

# USRP-2974

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The NI USRP-2974 is a high-performance, USRP software defined radio (SDR) stand-alone device for designing and deploying next generation wireless communications systems. The hardware architecture combines two extended-bandwidth daughterboard slots covering 10 MHz ? 6 GHz with up to 160 MHz of baseband bandwidth, multiple high-speed interface options (PCIe, dual 10 GigE), an onboard Intel Core i7 processor, and a large user-programmable Kintex-7 FPGA in a convenient desktop or rack-mountable half-wide 2U form factor.

The USRP-2974 is the equivalent to a USRP X310 with two UBX-160 boards, a GPSDO and an onboard Intel i7 computer. The USRP-2974 comes with NI Linux RTOS pre-installed, but in order to use it with open-source tool-chain, a user will need to install Linux (preferably Fedora or Ubuntu) and then the USRP Hardware driver (UHD). After these have been installed, any other open-source tools can be installed, such as GNU Radio.

- Intel Core i7 6822EQ 2GHz Quad CoreProcessor
- 16GB DDR4 Memory
- 512GB SSD
- USB-to-UART to the CPU
- Xilinx Kintex-7 XC7K410T FPGA
- 14 bit 200 MS/s ADC
- 16 bit 800 MS/s DAC
- Frequency range: 10 MHz - 6 GHz
- Up 160MHz\* bandwidth per channel
- 2 Transmit ports
- 2 Receive ports
- GPSDO
- Multiple high-speed interfaces (Dual 10G, PCIe Express, 1G)



System on module (SoM)	Congatec COM Express conga-TS170
CPU	Intel Core i7 6822EQ (2 GHz Quad Core)
Memory	SO-DIMM DDR4 16 GB
SFP+ <sup>1</sup>	10G ETH connection to the SoM
Cabled PCIe	PCIe Gen 2 x4
MicroUSB <sup>2</sup>	USB-to-UART to the SoM
RJ45	1G ETH host connection

<sup>1</sup> Can be bypassed to the FPGA.

<sup>2</sup> Device port for external host.

#### Transmitter

Number of channels	2
Frequency range	10 MHz to 6 GHz
Frequency step	<1kHz
Maximum output power	5 mW to 100 mW (7 dBm to 20 dBm)
Gain range <sup>1</sup>	0 dB to 31.5 dB
Gain step	0.5 dB
Maximum instantaneous real-time bandwidth	160 MHz

#### Receiver

Number of channels	2
Frequency range	10 MHz to 6 GHz
Frequency step	<1 kHz
Gain range <sup>2</sup>	0 dB to 37.5 dB
Gain step	0.5 dB
Maximum input power	-15 dBm
Noise Figure	5 dB to 7 dB
Maximum instantaneous real-time bandwidth <sup>3</sup>	160MHz

<sup>1</sup> The output power resulting from the gain setting varies over the frequency band and among devices.

<sup>2</sup>The received signal amplitude resulting from the gain setting varies over the frequency band and among devices.

<sup>3</sup>The USRP-2974 receiver path has 84 MHz of bandwidth for center frequencies from 10 MHz to 500 MHz

**NOTE:** As mentioned earlier, the USRP-2974 incorporates 2 UBX-160 daughterboards. Therefore, for more information on RF performance, please see the [UBX hardware resource page](#)

- Minimum version of UHD required: **3.14.1.0**

There are two master clock rates (MCR) supported on the USRP-2974 like on the X310: 200.0 MHz and 184.32 MHz.

The sampling rate must be an integer decimation rate of the MCR. Ideally, this decimation factor should be an even number. An odd decimation factor will result in additional unwanted attenuation (roll-off from the CIC filter in the DUC and DDC blocks in the FPGA). The valid decimation rates are between 1 and 1024.

For the MCR of 200.0 MHz, the achievable sampling rates using an even decimation factor are 200.0, 100.0, 50.0, 33.33, 25.0, 20.0, 16.67, 14.286 Msp/s, ... 195.31 Ksp/s.

For the MCR of 184.32 MHz, the achievable sampling rates using an even decimation factor are 184.32, 92.16, 46.08, 30.72, 23.04, 18.432, 15.36, 13.166 Msp/s, ... 180.0 Ksp/s.

If the desired sampling rate is not directly supported by the hardware, then it will be necessary to re-sample in software. This can be done in C++ using libraries such as Liquid DSP [1], or can be done in GNU Radio, in which there are three blocks that perform sampling rate conversion.

(L x W x H) 29.08 cm x 21.84 cm x 7.98 cm (11.45 in. x 8.60 in. x 3.14 in.)

3.34 kg (7.35 lb)

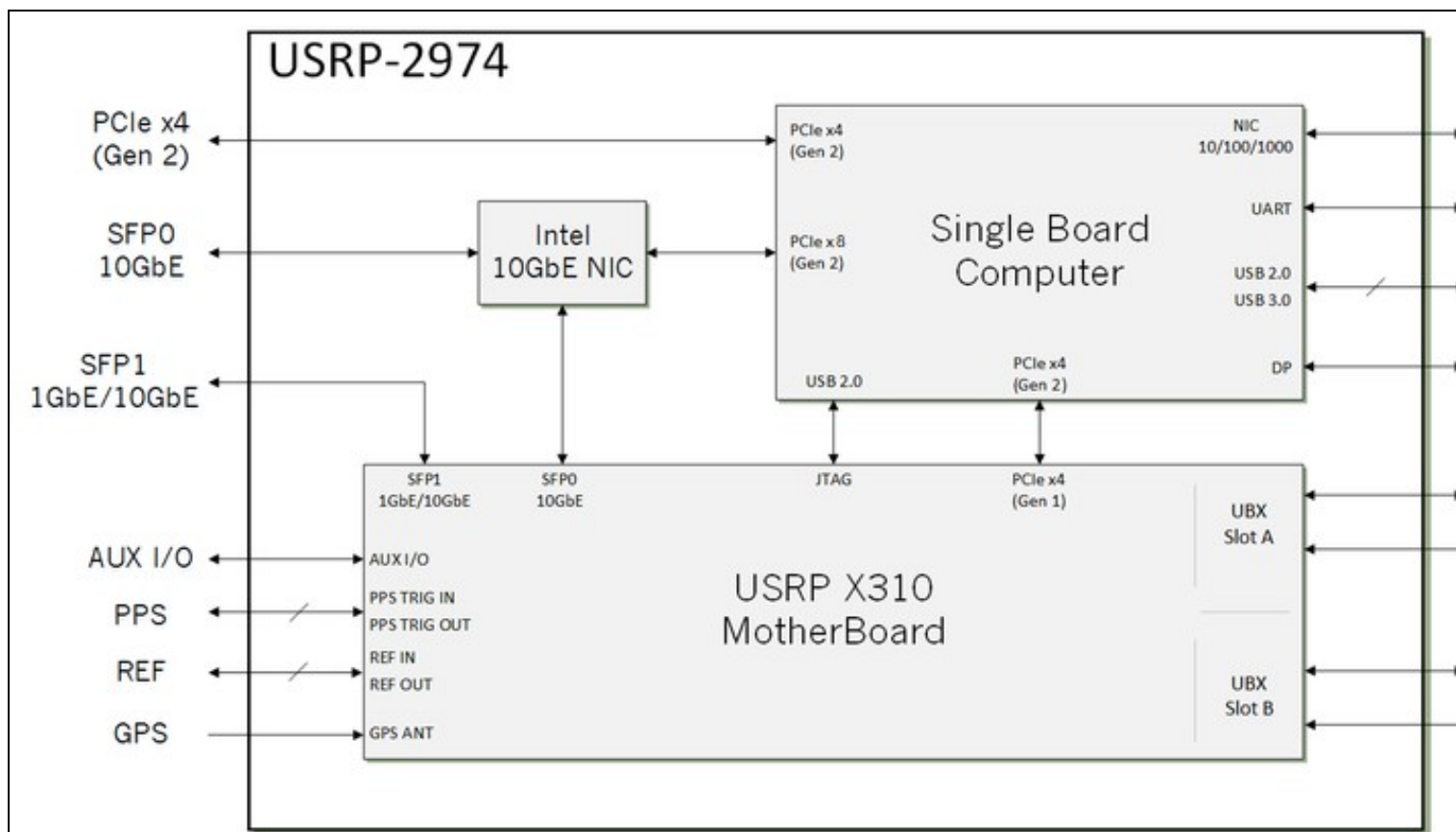
Voltage range 14.25 V to 15.75 V DC

Current 10 A, maximum

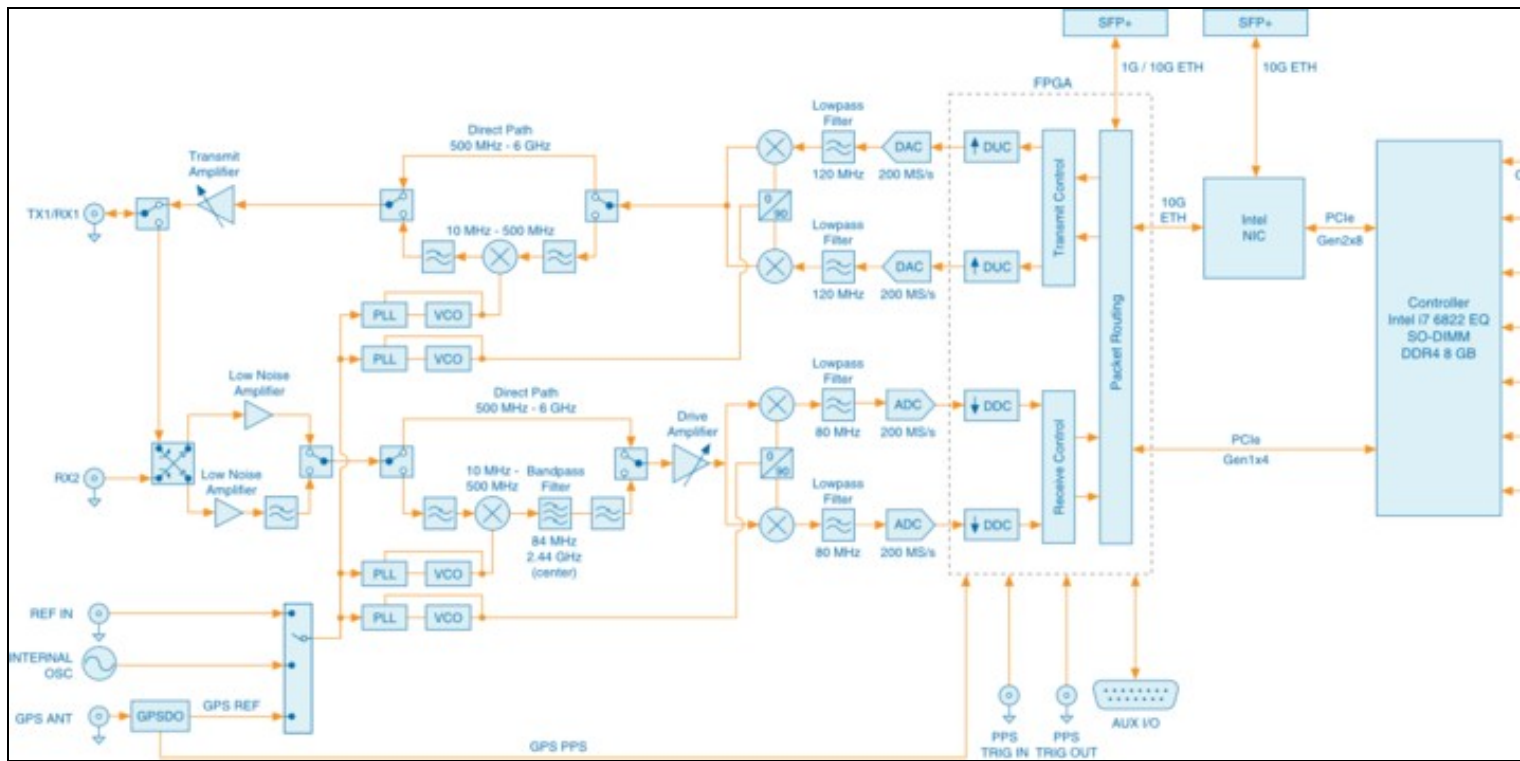
Power 150 W, maximum

**NOTE:** Indoor use only

- 0 °C to 50 °C
- 2,000 m (800 mbar) (at 25 °C ambient temperature)
- 10% to 90% non-condensing
- 2



High Level Block Diagram of the USRP 2974



Detailed System Block Diagram

Because the USRP-2974 is a combination of an Intel i7 SOM and an X310 USRP, a user can reference the X310 Schematics.

#### X310 Schematics

Part Number	Description	Schematic ID (Page)
conga-TS170	System on Module (SoM)	
XC7K410T	FPGA	U23 (3,5,8,9,10,18)
AD9146	Dual Channel, 16-Bit, 1230 MSPS DAC	U12, U36 (7)
ADS62P48	Dual Channel, 14-Bit 210 MSPS ADC	U11, U35 (6)
FIN1002	High Speed Differential Receiver	U3, U5, U31, U32 (4)
24LC256T	EEPROM	U530 (11)
LMK04816BISQ/NOPB_1/3	Jitter Cleaner With Dual Loop PLLs	U531 (11)
SY89547LMGTR	Multiplexer	U506 (12)
SN74AUP1T17	Single Schmitt-Trigger Buffer Gate	U6, U519 (12)
TPS54620RGYT	Synchronous Step Down SWIFT? Converter	U515 (21); U516 (26)
LT1764EQ-3.3	Voltage Regulator	U27 (21); U516 (26)
TPS7A47	Voltage Regulator	U28, U532 (21)
LTC3603EUF_TRPBF	Monolithic Synchronous Step-Down Regulator	U517 (23); U500 (25); U514, U513 (27)
TPS77625	Low-Dropout Voltage Regulators	U30 (23)
TPS79318_SM	Low-Dropout Voltage Regulators	U510 (27)
OSC-96MHZ-724821-01	Voltage Controlled Crystal Oscillator	U25 (11)

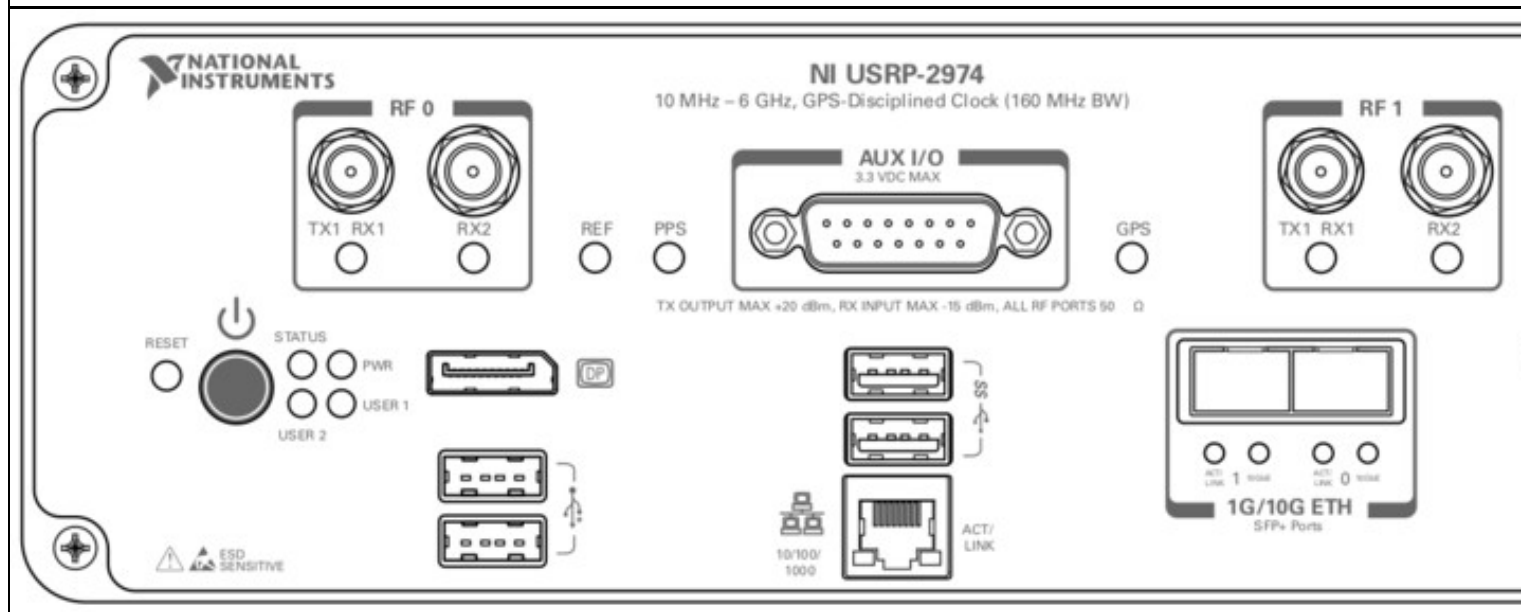
FPGA	Kintex-7 XC7K410T
DRAM	1 GB
Baseband analog-to-digital converter	14 bit
(ADC) resolution	16 bit
Baseband digital-to-analog converter	16 bit
(DAC) resolution	16 bit
ADC spurious-free dynamic range (sFDR)	88 dB
DAC sFDR	80 dB
Maximum I/Q sample rate	200 MS/s
SFP+ <sup>1</sup>	High speed serial link to one of the FPGA GTX transceivers

<sup>1</sup>Can be bypassed to the SoM if using the 10 GbE as protocol.

The Verilog code for the FPGA in the NI USRP-2974 is open-source, and users are free to modify and customize it for their needs. However, certain modifications may result in either bricking the device, or even in physical damage to the unit. Specifically, changing the I/O interface of the FPGA in any way (do not remove any of the I/O for the PCIe interface, such as `x300_pcie_int` and `LvFpga_Chinch_Interface`), or modifying the pin and timing constraint files, could result in physical damage to other components on the motherboard, external to the FPGA, and doing this will void the warranty. Also, even if the PCIe interface is not being used, you cannot remove or reassign these pins in the constraint file. The constraint files should not be modified. Please note that modifications to the FPGA are made at the risk of the user, and may not be covered by the warranty of the device.

Follow the links below for additional information on configuring each interface for the USRP-2974.

- [Dual 10 Gigabit Ethernet - 200 MS/s Full Duplex @ 16-bit](#)
- [PCIe Express \(Desktop\) - 200 MS/s Full Duplex @ 16-bit](#)
- [1 Gigabit Ethernet - 25 MS/s Full Duplex @ 16-bit](#)



**Connector**

**Use**

RF 0	TX1	Input and output terminal for the RF signal. TX1 RX1 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input or output channel.
	RX1	
	RX2	Input terminal for the RF signal. RX2 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input channel.
AUX I/O		General-purpose I/O (GPIO) port. AUX I/O is controlled by the FPGA.
RF 1	TX1	Input and output terminal for the RF signal. TX1 RX1 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input or output channel.
	RX1	
	RX2	Input terminal for the RF signal. RX2 is an SMA (f) connector with an impedance of 50 Ω and is a single-ended input channel.
DP		DisplayPort connector to connect one monitor for your controller.
USB2.0		USB ports that support common USB peripheral devices such as flash drives, hard drives, keyboards, and mice.
USB3.0		USB ports that support common USB peripheral devices such as flash drives, hard drives, keyboards, and mice.
1G ETH		RJ45 port used for 1G ETH connectivity to other ethernet devices.

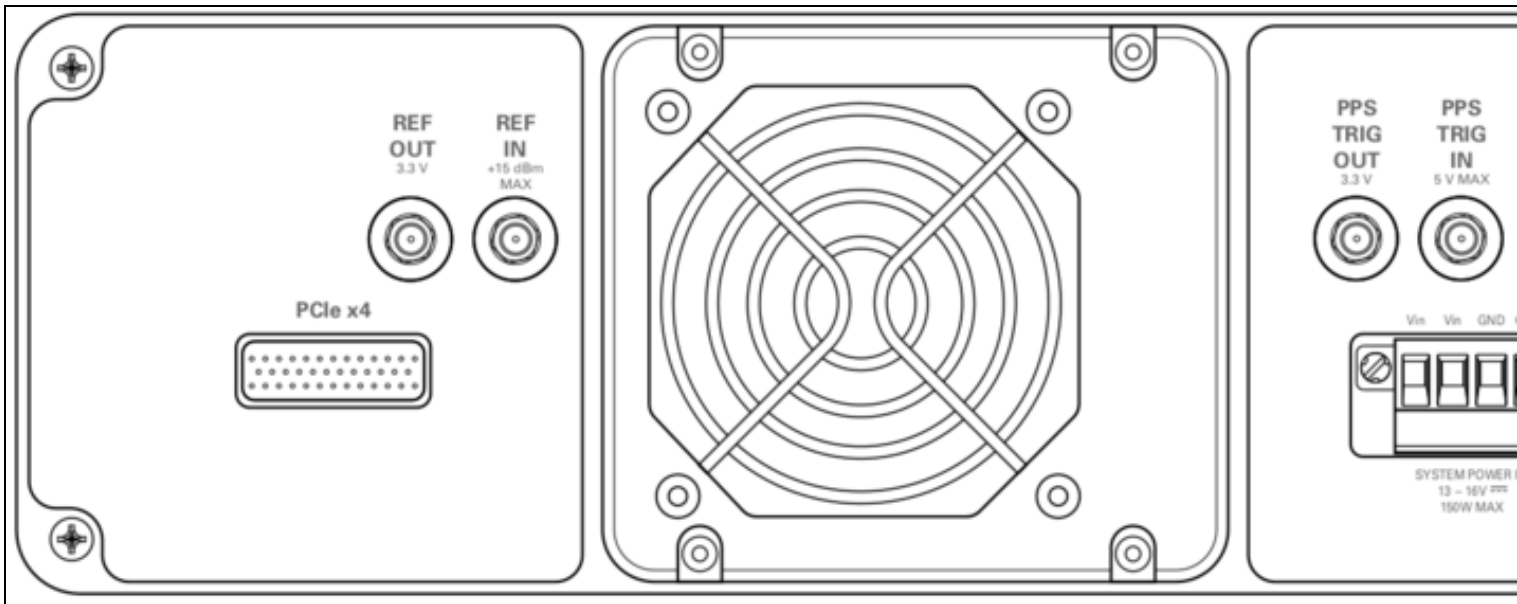
?USB USB port used for UART connectivity to the controller.

1G/10G ETH 0 SFP+ port used for 10G ETH connectivity to other ethernet devices. Connects to the embedded Linux computer for communication with LabVIEW RT.

1G/10G ETH 1 SFP+ port used for 1G/10G ETH connectivity to other ethernet devices. Connects to the FPGA. Not currently supported in LabVIEW Communications System Design Suite.

LED	Description	Color	State	Indication	
RF 0	TX1	Indicates the transmit status of the device	OFF	?	The device is not active.
		Red	Solid	The device is transmitting data.	
	RX1	Indicates the receive status of the device.	Green	Solid	The device is receiving data.
RF 1	TX1	Indicates the transmit status of the device	OFF	?	The device is not active.
		Red	Solid	The device is transmitting data.	
	RX1	Indicates the receive status of the device.	Green	Solid	The device is receiving data.
Status	TX2	Indicates the status of the device	OFF	?	The device is not receiving data.
		Green	Solid	The device is receiving data.	
	RX2	Indicates the status of the device	OFF	?	The device initialized successfully and is ready for use.
PPS	REF	Indicates the status of the reference signal.	Green	Blinking	The device is not locked to the reference signal.
		Solid	The device is locked to the reference signal.		
	PPS	Indicates the pulse per second (PPS).	OFF	?	There is no PPS timing reference signal, or the device is not locked to the reference signal.
GPS	GPS	Indicates whether the GPSDO is locked.	Green	Blinking	The device is locked to the PPS timing reference signal.
		Solid	The GPSDO is locked.		
	GPS	Indicates whether the GPSDO is locked.	OFF	?	There is no GPSDO or the GPSDO is not locked.
PWR	10/100/1000	Indicates the speed of the Gigabit Ethernet link.	Green	Solid	No link, or 10 Mbps link.
		Green	Solid	100 Mbps link.	
	Amber	Solid	1,000 Mbps link.		
ACT/LINK	ACT/LINK	Indicates the Gigabit Ethernet link activity or status.	OFF	?	No link has been established.
		Green	Solid	A link has been negotiated.	
	Blinking	Activity on the link.			
1G/10G ETH 0	ACT/LINK	Indicates the status of the SFP+ port.	OFF	?	The link is down.
		Green	Solid	The link is up.	
	Blinking	The link is active (transmitting and receiving).			
1G/10G ETH 1	10GbE	Indicates the status of the 10G ETH link.	OFF	?	The 10G ETH link is down.
		Green	Solid	The 10G ETH link is up.	
	10GbE	Indicates the status of the 10G ETH link.	OFF	?	The 10G ETH link is down.
Green	Solid	The 10G ETH link is up.			





Connector	Use
REF OUT	Output terminal for an external reference signal for the LO on the device. REF OUT is an SMA (f) connector with an impedance of 50 $\Omega$ , and it is a single-ended reference output. The output signal at this connector is 10 MHz at 3.3 V.
REF IN	Input terminal for an external reference signal for the LO on the device. REF IN is an SMA (f) connector with an impedance of 50 $\Omega$ , 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 Vpk-pk) and a maximum input power of 15 dBm (3.56 Vpk-pk). The optimal signal is a square wave.
PPS TRIG OUT	Output terminal for the PPS timing reference. PPS TRIG OUT is an SMA (f) connector with an impedance of 50 $\Omega$ and is a single-ended input. The output signal is 0 V to 3.3 V TTL. You can also use this port as a triggered output (TRIG OUT) that you program with the PPS Trig Out I/O signal.
PPS TRIG IN	Input terminal for PPS timing reference. PPS TRIG IN is an SMA (f) connector with an impedance of 50 $\Omega$ and is a single-ended input channel. PPS TRIG IN accepts 0 V to 3.3 V TTL and 0 V to 5 V TTL signals. You can also use this port as a triggered input (TRIG IN) that you control using NI-USRP software.
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 DC 5 V to power an active antenna. <b>Notice:</b> Do not terminate the GPS ANT port if you do not use it.
PCIe x4	Port for a PCI Express Generation 2, x4 bus connection through an MXI Express four-lane cable. Can be used to connect an external USRP device or external chassis.
SYSTEM POWER IN	Input that accepts a 15 V $\pm$ 5%, 10 A external DC power connector.

An external 10 MHz reference clock may be used. The optimal signal is a square wave as created by the [OctoClock/CDDA-2990](#). The input signal power level of the reference clock must not exceed +15 dBm.

Using a PPS signal for timestamp synchronization requires a square wave signal with the following a 5Vpp amplitude.

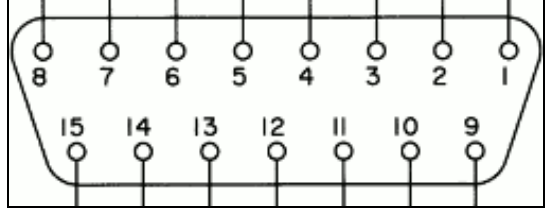
To test the PPS input, you can use the following tool from the UHD examples:

- <args> are device address arguments (optional if only one USRP device is on your machine)

```
cd <install-path>/lib/uhd/examples ./test_pps_input ?args=<args>
```

The GPIO port is not meant to drive big loads. You should not try to source more than 5mA per pin.

The +3.3V is for ESD clamping purposes only and not designed to deliver high currents.



The hardware power on state and UHD initial state for the front-panel GPIOs is high-Z. For the X3xx, there are no external pull-ups/pull-downs for the GPIO pins, but the FPGAs do have them and they are configured as follows: X3xx: pull-down.

- Pin 1: +3.3V
- Pin 2: Data[0]
- Pin 3: Data[1]
- Pin 4: Data[2]
- Pin 5: Data[3]
- Pin 6: Data[4]

- Pin 7: Data[5]
- Pin 8: Data[6]
- Pin 9: Data[7]
- Pin 10: Data[8]
- Pin 11: Data[9]
- Pin 12: Data[10]
- Pin 13: Data[11]
- Pin 14: 0V
- Pin 15: 0V

**Note:** Please see the [E3x0/X3x0 GPIO API](#) for information on configuring and using the GPIO bus.

As of December 1st, 2010 all NI/Ettus Research products are RoHS compliant unless otherwise noted. More information can be found at <http://ettus.com/legal/rohs-information>

## Management Methods for Controlling Pollution Caused by Electronic Information Products Regulation

### Chinese Customers

National Instruments is in compliance with the Chinese policy on the Restriction of Hazardous Substances (RoHS) used in Electronic Information Products. For more information about the National Instruments China RoHS compliance, visit [ni.com/environment/rohs\\_china](http://ni.com/environment/rohs_china).

### FPGA Resources

### UHD Stable Binaries

### UHD Source Code on Github

The USRP-2974 provides three interface options: 1 Gigabit Ethernet (1 GigE), 10 Gigabit Ethernet (10 GigE), and PCI-Express (PCIe). The PCIe interface is always available regardless of what FPGA image is loaded. Ettus ships two FPGA image variants, the HG or HGS image which has one 1 GigE interfaces and one 10 GigE interfaces, and the XG image which has two 10 GigE interfaces. Generally, Ettus Research recommends using 10 GigE to achieve the maximum throughput available from the USRP-2974. PCIe is recommended for applications that require the lowest possible latency, which is a desirable characteristic for PHY/MAC research. If your application does not require the full bandwidth of the USRP-2974, the 1 GigE interface serves as a cost-effective fall-back option. Ettus Research provides a complete interface kit for each of these options, which is also shown in the following table.

### Interface Performance Summary

Interface	Throughput (MS/s @ 16-bit)	Target	Recommended Kit
1 Gigabit	25 MS/s	Desktop/Laptop	SFP Adapter + GigE Cable
10 Gigabit	200 MS/s	Desktop	10 GigE Interface Kit
PCI-Express (PCIe, 4 lane)	200 MS/S	Desktop	PCI-Express Desktop Kit

In order to utilize the dual 10 Gigabit Ethernet interfaces, ensure the XG image is installed ([see FPGA Image Flavors](#)). In addition to burning the prerequisite FPGA image, it may also be necessary to tune the network interface card (NIC) to eliminate drops (Ds) and reduce overflows (Os). This is done by increasing the number of RX descriptors ([see Linux specific notes](#)).

The `benchmark_rate` tool can be used to test this capability. Run the following commands to test the X-series USRP over both 10 Gigabit Ethernet interfaces with the maximum rate of 200 Msp/s per channel:

```
cd <install-path>/lib/uhd/examples
./benchmark_rate --args="type=x300,addr=<Primary IP>,second_addr=<secondary IP>" --channels="0,1" --rx_rate 200e6
```

The second interface is specified by the extra argument `second_addr`.

### Recommended 10 Gigabit Ethernet Cards

- Intel X520-DA2
  - ◆ Intel® Ethernet Converged Network Adapter X520-DA2
- Intel X520-DA1
  - ◆ Intel® Ethernet Converged Network Adapter X520-DA1
- Intel X710-DA2
  - ◆ Intel® Ethernet Converged Network Adapter X710-DA2
- Intel X710-DA4
  - ◆ Intel® Ethernet Converged Network Adapter X710-DA4
- Mellanox MCX4121A-ACAT
  - ◆ Mellanox MCX4121A-ACAT

The USRP-2794 has a high-accuracy GPS-disciplined oscillator (GPSDO). The GPSDO improves the accuracy of the internal frequency reference to 20 ppb, or 0.1 ppb if the GPS is synchronized to the GPS constellation. When synchronized to the GPS constellation, all USRP? devices will also be synchronized in time within 50 ns.

- Support GPSDO NMEA Strings
- JacksonLabs LC\_XO

Frequency Reference	Internal TCXO	GPS-Disciplined Clock
	TCXO	OCXO



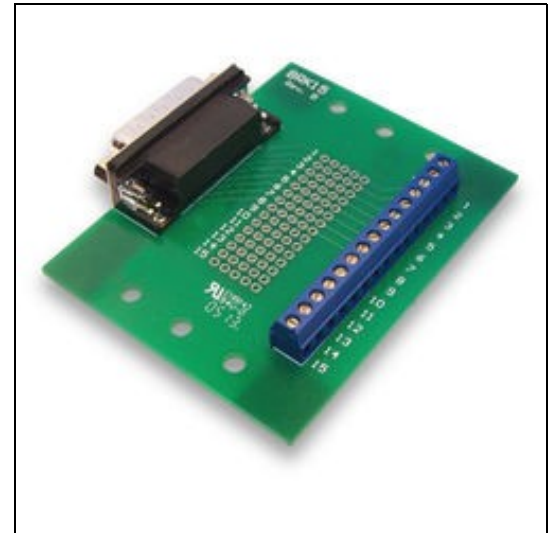
Frequency Accuracy	$\pm 2.5\text{ppm}$	$\pm 25\text{ppb}$
Frequency Accuracy	$\pm 2,500\text{ Hz @ 1 GHz}$	$\pm 25\text{ Hz @ 1 GHz}$
Frequency Accuracy (GPS-Disciplined)		$\pm 0.01\text{ppb}$ $\sim \pm 0.01\text{ Hz @ 1 GHz}$
GPS Time Sync Accuracy		$\pm 50\text{ns to UTC Time}^{**}$
10 MHz Reference Phase Drift with GPS Sync		$<\pm 20\text{ns After 1 Hour}^{**}$

You can query the lock status with the `gps_locked` sensor, as well as obtain raw NMEA sentences using the `gps_gprmc`, and `gps_gpgga` sensors. Location information can be parsed out of the `gps_gpgga` sensor by using `gpsd` or another NMEA parser.

This General Purpose Input/output (GPIO) breakout kit provides access to general purpose digital I/O signals with simple terminal blocks, and a prototyping area where wires and components can be soldered. Each GPIO pin is connected to an FPGA digital line allowing it to be configured as an input, or an output, using the various software frameworks that support the USRP? GPIO.

These GPIO signals can serve the following functions:

- Control of external devices, such as power amplifiers and RF switches
- Provide output signals that can help with debugging
- Provide observables to be analyzed by oscilloscopes or other external equipment
- Accept input from external devices for local, software-based triggering
- Implement a protocol line such as SPI or I2C



- 1 GPIO Breakout Board
- 1 DB-15, 1-meter cable
- GPIO Quick Reference

The GPIO signals exposed with this breakout kit are routed directly to the USRP device's FPGA with limited protection circuitry. However, the user must take precautionary measures to ensure input/output signals meet the specifications shown in this document. Over voltage, excess current draw, and other conditions can damage the USRP device and void the warranty. Special care should be taken when the USRP is powered off.

The GPIO breakout board can be mounted directly to the DB15 connector of a USRP ? device, or mounted remotely with the cable provided in this kit. The screws on the DB15 connector of the breakout board must be removed to mount the board directly. For remote mounting, the breakout board is supplied with rubber standoffs to avoid scratching surfaces, and several through-holes for hard mounting with screws or other hardware (not provided).

When used with UHD, or other third party frameworks that leverage UHD, the GPIO expansion can be controlled with simple API calls. For more information, on the C++ API, and examples of how to use the GPIO in frameworks such as GNU Radio, please see the [Application Notes](#) section of the [Ettus Research Knowledge Base](#).

Parameter	Typical
<b>Configured as Input</b>	
Default Voltage Standard	3.3V LVCMOS
Voltage High Threshold	2.0V
Voltage Low Threshold	0.8V
Voltage Input Limits (no damage)	-0.3V/3.45V
<b>Configured as Output</b>	
Voltage Standard	3.3V LVCMOS
Voltage High Output	2.8V
Voltage Low Output	0.4V
Current Source Capability	12 mA
Output Source Impedance	>33 ohms typical

The GPSDO Mini Kit will improve the accuracy of the USRP reference clock, even if it does not receive signals from the GPS Constellation. However, to achieve the best accuracy possible, and to achieve global timing alignment across multiple USRPs, Ettus Research recommends the GPSDO Mini Antenna Kit.

Multiple USRP-2974s can be synchronized for coherent operation by sharing a common 10 MHz and 1 PPS signal. We recommend using a star-distribution topology with an OctoClock or OctoClock-G, as seen in Figure 4. This requires matched length cables to be used for both 10 MHz and 1 PPS.

For more information about MIMO operation, please see the MIMO and Synchronization Application Note.

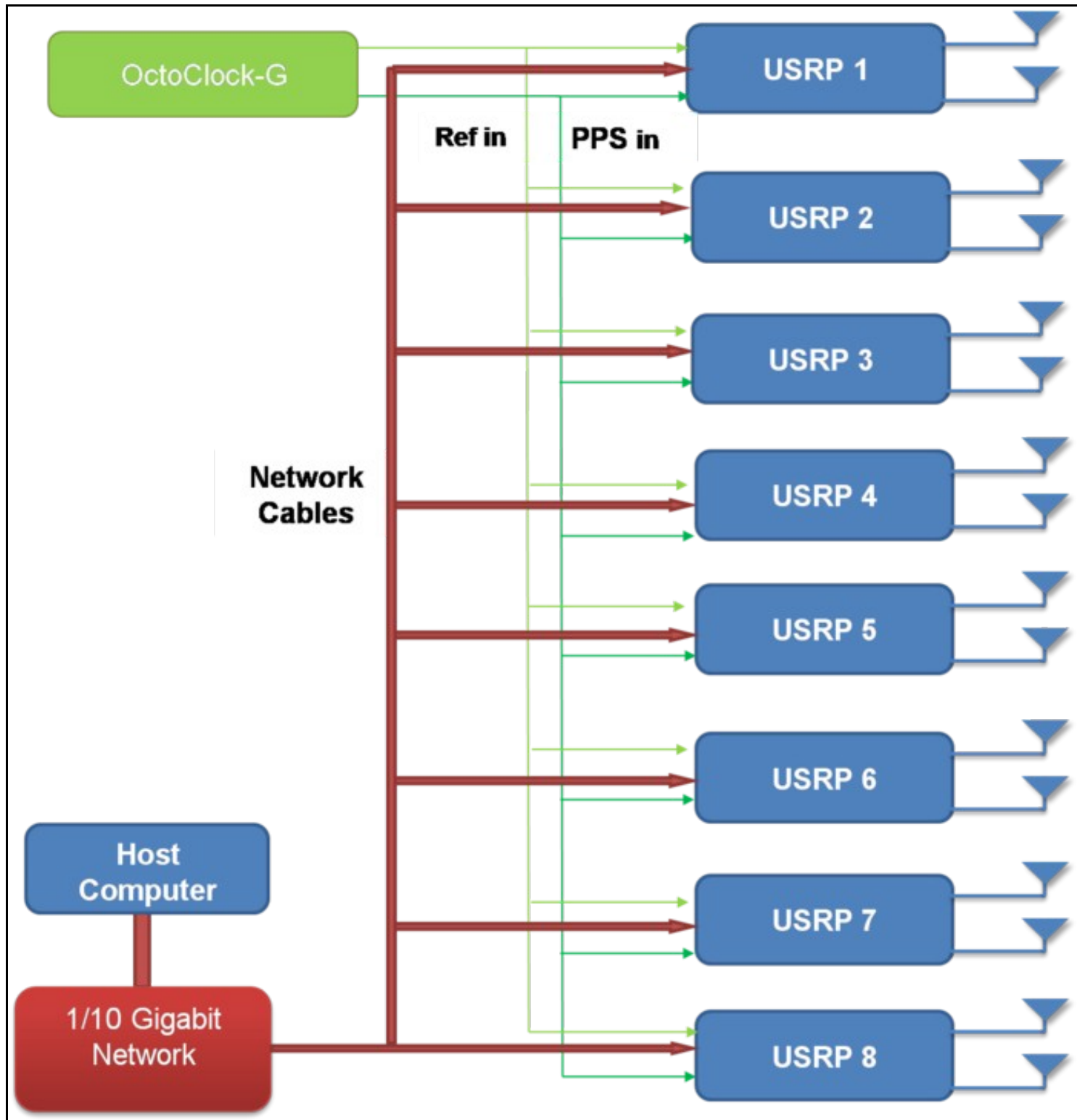


Figure 4 - Star-Distribution of 10 MHz/PPS Signals with OctoClock

• **What is the bandwidth of the USRP-2974**

The ADC rate on each analog RX channel is 200 MS/s quadrature, which provides a theoretical analog bandwidth of approximately 80% of the Nyquist bandwidth of +/- 100 MHz (+/- 80 MHz around the center frequency). The resulting maximum theoretical analog bandwidth is 160 MHz.

FPGA Processing Bandwidth: Up to 200 MS/s quadrature.

Host Bandwidth: Up to 200 MS/s quadrature, dependent on selected interface

For more information about achieving the maximum bandwidth with a USRP-2974, please see the "USRP X300/X310 Configuration Guide" or the "USRP System Bandwidth" application note.

- **How can I program the USRP-2974**

Like all other USRP models, the USRP-2974 is compatible with the USRP Hardware Driver (UHD) architecture. The UHD architecture is a common driver that allows users to develop and execute applications on the onboard or host computer. UHD provides a direct C++ API to control and stream to/from the USRP-2974. It also provides compatibility with a variety of third-party software frameworks including GNU Radio, LabVIEW, and MATLAB. You may also customize the FPGA image provided with UHD to integrate your own signal processing. For more information about UHD, and supported software frameworks, please see:

<http://files.ettus.com/manual/>

- **How do I update the FPGA images and firmware with the latest from UHD**

You can find more information about updating the FPGA image through PCIe, 1/10 GigE, and JTAG [here](#).

- **How can I modify the FPGA of the USRP-2974**

The source code (Verilog) for the USRP-2974 is available in the UHD repository. The build process leverages the existing CMAKE build system used to compile the host-side driver. A Linux-based setup will provide the best results.

Which FPGA toolchain required to build the FPGA images will depend upon your version of UHD. For more details please see the [UHD Software Resource](#) page.

- **How much free space is available in the USRP-2974 FPGA**

Please see the [#Utilization statistics](#) section of this resources page for more information.

- **What frequency range does the USRP-2974 cover**

10MHz to 6GHz.

- **What components do I need to purchase for a complete USRP-2974 system**

The USRP-2974 is a complete stand alone SDR. Additional components might include RF filters, antennas, RF power amplifiers or other RF components needed for a specific application.