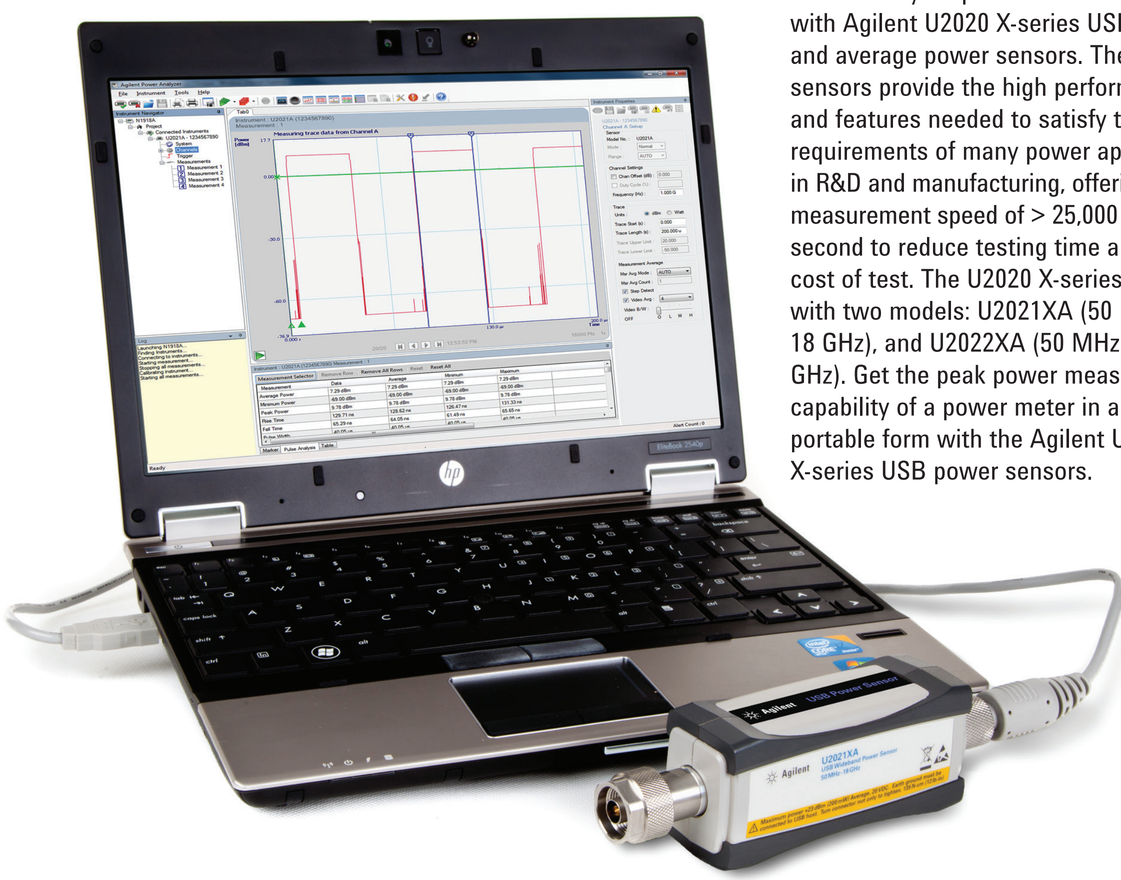
Agilent
U2020 X-Series USB Peak and Average Power Sensors

Data Sheet

Accelerate your production throughput



Accelerate your production throughput with Agilent U2020 X-series USB peak and average power sensors. These sensors provide the high performance and features needed to satisfy the requirements of many power applications in R&D and manufacturing, offering a fast measurement speed of > 25,000 readings/second to reduce testing time and cut cost of test. The U2020 X-series comes with two models: U2021XA (50 MHz to 18 GHz), and U2022XA (50 MHz to 40 GHz). Get the peak power measurement capability of a power meter in a compact, portable form with the Agilent U2020 X-series USB power sensors.

Accurate RMS power measurements

The U2020 X-Series have a wide 30 MHz video bandwidth and a 80 M-sample/s continuous sampling rate for fast, accurate and repeatable RMS power measurements. With its high frequency coverage of 40 GHz, wide dynamic range and extensive measurement capability, the X-Series is optimized for aerospace/defense, wireless communication (LTE, WCDMA, GSM) and wireless networking applications (WLAN)

A wide peak power dynamic range

The U2020 X-series sensors' dynamic range of –30 to +20 dBm for peak power measurements enables more accurate analysis of very small signals, across a broader range of peak power applications in the aerospace, defense and wireless industries.

Internal zero and calibration

Save time and reduce measurement uncertainty with the internal zero and calibration function. Each U2020 X-series sensor comes with technology that integrates a dc reference source and switching circuits into the body of the sensor so you can zero and 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.

The internal zero and calibration function is especially important in manufacturing and automated test environments where each second and each connection counts.

Built-in trigger in/trigger out

An external trigger enables accurate triggering of small signals close to the signal noise floor. The U2020 X-series USB 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 directly to the USB sensor through a standard BNC to SMB cable. The sensors also come with recorder/video-output features.

Compact and portable form factor

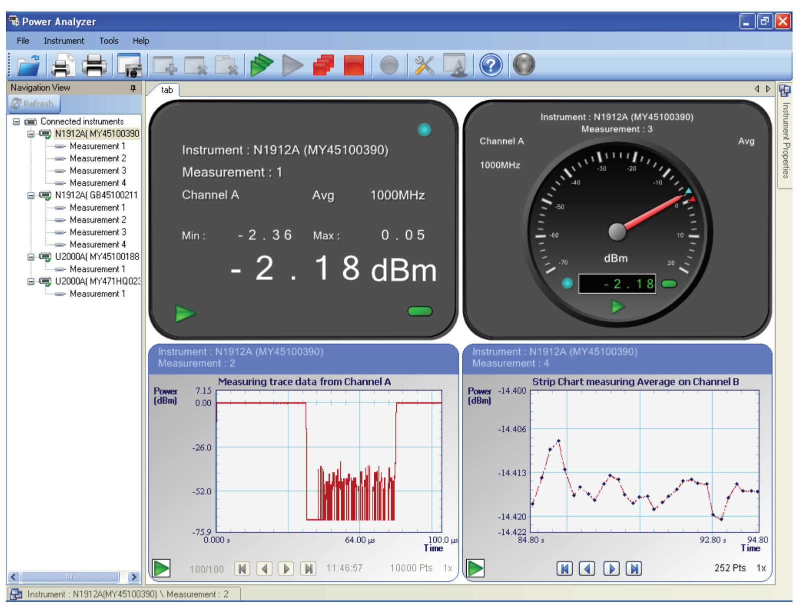
The U2020 X-series are standalone sensors that operate without the need of a power meter or an external power supply. The sensors draw power from a USB port and do not need additional triggering modules to operate, making them portable and lightweight solutions for field applications such as base station testing. Simply plug the sensor to the USB port of your PC or laptop, and start your power measurements.

Fast rise and fall time; wide video bandwidth

Accurately measure the output power and timing parameters of pulses when designing or manufacturing components and subcomponents for radar systems. The U2020 X-series USB power sensors come with a 30 MHz bandwidth and ≤ 13 ns rise and fall time, providing a high performance peak and average power solution that covers most high frequency test applications up to 40 GHz.

Built-in radar and wireless presets

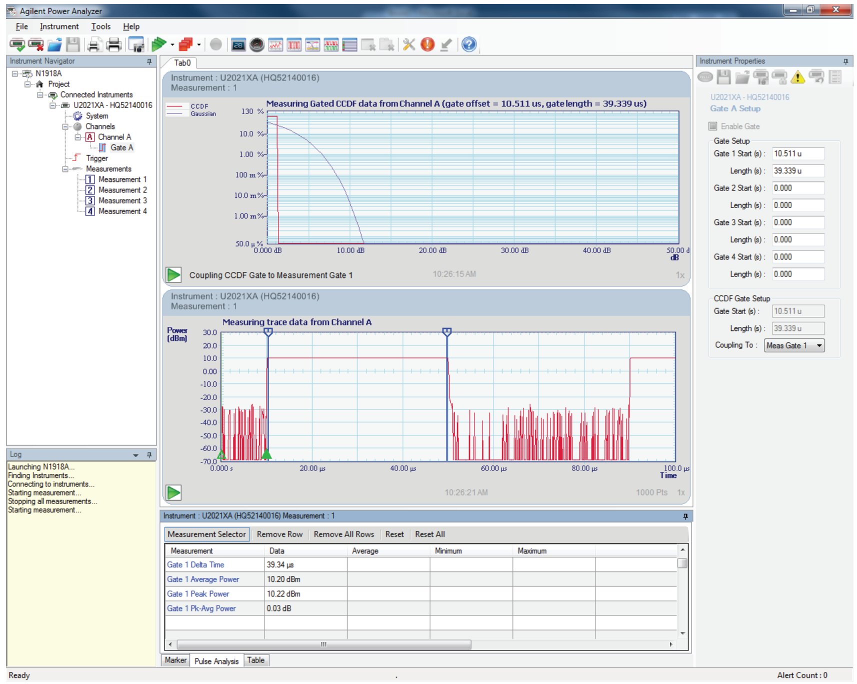
Begin testing faster; the U2020 X-series USB power sensors come with built-in radar and wireless presets for DME, GSM, EDGE, CDMA, WCDMA, WLAN, WiMAX, and LTE.



Bundled intuitive power analysis software

The U2020 X-series USB power sensors are bundled with a free N1918A Option 100 Power Analyzer PC license key. Simply connect the USB power sensor and the PC will recognize the license.

A N1918A Power Analysis Manager software CD will be shipped together with the U2021XA or U2022XA. Users can also download the software from **www.agilent.com/find/N1918A**.



Complementary Cumulative Distribution Function (CCDF) curves

CCDF characterizes the high power statistics of a digitally modulated signal, and is defined by how much time the waveform spends at or above a given power level. The U2020 X-series supports two types of CCDF curves. Normal CCDF displays the power statistics of the whole waveform under free run, internal or external trigger modes. Gated CCDF can be coupled with a measurement gate and only the waveform within the gated region is analyzed statistically. Gated CCDF is only applicable in internal trigger and external trigger modes.

Designers of components, such as power amplifiers, will compare the CCDF curves of a signal at the amplifier's input and output. A well designed component will produce curves that overlap each other. If the amplifier compresses the signal, then the peak-to-average ratio of the signal will be lower at the output of the amplifier. The designer will need to improve the range of the amplifier to handle high peak power.

List mode
List mode is a mode of operation where a predefined sequence of measurement steps can be programmed into the power sensor and repeatedly executed as many times as required. This mode is suitable for power and frequency sweeps which normally require changing the parameters via the appropriate SCPI commands before performing a measurement. The hardware handshaking communication between the power sensor and the signal source provides the fastest possible execution time in performing the test sequences.

Trigger and gating parameters control which part of the waveform to be included or excluded from the measurement. The list mode helps to analyze modulated signals with regular and time- slotted or frame structure. For example, eight time-slotted GSM bursts, LTE-FDD and LTE-TDD frames and sub-frames, WCDMA frames and slots, and time-slotted measurements are supported in this mode. The desired number of slots and their duration and exclusion intervals can be easily programmed.

For more information, please refer to the U2020 X-Series Programming Guide.

Variable aperture size
In average only mode and at normal measurement speed, the time interval length used to measure the average power of the signal can be adjusted by setting the aperture size to between 2 ms and 200 ms. This is useful for CW signals and noise-like modulated signals such as FDD-LTE and WCDMA by performing measurements over the full frames or sub-frames.

Decreasing the aperture size will improve the measurement throughput but reduce the signal-to-noise ratio of the measured signal. However, increasing the aperture size will improve the signal-to-noise ratio of the measured signal but reduce the measurement throughput.

Measurement speed	Default aperture size	Adjustable
NORMal	50 ms	Yes
DOUBle	26 ms	No
FAST	2 ms	No

Table 1. Aperture size

Auto burst detection
Auto burst detection helps the measurement setup of the trace or gate positions and sizes, and 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 the 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.

20-pulse measurements
The U2020 X-Series can measure up to 20 pulses. The measurement of radar pulse timing characteristics is greatly simplified and accelerated by performing analysis simultaneously on up to 20 pulses within a single capture. Individual pulse duration, period, duty cycle and separation, positive or negative transition duration, and time (relative to the delayed trigger point) are measured.

High average count reset
When high averaging factors have been set, any rapid adjustments to the amplitude of the measured signal will be delayed due to the need to allow the averaging filter to fill before a new measurement can be taken at a stable power level. The U2020 X-Series allows you to reset the long filter after the final adjustment to the signal's amplitude has been made.

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 characteristic specifications 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. There 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 'attributes'.

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'.

Conditions

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*.

U2020 X-Series USB Power Sensors Specifications

Key specifications		
Frequency range	U2021XA	50 MHz to 18 GHz
	U2022XA	50 MHz to 40 GHz
Dynamic power range	Normal mode	*–35 dBm to 20 dBm (≥ 500 MHz)*
		–30 dBm to 20 dBm (50 MHz to 500 MHz)
	Average only mode [1,2]	*–45 dBm to 20 dBm*
Damage level	23 dBm (average power)	
	30 dBm (< 1 µs duration) (peak power)	
Rise/fall time	≤ 13 ns [3]	
Maximum sampling rate	*80 Msamples/sec, continuous sampling*	
Video bandwidth	*≥ 30 MHz*	
Single-shot bandwidth	*≥ 30 MHz*	
Minimum pulse width	*50 ns* [4]	
Average power measurement accuracy	U2021XA	≤ ±0.2 dB or ±4.5% [5]
	U2022XA	≤ ±0.3 dB or ±6.7%
Maximum capture length	*1 s (decimated)* *1.2 ms (at full sampling rate)*	
Maximum pulse repetition rate	*10 MHz (based on 8 samples/period)*	
Connector type	U2021XA	N-Type (m)
	U2022XA	2.4 mm (m)

1. Internal zeroing, trigger output, and video output are disabled in average only mode.
2. It is advisable to perform zeroing when using the average path for the first time after power on, significant temperature changes, or long periods since the last zeroing. Ensure that the power sensor is isolated from the RF source when performing external zeroing in average only mode.
3. For frequencies ≥ 500 MHz. Only applicable when the Off video bandwidth is selected.
4. The Minimum Pulse Width is the recommended minimum pulse width viewable, where power measurements are meaningful and accurate, but not warranted.
5. Specification is valid over a range of –15 to +20 dBm, and a frequency range of 0.5 to 10 GHz, DUT Max. SWR <1.27 for the U2021XA, and a frequency range of 0.5 to 40 GHz, DUT Max. SWR <1.2 for the U2022XA. Averaging set to 32, in Free Run mode.

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

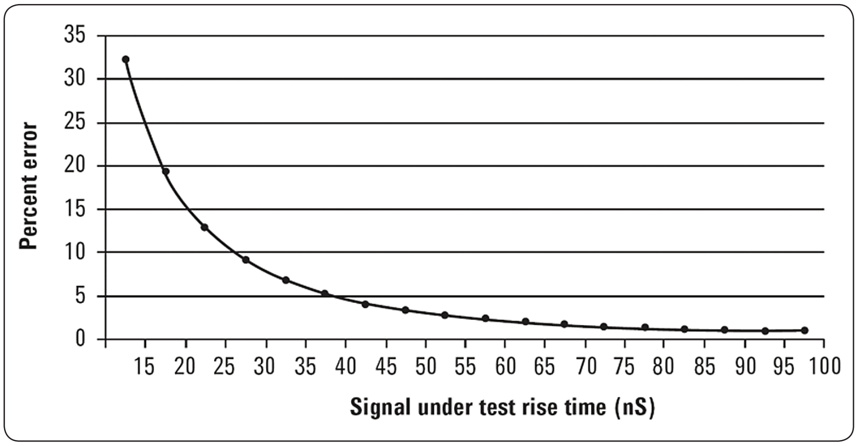


Figure 1. Measured rise time percentage error versus signal under test rise time

Although the rise time specification is ≤13 ns, this does not mean that the U2021XA/22XA can accurately measure a signal with a known rise time of 13 ns. The measured rise time is the root sum of the squares (RSS) of the signal-under-test (SUT) rise time and the system rise time (13 ns):

Measured rise time = √((SUT rise time)² + (system rise time)²)
and the % error is:

% Error = ((measured rise time – SUT rise time)/SUT rise time) × 100

Power Linearity

Power range	Linearity at 5 dB step (%)	
	25 °C	0 to 55 °C
–20 dBm to –10 dBm	*1.2*	*1.8*
–10 dBm to 15 dBm	*1.2*	*1.2*
15 dBm to 20 dBm	*1.4*	*2.1*

Video bandwidth

The video bandwidth in the U2021XA/22XA 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 2, "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		Low: 5 MHz	Medium: 15 MHz	High: 30 MHz	Off
Rise time/fall time[1]	< 500 MHz	*< 93 ns*	*< 75 ns*	*< 72 ns*	*< 73 ns*
	≥ 500 MHz	*< 82 ns*	*< 27 ns*	*< 17 ns*	< 13 ns
Overshoot[2]					*< 5%*

1. Specified as 10% to 90% for rise time and 90% to 10% for fall time on a 0 dBm pulse.
2. Specified as the overshoot relative to the settled pulse top power.

Recorder output and video output

The recorder output produces a voltage proportional to the selected power measurement and is updated at the measurement rate. Scaling can be selected with an output range of 0 to 1 V and impedance of 1 kΩ.

The video output is the direct signal output detected by the sensor diode, with no correction applied. The video output provides a DC voltage proportional to the measured input power. The DC voltage can be displayed on an oscilloscope for time measurement. The video output impedance is 50 Ω and the level is approximately 500 mV at 20 dBm CW. The trigger out and recorder/video out share the same port, and the level is approximately 250 mV at 20 dBm.

Characteristic peak flatness

The peak flatness is the flatness of a peak- to- average ratio measurement for various tone separations for an equal magnitude two- tone RF input. The figure 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.

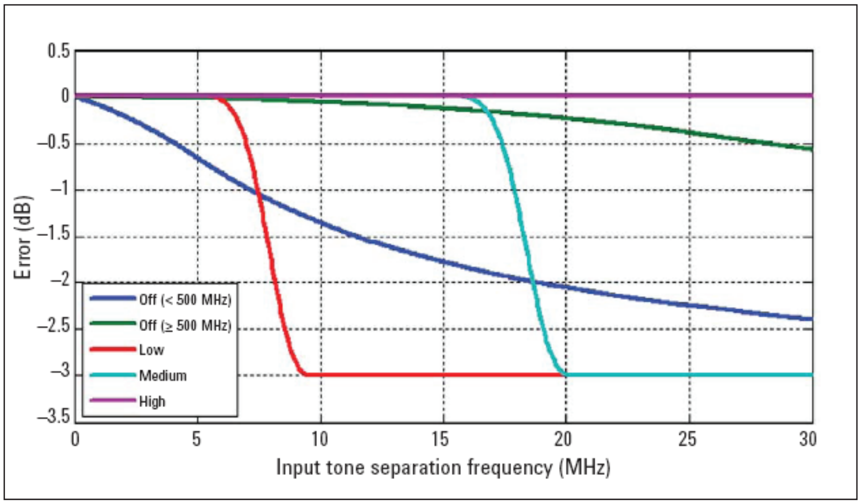


Figure 2. U2021XA/22XA error in peak-to-average measurements for a two-tone input (High, Medium, Low and Off Filters)

Noise and drift							
Mode	Zeroing	Zero set		Zero drift [1]	Noise per sample		Measurement noise
		< 500 MHz	≥ 500 MHz		< 500 MHz	≥ 500 MHz	
Normal	No RF on input	200 nW		*100 nW*	*3 μW*	*2.5 μW*	*100 nW* [2] (Free run)
	RF present	*200 nW*	200 nW				
Average only	No RF on input	10 nW		*6 nW*	*3 μW*	*2.5 μW*	*4 nW* [3]

Measurement average setting		1	2	4	8	16	32	64	128	256	512	1024
Normal mode	Free run noise multiplier	*1.00*	*0.9*	*0.8*	*0.7*	*0.6*	*0.5*	*0.45*	*0.4*	*0.3*	*0.25*	*0.2*
Average only	NORMal speed noise multiplier	*4.25*	*2.84*	*2.15*	*1.52*	*1.00*	*0.78*	*0.71*	*0.52*	*0.5*	*0.47*	*0.42*
	DOUBle speed noise multiplier	*5.88*	*4.00*	*2.93*	*1.89*	*1.56*	*1.00*	*0.73*	*0.55*	*0.52*	*0.48*	*0.44*

Video bandwidth setting		Low: 5 MHz	Medium: 15 MHz	High: 30 MHz	Off
Noise per sample multiplier	< 500 MHz	*0.6*	*1.3*	*2.7*	*1.00*
	≥ 500 MHz	*0.55*	*0.65*	*0.8*	*1.00*

For average only mode with aperture size of ≥ 12 ms and averaging set to 1, the measurement noise is calculated as follows:

Measurement noise = 120/√(aperture size in ms) nW

For average only mode with aperture size of <12 ms and averaging set to 1, the measurement noise is equal to 50 nW.

For example, if the aperture size is 50 ms and averaging set to 1, Measurement noise = 120/√(50) nW = 17 nW

1. Within 1 hour after zeroing, at a constant temperature, after a 24-hour warm-up of the U2020 X-Series. This component can be disregarded with the auto-zeroing mode set to ON.
2. Measured over a 1-minute interval, at NORMal speed, at a constant temperature, two standard deviations, with averaging set to 1.
3. Tested with averaging set to 16 at NORMal speed and 32 at DOUBle speed.

Effect of video bandwidth setting

The noise per sample is reduced by applying the video bandwidth filter setting (High, Medium, or Low). If averaging is implemented, this will dominate any effect of changing the video bandwidth.

Effect of time-gating on measurement noise

The measurement noise for a gated average measurement is calculated from the noise per sample specification. The noise for any particular gate is equal to $N_{sample}/\sqrt{(gate\ length/12.5\ ns)}$. The improvement in noise limits at the measurement noise specification of 100 nW.

Maximum SWR

Frequency band	U2021XA	U2022XA
50 MHz to 10 GHz	1.2	1.2
> 10 GHz to 18 GHz	1.26	1.26
> 18 GHz to 26.5 GHz		1.3
> 26.5 GHz to 40 GHz		1.5

Calibration uncertainty

Definition: Uncertainty resulting from non- linearity in the U2021XA/22XA 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.

Frequency band	U2021XA	U2022XA
50 MHz to 500 MHz	4.2%	4.3%
> 500 MHz to 1 GHz	4.0%	4.2%
> 1 GHz to 10 GHz	4.0%	4.5%
> 10 GHz to 18 GHz	4.5%	4.5%
> 18 GHz to 26.5 GHz		5.3%
> 26.5 GHz to 40 GHz		5.8%

Timebase and trigger specifications

Timebase	
Range	*2 ns to 100 ms/div*
Accuracy	±25 ppm
Jitter	*≤ 1 ns*
Trigger	
Internal trigger	
Range	*–20 to 20 dBm*
Resolution	*0.1 dB*
Level accuracy	*±0.5 dB*
Latency [1]	*225 ns ± 12.5 ns*
Jitter	*≤ 5 ns RMS*
External TTL trigger input	
High	*>2.4 V*
Low	*<0.7 V*
Latency [2]	*75 ns ± 12.5 ns*
Minimum trigger pulse width	*15 ns*
Minimum trigger repetition period	*50 ns*
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	*50 Ω, 100 kΩ (default)*
Jitter	*≤ 8 ns RMS*
External TTL trigger output	Low to high transition on trigger event
High	*> 2.4 V*
Low	*< 0.7 V*
Latency [3]	*50 ns ± 12.5 ns*
Impedance	*50 Ω*
Jitter	*≤ 5 ns RMS*
Trigger delay	
Range	*± 1.0 s, maximum*
Resolution	*1% of delay setting, 12.5 ns minimum*
Trigger holdoff	
Range	*1 µs to 400 ms*
Resolution	*1% of selected value (to a minimum of 12.5 ns)*
Trigger level threshold hysteresis	
Range	*± 3 dB*
Resolution	*0.05 dB*

1. Internal trigger latency is defined as the delay between the applied RF crossing the trigger level and the U2021XA/22XA switching into the triggered state.
2. External trigger latency is defined as the delay between the applied trigger crossing the trigger level and the U2021XA/22XA switching into the triggered state.
3. External trigger output latency is defined as the delay between the U2021XA/22XA entering the triggered state and the output signal switching.

General specifications

Inputs/Outputs	
Current requirement	450 mA max (approximately)
Recorder output	Analog 0 to 1 V, 1 kΩ output impedance, SMB connector
Video output	0 to 1 V, 50 Ω output impedance, SMB connector
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	USB 2.0 interface USB-TMC compliance
Command language	SCPI standard interface commands, IVI-COM, IVI-C driver and LabVIEW drivers
Maximum measurement speed	
Free run trigger measurement	*25,000 readings per second* [1]
External trigger time-gated measurement	*20,000 readings per second* [2]

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.

General Characteristics

Environmental Compliance	
Temperature	Operating condition: • 0 °C to 55 °C
	Storage condition: • – 40 °C to 70 °C
Humidity	Operating condition: • Maximum: 95% at 40 °C (non-condensing) • Minimum: 15% at 40 °C (non-condensing)
	Storage condition: • Up to 90% at 65°C (non-condensing)
Altitude	Operating condition: • Up to 3000 m (9840 ft)
	Storage condition: • Up to 15420 m (50000 ft)
Regulatory compliance	
The U2021XA/22XA USB peak power sensor complies with the following safety and EMC requirements:	• IEC 61010-1:2001 / EN 61010-1:2001 (2nd edition) • IEC 61326:2002 / EN 61326:1997 +A1:1998 +A2:2001 +A3:2003 • Canada: ICES-001:2004 • Australia/New Zealand: AS/NZS CISPR11:2004 • South Korea EMC (KC Mark) certification: RRA 2011-17
Dimensions (Length × Width × Height)	*140 mm × 45 mm × 35 mm*
Weight	• Net weight: ≤ *0.25 kg* • Shipping weight: *1.4 kg*
Connectivity	
USB 2.0, with the following cable lengths: (Selectable during sensor purchase)	• Option 301: 1.5 m • Option 302: 3 m • Option 303: 5 m
Recommended calibration interval	1 year
Warranty	1 year

Using the U2020 X-Series with the N1918A Power Analysis Manager

N1918A Power Analysis Manager is a powerful application software that complements the U2020 X-series and U2000 series USB power sensors, offering easy monitoring and analysis on a PC display.

The U2021XA and U2022XA each come with a free N1918A option 100 Power Analyzer PC license. The license will be recognized once the U2021XA or U2022XA is connected to a PC. A N1918A Power Analysis Manager software CD will be shipped together with the USB power sensor. Users can also download the software from www.agilent.com/find/N1918A.

The following tables show the available N1918A functions:

N1918A Power Analysis Manager functions	
Measurement displays	Compact mode display
	Soft panel (digital) display (enhanced with limits and alerts notifications)
	Gauge (analog) display (enhanced with limits and alerts notifications)
	Strip chart display
	Trace graph display
	Multiple tabs
	Multiple display per tab
	Multilist
Graph functions	Single marker (up to 10 markers per graph)
	Dual marker (up to 5 sets of markers per graph)
	Graph autoscaling
	Graph zooming
	Measurement math; delta, ratio
Save/Load file functions	Save measurement data with timestamp (applicable in Strip Chart and Trace Graph)
	Load measurement data (applicable in Strip Chart and Trace Graph)
	Data recording[1] with timestamp (applicable in Trace Graph[1], Soft Panel, Strip Chart and Gauge)
Instrument settings options	Save and restore instrument setting
	Time-gated measurements
	Instrument preset settings
	FDO table parameters
Measurement limit and alert functions	Limit and alert notification
	Alert summary
Support function	Print application screen

1. Recording time for trace graphs may vary based on trace graph setings.

Other software attributes	
Display units:	Absolute: Watts or dBm
	Relative: Percent or dB
Display resolution:	Resolution of 1.0, 0.1, 0.01 and 0.001 dB in log mode; one to four digits in linear mode
Default resolution:	0.01 dB in log mode; three digits in linear mode
Zero:	For performing internal and external zeroing
Range:	Sensor-dependent, configurable in 1-kHz steps
Relative:	Displays all successive measurements relative to the last referenced value
Offset:	Allows power measurements to be offset by –100 dB to +100 dB, configurable in 0.001 dB increments, to compensate for external loss or gain
Limits:	High and low limits can be set in the range between –150.00 dBm to +230.000 dBm, in 0.001 dBm increments
Preset default values:	Channel Offset (dB) = 0, Duty Cycle Off, Frequency 50 MHz, AUTO Average, AUTO Range, Free Run Mode, dBm mode

System requirements

Hardware	
Processor	Desktop PC: 1.3 GHz Pentium® IV or higher recommended
	Laptop PC: 900 MHz Pentium M or higher recommended
RAM	512 MB (1.0 GB or higher recommended)
Hard disk space	1.0 GB or more free disk space at runtime
Resolution	800 x 600 or higher (1280 x 1024 recommended)
Operating system and browser	
Operating system	Windows® 7 32-bit and 64-bit
	Windows Vista 32-bit and 64-bit
	Windows XP Professional 32-bit Service Pack 2 or higher
Browser	Microsoft Internet Explorer 5.1 (6.0 or higher recommended)
Others	Any of the following to be pre-installed • GPIB IO interface card • LAN interface card • USB/GPIB interface connector
Software	
Agilent IO Libraries Suite	Version 15.5 [1] or higher
Microsoft .NET Framework	Runtime version 3.5
Microsoft Visual C++ 2005 Runtime Libraries [2]	Version 1.0 or higher

1. Available on the Agilent Automation-Ready CD-ROM. Agilent IO Libraries Suite 15.5 is required if your PC is running on Windows Vista 32-bit operating system.
2. Bundled with N1918A Power Analysis Manager CD

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 underlined.]

Process:

1. Power level: . . . . [W]
2. Frequency: . . . . [ ]
3. Calculate sensor uncertainty:

   Calculate noise contribution

   - If in Free Run mode, Noise = **Measurement noise x free run multiplier**
   - If in Trigger 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

   (Sensor, frequency, power and temperature 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, $|\rho_{Sensor}|$ = (SWR–1)/(SWR+1) = ... [ ]

   Max DUT SWR (frequency dependent) = ... [ ]

   convert to reflection coefficient, $|\rho_{DUT}|$ = (SWR–1)/(SWR+1) = ... [ ]
8. Combined measurement uncertainty @ k=1

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

   Expanded uncertainty, k = 2, = $U_c \cdot 2$ = ... [%]

1. The noise to power ratio is capped for powers > 100 µW, in these cases use: Noise/100 µW.

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 <u>underlined</u>.]

Process:

1. Power level:	*1 mW*
2. Frequency:	*1 GHz*

3. Calculate sensor uncertainty:
In Free Run, auto zero mode average = 16

Calculate noise contribution

- If in Free Run mode, <u>Noise</u> = **Measurement noise x free run multiplier = 100 nW x 0.6 = 60 nW**
- If in Trigger mode, <u>Noise</u> = **Noise-per-sample x noise per sample multiplier**

Convert noise contribution to a relative term[1] = <u>Noise</u>/<u>Power</u> = 60 nW/100 µW	*0.06%*
Convert zero drift to relative term = Drift/Power = ***100 nW/1 mW***	*0.01%*
RSS of above terms = ...	*0.061%*

4. Zero uncertainty

(Mode and frequency-dependent) = Zero set/<u>Power</u> = ***200 nW/1 mW***	*0.02%*

5. Sensor calibration uncertainty

(Sensor, frequency, power and temperature-dependent) = ...	*4.0%*
6. <u>System contribution</u>, coverage factor of 2 ≥ sys_{rss} = ...	*4.0%*

(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

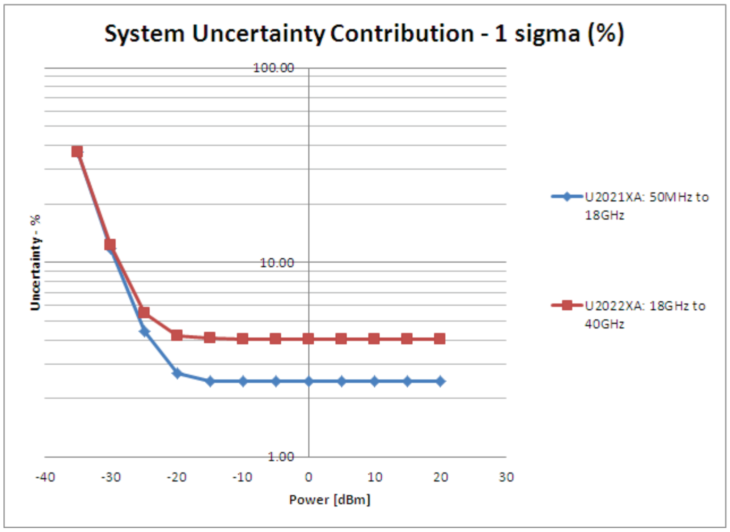
$$U_c = \sqrt{\left(\frac{Max(\rho_{DUT}) \cdot Max(\rho_{Sensor})}{\sqrt{2}}\right)^2 + \left(\frac{sys_{rss}}{2}\right)^2} \quad \ldots \quad 2.13\%$$

Expanded uncertainty, k = 2, = $U_c \cdot 2$ = ...	*4.27%*

1. The noise to power ratio is capped for powers > 100 µW, in these cases use: Noise/100 µW.

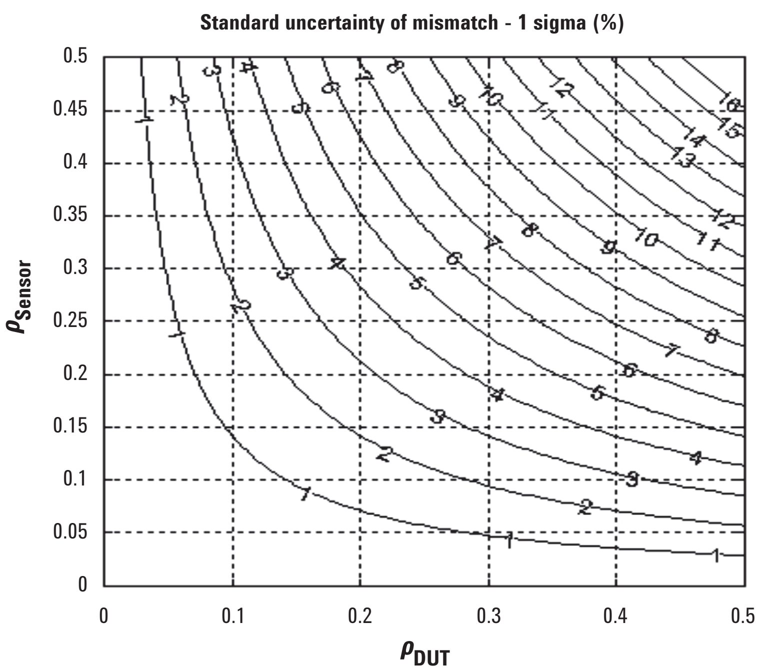
Graphical Example

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	ρ	SWR	ρ
1.0	0.00	1.8	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	0.46
1.5	0.20	2.80	0.47
1.6	0.23	2.90	0.49
1.7	0.26	3.00	0.50

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

C. Combine A & B

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

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

Ordering Information

Model	Description
U2021XA	X-Series USB peak and average power sensor, 50 MHz to 18 GHz
U2022XA	X-Series USB peak and average power sensor, 50 MHz to 40 GHz

Standard Shipped Items

- Power sensor cable 5 ft (1.5 m), default cable length
- BNC male to SMB female trigger cable, 50 ohm, 1.5 m (ships with 2 quantities)
- Certificate of calibration
- CD documentation
- N1918A Power Analysis Manager software CD
- Agilent IO Libraries Suite Software CD

Options	Description
Travel kits	
U2000A-201	Transit case
U2000A-202	Soft carrying case
U2000A-203	Holster
U2000A-204	Soft carrying pouch
Cables (selectable during sensor purchase)	
U2000A-301	Power sensor cable, 5 ft (1.5 m)
U2000A-302	Power sensor cable, 10 ft (3 m)
U2000A-303	Power sensor cable, 16.4 ft (5 m)
Cables (ordered standalone)	
U2031A	Power sensor cable, 5 ft (1.5 m)
U2031B	Power sensor cable, 10 ft (3 m)
U2031C	Power sensor cable, 16.4 ft (5 m)
U2032A	BNC male to SMB female trigger cable, 50 ohm, 1.5 m
Calibration	
U202xXA-1A7	ISO17025 compliant calibration and test data
U202xXA-A6J	ANZIZ540 compliant calibration and test data

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