The High Performance Software Defined Radio Project

Lyle Johnson, KK7P
18345 Osprey Ct
Mt Vernon WA 98274-7725
kk7p@hpsdr.org

Abstract

An open project to advance the state of Software Defined Radio within Amateur radio is described.

Introduction

The High Performance Software Defined Radio (HPSDR) project is an open effort that began spontaneously with a small group of Flex Radio SDR-1000 owners. It began as an investigation into creating a "soundcard replacement" for that product. This quickly evolved into a desire to provide all signals and control over s single USB connection. It has since ignited enthusiastic participation by a number of Amateurs with the vision to create a set of hardware building blocks that can be configured into any number of software defined radio architectures, as well as related test equipment.

This paper provides a brief introduction to the HPSDR project, outlines the current state of proposed modules, and provides links to further information.

Flex Radio Friends

An informal group of owners, or potential owners, of SDR-1000 radios meets on the Internet using a Voice over Internet Protocol (VoIP) conferencing system provided by Eric, AA4SW.

At one of the discussions late in 2005, mention was made of the frustration of getting really good performance from available soundcards, and the lack of suitable alternatives for USB-equipped laptop computers. One of the group had recently purchased a low-cost, USB-based Field Programmable Gate Array (FPGA) development board called Xylo (http://www.fpga4fun.com). Some thought it might be interesting to make a soundcard replacement using the technology represented by the Xylo board.

Soon, various Analog to Digital Converters (ADCs) were being breadboarded and tested to see if this was practical, and what sort of performance could be obtained.

Others offered the opinion that this should not be focused on the SDR-1000, but that it might form the basis of a more general project for Amateur experimentation and development of SDR.

The concept of a passive backplane, or bus, for distributing digital signals and power was quickly voiced. Various functional modules could then be developed and plugged into the backplane to allow almost unlimited configuration options.

HPSDR is Formed

These discussions led to a dramatic level of interest, and the email reflector became very active.

Early in 2006, a separate reflector was established by Don, AE5K, and the project took on the HPSDR name.

A website was quickly created. As information came from the developers at a rapid pace, a wiki was formed to help share the development experience.

HPSDR is not a formal organization, and is intended to never become one. It is just a place where interested parties can come to learn and perhaps help.

Open Source

No, this is not another Linux tirade. Rather, the developers of the HPSDR modules wanted to offer the results of their labors in the most open way they could, while at the same time protecting themselves from those who would take their work and claim it as their own.

Most modules in HPSDR have elements of hardware (the circuit boards and components) as well as software. The software isn't just code to be executed on a PC, but often is code that describes the behavior of configurable logic, either Complex Programmable Logic Devices (CPLDs) or FPGAs.

The Gnu Public License (GPL) offers a way for software authors to share their work and still protect their rights, and to encourage community participation in improving it.

Unfortunately, there seems to not be a similar license to protect hardware designs. Individual expressions of a design can be copyrighted, but protecting derivative works, and encouraging release of the derivatives into the community for everyone's benefit, is not part of copyright.

Tucson Amateur Packet Radio (TAPR), led by John, N8UR, is taking the lead to create the TAPR Open Hardware License (TAPR OHL). Several legal minds are donating their time to this effort.

The TAPR OHL will serve as the basis under which HPSDR developers will release their hardware designs. The GPL will be the most common basis under which HPSDR software will be released.

Modules – And a Bit of Fun

The backplane design quickly coalesced around the 96-pin DIN standard pin-and-socket connector. Power is supplied through a standard ATX power supply connector.

The backplane board size is 100mm x 140mm (3.94in x 5.50in) and spaces the modules on 20.3mm (0.8 in) centers. The modules which plug into it are one of several standard sizes:100mm x 120mm (3.94in x 4.72in) is the most common, with 100mm x 160mm (3.94in x 6.30in), 100mm x180mm (3.94in x 7.09in) and 100mm x 220mm (3.94in x 8.66in) as optional sizes.

Once the work was done in deciding these mundane technical issues, focus had to shift immediately to that most important of all topics: what to call the device!

Phil, N8VB, the designer of the backplane, called the design **Atlas** after the mythological character who held the world up. The use of names from mythology has since been adopted for most modules.

Janus is a four channel Analog interface card being designed by Phil, VK6APH and Bill, KD5TFD. It has two 24-bit, 192 kHz sampling rate analog inputs, and two digital outputs handled by pulse width modulation (PWM). The ADC is intended to follow a quadrature sampling detector (QSD), or other source of in-phase (I) and quadrature (Q) signals. The PWM-based DAC is intended to drive a quadrature sampling exciter (QSE).

In addition, two more channels of analog in and out sampled at 48 kHz and 16 bits are provided for microphones, headphones or speakers.

Finally, some control signals are provided for functions such as PTT. Details of Janus are on the wiki, referenced at the end of this paper. A companion paper on Janus is included in these Proceedings.

Ozymandias (Ozy) is a module that provides a USB 2.0 high-speed interface. It is based on a Cypress EZ-USB controller chip with includes an 8051 microcontroller. An Altera Cyclone II family FPGA provides the general logic for the module. Numerous digital I/O lines are included to provide direct control of an SDR-1000 or other external SDR hardware.

Phil, N8VB, is the project leader for Ozy.

Together, Ozy and Janus provide complete control of the SDR-1000 along with a very high performance analog interface.

Mercury is a 130 MHz sampling rate, 16-bit ADC with supporting FPGA and clock oscillator. It will form the basis for receivers and spectrum analyzers. It can, for example, sample the entire HF spectrum.

It is based on a Linear Technology LTC2208. Functional prototyping has been done with a Linear Technology evaluation board and a Xylo USB interface, in conjunction with PowerSDR console software.

Mercury may optionally have its own USB interface to allow it to be used without Atlas.

Project leaders are Phil, N8VB and Phil, VK6APH.

Sasquatch is being designed to wean the SDR from a PC. It will use a fast digital signal processor (DSP) chip and run the SDR algorithms that traditionally run on a user's PC. This opens the door for self-contained, but very flexible, radios for portable as well as desktop operation.

As currently proposed, Sasquatch will be based on a Texas Instruments TMS320C6726 floating point DSP chip. This choice is driven by the AMSAT (www.amsat.org) Eagle project's Software Defined Transponder. Use of this architecture will help leverage the software work being done for the SDX by Bob, N4HY and Frank, AB2KT.

Project leader for Sasquatch is Lyle, KK7P.

Gibraltar is a precision time and frequency reference. It will provide 10 MHz and 1 Hz signals which can be slaved to GPS.

Having numerous HPSDR receivers operating coherently opens a number of interesting applications for synthesized wide aperture antennas, propagation studies, and other Amateur investigative work. Or, it can simply be used to know your signal is precisely on the frequency you claim it is!

Project leaders are Rick, W2GPS and Steve, N7HPR.

Proteus is a prototyping board. It will provide a standard Atlas interface, local voltage regulation, and perhaps a CPLD or FPGA. It will incorporate an area to allow prototyping and development of hardware for future HPSDR functional modules.

Proteus is from a suggestion by Phil, N8VB.

Horton (not mythology, Dr. Seuss!) is a receiver, probably based on a QSD and perhaps with its own ADC. If so, it will likely use the same ADC as is used in Janus, the AK5394A from AKM.

Project leader is Phil, N8VB.

Pinocchio is an extender card. It simply brings the Janus bus connector physically higher than other cards to allow troubleshooting of existing cards and debugging of prototype cards. It provides test points for all Atlas bus signals.

Project leader is Lyle, KK7P.

CASMIR is a proposed receiver and transmitter card. It may include variants for HF, VHF and UHF.

Project leader is Alex, N3NP.

Phoenix is a QSD/QSE receiver and exciter module for HF, complete with synthesizer. It is intended to provide a basis to prototype high performance radio system using Janus and Ozy or Sasquatch.

Project leader is Ray, WB6TPU.

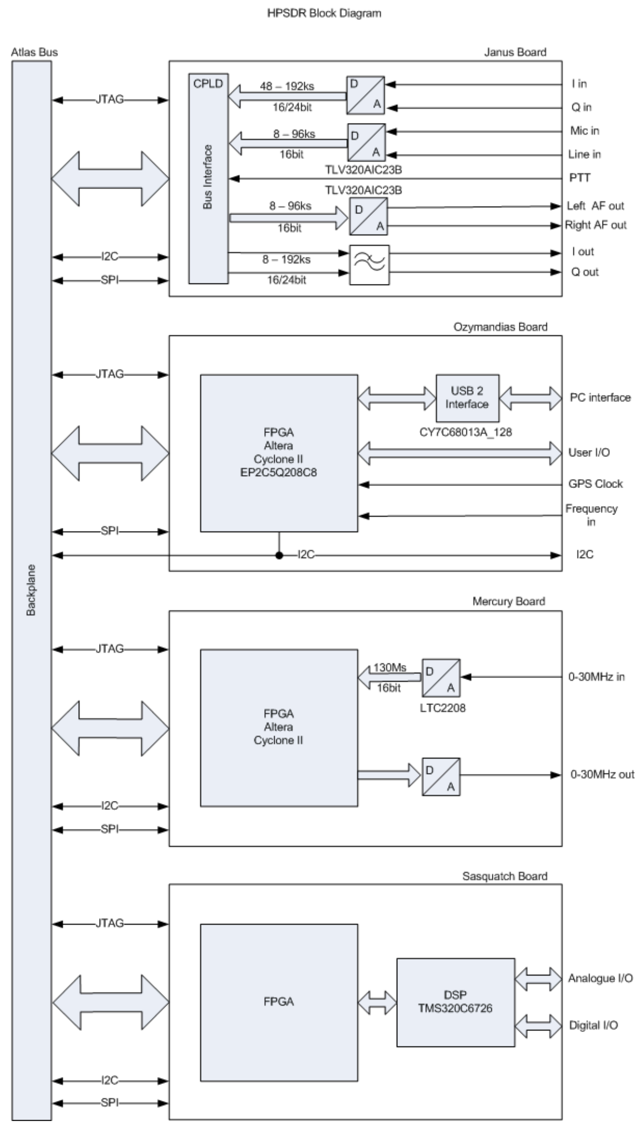
So, What is an HPSDR?

The HPSDR project is not a group of engineers focused on bringing a specific product to market. Rather, it is a loose confederation of enthusiasts trying to create the blocks out of which various systems may be built.

A good analogy is Lego ™. One gathers the blocks and applies imagination. There are limits as to what can be created, of course, but within those limits there lies a very large set of interesting possibilities.

Another analogy is a bazaar. You wander down the aisles and pick out those things that interest you, and use them to create something else.

Here is a figure showing one possible configuration of some early HPSDR modules (thanks to VK6APH for the drawing):



Status

This is merely a snapshot from late July, 2006.

The **Atlas** board design has been completed, and more than 400 shipped into the Amateur community. Boards and parts kits are available from TAPR (www.tapr.org).

Horst, DL6KBF, led the documentation effort for Atlas, providing English and German versions. He is working on manuals for the other boards as well. Hubert, F6GOG is doing French versions and Alberto, I2PHD, Italian.

The **Pinocchio** extender card has likewise been kitted and is available from TAPR.

Janus and **Ozymandias** are in the prototype stage. Initial units are working, and software and logic are being tested and integrated to mate with the SDR-1000.

The other modules are being defined or worked on, but no schematics or printed circuit boards have yet been published.

Developer Support

AMSAT (http://www.amsat.org) is actively providing access to professional software tools for the HPSDR developer community.

TAPR (http://www.tapr.org) is providing funding for prototype development, as well as creating the Open Hardware License.

Wrap Up

The HPSDR project is delivering the first modules. There are active discussions on the reflector. Names you will recognize are contributing to the effort. There is no formal organization; this is a collection of individuals doing what they love to do, and sharing with others for the benefit of the Amateur community.

A personal observation: I was heavily involved in the early years of Packet Radio. In the 20 years since, I have not seen the kind of community interest and engineering talent come together around a concept in Amateur radio – until HPSDR.

Acknowledgements

In addition to the individuals named in the body of this text, I extend my thanks to Phil, VK6APH, Eric, AA4SW, and Bill, KD5TFD, for their help in reviewing this document and providing suggestions for enhancing its content.

For Further Information

The primary website: http://hpsdr.org

Go here to get a better overview, download a video of an HPSDR introduction talk from the Dayton Hamvention ™, and subscribe to the email reflector.

You can also access the HPSDR wiki from this site.

Boards and kits: http://www.tapr.org

As modules are released, TAPR will be providing them.

Other organizations and websites:

http://ww.amsat.org

http://www.arrl.org