Ettus USRP X410 Getting Started Guide

Contents

Ettus USRP X410 Getting Started Guide

This document explains how to install, configure, and test the Ettus USRP X410 Software Defined Radio Device.

The Ettus USRP X410 can send and/or receive signals for use in various communications applications. You can use NI-USRP or the USRP Hardware Driver (UHD) to program the device.

Unpacking the Kit

> **(!) Notice** To prevent electrostatic discharge (ESD) from damaging the device, ground yourself using a grounding strap or by holding a grounded object, such as your computer chassis.

1. Touch the antistatic package to a metal part of the computer chassis.
2. Remove the device from the package and inspect the device for loose components or any other sign of damage.

> **(!) Notice** Never touch the exposed pins of connectors.
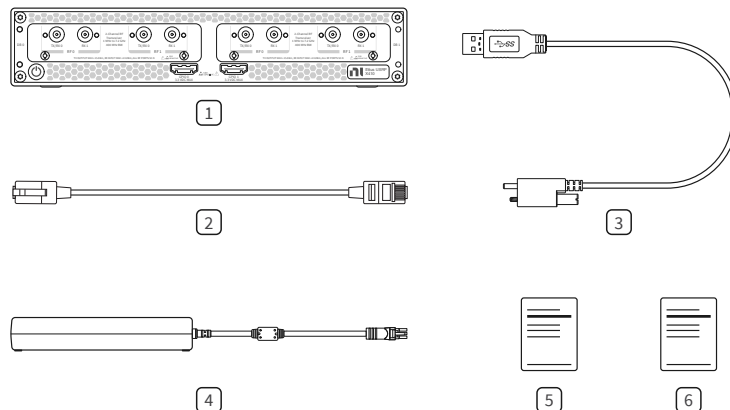
> **✎ Note** Do not install a device if it appears damaged in any way.

3. Unpack any other items and documentation from the kit.

Store the device in the antistatic package when the device is not in use.

Verifying the Kit Contents

Figure 1. Kit Contents

1. Ettus USRP X410
2. CAT 5E Ethernet Cable
3. USB-A (m) to USB-C (m) with Jack Screw Cable
4. Power Supply
5. Ettus USRP X410 Documentation Note
6. Ettus USRP X410 Safety, Environmental, and Regulatory Information

Additional Items for Device Setup

- Cables
  - PCIe/MXI express cable
  - QSFP28 to QSFP28 Ethernet cable
  - QSFP28 to 4xSFP28 Ethernet breakout cable
  - SMA (m)-to-SMA (m) cable
- Host PC
- PXI Express chassis
- PXIe-8881 or other PXI controller
- PXIe-8394 or other PXI bus extension module
- PCIe-8398 or other device for PXI remote control

- 10 Gb Ethernet network card or 100 Gb Ethernet network card

> **Tip** NI recommends using an Ethernet network card available in connectivity kits sold on www.ettus.com and ni.com.

- 30 dB attenuator

> **Note** If you directly connect or cable a signal generator to your device, or if you connect multiple devices together, use an attenuator to avoid damaging the device.

- SCA-14100 RF Signal Conditioning Accessory (optional)

> **Note** Refer to the SCA-14100 Getting Started Guide for information on including this acessory in your setup.

- Ettus USRP X410 Mounting Bracket Kit (optional)

> **Note** Refer to the Ettus USRP X410 Mounting Bracket Kit diagrams **here** to visualize how to setup your device(s) using this kit.
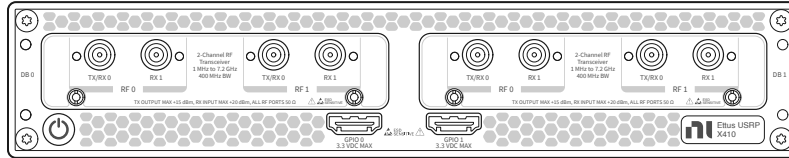
Verifying the System Requirements

To use NI-USRP or UHD, your system must meet certain requirements.

Refer to your driver's readme for more information about minimum system requirements, recommended system, and supported application development environments (ADEs). The **NI-USRP Readme** is available online on the driver software download page or at ni.com/manuals. The **UHD Readme** is available on The USRP Hardware Driver Repository.

Ettus USRP X410 Front Panel, Back Panel, and LEDs

Figure 2. Front Panel

Connector			Description
DB 0, DB 1	RF 0	TX/RX 0	Output and input terminal for the RF signal. TX/RX 0 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input or output channel.
		RX 1	Input terminal for the RF signal. RX 1 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input channel.
	RF 1	TX/RX 0	Output and input terminal for the RF signal. TX/RX 0 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input or output channel.
		RX 1	Input terminal for the RF signal. RX 1 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input channel.
GPIO 0, GPIO 1			General Purpose Input/Output (GPIO) digital terminals. GPIO 0 and GPIO 1 are HDMI Type-A connectors. Output voltage can be configured per individual connector, either 1.8 V (default), 2.5 V, or 3.3 V.

Table 1. Front Panel Connector Descriptions

Figure 3. Back Panel
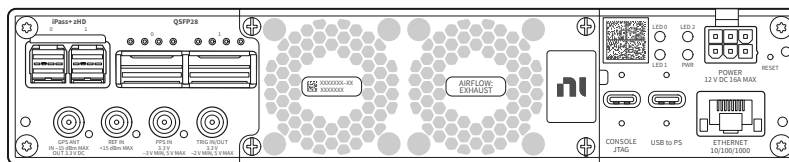
Connector	Description
iPass+ zHD	Provides a PCIe connection to a host PC for using the device with LabVIEW FPGA. Port 0 can be used alone for a Gen 3x4 connection. Port 0 and Port 1 can be used together for a Gen 3x8 connection.
QSFP28	Supports multiple configurations for streaming high-speed, low-latency data, depending on the FPGA image loaded. Designed for speeds of up to 25 Gbps per lane with 4 lanes in each connector and a bandwidth of up to 100 Gbps per connector.

Connector	Description
GPS ANT	Input terminal for the GPS antenna signal. GPS ANT is an SMA (f) connector with a maximum input power of -15 dBm and an output of 3.3 V DC to power an active antenna. ⚠ **Notice** Do not terminate the GPS ANT port if you do not use it.
REF IN	Input terminal for an external reference signal to synchronize the device. REF IN is an SMA (f) connector with an impedance of 50 Ω, and it is a single-ended reference input. REF IN accepts a 10 MHz signal with a minimum input power of 0 dBm (0.632 V pk-pk) and a maximum input power of 15 dBm (3.56 V pk-pk) for a square wave or sine wave.
PPS IN	Input terminal for PPS timing reference. PPS IN is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input channel. PPS IN accepts 0 V to 3.3 V TTL and 0 V to 5 V TTL signals.
TRIG IN/OUT	Input/Output trigger terminal. This port can be used to output the PPS timing reference. TRIG IN/OUT is an SMA (f) connector with an impedance of 50 Ω and is a single-ended port. The output voltage is 0 V to 3.3 V TTL. You can also use this port as a triggered output (TRIG OUT) that you program in LabVIEW FPGA.
POWER	Input that accepts a 12 V ± 5%, 16 A external DC power connector.
CONSOLE JTAG	A USB Type-C port that connects the host computer to the device FPGA for development and debugging. This port provides access to the FPGA JTAG, the PS serial console, and the SCU serial console. It should be used with the 115200 baud, 8 data bits, 1 stop bit, no parity. LabVIEW FPGA does not currently support configuring or programming the device FPGA using the JTAG connector.
USB to PS	A USB Type-C 2.0 port that can be used to connect peripheral devices to the processing system (PS), such as a USB mass storage device. May also be used to complete functions such as writing a new file system to the internal storage.
ETHERNET	1 Gigabit Ethernet Connection that interfaces with the onboard PS. Can be used to connect to the PS through SSH. Can be used for UHD management traffic in Network Mode. By default, the 1 Gb Ethernet connection is configured to use a DHCP assigned IP address.

Table 2. Back Panel Connector Descriptions

LED	Description	Color	State	Indication
LED 0	Indicates the status of the PS.	—	OFF	The processor is powered off.
		Green	Blinking	The frequency of blinks is proportional to the CPU load.

LED	Description	Color	State	Indication
			Solid	The processor is powered on.
LED 1	Indicates the status of the FPGA/ Programmable Logic (PL).	—	OFF	The FPGA/PL is not loaded.
		Green	Solid	The FPGA/PL is loaded.
LED 2	Indicates the status of the onboard eMMC storage activity.	—	OFF	The eMMC is idle.
		Green	Blinking	There is read or write activity on the eMMC.
			Solid	There is read or write activity on the eMMC.
PWR	Indicates the power state of the device.	—	OFF	The device is powered off.
		Green	Solid	The device is powered on and the power is good.
		Red	Solid	The device is in a power error state.
		Amber	Solid	The device is powered off and the power is good.

Table 3. Back Panel LEDs

Note The previous table describes default LED settings. LED functionality can be changed in software.

Selecting Your Driver

Both the USRP Hardware Driver™ (UHD) software API and NI-USRP driver support application development using the Ettus USRP X410.

Select the driver that best suits your application.

Feature	NI-USRP	UHD
Distribution Form	Closed-Source	Open-Source
Host OS	Windows	Windows
	NI Linux Real-Time for PXI	Linux

Feature	NI-USRP	UHD
		Mac OS
Host ADE	LabVIEW	GNU Radio
		C/C++
		MATLAB/Simulink
		Python
FPGA Development Environment	LabVIEW FPGA Module	VHDL
		Verilog
		HDL Coder
		RFNoC
Earliest Version with Ettus USRP X410 Support	21.0	4.1.0.2
Streaming/Host Interface Support	Cabled PCIe/MXI Express[1]	10 Gb Ethernet
		100 Gb Ethernet

Table 4. NI-USRP and UHD Comparison

NI-USRP utilizes portions of UHD and allows for programming in LabVIEW, NI's flagship intuitive development environment. The abstracted design environment helps accelerate the design of wireless systems and makes FPGA programming accessible to those without HDL design expertise. Using LabVIEW, you have the option to program the FPGA and host in a single development environment. Users have the option to customize the FPGA when using NI-USRP.

UHD uses a common, open-source software interface that increases code portability, allowing applications to transition to other USRP SDR platforms when development requirements expand or new platforms are available. UHD offers

cross-platform support for multiple industry-standard development environments and frameworks, including GNU Radio and MATLAB/Simulink.

Refer to the following sections that apply to the driver of your choice to continue setting up your device.

NI-USRP

Setting Up the Device

Ensure that all of your hardware components are powered off before installing.

1. Verify that you have all items included in your device kit and the following additional items.

   - PXIe chassis
   - PXIe-8881 or other PXI controller
   - PXIe-8394 or other PXI bus extension module
   - Network switch
   - PCIe/MXI express cable
   - CAT 5E Ethernet cable

   > **Note** Alternative configurations are possible. For example, the Ettus USRP X410 can also be set up with a host PC and PCIe-8398 instead of the PXI chassis, PXI controller, and PXI bus extension module.

2. Set all items on a flat surface near power outlets and a modem or router.
3. Follow the instructions included with your network switch to connect it to a modem or router.
4. Connect any additional attachments required for your project to the front panel terminals of the Ettus USRP X410.

Installing the Modules into the Chassis

Install the PXIe-8881 or other PXI controller in the first slot of your chassis and then the PXIe-8394 or other PXI bus extension module in a slot to the right of the controller by completing the following steps.

1. Ensure the AC power source is connected to the chassis before installing the module.
   The AC power cord grounds the chassis and protects it from electrical damage while you install the module.
2. Power off the chassis.
3. Inspect the slot pins on the chassis backplane for any bends or damage prior to installation. Do not install a module if the backplane is damaged.
4. Remove the black plastic covers from all the captive screws on the module front panel.
5. Identify a supported slot in the chassis. Refer to the following table to determine which slot types the PXI controller and PXI bus extension module are compatible with. Symbols along the bottom of the chassis indicate the slot type.

NI PXI Express Product	PXI Express Chassis		
	Controller ▲	Peripheral ●	Hybrid ●"
PXI controller	✓	—	—
PXI bus extension module	—	✓	✓

Table 5. Slot Type Compatibility

6. Touch any metal part of the chassis to discharge static electricity.
7. Ensure that the ejector handle is in the downward (unlatched) position.
8. Place the module edges into the module guides at the top and bottom of the chassis. Slide the module into the slot until it is fully inserted.

Figure 4. Module Installation
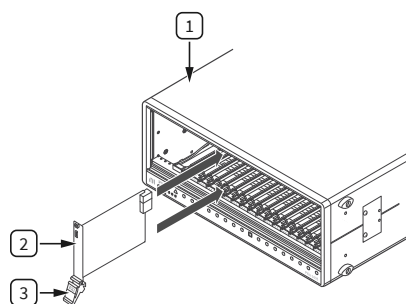
1. Chassis
2. Hardware module
3. Ejector handle in downward (unlatched position)

9. Latch the module in place by pulling up on the ejector handle.
10. Secure the module front panel to the chassis using the front-panel mounting screws.

> **Note** Tightening the top and bottom mounting screws increases mechanical stability and also electrically connects the front panel to the chassis, which can improve the signal quality and electromagnetic performance.

11. Complete steps 5 through 10 for the PXI controller and PXI bus extension module.
12. Cover all empty slots using either filler panels (standard or EMC) or slot blockers with filler panels, depending on your application.
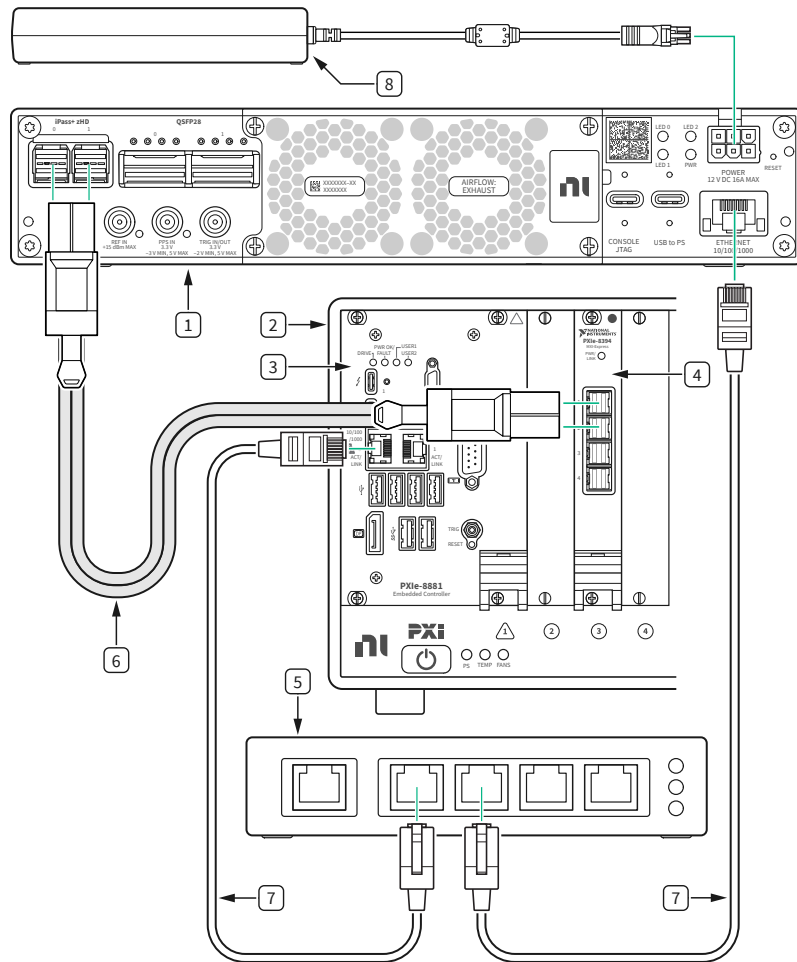
> **Note** For more information about installing slot blockers and filler panels, go to ni.com/r/pxiblocker.

Connecting the Device (NI-USRP)

The following describes one hardware configuration option. Other configurations are possible.

Connect your hardware as shown in the following diagram.

1. Ettus USRP X410

2. PXIe Chassis

3. PXIe-8881 or other PXI Controller

4. PXIe-8394 or other PXI Bus Extension Module

5. Network Switch (optional)

6. PCIe/MXI Express Cable

7. CAT 5E Ethernet Cable

8. Power Supply

Connector Type	Connection 1	Connection 2	Label in Figure
PCIe/MXI Express Cable	Ettus USRP X410, iPass+ zHD Ports	PXI Bus Extension Module, MXI-Express Gen-3 x16 Ports	6

Connector Type	Connection 1	Connection 2	Label in Figure
CAT 5E Ethernet Cable	PXI Controller, 10/100/1000 LAN Port	Network Switch	7
CAT 5E Ethernet Cable	Network Switch	Ettus USRP X410 ETHERNET Port	7
Power Supply	—	Ettus USRP X410 POWER Port	8

Table 7. Ettus USRP X410 Connections (NI-USRP)

> **Note** If you choose not to use the optional network switch, use one CAT 5E Ethernet cable to connect the Ettus USRP X410 to the PXI Controller. This hardware setup requires additional configuration in software. Either set a DHCP server on the PXI controller or set a static IP address on the Ettus USRP X410.

Powering on the Device

1. Connect the power supply to the Ettus USRP X410.
2. Plug the power supply into a wall outlet. Press the power button on the front of your device.
3. Power on the chassis and network switch.

Installing the Software

You must be an Administrator to install NI software on your computer.

1. Install your ADE, LabVIEW.
2. Download the driver software installer from ni.com/downloads.
   NI Package Manager downloads with the driver software to handle the installation. Refer to the NI Package Manager Manual for more information about installing, removing, and upgrading NI software using NI Package Manager.
3. Follow the instructions in the installation prompts.

> ✎ **Note** Windows users may see access and security messages during installation. Accept the prompts to complete the installation.

4. When the installer completes, select Restart in the dialog box that prompts you to restart, shut down, or restart later.

Programming the Device

You can use the NI-USRP instrument driver to create communications applications for the Ettus USRP X410.

Updating the File System

A file system update is required to use your device with NI-USRP.

Use the Windows Command Prompt to establish an SSH connection and update your file system, then use the NI-USRP Configuration Utility to write the new FPGA image to your device.

1. On your host PC running Windows 10 version 1809 or later, select Start » Windows System » Command Prompt to open the Windows Command Prompt.
2. To print information about your device, run the commands cd "C:\Program Files (x86)\National Instruments\NI-USRP\utilities" then uhd_find_devices.exe.
   Information about your device is output in the command prompt window, as shown in the following example.

   Device Address:

   serial: 32190B5

   addr: 10.89.8.21

   claimed: False

   fpga: X4_200

mgmt_addr: 10.89.8.21

product: x410

type: x4xx

Use the combination of numbers and letters following serial: as your unique serial number. The serial number is also printed on a label on the bottom of your device.

Use the IP address following addr: to identify your device in step 7.

3. Use an SSH connection to access your device's management console.

   1. To open an SSH connection, use your unique serial number to run the command ssh root@ni-x4xx-<serial>
      Running this command opens a session with the username root and a blank password.

   2. Type yes and press <Enter> if you are prompted to select whether you want to continue connecting.
      The first time you successfully connect, the following warning is output.

      ```
      Warning: permanently added 'ni-x4xx-<serial>' (ECDSA) to the list of
      known hosts.
      ```

      ```
      root@ni-x4xx-<serial>:~#
      ```

   3. Type exit and press <Enter> to exit the SSH connection.

4. Transfer the embedded file system image to the device
   by running the command scp "C:\Program Files (x86)\National Instruments\NI-USRP\filesystems\usrp_x4xx_fs_v4.1.0.4.mender" root@ni-x4xx-<serial>:/home/root/

   Note You may need to update the mender version referenced in this command depending on the version in use.

5. Update the file system image on your device.

1. To open a new SSH connection, run the command
   ssh root@ni-x4xx-<serial>.

2. Run the command
   mender install /home/root/usrp_x4xx_fs_v4.1.0.4.mender.

   > **Note** The required command may differ depending on the mender version installed.

   The output may take several minutes to print.

3. After the output from the previous command has printed, type reboot and press <Enter> to restart your device.
   Your SSH session closes. The restart should take less than three minutes.

6. Access the device and switch to a new embedded file system image.

   1. Run the command uhd_find_devices.exe.
      Information about your device is output in the command prompt window. If it does not appear, wait three minutes to ensure that the device has restarted and run the command again.

   2. To update the SSH security fingerprint of your device, run the command ssh-keygen -R ni-x4xx-<serial>.

   3. To reconnect to the management console, run the command ssh root@ni-x4xx-<serial>.

   4. Type yes and press <Enter> if you are asked whether you want to continue connecting.

   5. To verify that you are using the updated file system, run the command cat /etc/mender/artifact_info.
      The resulting output contains the version of your file system: artifact_name=<version>_x4xx. If you have successfully updated your file system, the version in the output should be the same as the mender version referenced in step 4.

   6. To commit the update and use the new file system, run the command mender commit.

7. Use NI-USRP Configuration Utility to write the new FPGA image to your device.

1. Select Start » All Programs » National Instruments » NI–USRP Configuration Utility to open NI-USRP Configuration Utility.

2. Select the N2xx/NI–29xx/X410 Image Updater tab of the utility.
Your device should appear in the Device ID column. Verify that the IP address matches the IP address for your device shown in step 2.

3. Select your device.
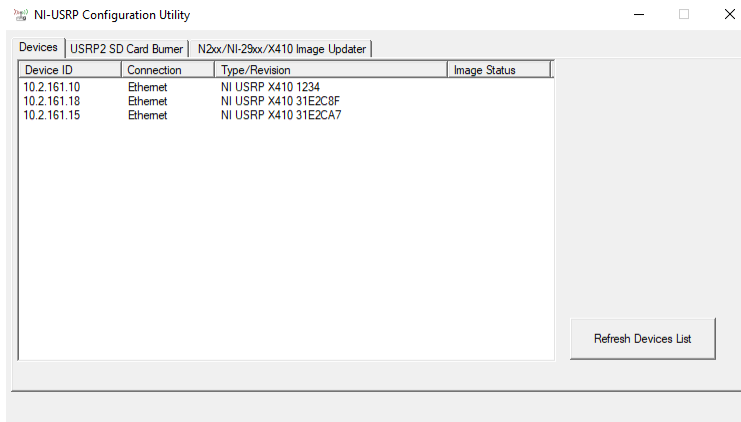
The FPGA Image field should populate.

4. Click WRITE IMAGES and select OK when prompted.
If you are successful, a confirmation will appear on screen.

5. Exit the NI-USRP Configuration Utility and restart your host PC.

Configuring the Ettus USRP X410 in MAX

Use Measurement & Automation Explorer (MAX) to configure your NI hardware. MAX informs other programs about which NI hardware products are in the system and how they are configured. MAX is automatically installed with NI-USRP.

1. Launch MAX.

2. In the configuration tree, expand Devices and Interfaces to see the list of installed NI hardware.
Installed modules appear under the name of their associated chassis.

3. Expand your Chassis tree item.
MAX lists all modules installed in the chassis. Your default names may vary.

> ✎ **Note** If you do not see your module listed, press <F5> to refresh the list of installed modules. If the module is still not listed, power off the system, ensure the module is correctly installed, and restart.

4. Record the identifier MAX assigns to the hardware. Use this identifier to reference the Ettus USRP X410.

Verifying the Device Connection Using LabVIEW

Perform a loopback test to confirm that the device transmits and receives signals and is connected correctly to the host computer.

1. Attach the 30 dB attenuator to one end of the SMA (m)-to-SMA (m) cable.

2. Connect the 30 dB attenuator to the RF 0 - TX/RX 0 connector on the front panel of the USRP device and connect the other end of the SMA (m)-to-SMA (m) cable to the RF 0 - RX 1 port.

3. On the host computer, navigate to ⟨NIDIR⟩ » National Instruments » LabVIEW ⟨Year⟩ » examples » instr » niUSRP.

4. Open the niUSRP EX Tx Continuous Async example VI.

    1. Change the Device Name to the default name listed for you device in MAX.

    2. Change the Antenna to TX/RX0.

    3. Run the VI.

    If the device is transmitting signals, the I/Q graph displays I and Q waveforms.

5. Open the niUSRP EX Rx Continuous Async example VI and run it.

    1. Change the Device Name to the default name listed for you device in MAX.

    2. Change the Antenna to RX1.

    3. Run the VI.

    If the device is transmitting signals, the I/Q graph displays I and Q waveforms.

NI-USRP Examples

NI-USRP includes several example applications that serve as interactive tools, programming models, and building blocks in your own applications.

NI-USRP examples are available in the following locations.

- From the Start menu at Start » All Programs » National Instruments » NI–USRP » Examples
- From the LabVIEW Functions palette at Instrument I/O » Instrument Drivers » NI–USRP » Examples

Note You can access additional examples from the Code Sharing Community at ni.com/usrp.

Note The NI Example Finder does not include NI-USRP examples.

Troubleshooting

If an issue persists after you complete a troubleshooting procedure, search our KnowledgeBase for additional information our technical support engineers create as they answer common user questions and resolve unexpected issues.

Why Can't I Open a Session to My Ettus USRP X410 with LabVIEW?

Ensure that PCIe and Ethernet connections are available between the computer and the X410:

- Verify that the PCIe connection is available by checking that the device is listed in MAX.
- Verify that the Ethernet is available. On your host PC, open Windows Command prompt and run uhd_find_devices.exe. If the device does not show up in the output, the device is not in communication with the host PC. If the

X410 is listed but part of the output reads Reachable: no, then your firewall is blocking some communication with the device. If there are no problems indicated by the output, run uhd_usrp_probe --args addr=<device IP address> to test connectivity over Ethernet. If the command runs successfully but LabVIEW still cannot connect, load a different bitfile on the device.

Why Can't I Detect My Device in LabVIEW?

Complete one or more of the following options to detect your device in LabVIEW:

- Ensure that the device has been updated with an NI-USRP compatible FPGA.
- Ensure that the device is powered on and has a valid IP address.
- Refer to the **NI-USRP Readme** to verify that your version of the NI-USRP instrument driver supports the Ettus USRP X410.

UHD

Setting Up the Device

Ensure that all of your hardware components are powered off before installing.

1. Verify that you have all items included in your device kit and the following additional items.

    - Host PC
    - Network switch
    - CAT 5E Ethernet Cable (optional)
    - One of the following:

        - QSFP28 to QSFP28 Ethernet cable and 100 Gb Ethernet network card
        - QSFP28 to 4xSFP28 Ethernet breakout cable and 10 Gb Ethernet network card

2. Set all items on a flat surface near power outlets and a modem or router.
3. Follow the instructions included with your network switch to connect it to a modem or router.

4. Follow the instructions included with your host PC to connect it to power and complete your computer setup.

5. Connect any additional attachments required for your project to the front panel terminals of the Ettus USRP X410.

Connecting the Device (UHD)

The following describes one hardware configuration option. Other configurations are possible.

Connect your hardware as shown in the following diagram.
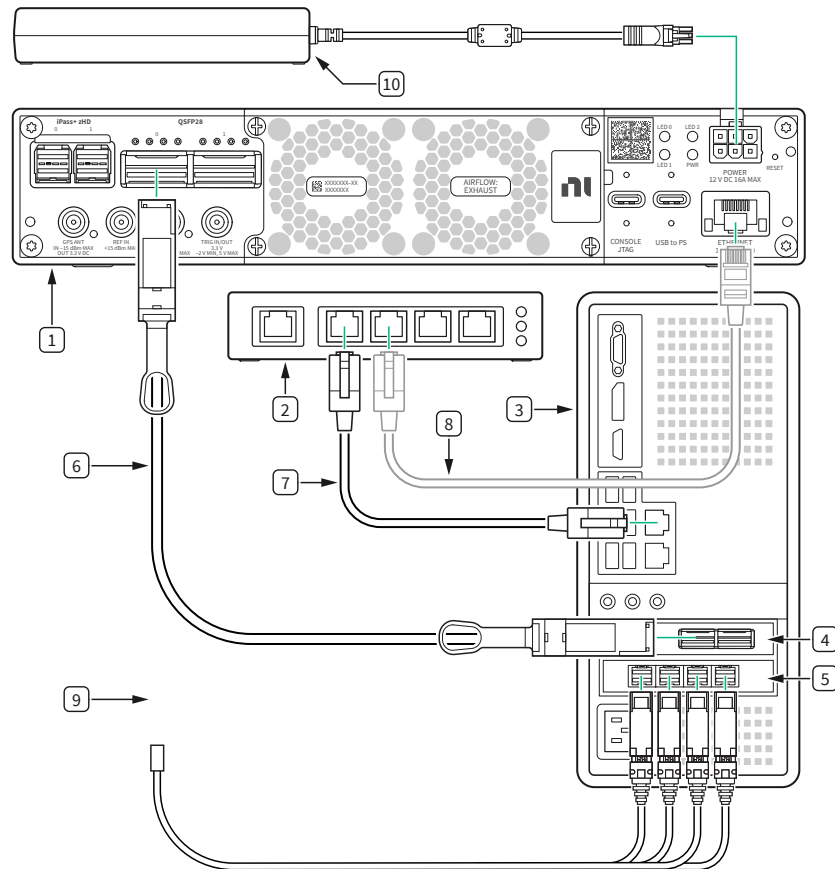
1. Ettus USRP X410
2. Network Switch (optional)
3. Host PC
4. 100 G Ethernet Network Card
5. 10 G Ethernet Network Card
6. QSFP28 to QSFP28 Ethernet Cable (optional)
7. CAT 5E Ethernet Cable (optional)
8. CAT 5E Ethernet Cable (optional)
9. QSFP28 to 4xSFP28 Ethernet Breakout Cable (optional)
10. Power Supply

Connector Type	Connection 1	Connection 2	Label in Figure
QSFP28 to QSFP28 Ethernet Cable	Ettus USRP X410, QSFP28, 0 Port	100 G Ethernet Network Card	6

Connector Type	Connection 1	Connection 2	Label in Figure
CAT 5E Ethernet Cable	Host PC	Network Switch	7
CAT 5E Ethernet Cable	Network Switch	Ettus USRP X410 ETHERNET Port	8
QSFP28 to 4xSFP28 Ethernet Breakout Cable	Ettus USRP X410, QSFP28, 0 Port	10 G Ethernet Network Card	9
Power Supply	—	Ettus USRP X410 POWER Port	10

Table 7. Ettus USRP X410 Connections (UHD)

> **Note** If you choose not to use the optional network switch, use one CAT 5E Ethernet cable to connect the Ettus USRP X410 to the PXI Controller. This hardware setup requires additional configuration in software. Either set a DHCP server on the PXI controller or set a static IP address on the Ettus USRP X410.

Powering on the Device

1. Connect the power supply to the Ettus USRP X410.
2. Plug the power supply into a wall outlet. Press the power button on the front of your device.
3. Power on the host PC and network switch.

Installing the Software

To program your device with UHD, install UHD on your host computer.

Navigate to the installation guide that applies to your operating system.

- Linux: ni.com/r/linuxuhdinstall
- OS X: ni.com/r/osxuhdinstall
- Windows: ni.com/r/windowsuhdinstall

> ✎ **Note** The Ettus USRP X410 requires UHD version 4.1.0.2 or later. If you are using a host machine, the version of UHD on the host machine and device must match.

Programming the Device

For detailed information on programming your device with UHD, navigate to ni.com/r/uhdx410gettingstarted.
There, you can read about how to:

- Utilize the eMMC storage
- Update your filesystem
- Update your FPGA
- Update your security settings
- Establish a serial connection
- Establish an SSH connection
- Customize LED behavior

UHD Examples

Various C++, Python, and RFNoC examples for using the UHD API are provided in the Ettus Research Github Repository, at host » examples. These examples are installed with UHD and will be located at the $prefix » lib » uhd » examples directory of your system.

NI Services

Visit ni.com/support to find support resources including documentation, downloads, and troubleshooting and application development self-help such as tutorials and examples.

Visit ni.com/services to learn about NI service offerings such as calibration options, repair, and replacement.

Visit ni.com/register to register your NI product. Product registration facilitates technical support and ensures that you receive important information updates from NI.

NI corporate headquarters is located at 11500 N Mopac Expwy, Austin, TX, 78759-3504, USA.

[1] Also requires a 1 Gb Ethernet connection to the device.