Selecting a USRP SDR Model

Contents

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Authors: John Smith and Jane Smith

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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. This link provides access to several resources that may be helpful in understanding the basics.

http://gnuradio.org/redmine/projects/gnuradio/wiki/SuggestedReading

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	SBX
Radar Research	N200/N210	SBX
OpenBTS Deployment	B100	WBX/SBX
Education	N200/N210	WBX/SBX
HF Communications	B100	LFRX/LFTX
Signals Intelligence	N200/N210	WBX/SBX
Distributed RF Sensors	E100/E110	WBX/SBX
Mobile Radios	E100/E110	WBX/SBX

Application Area	Common USRP Model	Common Daughterboard
PHY/MAC Research	N200/N210 X300/X310	SBX
Radar Research	N200/N210 X300/X310	SBX
OpenBTS Deployment	B200/B210	N/A
Amarisoft LTE 100	X300/X310	SBX/CBX/UBX
Education	N200/N210 X300/X310	WBX/SBX/CBX/UBX
HF Communications	N200/N210 X300/X310	LFRX/LFTX
Signals Intelligence	N200/N210 X300/X310	WBX/SBX/CBX/UBX
Distributed RF Sensors	E310	N/A
Mobile Radios	E310	N/A

Table 1 - Recommended USRP Selection for Various Application Areas

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 (bis)	DAC Rate (MSPS)	MIMO Capable	Internal GPS Disciplined Oscillator (Optional)	1 PPS/Ref Inputs
N210	GigE	50/100	1	14	100	16	400	Yes	Yes	Yes
N200	GigE	50/100	1	14	100	16	400	Yes	Yes	Yes
B100	USB 2.0	8/16	1	12	64	14	128	No	No	No
USRP1	USB 2.0	8/*	2	12	64	14	128	Yes	No	No
E100	Embedded	8/16	1	12	64	14	128	No	Yes	Yes
E110	Embedded	8/16	1	12	64	14	128	No	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
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

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 E100/E100 is the most appropriate. The USRP E100/E110 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, B100, or USRP1. 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 B100 or USRP N200/N210, then port the code to the USRP E100/110. The UHD (USRP Hardware Driver) enables this portability. You must also consider the different processing capabilities of the host machine and OMAP processor used on the USRP UE100/E110.

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 or USRP N210. 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.

The USRP1 can serve a 2x2 MIMO capability because it has two daughterbaord slots. However, the USB 2.0 interface limits the bandwidth per channel. The combined throughput of all transmit and receive channels cannot exceed 8 MS/s.

In most cases the USRP B100 and E100/E110 are not appropriate for applications requiring a MIMO system. However, if you intend to operate at low frequencies it may be possible to use the LFRX/TX and BasicRX/TX, which can provide two channels on each daughterboard. If only receive capability is needed, the TVRX2 can meet the requirements for multiple-input capability in all USRP devices.

USRP Model	BW Capability (MSPS w/ 16-bit)	MIMO Capable	Ext Ref. Input	1 PPS Input	Internal GPS Disiplined Oscillator (Optional)	Plug and Play MIMO
USRP1	8	X				
N200	25	X	X	X	X	X
N210	25	X	X	X	X	X
E100	4		X	X	X	
E110	4		X	X	X	
B100	8		X	X		
B200mini	61.44		X	X		
B205mini	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

Table 3 - Synchronization Capability of USRP Devices

USRP Model	2 x 2 MIMO	4 x 4 MIMO	M x N MIMO
USRP1	2x Daughterboard	Not Recommended	Not Recommended
N200/N210	MIMO Cable	MIMO Cable + External	External
E100/E110	Not Recommended	Not Recommended	Not Recommended
B100	Not Recommended	Not Recommended	Not Recommended
B200mini	Not Recommended	Not Recommended	

			Not Recommended
B205mini	Not Recommended	Not Recommended	Not Recommended
B200	Not Recommended	Not Recommended	Not Recommended
B210	Integrated	Not Recommended	Not Recommended
X300	2x Daughterboard	OctoClock	OctoClock
X310	2x Daughterboard	OctoClock	OctoClock
E310	Integrated	Not Recommended	Not Recommended
E312	Integrated	Not Recommended	Not Recommended

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 B100 is capable of streaming up to 8 MS/s and 16 MS/s total in 16-bit and 8-bit modes, respectively. The USRP1 only operates in 16-bit modes, and is limited to 8 MS/s applications, such as OpenBTS, only utilizing a few hundred kHz of instantaneous BW. In these cases, the BW capability of the USRP1 and USRP B100 are more than adequate.

However, if there is interest in transmit and/or receiving larger bandwidth signals such as 802.11, the USRP N200/N210 would be more appropriate. Note these limitations are based on the data throughputs 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.

The USRP E100/110 FPGA interface provides a maximum throughput of 40 MB/s. This bandwidth can be used distributed across transmit and receive sample transfer. At 4 bytes/sample, this provides for a total of 10 MS/s. Note this does not guarantee that the embedded processor will be able to process that many samples. Additional care must be taken to understand the processing limitations and best DSP practices for optimum performance.

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 2.0 ports are more plentiful on computers. This makes the USRP B100 and USRP1 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 adaptor.

The Gigabit Ethernet interface of the USRP N200/N210 can operate over significantly longer ranges. 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.

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 USRP radio. 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.

	N210	N200	E110	E100	USRP1	B100	B200mini	B205mini	B200	B210	X300	X310	E310	E312
FPGA Vender	Xilinx	Xilinx	Xilinx	Xilinx	Altera	Xilinx								
FPGA Series	Spartan 3A DSP	Spartan 3A DSP	Spartan 3A DSP	Spartan 3A DSP	Cyclone	Spartan 3A								
FPGA Part Number	XC3SD3400A	XC3SD1800A	XC3SD3400A	XC3SD1800A		XC3S1400A								
System Gates	3200k	1800k	3200k	1800k		1400k								
Logic Elements	-	-	-	-	12000	-								
Logic Cells	53714	37440	53714	37440	-	25344								
Slices	23872	16640	23872	16640	-	11264								
DSP48's	126	84	126	84	0	0								
BRAM	373k	260k	373k	260k	234k	576k								
DCM's	8	8	8	8	2	8								
Free Tools?	No	Yes	No	Yes	Yes	Yes								

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. The USRP E100/110 use the same, respective FPGA sizes as the USRP N200/N210.

The USRP B100 provides a cost-optimized Spartan 3A-1400 FPGA. This can also be modified by the free version of Xilinx tools. The USRP B100 FPGA design does not contain many unused resources.

Do I need flexible sample clock frequencies? Some applications may benefit from a flexible sample clock frequency. The USRP E100/110 and USRP B100 both 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 B100, E100/E110, and N200/N210 can all be mounted in the Ettus Research 3U rack chassis. Up to four USRP devices can be mounted in the chassis. Note there is no off- the-shelf rack mounting solution for the USRP1 device.

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 B100, may meet your immediate requirements, it is possible that the USRP N200/N210 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 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 B100 will generally work on a USRP N200/N210. 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. If you have any additional questions, do not hesitate to contact us at sales@ettus.com.