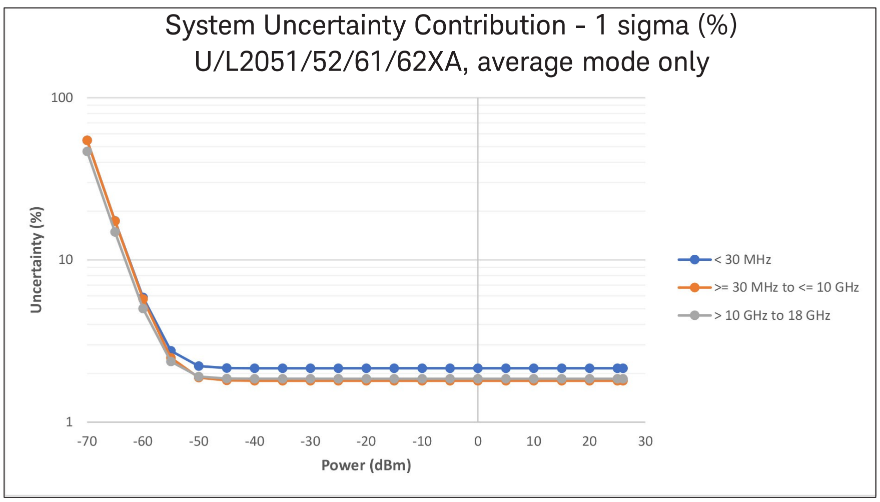
1. The noise to power ratio for average only mode is capped at 0.01% for measurement uncertainty calculation purposes.

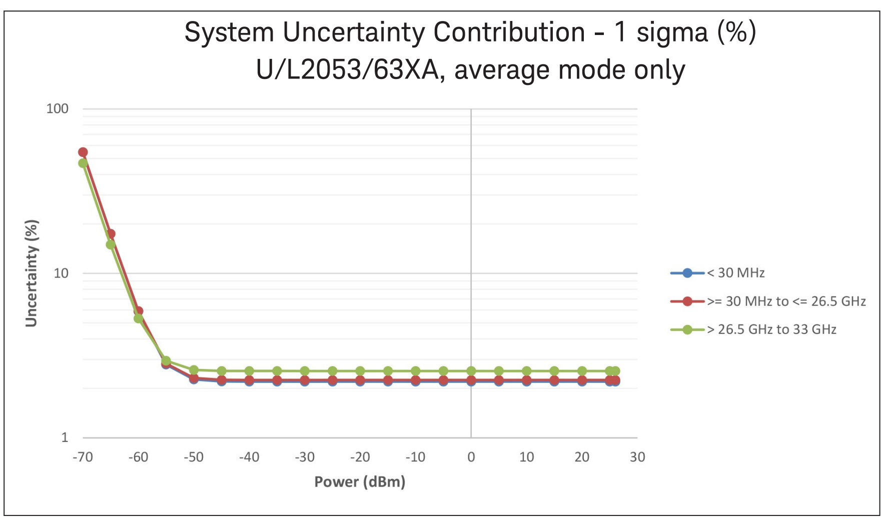
## Graphical Example

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

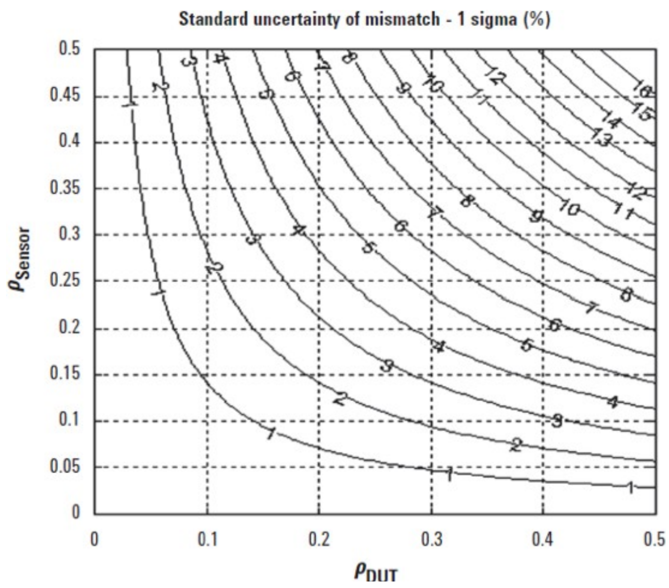



Note: The above graph is valid for conditions of free-run operation, with a signal within the video bandwidth setting on the system. Humidity < 70 %.



## 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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