Keysight U2040 X-Series Wide Dynamic Range Power Sensors

Wide dynamic range power sensors for any modulated signals

KEYSIGHT TECHNOLOGIES

User's Guide

Notices

Copyright Notice

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A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Environmental Conditions

The U2040 X-Series is designed for indoor use and in an area with low condensation. The table below shows the general environmental requirements for this instrument.

Environmental condition	Requirement
Temperature	Operating condition – 0 °C to 55 °C [For U2049XA Option TVA, this operating condition is applicable for both standard atmospheric environment and thermal vacuum environment.] Storage condition – –40 °C to 70 °C – –40 °C to 100 °C (for U2049XA Option TVA)
Humidity	Operating condition – Up to 95% RH at 40°C (non-condensing) Storage condition – Up to 90% RH at 65°C (non-condensing)
Altitude	Operating condition – Up to 3000 m (9840 ft) Storage condition – Up to 15420 m (50000 ft)

Regulatory Information

The U2040 X-Series complies with the following Electromagnetic Compatibility (EMC) compliances:

- IEC 61326-1/EN 61326-1
- Canada: ICES/NMB-001
- Australia/New Zealand: AS/NZS CISPR11

Regulatory Markings

	The RCM mark is a registered trademark of the Spectrum Management Agency of Australia. This signifies compliance with the Australian EMC Framework Regulations under the terms of the Radio Communications Act of 1992.		The CE mark is a registered trademark of the European Community. This CE mark shows that the product complies with all the relevant European Legal Directives. ICES/NMB-001 indicates that this ISM product complies with the Canadian ICES-001. Cet appareil ISM est confomre a la norme NMB-001 du Canada. ISM GRP.1 Class A indicates that this is an Industrial Scientific and Medical Group 1 Class A product.
	This symbol indicates the time period during which no hazardous or toxic substance elements are expected to leak or deteriorate during normal use. Forty years is the expected useful life of the product.		This product complies with the WEEE Directive (2002/96/EC) marking requirement. This affixed product label indicates that you must not discard this electrical/electronic product in domestic household waste.
 **MSIP-REM-Kst-XXXXXXXXX**	This symbol is a South Korean Class A EMC Declaration. This is a Class A instrument suitable for professional use and in electromagnetic environment outside of the home.		

Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC

This instrument complies with the WEEE Directive (2002/96/EC) marking requirement. This affixed product label indicates that you must not discard this electrical or electronic product in domestic household waste.

Product category

With reference to the equipment types in the WEEE directive Annex 1, this instrument is classified as a “Monitoring and Control Instrument” product.

The affixed product label is as shown below.

Do not dispose in domestic household waste.

To return this unwanted instrument, contact your nearest Keysight Service Center, or visit http://about.keysight.com/en/companyinfo/environment/takeback.shtml for more information.

Sales and Technical Support

To contact Keysight for sales and technical support, refer to the support links on the following Keysight websites:

- www.keysight.com/find/widedynamicsensor
  (product-specific information and support, software and documentation updates)
- www.keysight.com/find/assist
  (worldwide contact information for repair and service)

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Keysight U2040 X-Series
Wide Dynamic Range Power Sensors

User's Guide

1 Getting Started

This chapter gets you started with the U2040 X-Series wide dynamic range power sensors.

KEYSIGHT TECHNOLOGIES

Overview

The U2040 X-Series wide dynamic range power sensors consist of four USB models and a LAN model:

- 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 LAN power sensor (10 MHz to 33 GHz, LXI Class C compliant)

The U2040 X-Series is capable of measuring the average and peak power of modulated, pulsed, and continuous wave (CW) signals in 10 MHz to 33 GHz frequency range and –70 dBm to 26 dBm power range.

The U2049XA is capable of long distance remote monitoring of up to 100 meters via the Power over Ethernet (PoE)/LAN connectivity. The PoE connectivity is compliant to the IEEE 3 W, 802.3af or 802.3at Type 1 standard.

NOTE The typical LAN port on your PC or Keysight instruments is not able to power up the U2049XA. The U2049XA must be connected to a PoE port, which supplies the DC power required to power up the U2049XA and to transfer data.

The U2049XA is provided with two options; Option 100 and Option TVA. Option TVA is a thermal vacuum option for use within a thermal vacuum (TVAC) chamber.

CAUTION Ensure that the U2049XA Option 100 is covered with the LAN sensor casing provided to meet performance specifications during operation. It is strongly recommended not to remove the sensor casing.

CAUTION As the U2049XA Option TVA is fully enclosed in metal, it is strongly recommended to mount it on a cooling plate (with the thermal interface material provided) during operation to avoid overheating. Refer to "**Mount the U2049XA Option TVA**" on page 39 for more information.

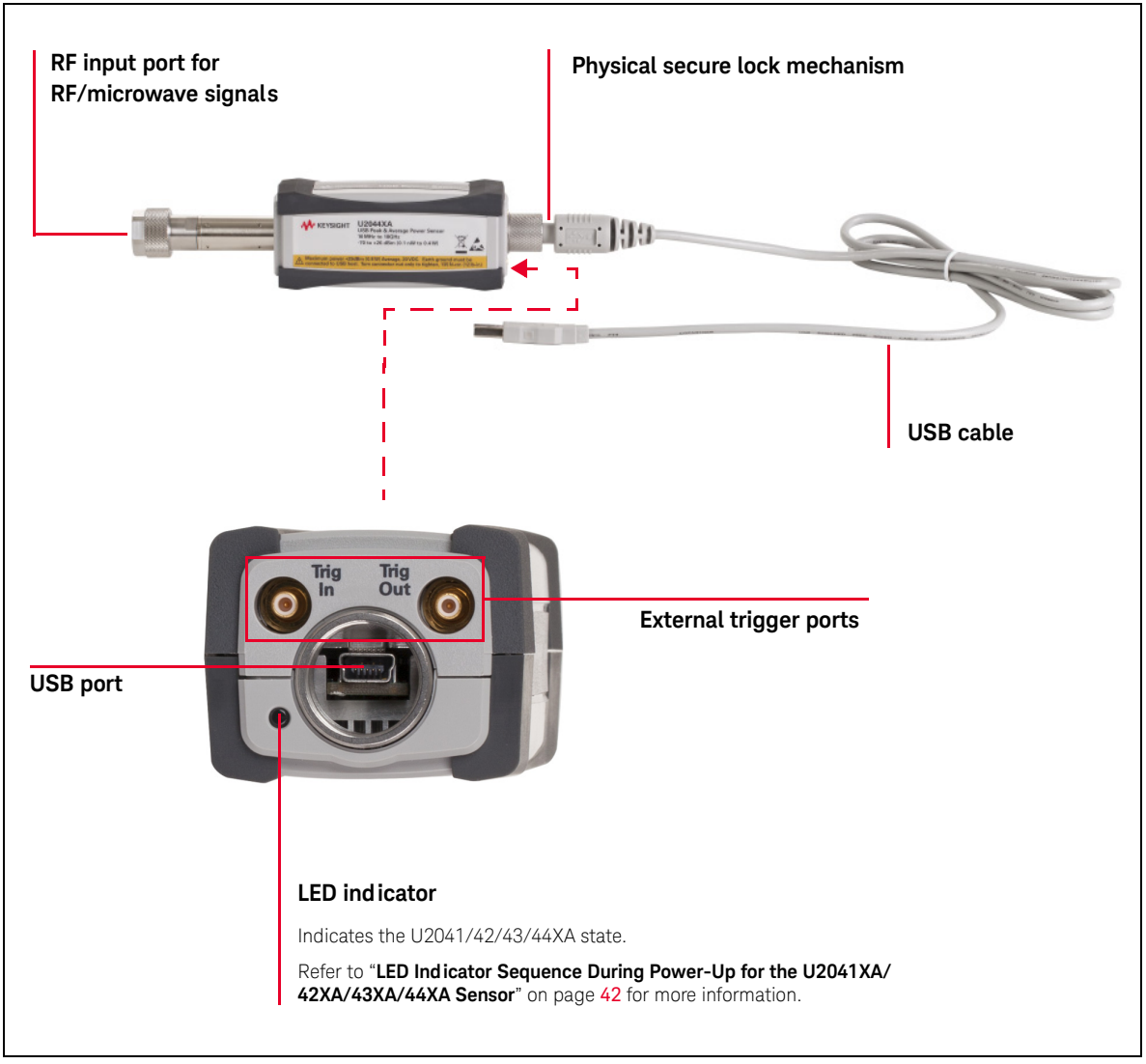
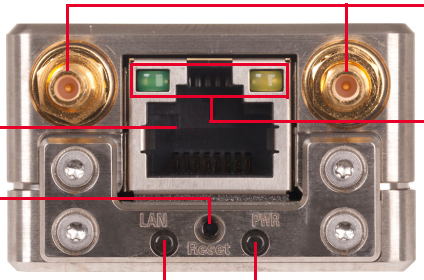


Figure 1-1 U2041/42/43/44XA sensor

RF input port for RF/microwave signals

LAN cable

External trigger ports



LAN port

LAN reset switch

Push the switch button (a straightened paper clip will do the job) to reset the U2049XA LAN configuration to a known default state.

Link state LED indicators

Indicate the U2049XA link states:

- Green solid ( ): Link speed indicator.
  Lights up when the operating speed is 100 Mbps. No indication when the operating speed is 10 Mbps or during line isolation.
- Amber blinking ( ): Link activity indicator.
  Blinks when a valid link activity is detected.

LED indicators

Indicate the U2049XA state.

Refer to "**LED Indicator Sequences for the U2049XA Sensor**" on page 43 for more information.

Figure 1-2 U2049XA sensor

Theory of Operation

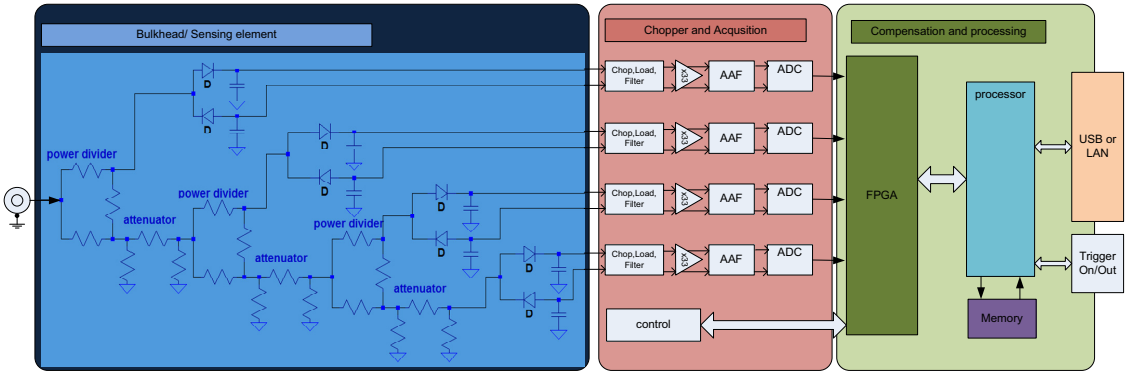


Figure 1-3 U2040 X-Series sensor block diagram

The U2040 X-Series sensors utilize 4-planer doped-barrier diode-powered sensors in a 4-path microwave circuit that enables fast average power measurements over a wide dynamic range. The 4-path network splits the input signal into 4 different power ranges for each of the 4 diodes allowing the 4 diodes to operate in their square-law region. Ensuring that the diode power sensors operate within the square-law region means the diode power sensors convert RF power to voltage in a linear manner, regardless of the signal being measured. A single diode sensor square-law behavior may provide an estimated 40 dB of fast dynamic range. Following each of the diodes with their own signal conditioning and analog-to-digital converter allow the digital processing that follows to seamlessly select the best diode for the signal being measured. This in turn presents a user experience that matches a single high dynamic range square-law power sensor.

The U2040 X-Series is a universal power sensor that allows you to measure different kinds of power measurements. Primarily operating as an average power sensor and traditionally this type of measurement means that an instrument will output a numeric result at some rate determined by the instrument. In Average mode the sensor enables a chopper amplifier circuit that allows low level signals to be measured in the presence of low frequency noise. This chopper circuit operates by modulating the signal prior to amplification; the modulation takes the form of passing or negating the signal for half-periods of the chopper signal. Recovering the original signal within the digital processing is achieved by averaging the “passing” half-period samples together with the negated “negating” half-period samples, to provide a new answer once for each period of the chopper. The corresponding "dechopping" is carried out in the digital section to allow proper correction and measurement of the input signal. The chopper stabilization circuit essentially removes the offset and low frequency noise contribution of the signal condition stages from affecting the input signal. In the U2040 X-Series, the chopper concept is extended to allow the user to set an “aperture” to calculate this averaging. This aperture is selectable from 20 μs to 200 ms with 100 ns resolution and provides a powerful mechanism for precisely tuning the instrument to the signal being measured. In addition to allow the

aperture to match a particular epoch of the RF signal, for example setting the aperture equal to a multiple of modulation frequencies in an AM signal, there is the ability to precisely trigger the occurrence of each measurement. This allows synchronization between the device under test and the measurement system.

Sometimes it is necessary to examine the time varying characteristics of the power envelope. This allows measurements of pulse duration time or pulse period for example. The U2040 X-Series can change when Normal mode is selected to provide 20 MHz sampling of the power envelope. Similar to the Average mode, the best diode from the 4 ranges is selected transparently within the digital processing. In contrast to Average mode, no chopper switching is performed and the signal path is a direct coupled differential amplifier. The analog signal conditioning allows the load resistor and the low pass filter characteristics to be adjusted. Changing the load resistor also changes the responsiveness (V/W) of the diode detector and the video bandwidth. Changing the load capacitance will affect the bandwidth but not the responsiveness. Used together, these controls reduce the noise of the measurements for low level signals at the expense of video bandwidth.

A high speed trigger input and trigger output are also present in each U2040 X-Series sensor to allow proper synchronization between test instruments. Besides that, the Average and Normal mode do support internal level trigger mode on top of external trigger mode. This allows flexibility in triggering for different input signals over a wide dynamic range.

A high speed acquisition and processing engine is also present in the U2040 X-Series sensor to enable a complex calibration scheme to track the performance of various modes across frequency, input power and temperature. The robust back end system also allows the U2040 X-Series sensor to be paired with either conventional USB or LAN based interface. On top of that, the U2040 X-Series sensor is also designed to be thermal vacuum compliant (TVAC) by controlling the outgas property of the components being used.

Initial Inspection

When you receive your U2040 X-Series sensor, inspect the shipping container for damages. If the shipping container or packaging material is damaged, it should be kept until the contents of the shipment have been checked mechanically and electrically. If there is any mechanical damage, notify the nearest Keysight Sales and Service Office. Keep the damaged shipping materials (if any) for inspection by the carrier and a Keysight representative.

Standard shipped items

Verify that you have received the following items. If anything is missing or damaged, please contact the nearest Keysight Sales Office.

U2041XA/42XA/43XA/44XA USB power sensor:

U2041XA/42XA/43XA/44XA USB power sensor

U2040 X-Series
Product Reference CD-ROM

Keysight Instrument Control
Software CD-ROM

USB cable 5 ft (1.5 m), default cable length

Trigger cable, BNC male to SMB female, 50 Ω, 1.5 m (Quantity: 2)

Certificate of calibration

Certificate of calibration

U2049XA LAN power sensor:

U2049XA LAN power sensor

U2040 X-Series
Product Reference CD-ROM

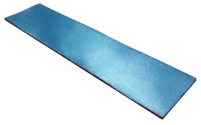
Keysight Instrument Control
Software CD-ROM

Trigger cable, BNC male to SMB
female, 50 Ω, 1.5 m (Quantity: 2)
(for Option 100)

Thermal vacuum (TVAC) trigger cable,
BNC male to SMB female, 50 Ω, 1.5 m
(Quantity: 2) (for Option TVA)

LAN sensor casing
(for Option 100)

TVAC sensor bracket (Quantity: 2)
(for Option TVA)



Thermal interface material
(for Option TVA)

Shielded LAN cable 5 ft (1.5 m),
default cable length
(for Option 100)

Thermal vacuum (TVAC) LAN cable 5 ft
(1.5 m), default cable length
(for Option TVA)

Certificate of calibration

Certificate of calibration

Hardware Installation and Configuration

NOTE For power measurements of < –60 dBm, it is recommended to turn on the U2040 X-Series for 1.5 hours (with the U2040 X-Series connected to the device-under-test).

Prior to using the U2040 X-Series, ensure that the following minimum requirements are met:

- PC with USB and LAN host capability
- Keysight IO Libraries Suite 17.0 or higher installed
- Keysight BenchVue installed

Connect the U2041XA/42XA/43XA/44XA sensor

1 Connect the power sensor to the PC. The sensor driver is detected and installed automatically.

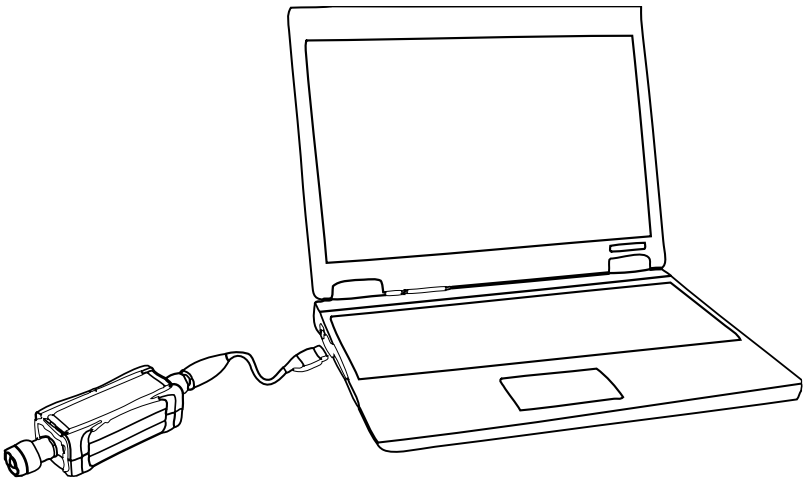


Figure 1-4 Connect the U2041XA/42XA/43XA/44XA sensor to the PC

2 Launch the Keysight Connection Expert by selecting the IO icon ( ). Auto-locate the sensor as shown in **Figure 1-5**. Click **Rescan** to start searching.

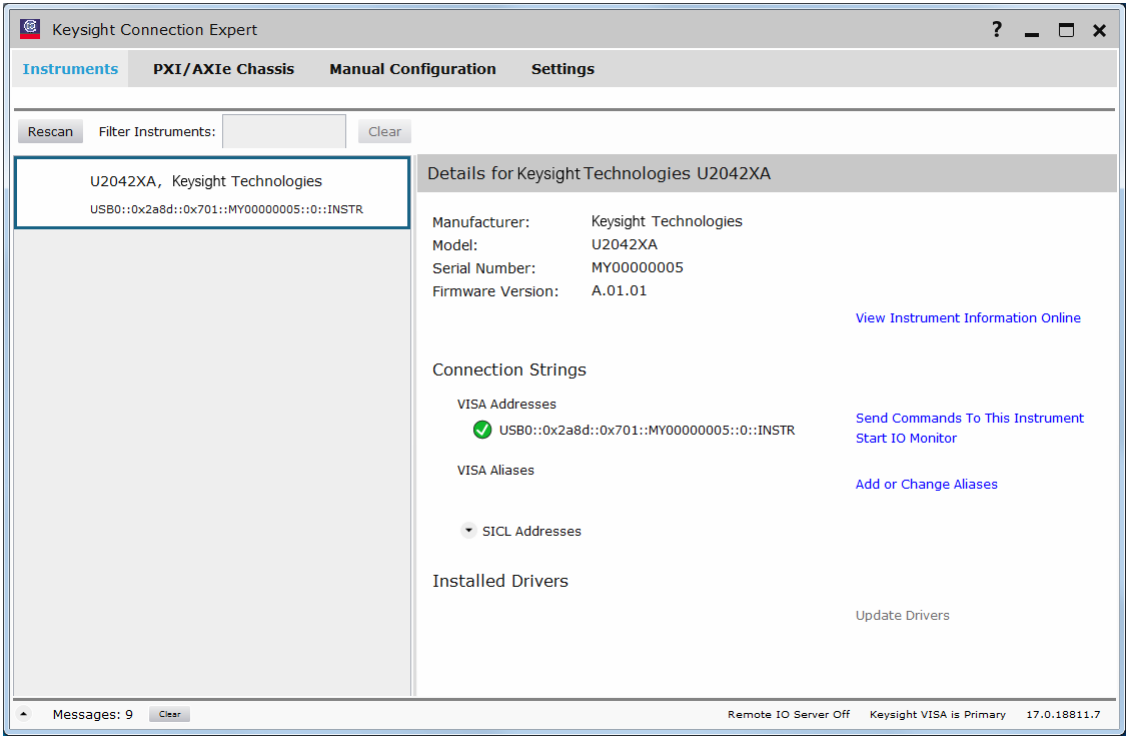


Figure 1-5 Auto-locate a USB instrument in Keysight Connection Expert

3 Click **Send Commands To This Instrument** > **Send & Read** to verify the sensor is connected.

4 When the sensor is connected, go to **Chapter 2**, "Using the U2040 X-Series with the Keysight BenchVue" to launch the BenchVue Power Meter application, or proceed to operate the sensor via remote programming.

Operating the sensor remotely using SCPI commands

You can send SCPI commands to operate the sensor. Refer to the *U2040 X-Series Programming Guide* for details.

Connect the U2049XA sensor

Connect the U2049XA via any of the following LAN operating modes:

- Dynamic IP (Dynamic Host Configuration Protocol or DHCP)
- Auto IP (Local PC control or isolated (non-site) LAN)
- Static IP (Manual mode)

The default LAN operating mode of the U2049XA is Dynamic IP.

Dynamic IP and Auto IP are enabled on the U2049XA shipped from Keysight. This allows the U2049XA to automatically obtain an address on the network.

The U2049XA communicates with the DHCP server to obtain the LAN interface configuration. If the DHCP server is not detected, then either the DHCP server is not present or it does not allow the U2049XA to obtain an IP address. The U2049XA will then try to obtain the LAN configuration using AutoIP if enabled, otherwise the U2049XA will try to use the static IP set in the U2049XA. If required, push the LAN reset switch to reset the U2049XA LAN configuration to a known default state.

NOTE

The LED indicator will turn red indicating the following error when the DHCP server is not detected:
-310, "System error;The sensor could not obtain a LAN configuration using DHCP. The sensor will try to obtain IP address using AutoIP if enabled".

For more information on LAN instrument connectivity, refer to the *Keysight IO Libraries Suite Connectivity Guide*.

Dynamic IP mode

In this mode, the IP address, subnet mask, and default gateway values are obtained from a DHCP server.

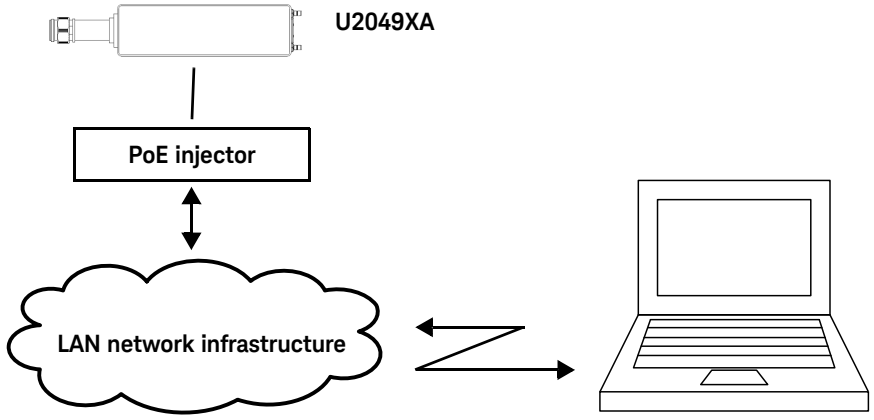


Figure 1-6 Connect the U2049XA via Dynamic IP

1 Set up the connection as shown in **Figure 1-6**.

2 On your PC, set the LAN settings to the automatic configuration. Go to **Start** > **Control Panel** > **Network and Internet** > **Network and Sharing Center** > **Local Area Connection** > **Properties** and set the following properties.

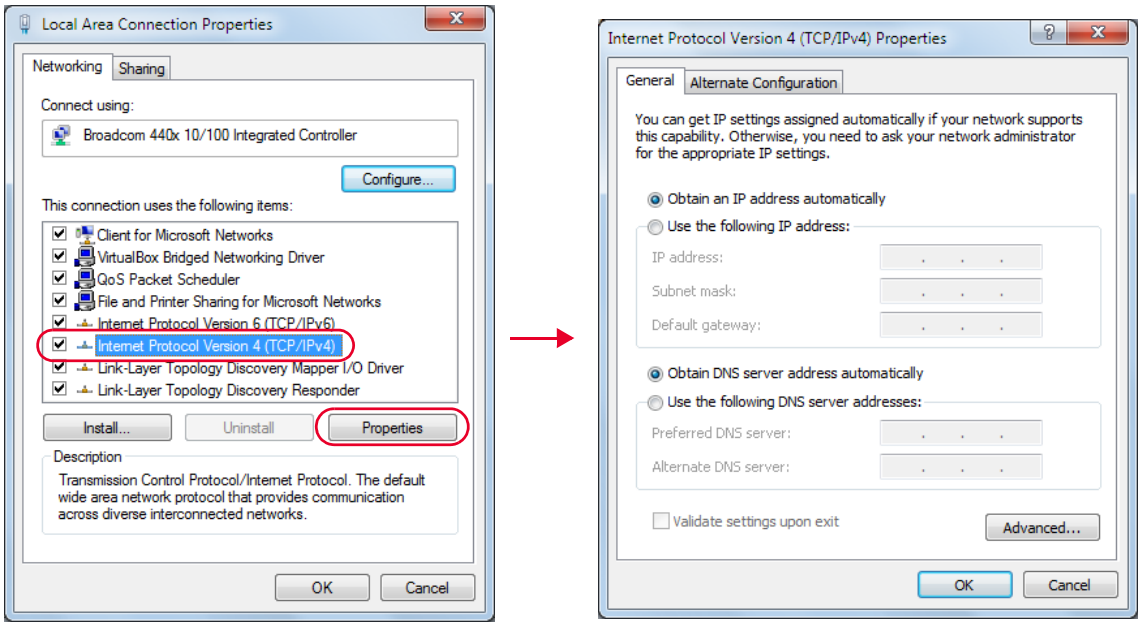


Figure 1-7 Set automatic LAN settings on the PC

3 Launch the Keysight Connection Expert by selecting the IO icon ( ). Set the instrument host name (**Figure 1-8**). Every U2049XA has a default host name in the form of:

K-U2049XA-XXXXX

where "**XXXXX**" is the last five digits of the instrument serial number.

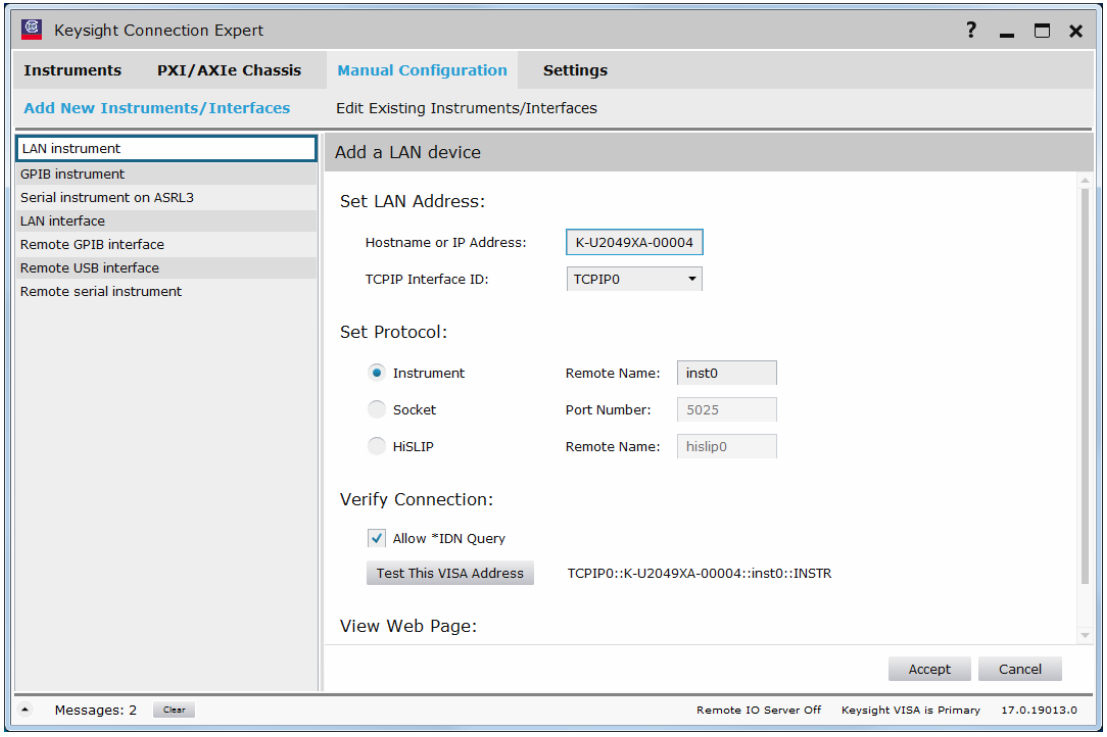


Figure 1-8 Add a LAN instrument in Keysight Connection Expert via host name

4 Select **Allow *IDN Query** and click **Test This VISA Address** to verify the U2049XA is connected. Once verified, click **Accept**.

5 Alternatively, you can auto-locate the U2049XA as shown in **Figure 1-9**. Click **Rescan** to start searching.

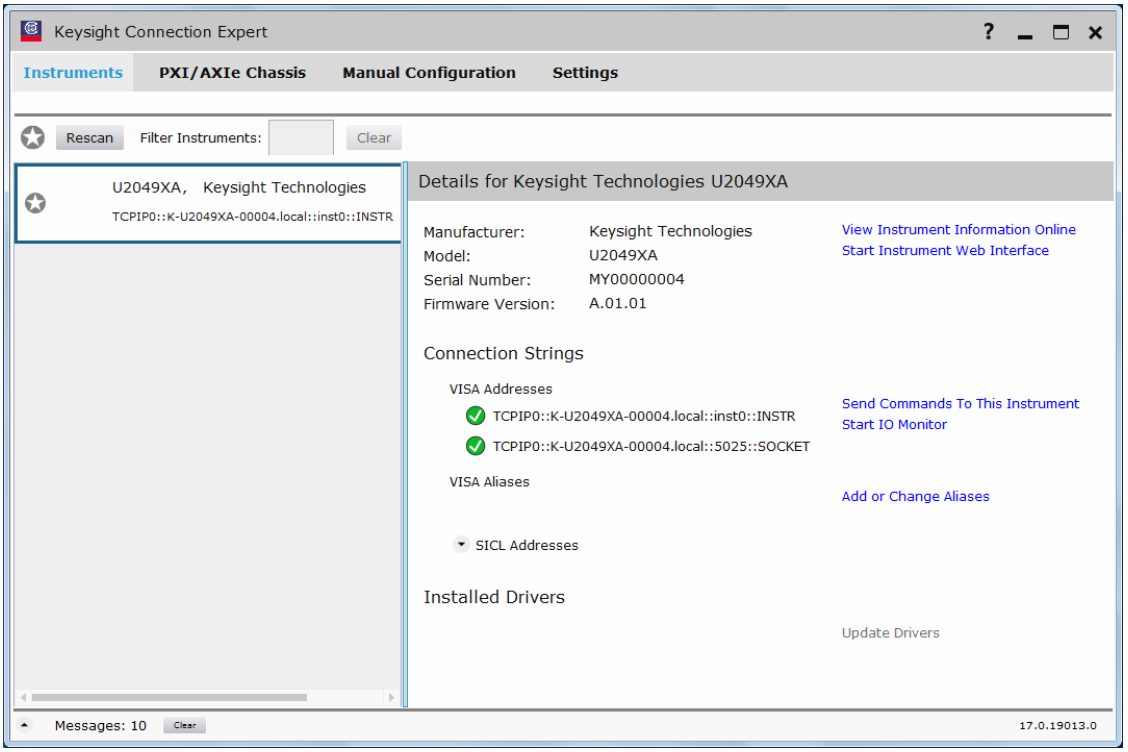


Figure 1-9 Auto-locate a LAN instrument in Keysight Connection Expert via Dynamic IP

6 Click **Send Commands To This Instrument** > **Send & Read** to verify the U2049XA is connected.

7 When the U2049XA is connected, go to **Chapter 2**, "Using the U2040 X-Series with the Keysight BenchVue" to launch the BenchVue, or proceed to operate the U2049XA via remote programming.

Auto IP mode

Use this procedure if you require local PC control or you are working in a private (non-site) LAN environment.

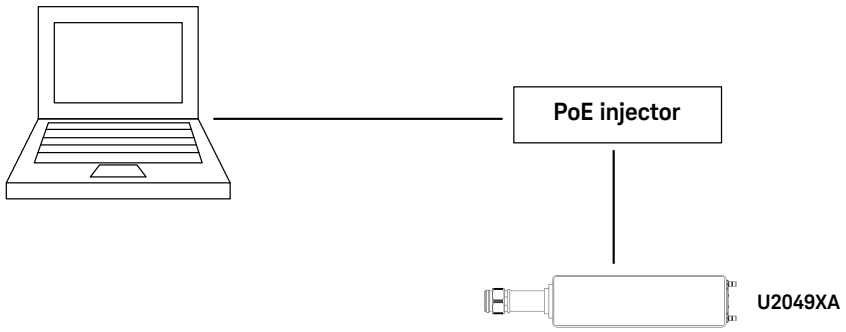
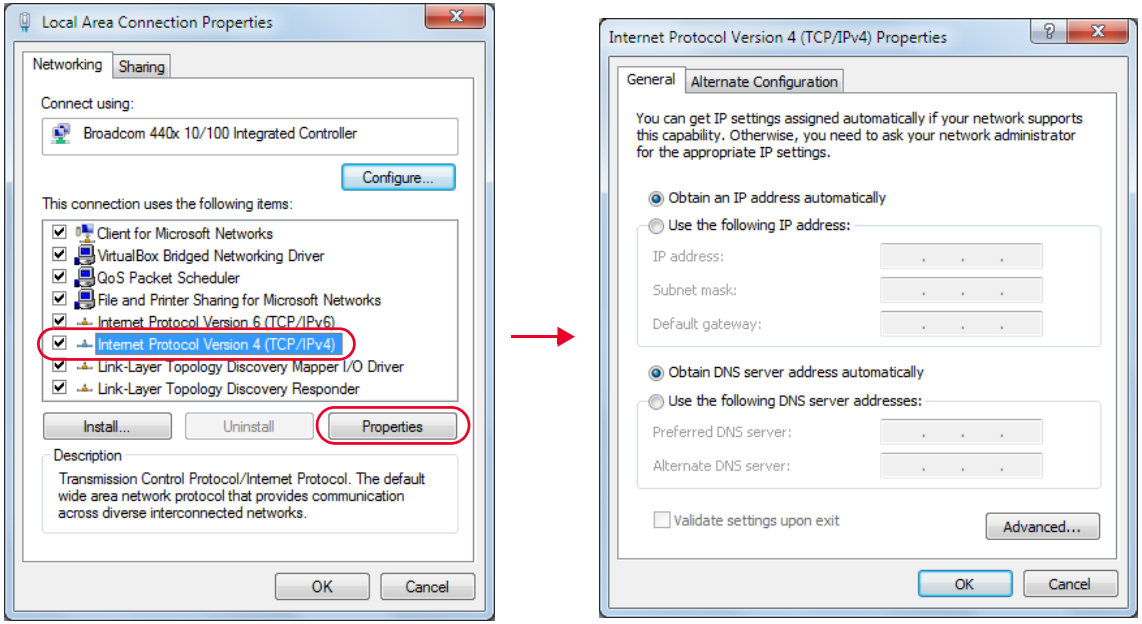


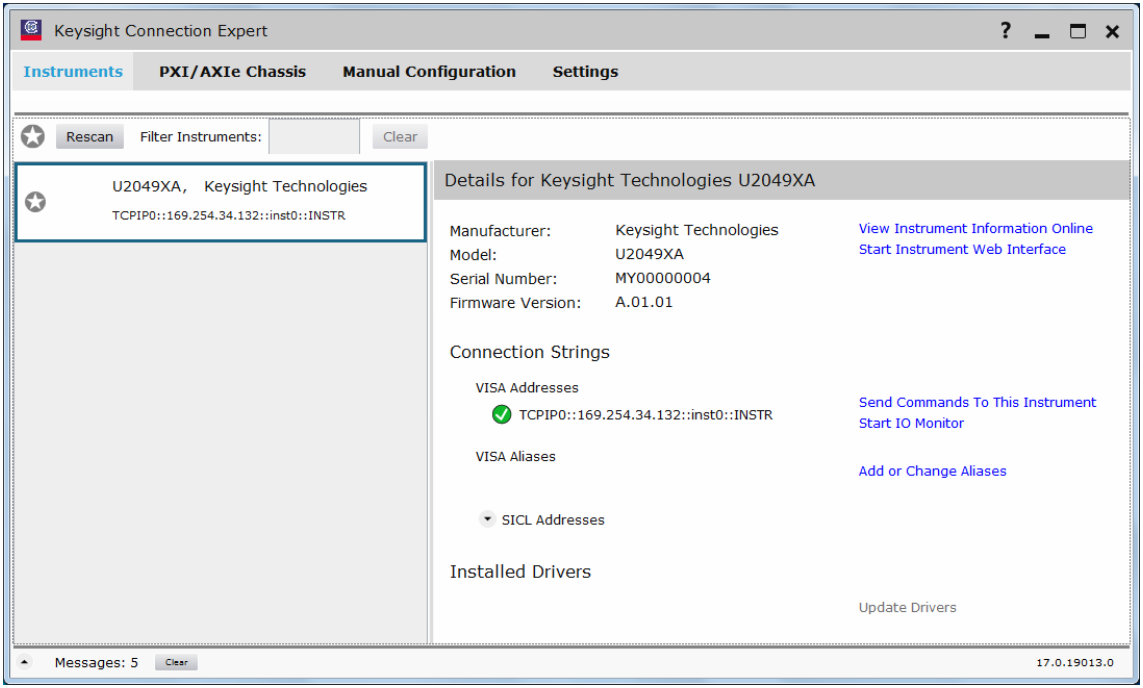
Figure 1-10 Connect the U2049XA via Auto IP

1 Set up the connection as shown above.

2 On your PC, set the LAN settings to the automatic configuration. Go to **Start** > **Control Panel** > **Network and Internet** > **Network and Sharing Center** > **Local Area Connection** > **Properties** and set the following properties.



3 Launch the Keysight Connection Expert by selecting the IO icon ( ). Auto-locate the U2049XA as shown below. Click **Rescan** to start searching.



4 Click **Send Commands To This Instrument** > **Send & Read** to verify the U2049XA is connected.

5 When the U2049XA is connected, go to **Chapter 2**, "Using the U2040 X-Series with the Keysight BenchVue" to launch the BenchVue, or proceed to operate the U2049XA via remote programming.

Static IP mode (configuring the LAN manually)

In static IP mode, you must set up the IP address, subnet mask, and default gateway that are compatible with your network infrastructure (PC configuration).

Using a static IP address is useful if you always want to communicate with the instrument using the same IP address every time it is turned on.

NOTE After configuring LAN settings, you must first power cycle the U2049XA. This enables the new network settings to become effective.

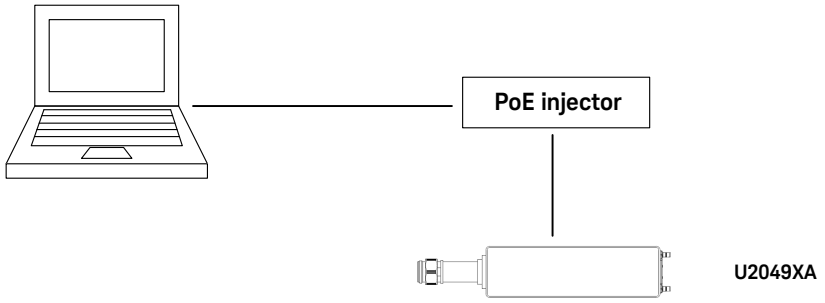
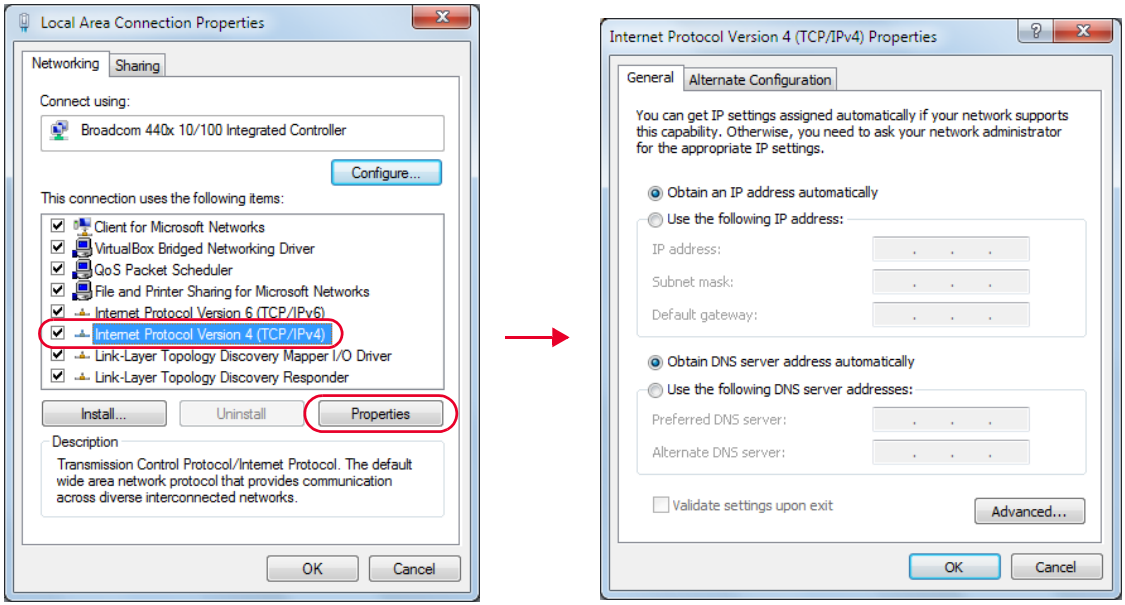


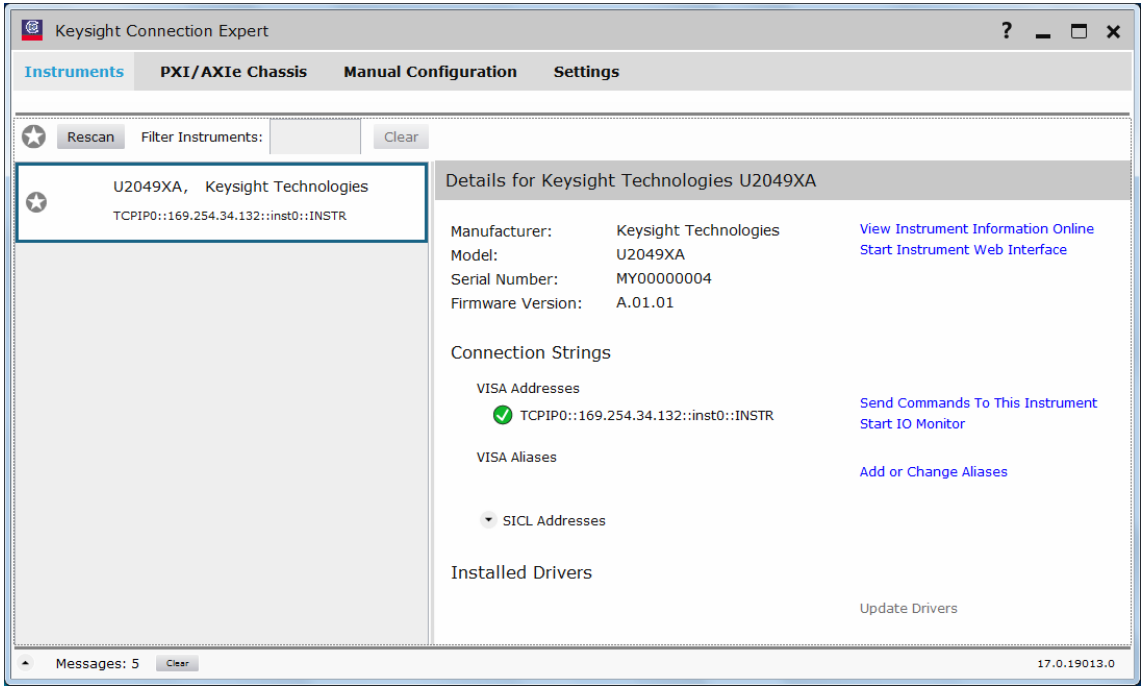
Figure 1-11 Connect the U2049XA via Static IP

1 Set up the connection as shown above.

2 On your PC, set the LAN settings to the automatic configuration. Go to **Start** > **Control Panel** > **Network and Internet** > **Network and Sharing Center** > **Local Area Connection** > **Properties** and set the following properties.



3 Launch the Keysight Connection Expert by selecting the IO icon ( ). Auto-locate the U2049XA as shown below. Click **Rescan** to start searching.



4 To enable static IP, click **Send Commands To This Instrument** and send the following SCPI commands:

- `SYSTem:COMMunicate:LAN:DHCP[:STATe] 0` *//Turns off Dynamic IP*
- `SYSTem:COMMunicate:LAN:AIP[:STATe] 0` *//Turns off Auto IP*
- `SYSTem:COMMunicate:LAN:RESTart` *//Restarts the LAN network for the above setup to take effect*

NOTE For more information on remote SCPI programming, refer to the *U2040 X-Series Programming Guide*.

Alternatively, you can set these configurations using the U2049XA web-based interface (see "**Using the Instrument Web Browser**" on page 35).

On the **Configuring your U2049XA Power Sensor** page, set the **DHCP** and **Auto IP** buttons to **OFF**. Click **Save** to save the new settings. Then click **Renew LAN Settings** for the changes to take effect.

5 Set the PC IP address and subnet mask. Go to **Start** > **Control Panel** > **Network and Internet** > **Network and Sharing Center** > **Local Area Connection** > **Properties** and set the following properties.

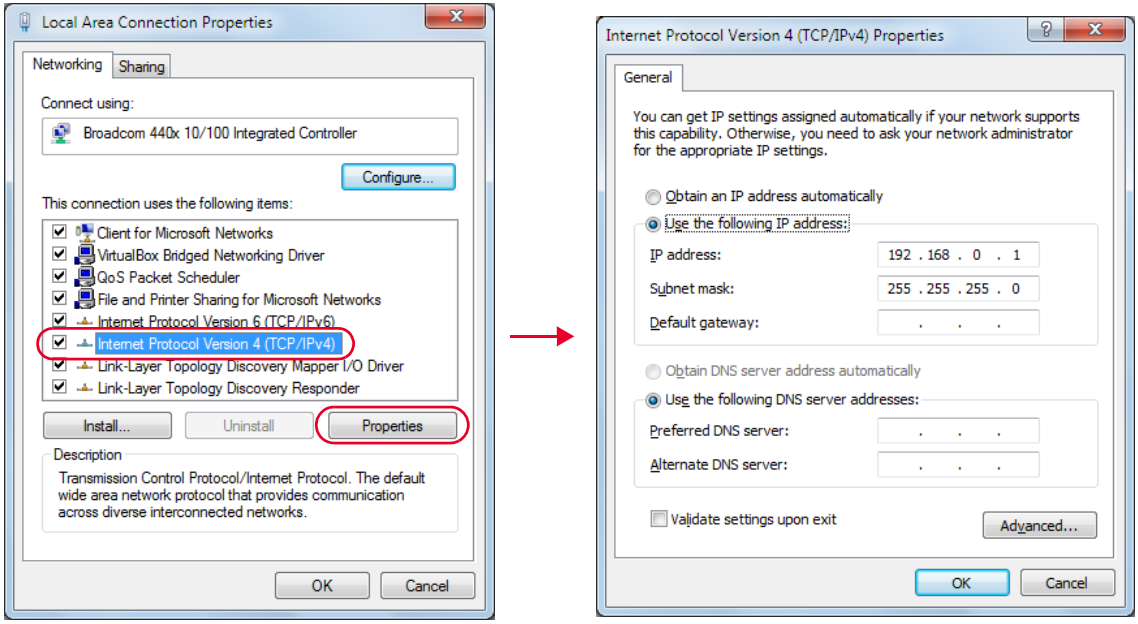


Figure 1-12 Set manual LAN settings on the PC

NOTE

- For the new network settings to become effective, you must first power cycle the U2049XA.
- The static IP addresses for the host PC and the U2049XA must be different from the IP address of the PoE injector to avoid conflict.

6 Launch the Keysight Connection Expert by selecting the IO icon ( ). Auto-locate the U2049XA as shown in **Figure 1-13**. Click **Rescan** to start searching.

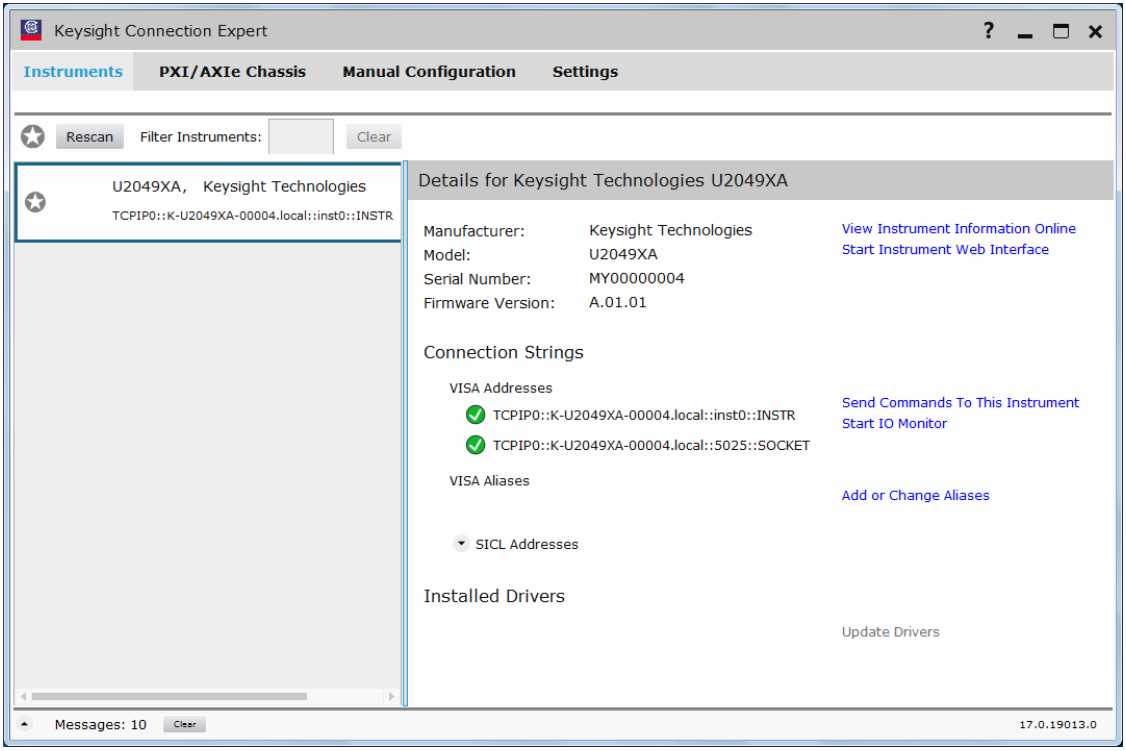


Figure 1-13 Auto-locate a LAN instrument in Keysight Connection Expert via Static IP

7 Click **Send Commands To This Instrument** > **Send & Read** to verify the U2049XA is connected.

NOTE Alternatively, you can locate the U2049XA by entering its default static IP address (*192.168.0.10*) at the **Manual Configuration** tab.

8 When the U2049XA is connected, go to **Chapter 2**, "Using the U2040 X-Series with the Keysight BenchVue" to launch the BenchVue, or proceed to operate the U2049XA via remote programming.

NOTE

To revert to the Dynamic IP mode from the static IP mode, you can either:

- send the following SCPI commands.
  - `SYSTem:COMMunicate:LAN:DHCP[:STATe] 1`
  - `SYSTem:COMMunicate:LAN:AIP[:STATe] 1`
  - `SYSTem:COMMunicate:LAN:RESTart`
- configure and renew the LAN settings via the instrument web browser.

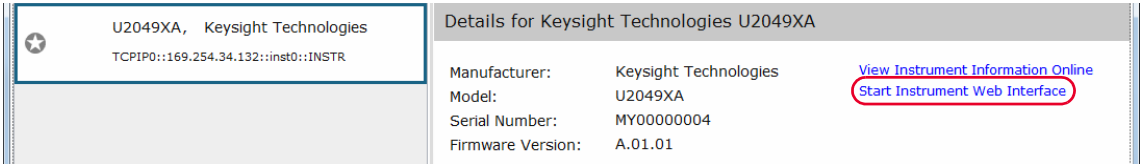
Refer to "**Dynamic IP mode**" on page 23 for the procedure. You will need to power cycle the U2049XA for the new network settings to take effect.

Using the Instrument Web Browser

The U2049XA can be programmed using its web-based interface (web browser). The web browser functions as a virtual front panel which can also be used for:

- interactive IO
- familiarization with instrument capabilities
- determining/changing instrument configuration

1 On the Keysight Connection Expert, click **Start Instrument Web Interface** to launch the U2049XA web-based interface.



NOTE The web-based interface can also be opened directly from a web browser by entering the U2049XA's IP address or hostname in the 'address' bar of the browser.

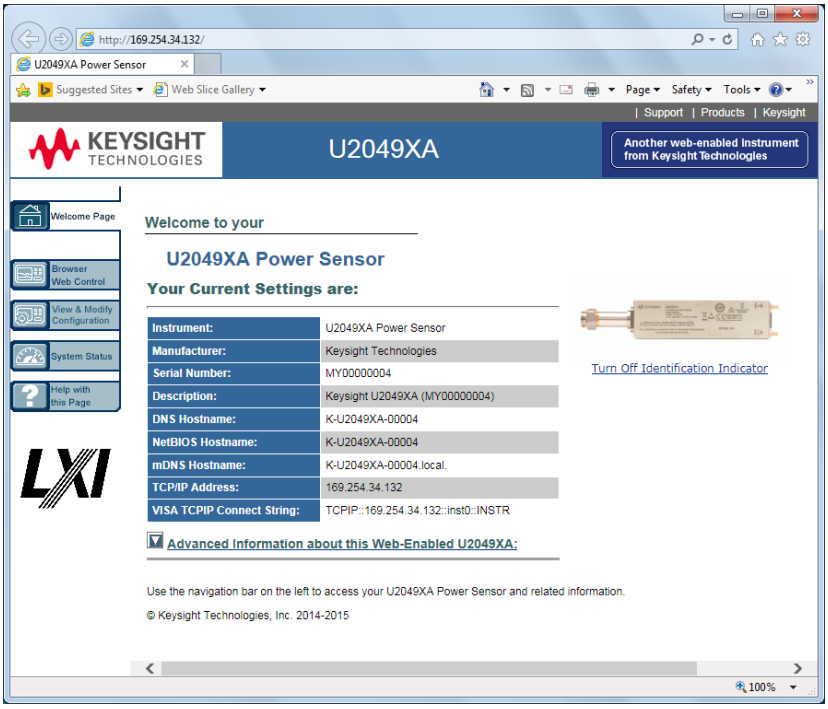
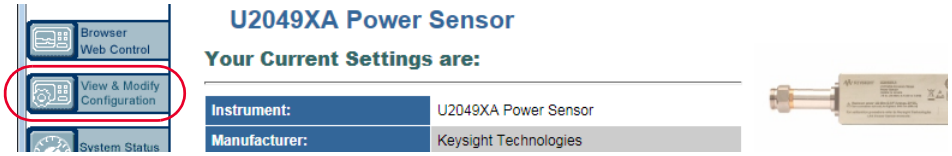


Figure 1-14 U2049XA web-based interface (Welcome page)

2 Click **View & Modify Configuration** to access the LAN configuration settings.



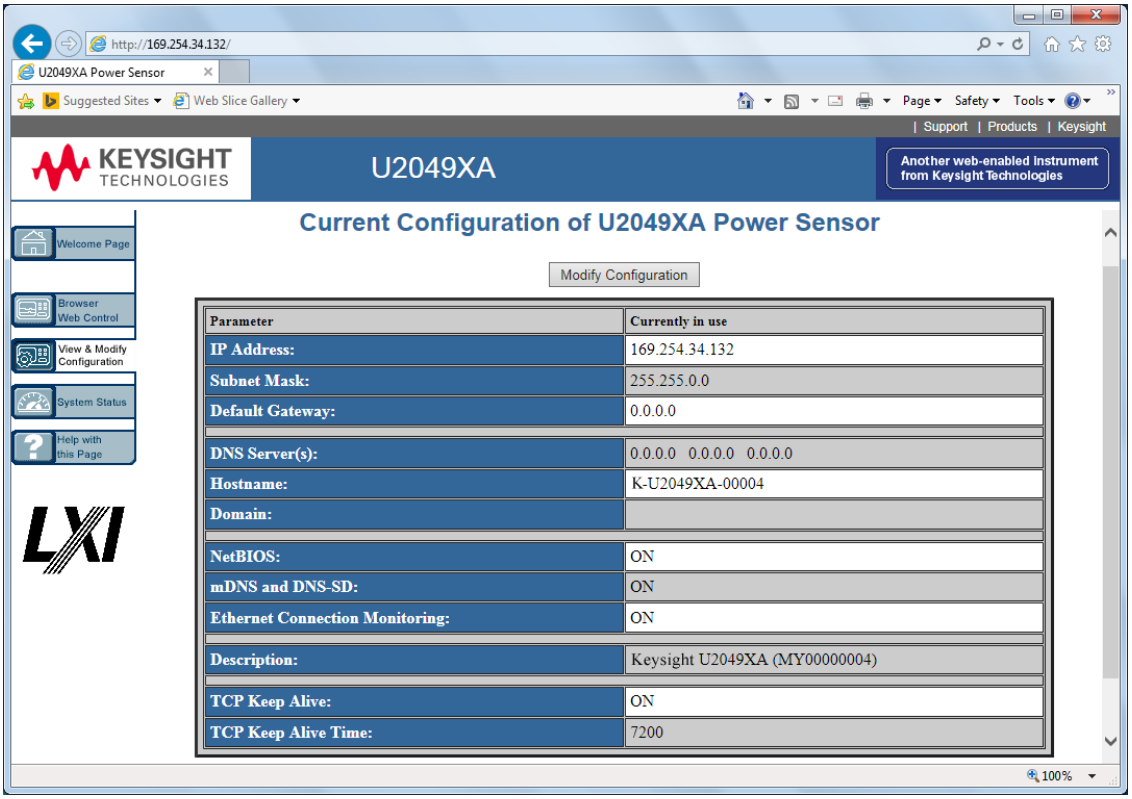
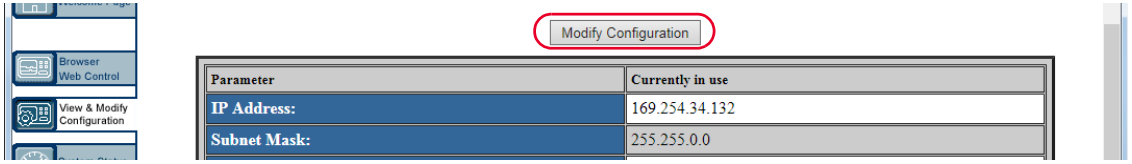


Figure 1-15 View and modify LAN configuration settings

3 Click **Modify Configuration** to edit the LAN configuration settings.



4 Enter the default password “*keysight*”.

5 On this page, you can configure and renew the LAN settings, as well as power cycle the U2049XA or reset the LAN settings.

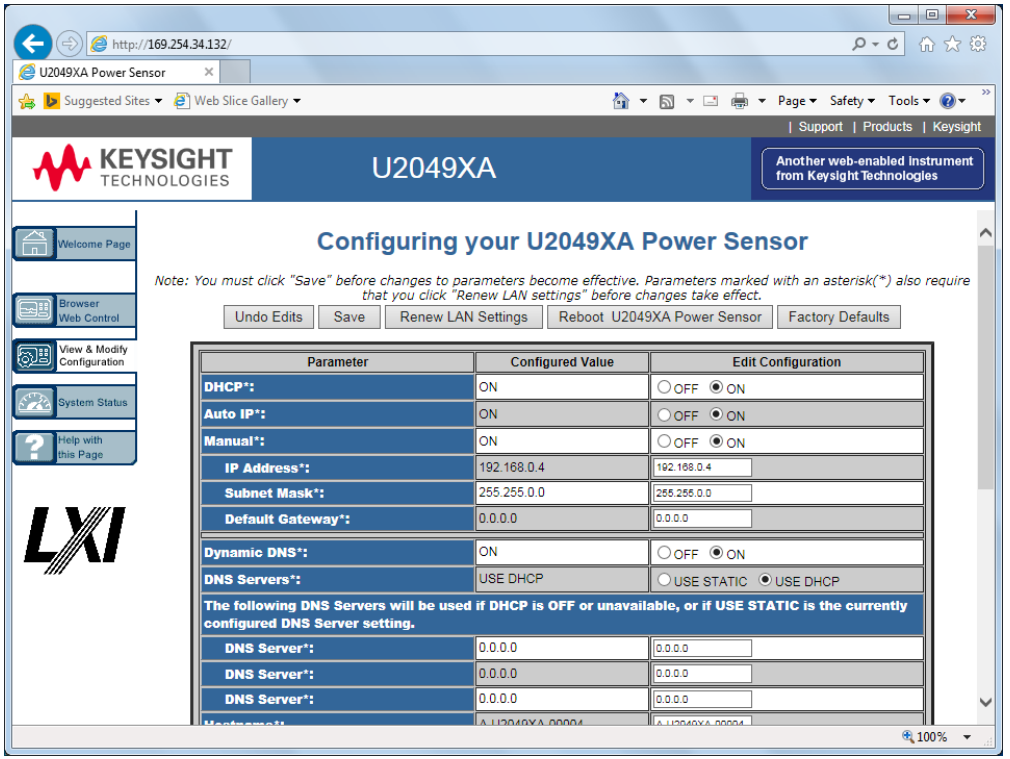


Figure 1-16 Modify and renew LAN configuration settings

NOTE If you have changed the password, resetting the LAN configuration will reset the password to default as well.

Configuring the LAN remotely using SCPI commands

You can send SCPI commands to automatically or manually configure the LAN settings for the U2049XA. Refer to the *U2040 X-Series Programming Guide* for details.

Mount the U2049XA Option TVA

The U2049XA Option TVA is strongly recommended to be mounted on a cooling plate for more effective heat dissipation when used in a TVAC chamber.

The cooling plate consists of four mounting threaded holes and the minimum thread height of each hole is 6 mm.

Mounting dimensions

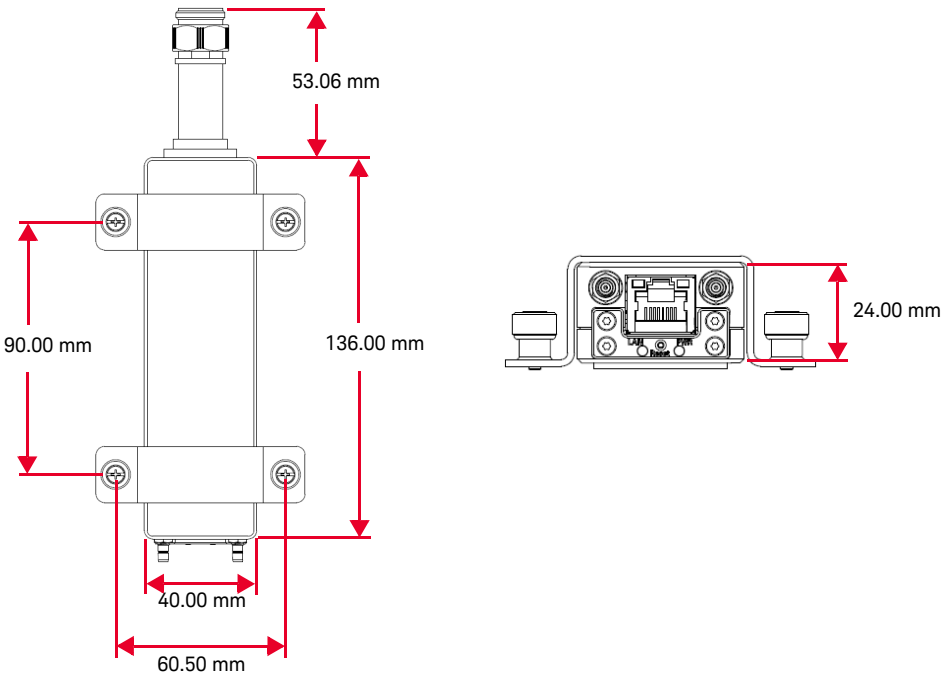
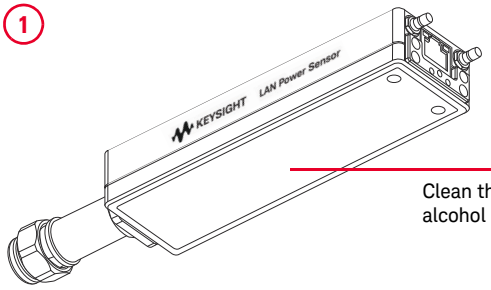


Figure 1-17 U2049XA Option TVA mounting dimensions

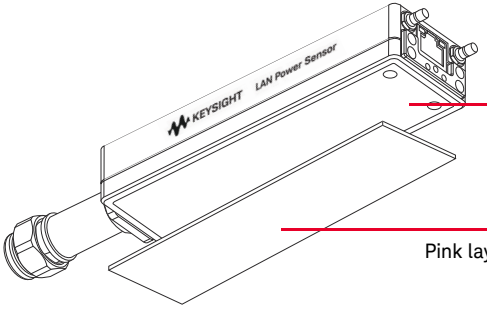
Mounting procedure

1



Clean the surface thoroughly with isopropyl alcohol and let it dry.

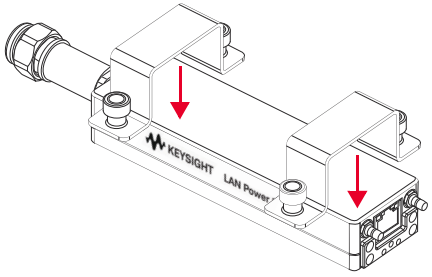
2 Install the thermal interface material on to the sensor's surface.

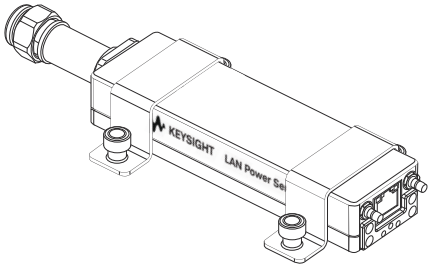


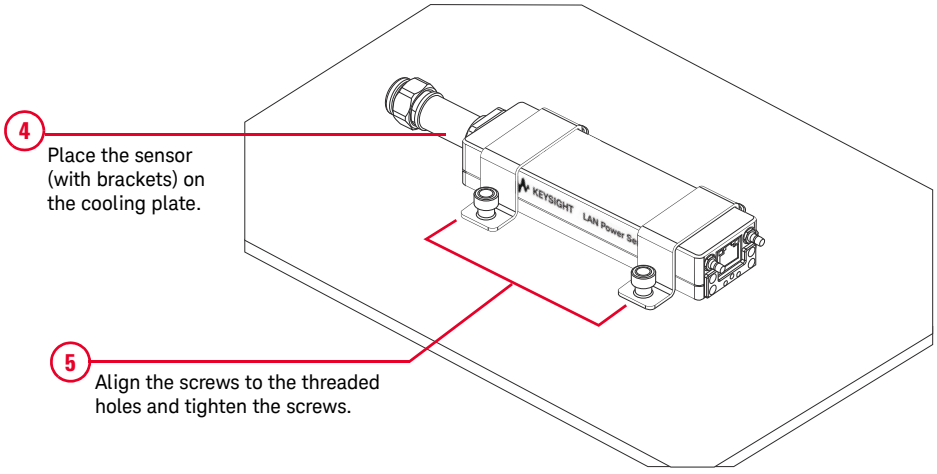
Stick the silver layer onto the surface

Pink layer facing outward

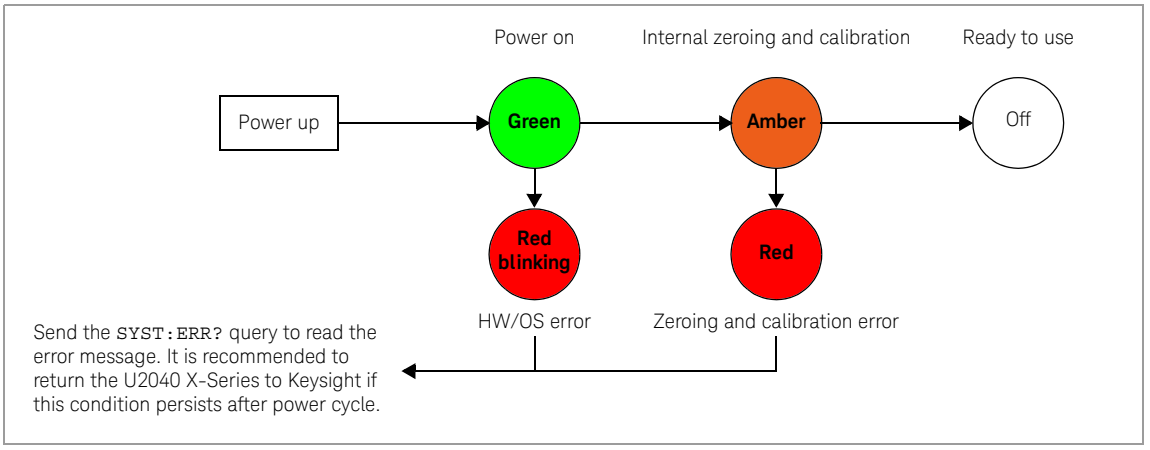
3 Briefly install the brackets.






4
Place the sensor (with brackets) on the cooling plate.
5
Align the screws to the threaded holes and tighten the screws.
KEYSIGHT

LED Indicator Sequence During Power-Up for the U2041XA/42XA/43XA/44XA Sensor



Other LED indicators

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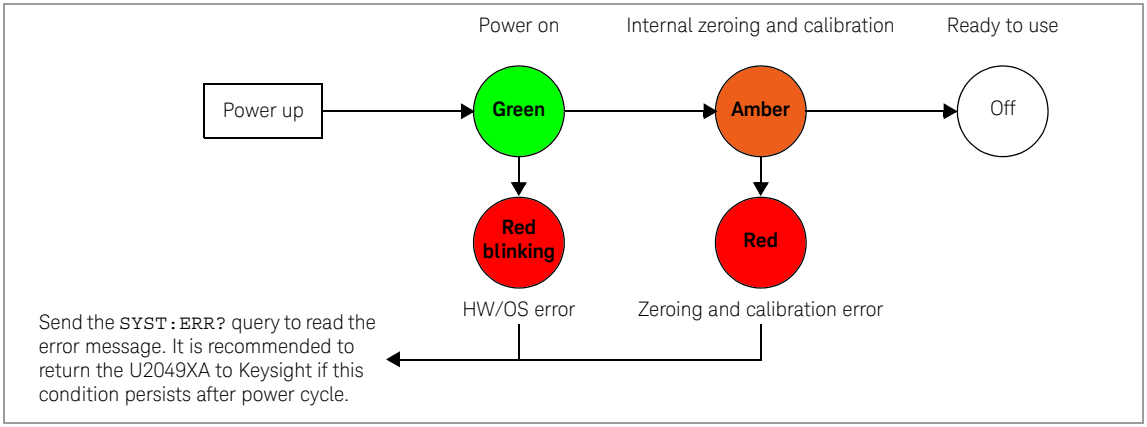
Table 1-1 Other LED indicators

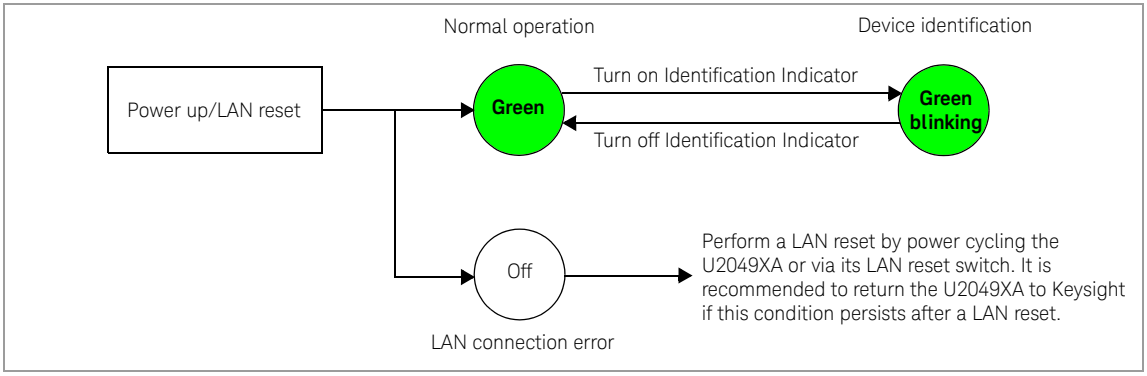
Amber	Secure erase, flash formatting, or firmware update in progress.
Red	An error is present in the SCPI error queue including input overload. If the error queue is cleared (via the `*CLS` command) or the last error is read from the queue (via the `SYST:ERR?` query), the indicator will turn off.
Green blinking	USB activity in progress.

LED Indicator Sequences for the U2049XA Sensor

During power-up (via PWR LED indicator)



For LAN activity (via LAN LED indicator)



Other LED indicators

Table 1-2 Other LED indicators

Amber	Secure erase, flash formatting, or firmware update in progress.
Red	An error is present in the SCPI error queue including input overload. If the error queue is cleared (via the `*CLS` command) or the last error is read from the queue (via the `SYST:ERR?` query), the indicator will turn off.

Firmware Upgrade

To download the latest firmware version for the U2040 X-Series, go to www.keysight.com/find/pm_firmware. The latest firmware includes the executable file and help file for installing the Firmware Upgrade Utility application in order to upgrade the U2040 X-Series.

2 General Operating Information

This chapter describes the general operating information of the U2040 X-Series.

Using the U2040 X-Series with the Keysight BenchVue

The BenchVue Power Meter application provides a virtual operating interface for the U2040 X-Series. This chapter describes the U2040 X-Series functions in the BenchVue Power Meter application in general.

NOTE For more information on how to configure each U2040 X-Series function or use each BenchVue Power Meter feature, refer to the Keysight BenchVue Power Meter help documentation.

Go to **Start > All Programs > Keysight > Keysight BenchVue > Keysight BenchVue** to launch the BenchVue Power Meter application.

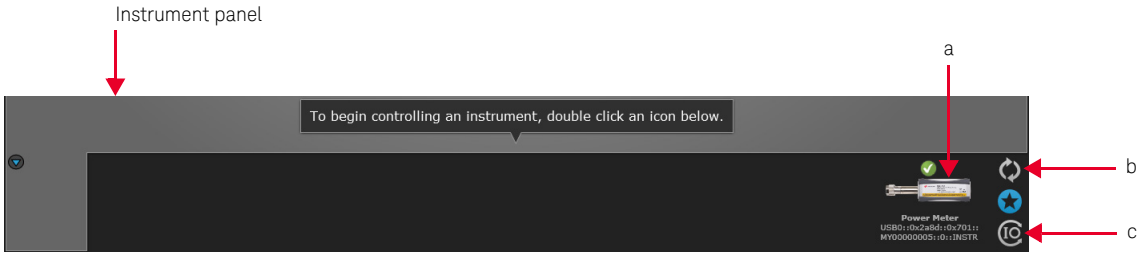


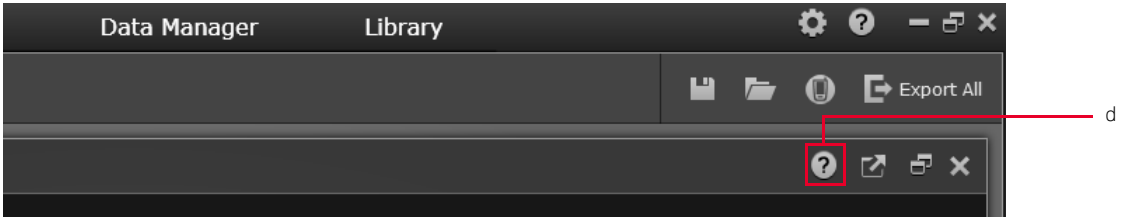
Figure 2-1 Launch the Keysight BenchVue

a Double-click the connected sensor () at the Instrument panel to start controlling the power sensor.

b If the sensor is found in the Keysight Connection Expert but is not shown in the BenchVue Instrument panel, select the refresh icon () to refresh the instrument list.

c If the sensor is not found, select the IO icon () to launch the Keysight Connection Expert to verify that the power sensor is connected properly.

When you launch the BenchVue Power Meter application, the Digital Meter is displayed by default.



d Click () to access the BenchVue Power Meter help documentation.

Quick start example to perform an average power measurement

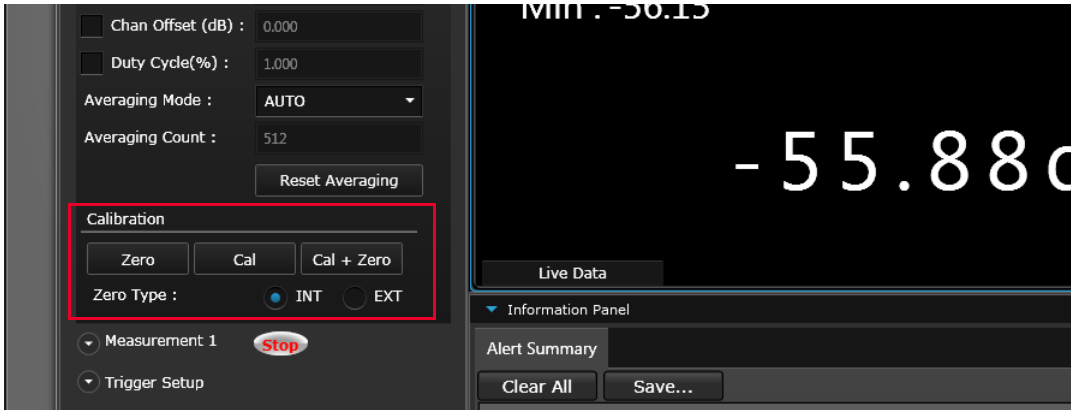
The following example guides you on how to quickly measure average power via BenchVue.

It is assumed that the U2040 X-Series is already connected to a signal generator.

1 Set up the signal generator as follows:
   - Amplitude: 0 dBm
   - Frequency: 1 GHz
   - Modulation: Disabled

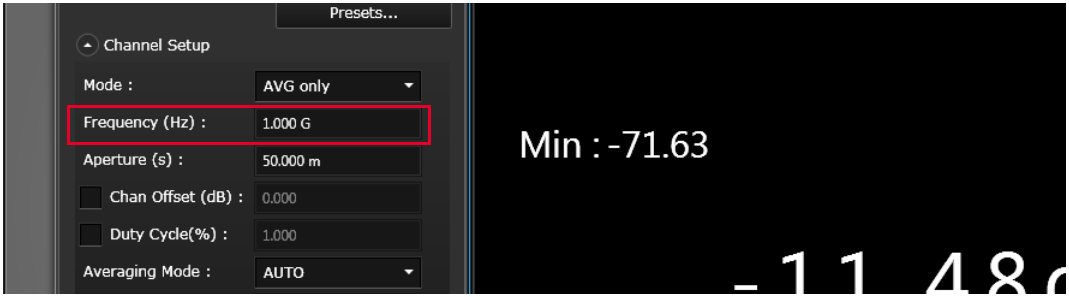
2 Turn on the RF output of the signal generator. Launch the BenchVue Power Meter application (refer to **page 46**). By default the power meter mode is already set to Average only.

3 Perform calibration and zeroing for an accurate measurement result.



NOTE For power measurements below –50 dBm, it is recommended to perform external zeroing and turn off the RF output for better accuracy and repeatability.

4 Set the frequency of the U2040 X-Series to 1 GHz.



5 You should be able to view the average power measurement results in the Digital Meter display view.

a Indicates acquisition of measurements in the Run mode

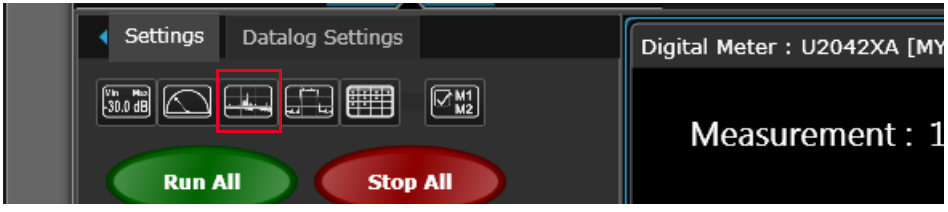
b Indicates the measurement status

c Change the title at the top of the display view

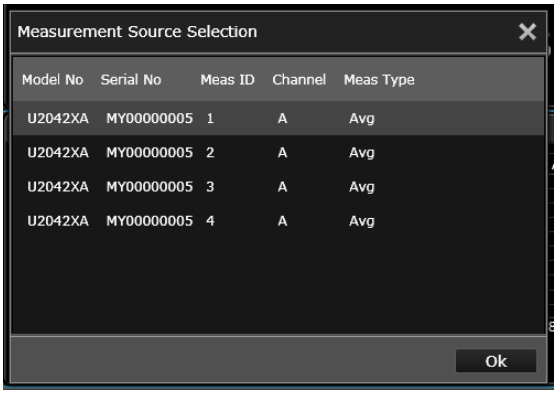
Reset the displayed Minimum/Maximum measured values

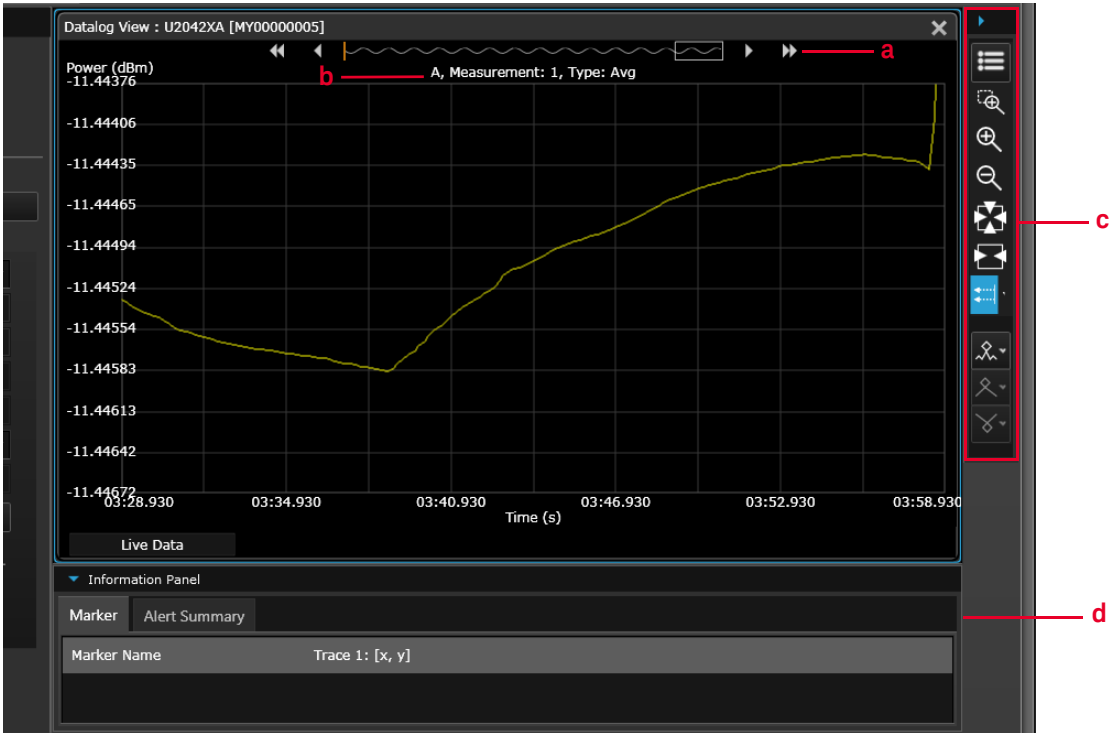
d Summary of alert limit conditions for the current measurement

6 To monitor the average power over a period of time, create a Datalog display view by clicking .



Select one of the available measurements from the list and click **Ok**.





a Data preview bar

b Indicates the channel name, measurement number, measurement type

c Tools palette to provide control for the datalog chart (refer to the BenchVue Power Meter help documentation for details)

d Summary of marker measurements and alert limit conditions for the current measurement.

7 Place a marker (or up to five markers) on the chart by clicking  to obtain the reading.

Quick start example to set up a measurement in the Trace view

The following example guides you on how to set up a basic peak power measurement for RF pulses via BenchVue.

NOTE

The default power meter mode is Average only. It will change to the Normal mode when the Trace view is selected. As the Normal mode provides a lower dynamic range, the measurable power range will automatically narrow down.

To obtain a wider dynamic range for low power measurements (< –40 dBm), you will need to set to the Average only mode. If the measurement is in the Trace view, a warning message will appear as the Trace view is only applicable for the sensor's Normal mode.

It is assumed that the U2040 X-Series is already connected to a signal generator.

1 Set up the signal generator as follows:
   - Pulse period: 500 µs
   - Pulse width: 100 µs
   - Amplitude: 5 dBm
   - Frequency: 1 GHz
   - Pulse: Enabled

2 Turn on the RF output of the signal generator. Launch the BenchVue Power Meter application (refer to **page 46**).

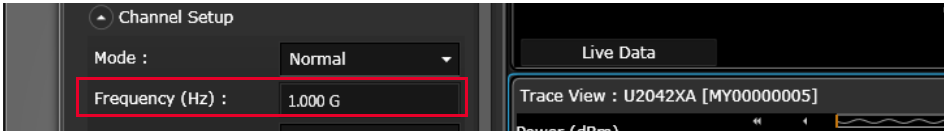
3 Create a Trace display view by clicking  .

4 Perform calibration and zeroing for an accurate measurement result.

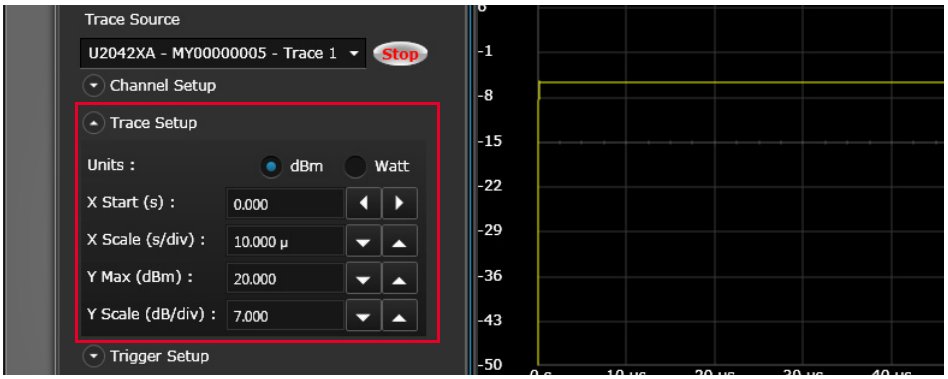
NOTE

- For power measurements below –50 dBm, it is recommended to perform external zeroing and turn off the RF output for better accuracy and repeatability.
- Ensure that modulation is enabled.

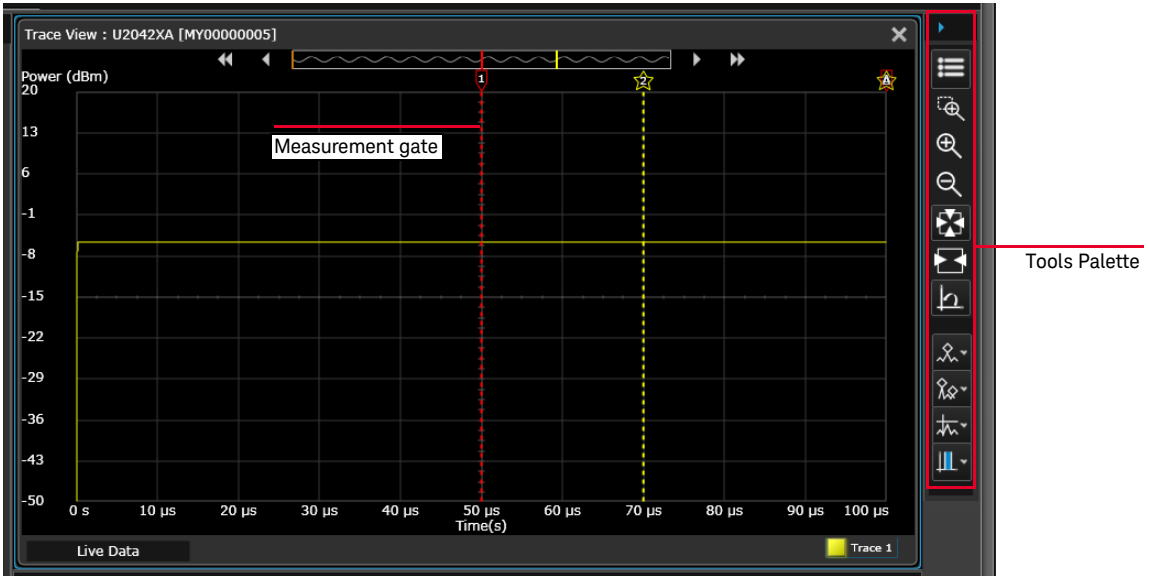
5 Set the frequency of the U2040 X-Series to 1 GHz.



6 You can set the trace scales to configure the pulse on the trace display.

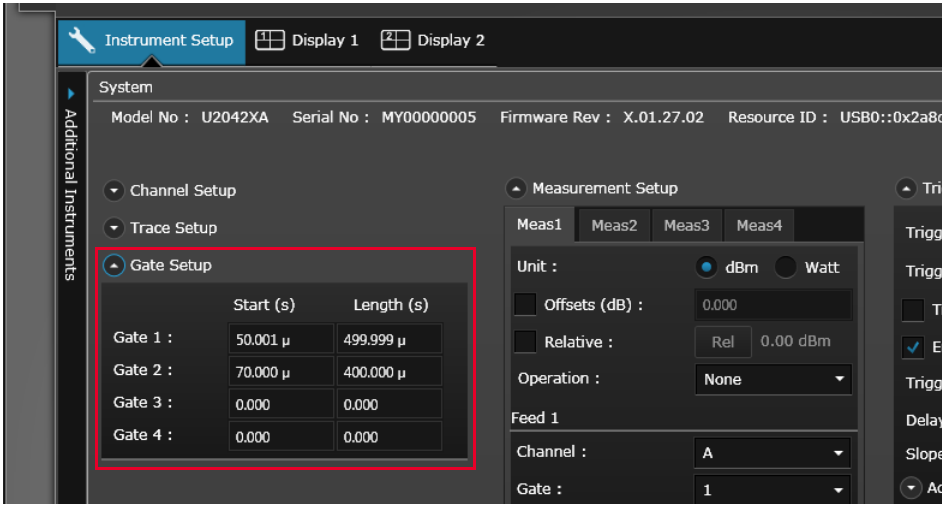


7 To enable gates on the trace, click  at the Tools Palette.



NOTE You can add markers or configure the trace using the Tools Palette controls. Refer to the BenchVue Power Meter help documentation for details on each control.

For more precise control of your gate parameters, you can set up the gates via the **Instrument Setup** tab and enter a starting point and length (in seconds) for each of the four gate controls.



8 View the power measurement results of the pulse at the **Pulse Analysis** tab under **Information Panel**.

You can select additional pulse and gate measurements to display by clicking the **Measurement Selector** tab.

Quick overview of the BenchVue Power Meter

NOTE For details on each of the BenchVue Power Meter features, refer to the Keysight BenchVue Power Meter help documentation.

a Access the common measurement settings for the current measurement display view.

-- Click  to create a new Digital Meter display view.

-- Click  to create a new Analog Meter display view.

-- Click  to create a new Data Log display view.

-- Click  to create a new Trace display view.

-- Click  to create a new MultiList display view.

-- Click  to assign a measurement to the selected display view.

-- Click  to start or stop all assigned measurements on all display views simultaneously.

For more information, refer to "**Power meter settings in the Average only mode**" on page 58 and "**Power meter settings in the Normal mode**" on page 60.

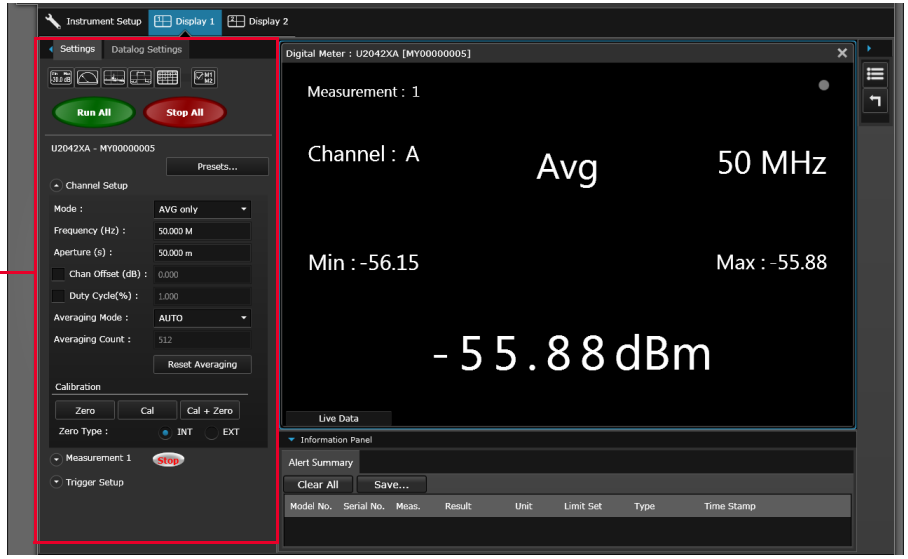


Figure 2-2 Common measurement settings pane

To access the data logger settings, click the **Datalog Settings** tab. To enable data logging, you need to stop the measurement acquisition.

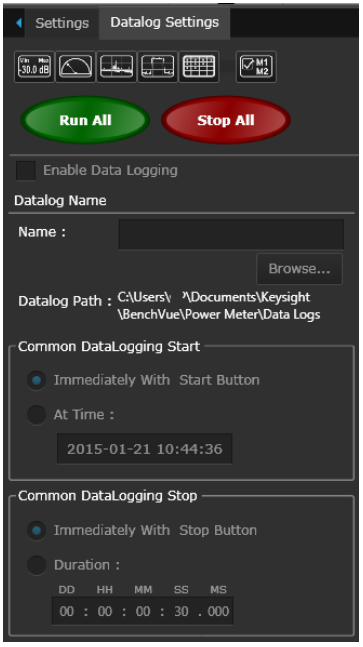


Figure 2-3 Datalog settings pane

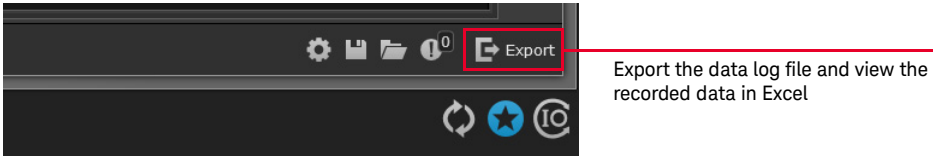


Figure 2-4 Export the data log file

b Save or load the instrument state of the current bench application in a proprietary format with a **.state* file extension.

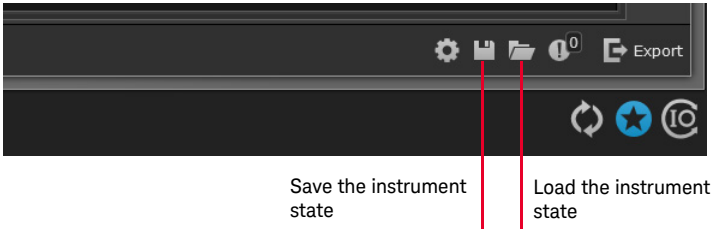


Figure 2-5 Save/load the instrument state

c Access advanced settings such as corrections (frequency-dependent offset, gamma, and S-parameter), alert limits, recorder output, trace/pulse duration reference levels, input impedance, and trigger output.

For more information, refer to "**Instrument Setup tab**" on page 63.

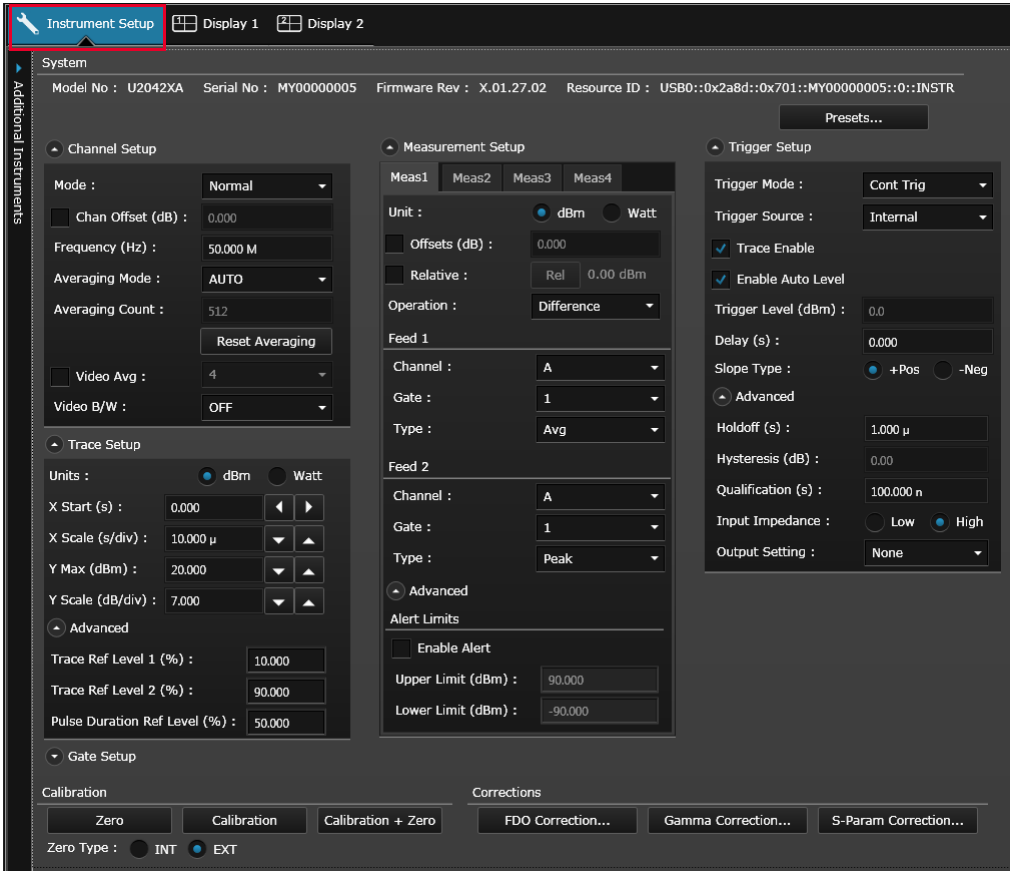


Figure 2-6 Instrument setup (advanced settings) pane

Power meter settings in the Average only mode

Common Average only mode power measurement settings

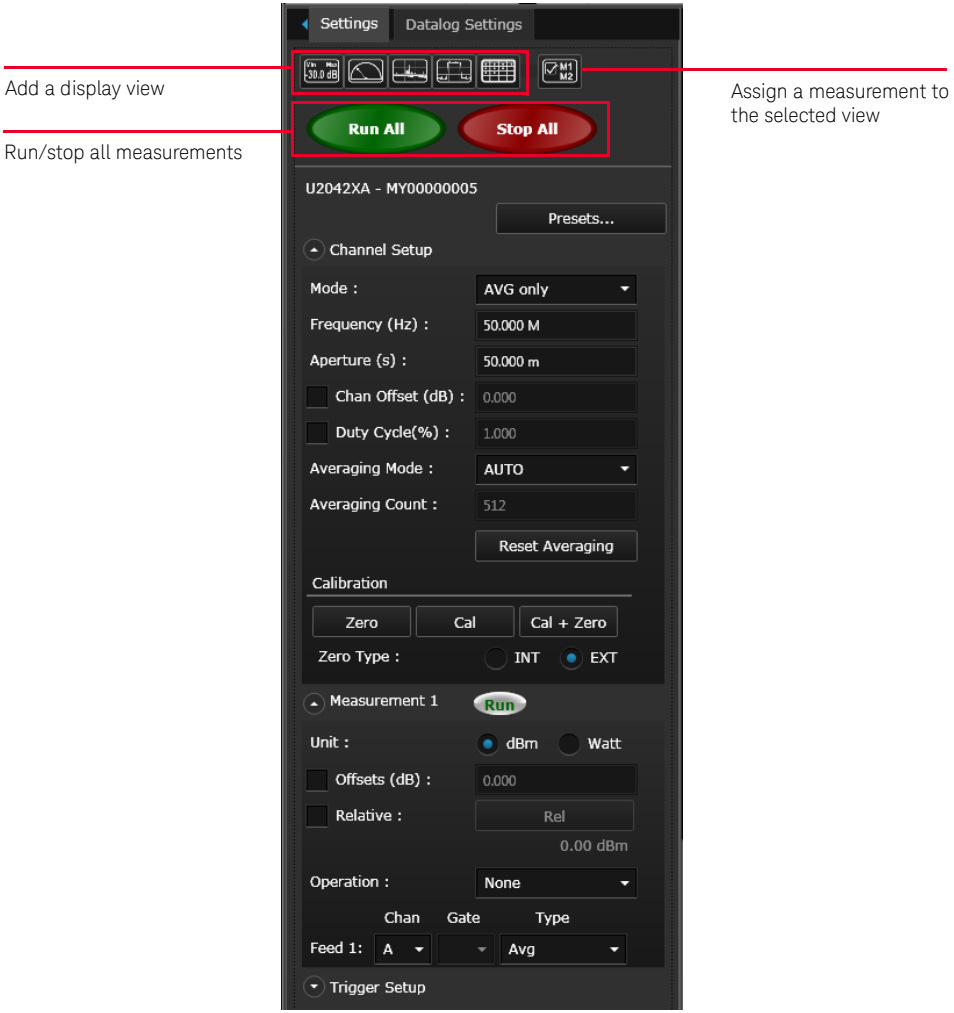


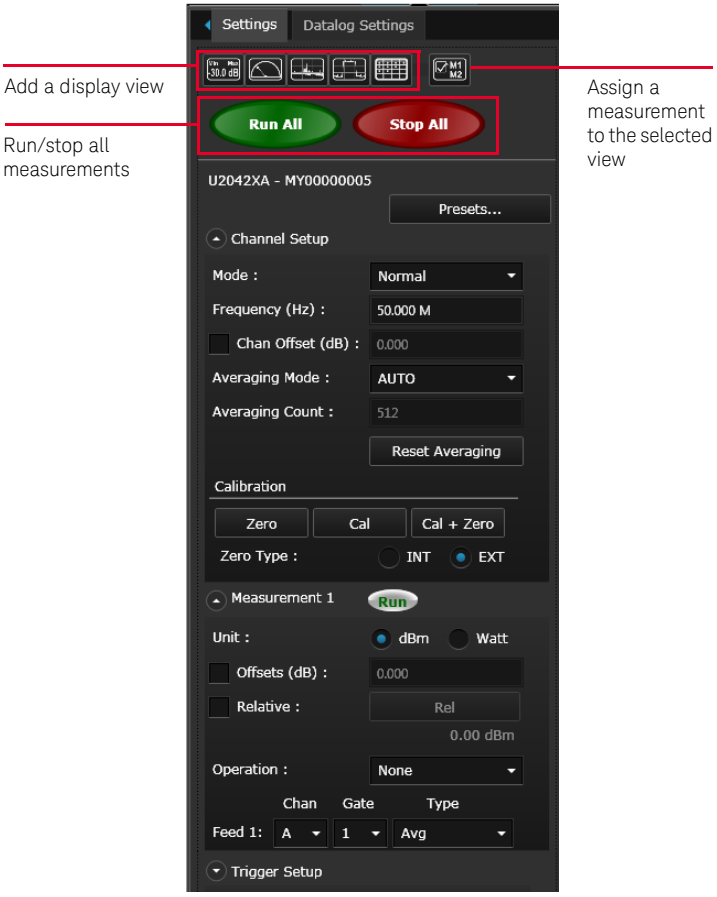
Figure 2-7 Power meter settings in the Average only mode

Table 2-1 Power meter settings in the Average only mode description

Item	Description
Presets	– Preset the instrument to its default values or values appropriate for measuring the communications format. The data stored in the correction (FDO, gamma, and S-parameter) tables, the selected correction table, and the zeroing and calibration data are not affected by a preset. – Perform a system reset.
Channel Setup	– Set the channel mode to the Normal or Average Only mode. – Set the measurement frequency. – Set the aperture size. – Set the channel offset which is applied to the measured power prior to any mathematical functions. Refer to "**Simplified Measurement Path**" on page 78. – Set the duty cycle. – Set the automatic or manual measurement average mode. The number of readings averaged can range from 1 to 1024. Increasing the value of the measurement average reduces measurement noise, but increases measurement time. The measurement average filter can also be reset. Refer to "**Typical Averaged Readings**" on page 79.
Calibration	Auto-calibrate the U2040 X-Series without having to connect it to a power reference, or auto-zero the U2040 X-Series internally or externally. Internal zeroing can be performed with or without the RF/microwave signal present, while external zeroing must be performed without any RF/microwave signal present.
Measurement	– Run/stop the measurement. – Set the logarithmic (dBm) or linear (Watt) measurement unit. – Set the measurement offset factor. The U2040 X-Series corrects every measurement by this factor to compensate for the gain/loss. – Enable the relative mode, which computes the measurement result relative (as a ratio) to a reference value. When enabled, the reference value can be set using the <**Rel**> control. The relative reading is displayed in either dB or %. – Measurement feed operation is not available in the Average only mode.
Trigger Setup	– Set the single, free run, or continuous trigger mode. The free run mode does not allow any trigger setup. – Set the trigger source to an external source in the single or continuous trigger mode. – Set the delay time to be applied between the trigger event and all the gate start times. This allows you to time-shift all the gates by the same amount with one setting change. – Select the positive or negative slope type to determine if the trigger event is recognized on the rising or falling edge of a signal respectively. – Set the holdoff time to disable the trigger mechanism after a trigger event occurs. – Set the qualification value.

Power meter settings in the Normal mode

Common Normal mode power measurement settings



Common Normal mode Trace view settings

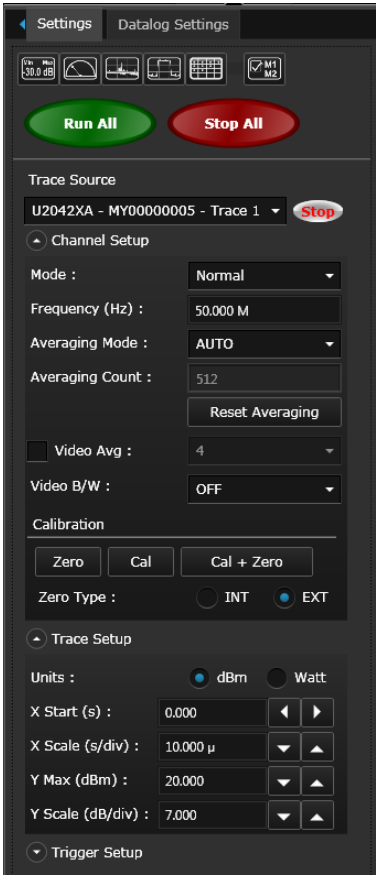


Figure 2-8 Power meter settings in the Normal mode

Table 2-2 Power meter settings in the Normal mode description

Item	Description
Presets	– Preset the instrument to its default values or values appropriate for measuring the communications format. The data stored in the correction (FDO, gamma, and S-parameter) tables, the selected correction table, and the zeroing and calibration data are not affected by a preset. – Perform a system reset.
Channel Setup	– Set the channel mode to the Normal or Average Only mode. – Set the measurement frequency. – Set the channel offset which is applied to the measured power prior to any mathematical functions. Refer to "**Simplified Measurement Path**" on page 78. – Set the automatic or manual measurement average mode. The number of readings averaged can range from 1 to 1024. Increasing the value of the measurement average reduces measurement noise, but increases measurement time. The measurement average filter can also be reset. Refer to "**Typical Averaged Readings**" on page 79.
Calibration	Auto-calibrate the U2040 X-Series without having to connect it to a power reference, or auto-zero the U2040 X-Series internally or externally. Internal zeroing can be performed with or without the RF/microwave signal present, while external zeroing must be performed without any RF/microwave signal present.
Measurement	– Run/stop the measurement. – Set the logarithmic (dBm) or linear (Watt) measurement unit. – Set the measurement offset factor. The U2040 X-Series corrects every measurement by this factor to compensate for the gain/loss. – Enable the relative mode, which computes the measurement result relative (as a ratio) to a reference value. When enabled, the reference value can be set using the <**Rel**> control. The relative reading is displayed in either dB or %. – Enable the difference or ratio measurement, or disable all operations between feed 1 and feed 2. – Configure the gate and acquired measurement type for the feed.
Trigger Setup	– Set the single, free run, or continuous trigger mode. The free run mode does not allow any trigger setup. – Set the trigger source to an internal or external source. – Enable auto level or manually set the trigger level for the internal trigger source. – Set the delay time to be applied between the trigger event and all the gate start times. This allows you to time-shift all the gates by the same amount with one setting change. – Select the positive or negative slope type to determine if the trigger event is recognized on the rising or falling edge of a signal respectively. – Set the holdoff time to disable the trigger mechanism after a trigger event occurs. – Set the hysteresis to help generate a more stable trigger by preventing triggering unless the RF power level achieves the trigger level and the additional hysteresis value. It can be applied to both rising and falling edge trigger generation. Hysteresis is only available for the internal trigger source and manual trigger level. – Set the qualification value.

Table 2-2 Power meter settings in the Normal mode description (continued)

Item	Description
Channel Setup (in the Trace view)	– Set the video averaging to average repetitions of a triggered signal, with a count of 1 to 256 in multiples of 2^n. With video averaging, the average of a number of acquisitions is calculated to smooth the displayed trace and reduce apparent noise. The measurement requires a continuously repeating signal. – Set the video bandwidth. The Low, Medium, and High pass band shapes achieved by the video bandwidth settings provide flat filter responses with very sharp cut-off points by applying digital signal processing techniques to ensure accurate power measurement within the specified band. When the video bandwidth is set to Off, it removes all digital signal conditioning. This provides less than 3 dB roll-off[a] and is best suited for capturing an accurate trace, minimizing overshoot, and removing any ringing effects caused by the sharp cut-off filters used in the Low, Med, and High settings. Refer to **"Bandwidth Filter Shapes"** on page 81.
Trace Setup	Set the trace unit, start time, X-axis scale, Y-axis maximum value, and Y-axis scale.
Trigger Setup (in the Trace view)	Select to enable trace for the single and continuous trigger modes.

[a] When the U2040 X-Series frequency is set to ≥300 MHz.

Instrument Setup tab

This tab provides you an option to configure additional instrument settings for your measurements as described in **Table 2-3**.

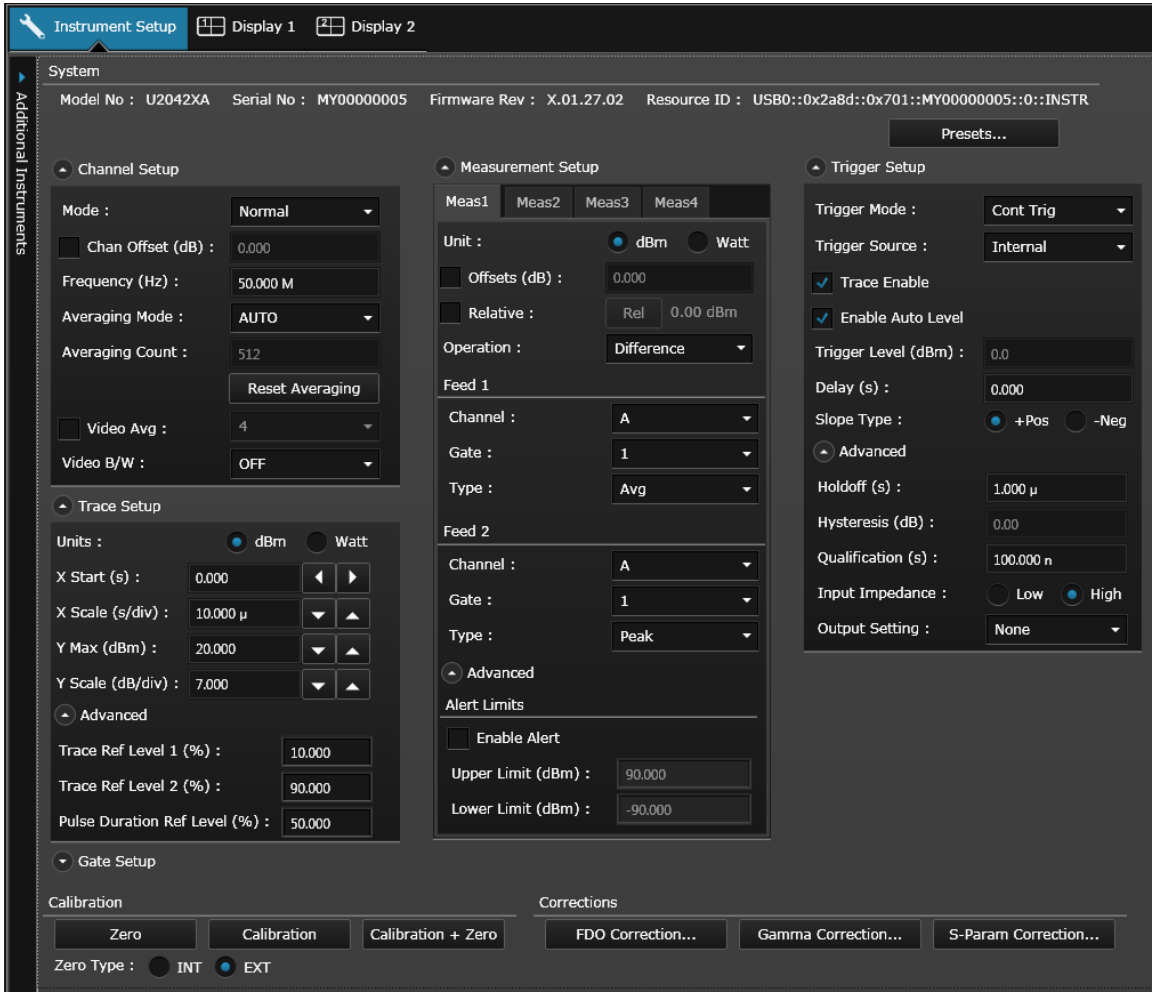


Figure 2-9 Instrument Setup tab

Table 2-3 Additional Instrument Setup tab settings description

Item	Available settings
Trace Setup	**Advanced:** – Set the trace reference levels to be used in the calculation of transition durations and occurrences. This allows transition measurements between non-standard reference levels. – Set the trace reference level to be used in the calculation of pulse durations. This allows pulse duration measurements between non-standard reference levels.
Gate Setup	Set the gate start time and length. The gate start time is relative to the trigger event. Positive values set a measurement gate to a maximum time of 1 second after the trigger. Negative values set a measurement gate to a maximum time of 1 second before the trigger. Refer to "**Measurement Gates**" on page 82 for more information.
Corrections	– Set the frequency-dependent offset (FDO) which compensates for frequency-related changes in the response of your test system. The BenchVue Power Meter application can store 10 FDO tables with 512 frequency points each. – Set the gamma and S-parameter corrections. The BenchVue Power Meter application can store 10 gamma/S-parameter tables with 1024 magnitude-phase pairs each. Refer to "**Gamma correction**" on page 71 and "**S-parameter correction**" on page 72 for details. Also refer to "**Simplified Measurement Path**" on page 78 for the above corrections.
Measurement Setup	**Advanced:** Enable alerts to detect when a measurement has crossed over a predefined upper and/or lower limit value. Refer to "**Limit Checking Application Example**" on page 83 for more information.
Trigger Setup	**Advanced:** – Set the input impedance for the external TTL trigger to Low (50 Ω) or High (100 kΩ). – Enable the trigger output where a TTL level high is produced at the Trig Out connector when the U2040 X-Series is triggered. – Enable the 10 MHz timebase.
Additional Instruments	View all connected instruments and select any instrument to use on the BenchVue Power Meter application. You can connect up to 15 instruments per BenchVue Power Meter application.

Overview of Multiple Power Sensor Operation

This section provides examples on how to operate multiple sensors using the BenchVue Power Meter application.

Single bench operation

Multiple Digital Meter display views

Select the instruments to use at **Instrument Setup** > **Additional Instruments**. Add up to four Digital Meter display views by clicking  and selecting the measurement sources to display.

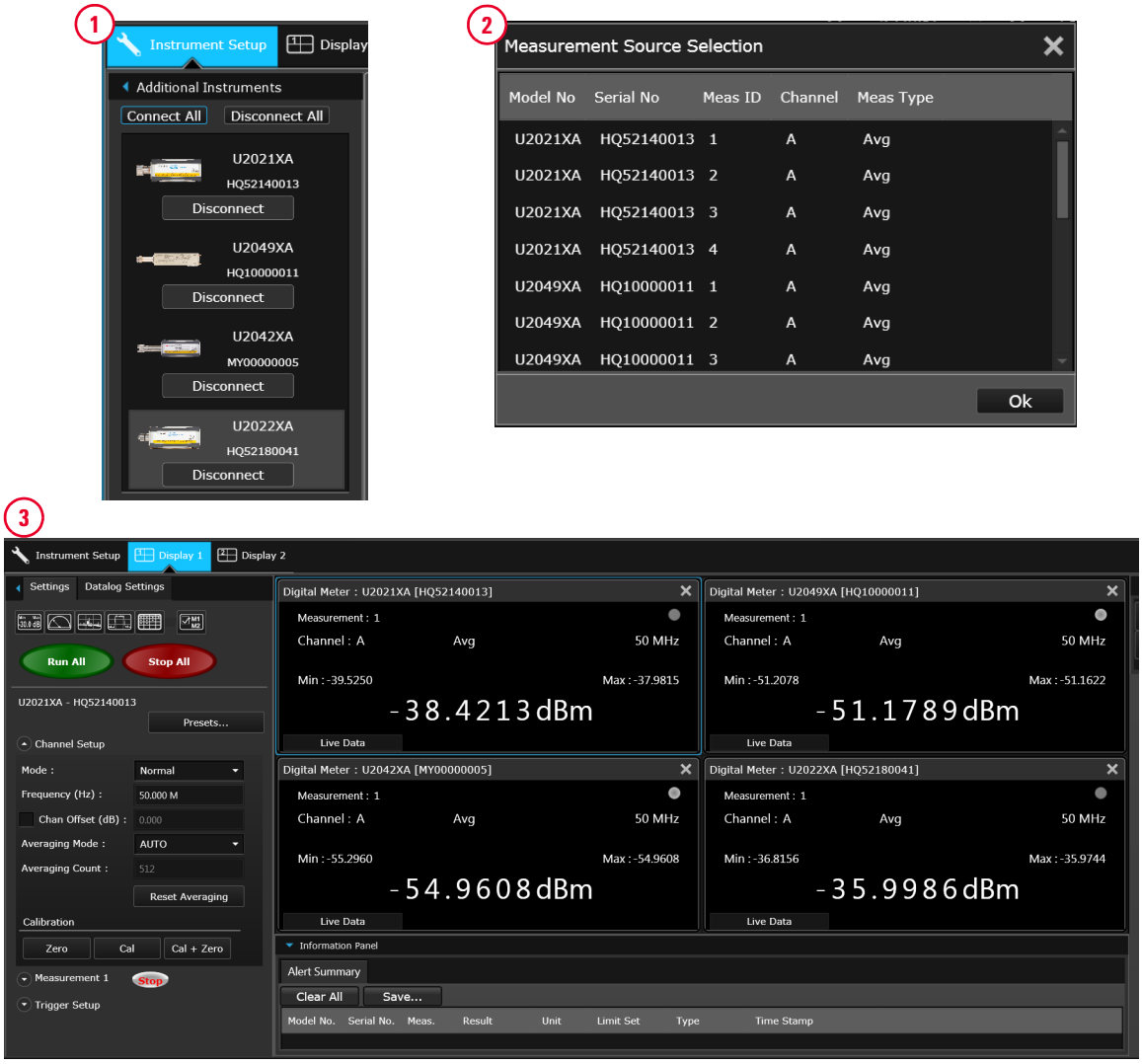


Figure 2-10 Multiple Digital Meter display example

Multilist display view

Select the instruments to use at **Instrument Setup** > **Additional Instruments**. Add a Multilist display view by clicking  and selecting the measurement sources to display.

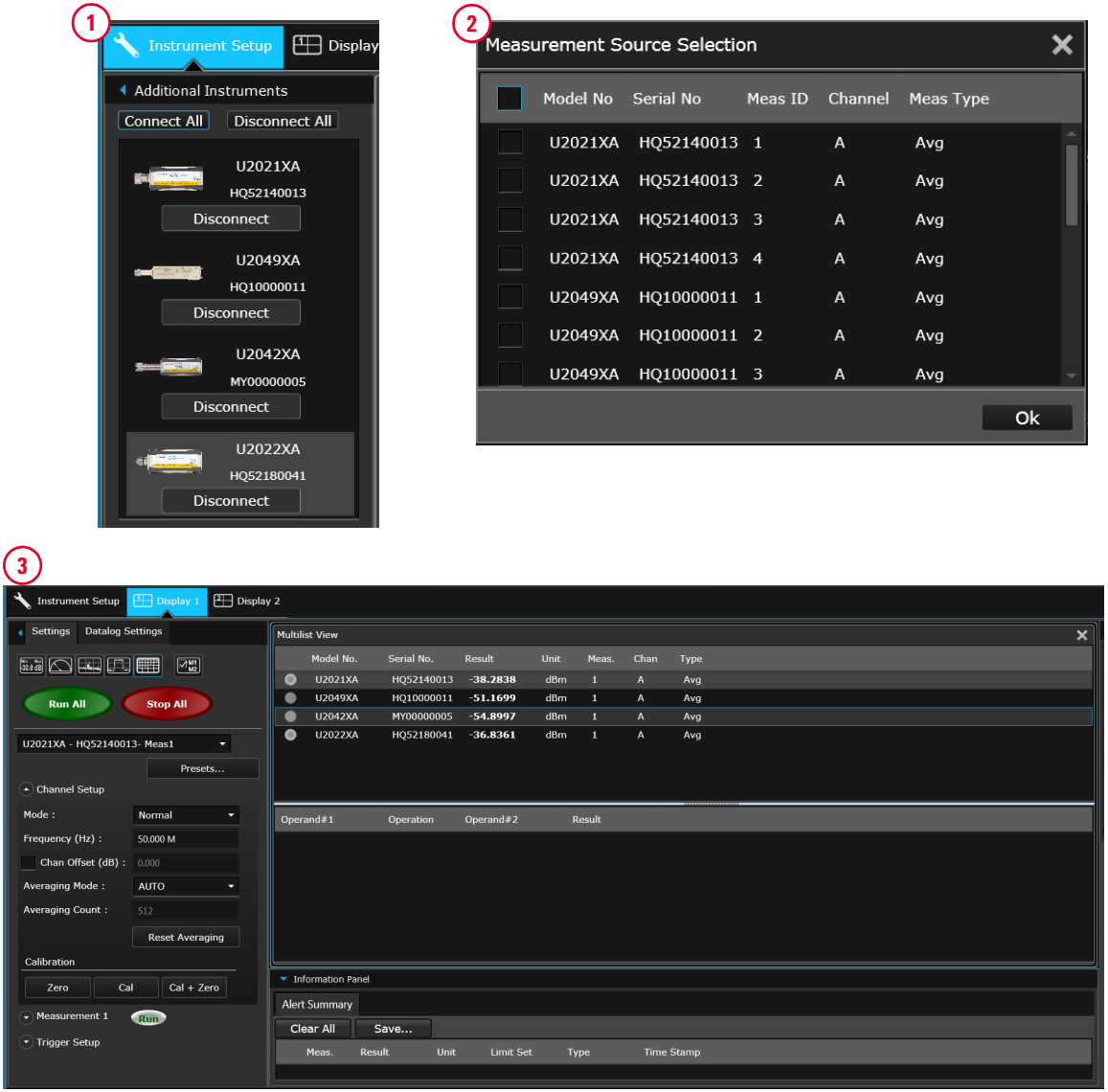


Figure 2-11 Multilist display example

Single Trace display view with multiple traces

Select the instruments to use at **Instrument Setup** > **Additional Instruments**. Add a Trace display view by clicking  and selecting the trace sources to display.

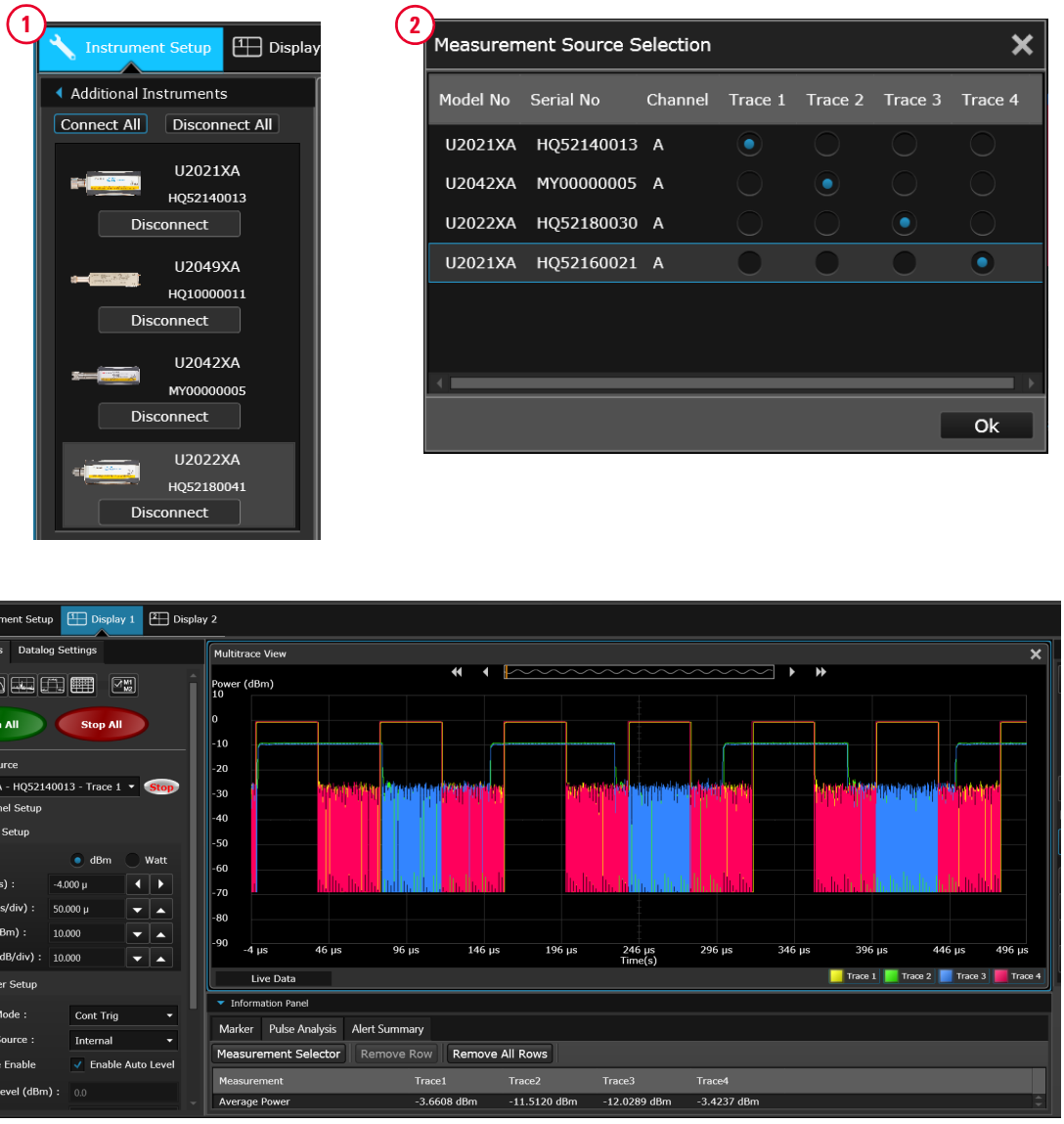


Figure 2-12 Multitrace example

Multiple bench operation

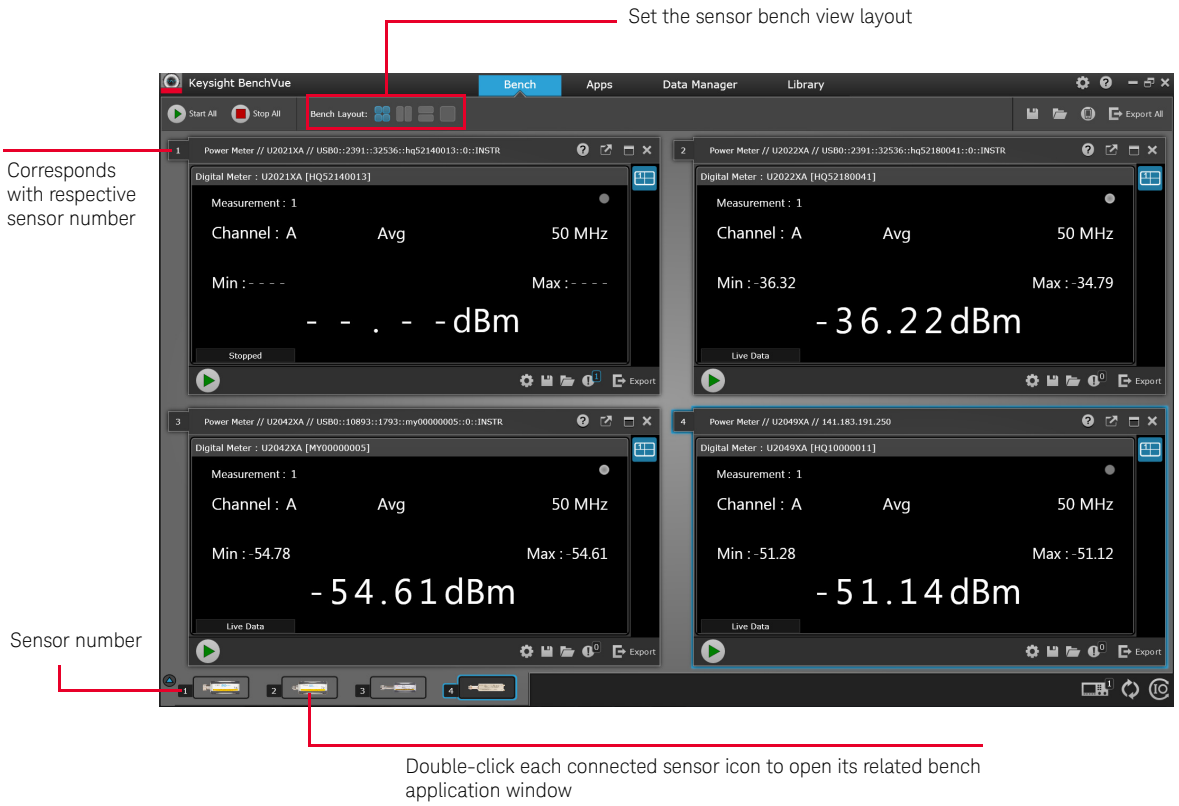


Figure 2-13 Multiple bench display example

U2040 X-Series Features

Broadband coverage for any modulated signal formats

The U2040 X-Series measures accurate average or time-gated average power for any modulated signal including all common wireless signals such as LTE, LTE-Advanced with 100 MHz bandwidth, and WLAN 802.11ac with 80/160 MHz bandwidth.

List mode/test sequencing

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.

NOTE Refer to the *U2040 X-Series Programming Guide* for more information.

Variable aperture size

In average mode and at normal/double/fast 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 20 μs[1] 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.

[1] Only applicable for ≥300 MHz. For <300 MHz, the minimum aperture size is 50 μs. If the existing aperture size is set to <50 μs and the frequency is changed from ≥300 MHz to <300 MHz, the aperture size will automatically be changed to 50 μs.

Table 2-4 Aperture size

Measurement speed	Default aperture size	Adjustable
Normal	50 ms	Yes
Double	25 ms	Yes
Fast	2 ms	Yes

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 U2040 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 U2040 X-Series allows you to reset the long filter after the final adjustment to the signal's amplitude has been made.

Built-in radar and wireless presets

The U2040 X-Series provides built-in radar and wireless presets for common signals such as DME, GSM, EDGE, WCDMA, WLAN, and LTE.

Gamma correction

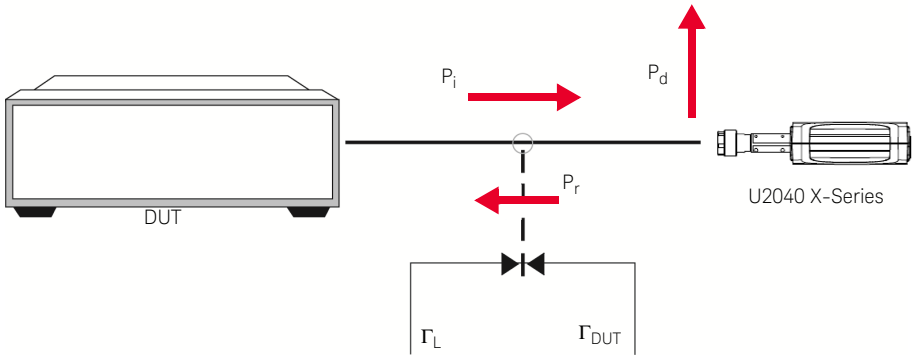


Figure 2-14 DUT to U2040 X-Series connection diagram

In a realistic measurement environment, the Device-Under-Test (DUT) impedance or the reference impedance (Z_o) is not equal to the U2040 X-Series impedance. The mismatch in impedance values causes a portion of the signal voltage to be reflected. This is quantified by the reflection coefficient, or gamma (Γ). A portion of the incident power to the U2040 X-Series, P_i, is reflected back to the DUT as P_r. The remaining power, P_d, gets delivered to the U2040 X-Series. A generic DUT will reflect part of P_r back to the U2040 X-Series, and the reflected portion will be superimposed onto P_i. The nominal power, P_{zo} – the power generated after factoring in Z_o – may be calculated as follows:

$$P_{zo} = P_i\left|1 - \Gamma_{DUT}\Gamma_L\right|^2$$

Gamma correction compensates for impedance mismatch via two options, which are Single Point Gamma and Table-based Gamma.

Single Point Gamma

Single Point Gamma correction is used when you have a known and constant frequency, so a single gamma value can be used for calculation. The value for Γ_{DUT} may be entered as a Single Point Gamma which may be applied across all measurement frequencies in the U2040 X-Series operating range.

Table-based Gamma

Table-based Gamma is used when there are multiple known frequencies, leading to multiple gamma values. This option supports a list of up to 1024 measurement frequency values.

NOTE The U2040 X-Series supports up to 10 gamma tables that are retained across reset and power cycles.

The Γ_L values for factory calibration frequencies within the U2040 X-Series operating range are already pre-loaded in the U2040 X-Series. These Γ_L values are retained across reset and power cycles.

S-parameter correction

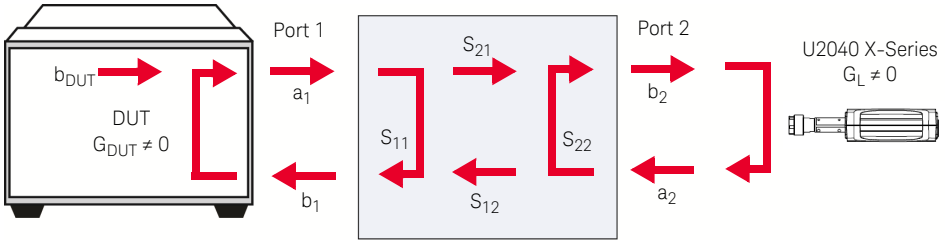


Figure 2-15 Non-ideal 2-port device

A Device-Under-Test (DUT) that has n number of ports has n^2 S-parameters. These S-parameters represent reflected energy which interferes with the power measurements. These errors are usually caused by additional components such as attenuators, adapters, or matching pads, which are inserted between the DUT and the U2040 X-Series. Typically, DUTs are non-ideal, as illustrated in **Figure 2-15**. When power is transmitted from the DUT, the U2040 X-Series will reflect a part of its incident wave back to the 2-port device. The 2-port device will reflect this wave back to the U2040 X-Series. The power from the DUT may therefore be calculated as follows:

$$b_{DUT} = b_2 \frac{(1 - S_{11}\Gamma_{DUT})(1 - S_{22}\Gamma_L)}{S_{21}} - S_{12}\Gamma_{DUT}\Gamma_L$$

The result is the same as if gamma correction was enabled. This feature enables you to correct for the effect of 2-port devices in your test setup. You may enter the S-parameter data for the DUT in the .S2P file format (magnitude-phase or dB-phase or real-imaginary).

NOTE The U2040 X-Series supports up to 10 S-parameter tables that are retained across reset and power cycles.

Tilt measurement

Tilt measurement is used to measure the amount of tilted droop (A_D) of the input signal as shown below.

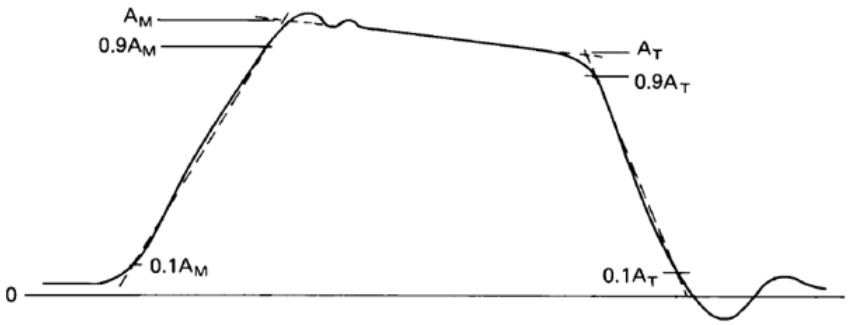


Figure 2-16 Tilt measurement graph

Pulse amplitude, A_M

The pulse amplitude quantity is determined by the intersection of a line passing through the points on the rising edge, where the instantaneous value reaches 10% and 90% of A_M and a straight line that is the best least-squares fit to the pulse in the pulse-top region.

Trailing edge (last transition) amplitude, A_T

The trailing edge amplitude quantity is determined by the intersection of a line passing through the points on the falling edge where the instantaneous value reaches 90% and 10% of A_T, and the straight-line segment fitted to the top of the pulse in determining A_M.

Tilt, A_D

Tilt is the difference between A_M and A_T. It is expressed in percentage of A_M or in dB.

$$TILT(\%) = \frac{A_M - A_T}{A_M} \times 100$$

$$TILT(dB) = 10 \times log10\left(\frac{A_M}{A_T}\right)$$

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3 Characteristics and Specifications

NOTE For the characteristics and specifications of the U2040 X-Series, refer to the datasheet at http://literature.cdn.keysight.com/litweb/pdf/5992-0040EN.pdf.

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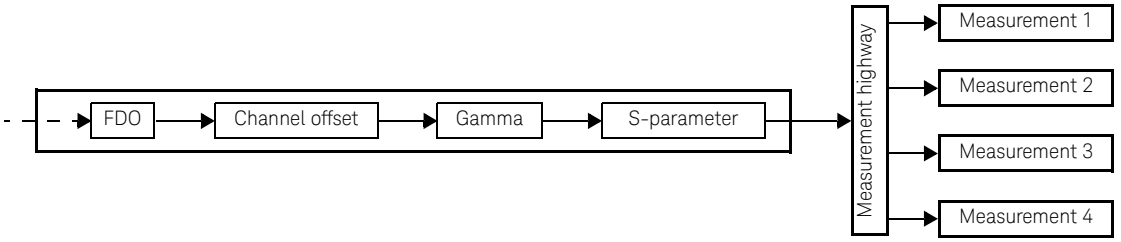
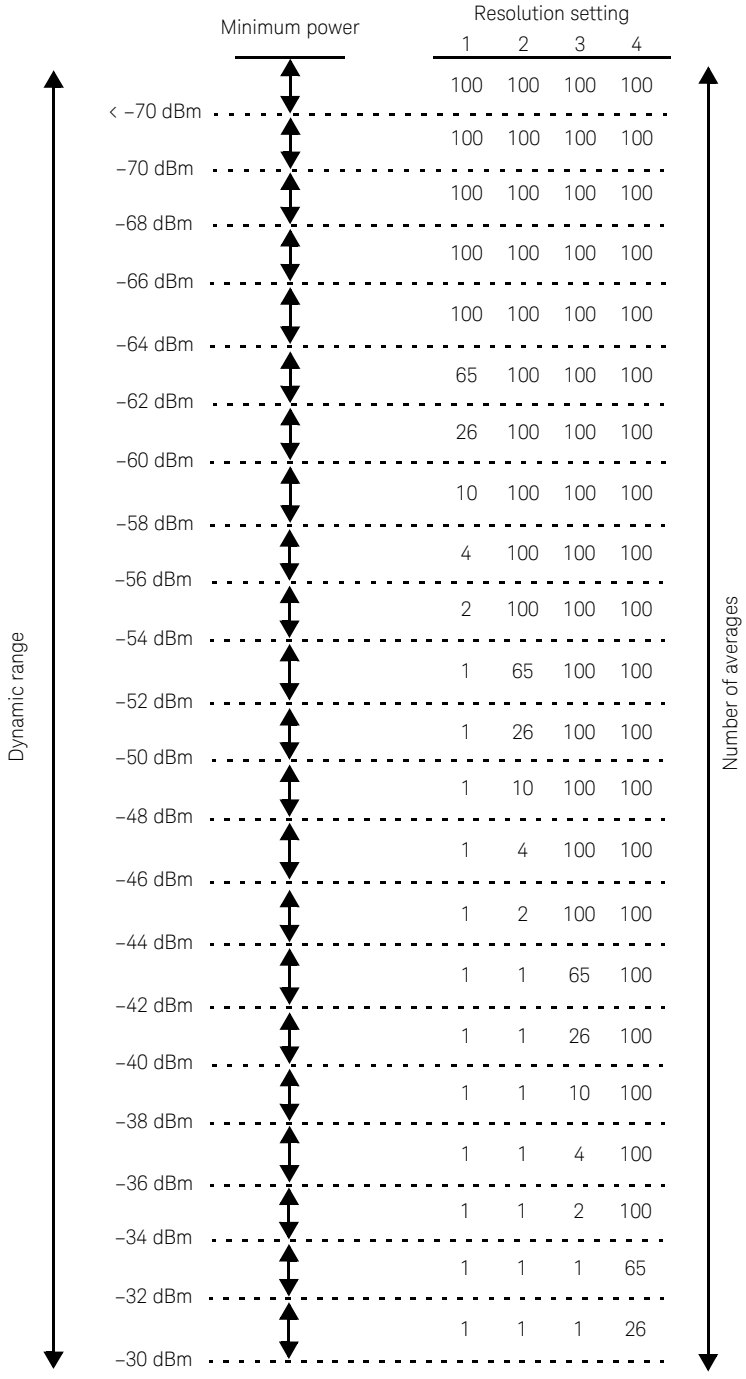
A Appendix

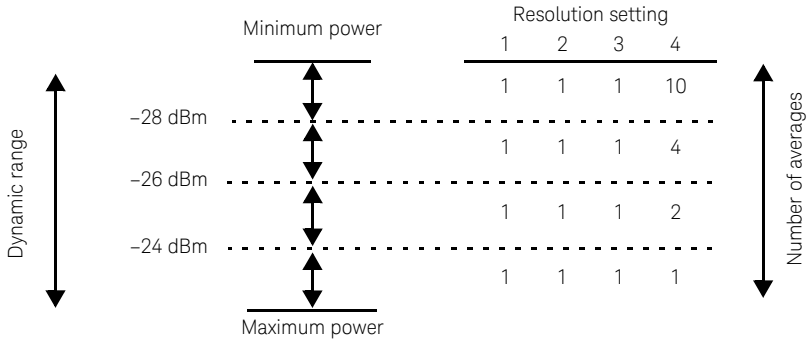
Simplified Measurement Path



Typical Averaged Readings

Below shows the typical number of averages for each range and resolution when the U2040 X-Series is in the auto-average mode and set to the normal speed mode.

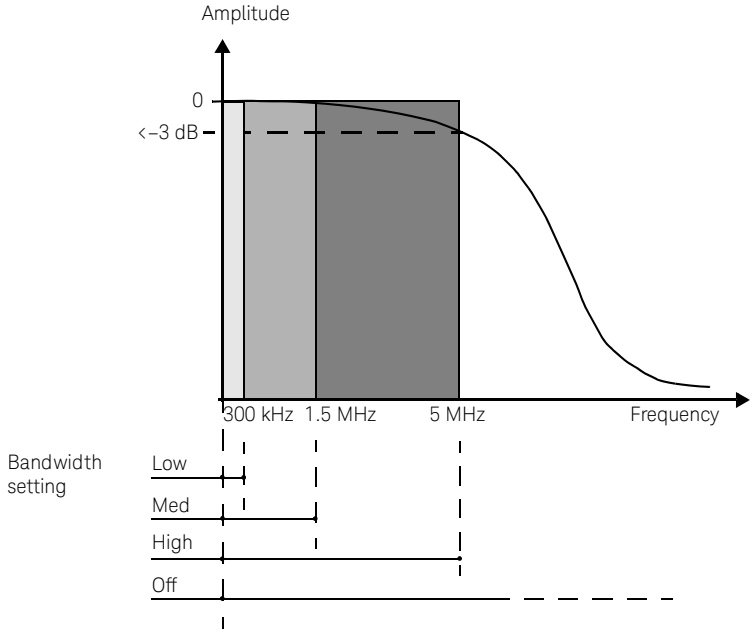




The four resolution levels represent:

- 1, 0.1, 0.01, 0.001 dB respectively if the measurement suffix is dBm or dB.
- 1, 2, 3, or 4 significant digits respectively if the measurement suffix is W or %.

Bandwidth Filter Shapes[1]



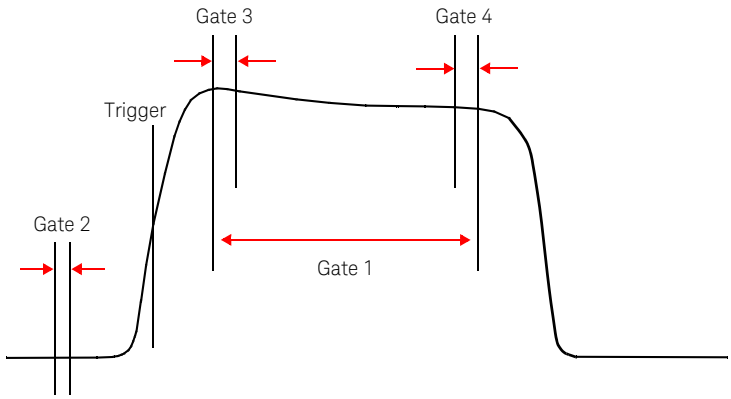
[1] When the U2040 X-Series frequency is set to ≥300 MHz.

Measurement Gates

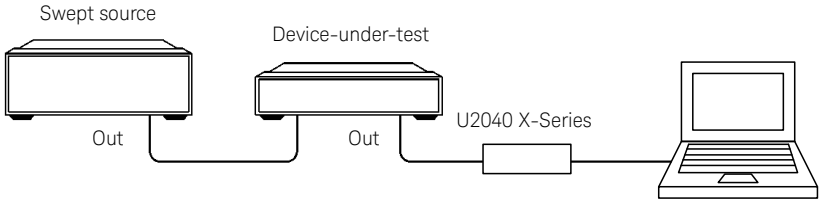
A measurement gate allows measurements to be performed on particular sections of the input signal. The gate is defined by a start time relative to the trigger event and a duration. Signal samples acquired during the time interval specified by the gate are used for the measurements in that gate. A system of up to four independent gates is provided.

Below is an example of a 4-gate setup to perform the following measurements simultaneously:

Average power level of the pulse	Gate 1, average measurement
Average “off” power level ahead of the pulse	Gate 2, average measurement
Peak-to-average ratio	Gate 1, peak-to-average measurement
Pulse droop	Gate 3, average measurement, minus Gate 4, average measurement



Limit Checking Application Example



The limits have been set at +4 dBm and +10 dBm for the above application. A fail occurs each time the output power is outside these limits as shown below.

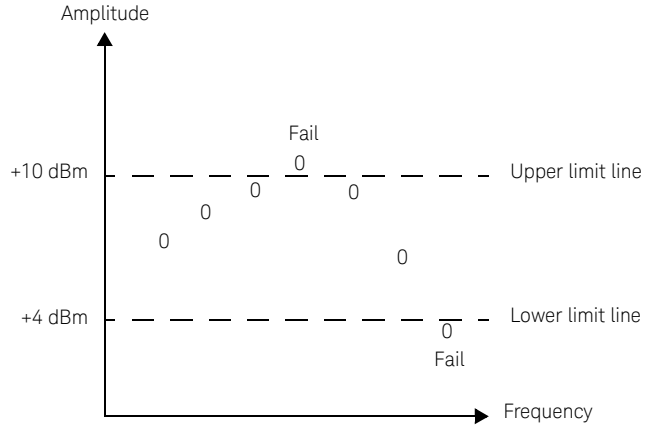


Table A-1 Range of values for limits

Unit	Maximum	Minimum	Default maximum	Default minimum
dB	+200 dB	–180 dB	60 dB	–120 dB
dBm	+230 dBm	–150 dBm	90 dBm	–90 dBm
%	10.0 Z%	100.0 a%	100.0 M%	100.0 p%
W	100.000 EW	1.000 aW	1.000 MW	1.000 pW

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