Selecting a USRP Device

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This AN explores the USRP family at a high level, compares devices across several primary features, and walks the reader through the process of selecting a particular device for the their application.

The USRP Product Selector will help you choose the Ettus Research USRP Software Defined Radio products that are the best fit for your application. Based on your answers to a series of questions, the USRP Product Selector will generate a PDF price quote and e-mail it to you. The Ettus Research sales team may follow up with you to answer any additional questions that you might have.

This guide is provided by Ettus Research to help users select the most appropriate Universal Software Radio Peripheral (USRP?) for their specific application. In order to make the selection process as straightforward as possible, a table showing various features is provided as a basis for the selection process.

If you are new to the USRP family of products, software defined radio, or digital signal processing in general, it may be useful to perform some simulation of the signals you wish to manipulate before selecting USRP hardware. Simulating signals and algorithms in software frameworks such as GNU Radio or LabVIEW will ensure a proper understanding of various concepts, such as Nyquist theorem, ADC/DAC and limitations, for example. Understanding the basics of signal theory and digital signal processing is the first step towards understanding how to make the best use of an appropriate USRP model. The Suggested Reading page provides access to several resources that may be helpful in understanding the basics.

Table 1 shows USRP/daughterboard combinations commonly used in various application areas. While Table 1 can serve as a starting point for selecting a USRP device, Ettus Research recommends new users evaluate their application requirements against the specifications of the USRP devices. sections of this document will assist in the selection process.

Application Area	Common USRP Model	Common Daughterboard
PHY/MAC Research	N200/N210 X300/X310 N300/N310[1]	WBX/SBX/UBX/CBX
Radar Research	X300/X310	SBX/UBX
OpenBTS	B200/B210[1] X300/X310 E310/E312[1] N200/N210 N300/N310[1] E320[1]	WBX/SBX/UBX/CBX
Amarisoft LTE	N200/N210 X300/X310 B210[1] E320[1] N300/N310[1]	WBX/SBX/UBX/CBX
Education	B200/B210[1] X300/X310 E310/E312[1] N200/N210 N300/N310[1] E320[1]	WBX/SBX/CBX/UBX
HF Communications	N200/N210 X300/X310	LFRX/LFTX
Signals Intelligence	X300/X310 N300/N310[1] E320[1]	SBX/UBX
Distributed RF Sensors	E310/E312 N300/N310 E320	N/A
Mobile Radios	E310/E312 E320	N/A
MIMO	X300/X310 N310[1]	SBX/UBX
Phased Array	X300/X310	SBX/UBX
FPGA Computing	X310 N310[1] E320[1]	WBX/SBX/UBX/CBX
Embedded Computing	E310/E312 E320	N/A
Small Form Factor (SWaP)	B200mini/205mini/206mini E310/E312 E320	N/A

Table 1 - Recommended USRP Selection for Various Application Areas

[1] - The B2xx, E3xx and N3xx do not support swappable daughterboards

Table 2 shows the key characteristics of all USRP models available from Ettus Research. The table is useful for determining the interface type, bandwidth capabilities, and synchronization mechanisms specified for each USRP model. You can use this information, and the requirements for the application in question, to select a USRP radio.

USRP Model	Interface	Total Host BW (MSPS 16b/8b)	Daughterboard Slots	ADC Resolution (bits)	ADC Rate (MSPS)	DAC Resolution (bits)	DAC Rate (MSPS)	MIMO Capable	Internal GPS Disciplined Oscillator (Optional)	1 PPS/Ref Inputs

N210	GigE	25/50	1	14	100	16	400	Yes	Yes	Yes
N200	GigE	25/50	1	14	100	16	400	Yes	Yes	Yes
N300	1 GigE 10 GigE	153.6, 125, 122.88	2	16	153.6, 125, 122.88	14	153.6, 125, 122.88	Yes	Yes	Yes
N310	1 GigE 10 GigE	153.6, 125, 122.88	2	16	153.6, 125, 122.88	14	153.6, 125, 122.88	Yes	Yes	Yes
B200mini	USB 3.0	61.44	N/A	12	61.44	12	61.44	No	No	Yes
B205mini	USB 3.0	61.44	N/A	12	61.44	12	61.44	No	No	Yes
B206mini	USB 3.0	61.44	N/A	12	61.44	12	61.44	No	No	Yes
B200	USB 3.0	61.44	N/A	12	61.44	12	61.44	No	Yes	Yes
B210	USB 3.0	61.44	N/A	12	61.44	12	61.44	Yes	Yes	Yes
X300	USB 3.0 1 GigE 10 GigE PCIe	200	2	14	200	16	800	Yes	Yes	Yes
X310	USB 3.0 1 GigE 10 GigE PCIe	200	2	14	200	16	800	Yes	Yes	Yes
E310	Embedded	61.44	N/A	12	61.44	12	61.44	Yes	No	Yes
E312	Embedded	61.44	N/A	12	61.44	12	61.44	Yes	No	Yes
E320	Embedded 1 GigE 10 GigE	61.44	N/A	12	61.44	12	61.44	Yes	Yes	Yes

Table 2 - USRP Characteristics by Model

The following sections cover frequently asked questions in choosing a USRP device that?s right for your application.

Do I want to perform processing on a host PC, or operate the USRP device in a standalone fashion?

This is an obvious differentiator of the USRP Embedded Series. If you need the USRP to operate a USRP radio without a host PC, the USRP E310/E312/E320 is the most appropriate. The USRP E310/E312/E320 is ideal for applications that might require mobile transceivers or distributed RF sensors. Unless the user has a clear requirement for embedded operation, Ettus Research recommends the USRP N200, N210, B200/210/200mini/205mini/206mini, X300, X310, N300 or N310. Developing with a host-based platform typically involves less risk and will require less effort to optimize various pieces of the software radio.

In many cases it may be easier to develop with a USRP B200/210/200mini/205mini/206mini or USRP N200/N210, then port the code to the USRP E310/E312/E320. The UHD (USRP Hardware Driver) enables this portability. You must also consider the different processing capabilities of the host machine and ARM processor used on the USRP E310/E312/E320.

Do I Need Synchronization and/or MIMO Capability?

Table 3 summarizes the synchronization features of each USRP device. Table 4 shows recommended solutions for MIMO systems of various sizes.

If you need MIMO capability for your application, Ettus Research recommends the USRP N200/N210, X300/X310, N300/N310 or E320. These units can be synchronized by providing a common time and frequency reference. Two USRP N200/N210s can be synchronized for MIMO operation with an Ettus Research MIMO cable. Alternatively, external 10 MHz reference and 1 PPS signals can be distributed to multiple USRP radios. With proper consideration for interface issues, it is possible to create MIMO system of arbitrary size with the USRP N200/N210, X300/X310, N300/N310 and E320.

The USRP B210, N300, E310/E312/E320 can serve a 2x2 MIMO capability because it has two integrated RF channels. When using the USRP B210 the available bandwidth is limited dependent upon the USB controller, and selected MIMO configuration. The USRP E310/E312's streaming bandwidth is limited to the 1 GigE interface to the ARM CPU. The USRP E320 supports streaming at full rate of 61.44 MS/s (SISO) or 30.72 MS/s (MIMO) via the 10 Gb interface. The USRP N300 supports streaming at 153.6 MS/s (SISO) and 125 MS/s (MIMO) via the 10Gb interface.

USRP Model	BW Capability (MSPS w/ 16-bit)	MIMO Capable	Ext Ref. Input	1 PPS Input	Internal GPS Disciplined Oscillator (Optional)	Plug and Play MIMO
N200	25	X	X	X	X	X
N210	25	X	X	X	X	X
N300	153.6, 125, 122.88	X	X	X	X	X
N310	153.6, 125, 122.88	X	X	X	X	X
B200mini	61.44		X	X		
B205mini	61.44		X	X		
B206mini	61.44		X	X		
B200	61.44		X	X	X	
B210	61.44	X	X	X	X	X
X300	200	X	X	X	X	X
X310	200	X	X	X	X	X
E310	61.44	X	X	X		X

E312	61.44	X	X	X			X
E320	61.44	X	X	X	X		X

Table 3 - Synchronization Capability of USRP Devices

USRP Model	2 x 2 MIMO	4 x 4 MIMO	M x N MIMO
N200/N210	MIMO Cable	OctoClock	OctoClock
N300	Integrated	Octoclock, White Rabbit	Octoclock, White Rabbit
N310	Integrated	Integrated	Octoclock, White Rabbit
B200mini	Not Recommended (SISO Only)	Not Recommended	Not Recommended
B205mini	Not Recommended (SISO Only)	Not Recommended	Not Recommended
B206mini	Not Recommended (SISO Only)	Not Recommended	Not Recommended
B200	Not Recommended (SISO Only)	Not Recommended	Not Recommended
B210	Integrated	Not Recommended	Not Recommended
X300	Integrated with Dual Daughterboards	OctoClock	OctoClock
X310	Integrated with Dual Daughterboards	OctoClock	OctoClock
E310	Integrated	Not Recommended	Not Recommended
E312	Integrated	Not Recommended	Not Recommended
E320	Integrated	Octoclock	Octoclock

Table 4 - Recommended Models for MIMO Systems

What Are My Bandwidth Requirements?

Many Bandwidth requirements can also be used to narrow down the USRP selection. As seen in the table, the USRP N200/N210 is capable of streaming up to 50 MS/s in each direction in 8-bit mode, and 25 MS/s in 16-bit mode. The USRP B200 is capable of streaming up to 61.44MS/s total in 16-bit, 12-bit or 8-bit modes. The USRP E320 is capable of streaming up to 61.44 MS/s in 16-bit mode. The X300/X310 is capable of streaming up to 200 MS/s per channel (400 MS/s total) with 160 MHz of usable bandwidth per channel. The N300/N310 is capable of streaming up 122.88, 125 or 153.6 MS/s per channel. The N300/N310 is limited to 2x2 operation when using a 153.6 MS/s sample rate.

However, if there is interest in transmit and/or receiving larger bandwidth signals such as 802.11, the USRP N200/N210, X300/X310, N300/N310 or E320 would be appropriate. Note these limitations are based on the data throughput provided by the corresponding interfaces. It is important to consider the performance of the processing platform, and the computational intensity of the application. The constraints of the processing platform are independent of the full capability of the Ettus Research USRP radio and UHD.

What interface do I prefer to work with?

Assuming you have narrowed the viable devices down based on bandwidth, MIMO and channel count requirements, it is possible to select a USRP device based on the interface.

In general, USB 3.0 ports are more plentiful on computers. This makes the USRP B200/B210/B200mini/B205mini/B206mini slightly more usable at short ranges. The USRP N200/N210 requires a Gigabit Ethernet port and a PC typically only provides one such port. If internet access is required, the user will also need to plan for an additional network adapter. The USRP X300/X310, N300/N310 and USRP E320 all support streaming via either a 1 GigE or 10 GigE interface.

The Gigabit Ethernet interface of the USRP N200/N210 can operate over significantly longer ranges (typically up to 100ft) compared to the USB interface of the USRP B2xx. This makes it possible to operate the USRP radio it more remote locations further from the host computer. The GigE interface can be accessed via a Gigabit Ethernet switch, allowing access to multiple devices. However, Ettus Research recommends a homogeneous network without other devices, such as network routers attached.

The 10 Gigabit Ethernet interfaces of the USRP N300/N310, X300/X310 and E320 can be operated using multimode fiber optic cables with appropriate adapters which increases the distance from the host computer.

Will I develop custom IP for the USRP device?s FPGA?

While most users deploy their USRP devices in a stock configuration, many others customize the FPGA with their own functionality. For example, you may want to offload modulation, demodulation, or other PHY/ MAC operations to the FPGA. This reduces host processing requirements, and may allow data reduction before passing data over the host interface. A summary of the FPGAs used on each USRP model are shown in Table 5.

Model	FPGA Vendor	FPGA Series	FPGA Part Number	System Gates	Logic Elements	Logic Cells	Slices	DSP48's	BRAM	DCM's	Free Tools?
N200	Xilinx	Spartan 3A DSP	XC3SD1800A	1800k	-	37,440	16,640	84	260k	8	Yes
N210	Xilinx	Spartan 3A DSP	XC3SD3400A	3200k	-	53,714	23,872	126	373k	8	No
B200mini	Xilinx	Spartan-6	XC6SLX75	-	-	74,637	93,296	132	3,096k	12	Yes
B205mini	Xilinx	Spartan-6	XC6SLX150	-	-	147,443	184,304	180	4,824k	12	No
B206mini	Xilinx	Spartan-6	XC6SLX150	-	-	147,443	184,304	180	4,824k	12	No
B200	Xilinx	Spartan 6	XC6SLX75	-	-	74,637	93,296	132	3,096k	12	Yes
B210	Xilinx	Spartan 6	XC6SLX150	-	-	147,443	184,304	180	4,824k	12	No

X300	Xilinx	Kintex-7	XC7K325T	-	-	321k	407,600	840	16,020k	-	No
X310	Xilinx	Kintex-7	XC7K410T	-	-	406k	508,400	1540	28,620k	-	No
E310	Xilinx	Zynq-7000	XC7Z020	-	-	85k	106,400	220	560k	-	Yes
E312	Xilinx	Zynq-7000	XC7Z020	-	-	85k	106,400	220	560k	-	Yes
E320	Xilinx	Zynq-7000	XC7Z045	-	-	350k	437,200	900	19.2 Mb	-	No
N300	Xilinx	Zynq-7000	XC7Z035	-	-	275k	343,800	900	17.6 Mb	-	No
N310	Xilinx	Zynq-7000	XC7Z100	-	-	444K	554,800	2020	26.5 Mb	-	No

Table 5 - FPGA Resources

The USRP N200 and USRP N210 are great, generic platforms to experiment with FPGA development. However, the important difference between these two is the FPGA size, and requirements for Xilinx development tools. The USRP N200 includes a Xilinx Spartan XC3SD1800A FPGA. This FPGA is optimized for DSP capability, and the logic can be modified with free Xilinx ISE tools. The USRP N210 includes a Xilinx Spartan XC3D3400A FPGA. This FPGA provides nearly twice the resources, but requires a licensed seat of the Xilinx development tools for development.

Do I need flexible sample clock frequencies?

Some applications may benefit from a flexible sample clock frequency. The USRP E310/E312/E320 and USRP B200/B210/B200mini/B205mini/B206mini include a flexible frequency clocking solution. This flexibility allows ideal sample clock frequencies to be used for various communications standards. For example, the GSM implementations commonly use a 52 MHz sample clock.

Do I want or need a rack-mountable solution?

Generally speaking, the selection of the USRP is based on performance requirements of the electrical components. However, the convenience of a rack-mounted solution may be an attractive feature that drives your decision. The USRP N200/N210, X300/X310 and N300/N310 can all be mounted in Ettus Research rack chassis. Up to four N200/N210 USRP devices can be mounted in the 3U chassis. Up to two X300/X310 or N300/N310 USRP devices can be mounted in the 1U chassis.

Will my requirements become more demanding as I learn more about the USRP and RF systems?

One final thing to consider is how your requirements will change over time. While a lower-cost USRP device, such as the USRP B200/B200mini, may meet your immediate requirements, it is possible that the USRP N200/N210, N300/N310 or E320 would be a more appropriate platform as you continue to develop more advanced RF systems. Key improvements to note in the higher-end USRP N200/N210/X300/X310/N300/N310/E320 is the increased bandwidth, increased dynamic range, and MIMO capability.

Fortunately, UHD allows the user to develop a single application compatible with all USRP models. Within certain limitations, the code you develop to work on a USRP B2xx will generally work on any other USRP. You must still consider variables such as sample rate, host interface bandwidth, and synchronization features to ensure compatibility.

This application note presents the functional specifications of each USRP device sold by Ettus Research. The data from this document can be used to make an educated selection of the most appropriate USRP device for a particular user or application.