High Performance Software Defined Radio

OpenHPSDR Project Update
September 2011

Scotty Cowling, WA2DFI

2011 TAPR/ARRL Digital Communications Conference
What is the OpenHPSDR Project...?

The OpenHPSDR Project is a modular, open source hardware and software platform for development of all components of a Software Defined Radio.

It is also a group of volunteers dedicated to the building of a pool of open-source Software Defined Radio design information.
What is an OpenHPSDR radio?

**High Performance Software Defined Radio**

An OpenHPSDR radio has the following features:

- Very High Performance
- Based upon an open source model (OHL/NCL hardware, GPL software)
- Generally modular and expandable
- Advances the State of the Radio Art
TAPR’s MISSION

Support OpenHPSDR development with:
R&D funding
  ▼ Breadboard prototypes
  ▼ Alpha PCBs
Early volume production
  ▼ Put leading edge technology into many hands
TAPR’s MISSION

Result: An ever growing pool of contributors, experimenters and subsequent advancement of the radio art

OpenHPSDR and TAPR are separate entities

but:

They complement each other
openHPSDR Board Availability

**Problem:** TAPR is an R&D facilitator, not a manufacturer

**Solution:** *someone* needs to produce OHL boards after TAPR sells out the initial production run, but who?

**Announcing iQuadLabs, LLC**

- Not affiliated with TAPR
- Web-based retail outlet for openHPSDR boards
- Offers OHL hardware at low margins with user support
- Currently offering Magister, Mercury and Pennylane
- Other SDR-related hardware to be offered in the future

www.iQuadLabs.com
The Boards

Basic 1/2W OpenHPSDR Direct Sampling Radio

- Backplane: **Atlas** 6-slot backplane
- PC Interface:
  - **Magister or Ozy** USB gateway OR
  - **Metis** Gigabit Ethernet interface
- Transmitter:
  - **Penelope** Transmitter/Exciter OR
  - **Pennylane** Transmitter/Exciter
- Receiver: **Mercury** Direct Sampling Receiver
- Power supply: **LPU** Linear Power Unit
- Enclosure: **Pandora** chassis enclosure

© 2011 Scotty Cowling WA2DFI
The Boards

Basic 1W OpenHPSDR QSD/QSE Radio

- Backplane: **Atlas** 6-slot backplane
- PC Interface: **Magister/Ozy** USB gateway
- Baseband A/D - D/A Converter: **Janus**
- Power supply: **LPU** Linear Power Unit
- Enclosure: **Pandora** chassis enclosure
- QSD/QSE Front End:
  - **Softrock** RX/TX Ensemble
The Boards

Advanced 20W OpenHPSDR Direct Sampling Radio

- Backplane: **Atlas** 6-slot backplane
- PC Interface: **Metis** Gigabit Ethernet interface
- Transmitter: **Pennylane** Transmitter/Exciter
- Receiver: **Mercury** Direct Sampling Receiver
- Power supply: **LPU** Linear Power Unit
- Enclosure: **Pandora** chassis enclosure
- Power Amplifier: **Pennywhistle** 20W PA
- RX & TX Filters: **Alexiares** LP/HP Filter Set
The Boards

OpenHPSDR Boards

- **Atlas**: The Backplane
- **Magister**: USB gateway
- **Metis**: Gigabit Ethernet interface
- **Pennylane**: Transmitter/Exciter
- **Mercury**: Direct Sampling Receiver
The Boards

OpenHPSDR Boards, cont’d

- **LPU**: Linear Power Unit
- **Pandora**: OpenHPSDR Chassis
- **Alexiares**: LP/HP Filter Set
- **Pennywhistle**: 20W PA
OpenHPSDR Boards, Useful Additions

- **Janus**: Baseband A/D and D/A
- **Pinocchio**: The Extender
- **Excalibur**: 10MHz reference
- **DJ8AY**: Atlas 3-slot backplane
- **DJ8AY**: Antenna Switch and 6M LNA
Status: Kits available from TAPR
Ozymandias USB Gateway

USB interface to Atlas bus with parallel I/O

Status: superseded by Magister
Magister USB Gateway

USB interface to Atlas bus

Status: Available from iQuadLabs
Metis Gigabit Ethernet Interface

Gigabit Ethernet interface to Atlas bus

Status: Available from TAPR
Penelope Transmitter/Exciter

Digital Up Conversion (DUC) ½ W transmitter/exciter

Status: superseded by Pennylane

© 2011 Scotty Cowling WA2DFI
Pennylane Transmitter/Exciter

Digital Up Conversion (DUC) \( \frac{1}{2} \) W transmitter/exciter

Status: Available from iQuadLabs
Mercury Direct Sampling Receiver

0-65MHz direct sampling receiver

Status: Available from iQuadLabs
LPU

Linear Power Unit

Status: Kits available from TAPR
Pandora Enclosure

OpenHPSDR Chassis

Status: Available from TAPR
Alexiares RF Bandpass Filters

Alex Quick Features

- Two board set
  - RX-HPF High-Pass Filter board
  - TX-LPF Low-Pass filter board
- 160mm x 100mm boards fit into standard Euroboard housing
- SPI bus controlled (from Mercury or other SPI)
- Power requirement: nominal +12V @ 180mA maximum
- Can operate stand-alone for other applications
- Low insertion loss
  - < 2.0dB on receive paths, < 0.5dB on transmit paths
- No degradation of Mercury IP3
- No continuously running internal oscillators

© 2011 Scotty Cowling WA2DFI
Pennywhistle 20W PA

20W Power Amplifier

Status: Kits available from TAPR
Janus A/D – D/A Converter

High speed full-duplex A-to-D and D-to-A converter

Status: Available from TAPR

© 2011 Scotty Cowling WA2DFI
Pinocchio Extender

Status: Kits available from TAPR
OpenHPSDR Boards available from DJ8AY

- 3-slot Atlas backplane
- Antenna T/R switch and 6M LNA

For availability, contact:

Gerd Loch DJ8AY

g.loch@nt-electronics.de
Boards Coming Soon

- **Hermes**: DUC/DDC transceiver
- **Apollo**: 15W PA/LPF/ATU
- **Munin**: 100W PA
- **Cyclops**: 1GHz Spectrum Analyzer
- **Griffin**: GPS locked WSPR beacon TX
Hermes

Single-board DUC/DDC Transceiver A4 Features

- Direct Sampling RX and Direct Up Conversion TX on single board
  - Mercury front end/sampling section: continuous 50kHz - 54MHz coverage
  - Pennylane CODEC and TX section with 500mW PA
- Single Altera EP3C40 Cyclone III FPGA for filtering and data processing
- Metis Gigabit Ethernet Interface, 10/100/1000
- Mercury SPI Interface to Apollo/Hermes Companion/Alex
- Digital I/O: 7 - OC digital outputs, 3 - digital inputs, 4 - 12 bit analog inputs
- Key, paddle and PTT inputs, jumper selectable electret microphone bias
- Input attenuator: 31dB software switchable in 1dB steps
- Preamp: -135dBm noise floor (@500Hz BW)
- LA2NI On-board low noise SMPS: typ 400mA from 13.8V supply
- Larger standard 120mm x 160mm card, 8 layer PCB
Single-board DUC/DDC Transceiver Features, cont’d

- Full-duplex operation, **any frequency/mode split**
- 122.88MHz master clock, can be locked to TCXO or external reference (GPS)
- Stereo audio: 1W speaker out, headphone out, line out
- Dedicated 0dBm transverter output
- TX/RX image rejection: greater than 110dB
- Blocking Dynamic Range (BDR): typical 125dB
- Eight independent receivers will fit can be implemented within 3C40 FPGA
- Software support: KISS Konsole, PowerSDR, GHPSDR

**Status:**
Second GiG-E prototype (A-4) built and tested. All spur issues resolved. Pre-production build underway.

© 2011 Scotty Cowling WA2DFI
Hermes DUC/DDC Transceiver Architecture

© 2011 Scotty Cowling WA2DFI
Hermes

Single-board DUC/DDC Transceiver
Hermes Companion

Single-board 15W PA/Low Pass Filter

- Filter selection scheme similar to Alex
- T/R switch
- Three-way antenna selection
- Directional coupler for forward and reverse power measurement
- RD06 driver and push-pull RD15 PA MOSFETs
- 15W on all bands 160M ÷ 6M with spurious/harmonics better than -40dBc
- Option: Apollo without ATU

Status:

Prototype designed, built and tested by Abhi Arunoday.
Production is TBD.

© 2011 Scotty Cowling WA2DFI
Hermes Companion

Single-board 15W PA/Low Pass Filter
Apollo 15W PA-LPF-ATU

- Combine with Hermes for a single box OpenHPSDR transceiver
- 15W PA based on Pennywhistle design
- Low Pass Filters based on Alex design at reduced power
- SPI control from Hermes DUC/DDC Transceiver board
- Low-power automatic Antenna Tuning Unit using Atmel AVR MCU
- Form-factor updated to piggy-back onto new, 120x160mm Hermes

**Status:**
Artwork update nearly complete
Project leader Kjell, LA2NI
Planned for release slightly after Hermes
Apollo 15W PA - LPF - ATU
Well, almost!

Hermes and Apollo share a standard enclosure

This is the smaller Alpha -2 build form factor

(100mm x 160mm)
Simplified Block Diagram

Hermes
Mercury / Penelope / Magister

Apollo
15W PA/Filters

USB
13.8v in

To Antenna
Munin 100W PA

- RD06 pre-driver, pair of RD15 drivers
- Pair of 100HHF1 MOSFETs in push-pull
- Redesigned transformer for higher output and improved efficiency
- Measured power output, spurious outputs @ -30dBc or better:
  - 120W output on 160M
  - 130-140W output on 80M ï 10M
  - 102W on 6M
- 500mW drive for full output can be driven by Penelope/Pennylane

**Status:**

Alpha unit built and under test
Project leader Kjell, LA2NI
Availability TBD

© 2011 Scotty Cowling WA2DFI
Cyclops

1GHz Spectrum Analyzer

- First IF at 1030MHz / Second IF at 96MHz
- Second LO output for future tracking generator
- For use with HPSDR Mercury or Quicksilver
- 120mm x 100mm Atlas card

Status:

Alpha-2 units built and under test by VK6APH and VK5ABN
FPGA firmware and PC test program (Win XP) written
Project suspended
Cyclops

Cyclops 1GHz Spectrum Analyzer Block Diagram

© 2011 Scotty Cowling WA2DFI
Cyclops

1GHz Spectrum Analyzer

Cyclops
Alpha-1
Build
Cyclops

Screen Shot: 1μV @ 1GHz
New & Improved Cyclops

4 GHz Spectrum Analyzer

- Project re-activated
- New devices available to extend range beyond 4 GHz
- Evaluating ADF4350 synthesizer, DC ï 4.4 GHz
- Will use Mercury/Metis for IF

**Status:**

Project leaders: Phil, VK6APH and Berndt, VK5ABN

In concept phase
**Griffin**

**HF/VHF Chirp Beacon Exciter**

- Low-power WSPR and chirp beacon exciter for HF/6M/2M
- Prototype built and tested using Penelope transmitter
- Jupiter GPS provides:
  - 10kHz reference to phase lock transmitter
  - 1 pps for time sync
- Mercury FPGA code to time-stamp data using LSB of mic data
- Hermann, DL3HVH is writing decode software in CUDA
- Kurt, DL9SM has chirp beacon working, 20km from DL3HVH

→ Results expected shortly ←
Griffin

**HF/VHF Chirp Beacon Exciter**

- Andrew, VK3OE has remote HF/6M chirp beacon working
  - Presently using Matlab to decode data
  - Propagation data is proving to be very accurate & reliable

**Status:**

Project leaders: Phil VK6APH and Kevin M0KHZ
Currently under development
Griffin

HF/VHF Beacon Exciter
Multiple Receivers, F/W

For those with more than twice as many ears as noses …

- FPGA firmware based
- FOUR independent receivers can reside on OpenHPSDR Mercury
- Hermes can support EIGHT receivers due to increased FPGA size
- How does this work?
  - High-speed ADC digitizes entire 54MHz wide spectrum
  - FPGA creates separate 192kHz wide data stream for each receiver
  - PC demodulates each data stream as a separate virtual receiver

Since each data stream is created from all of the HF data, each virtual receiver is fully independent: frequency, mode, bandwidth, AGC, etc
Multiple Receivers, F/W

Screen Shot from Ken, N9VV

© 2011 Scotty Cowling WA2DFI
Multiple Receivers, H/W

For those with more antennas than receivers…

Joe, K5SO is working on a multiple hardware receiver setup

- FOUR phase-locked Mercury receivers on one Atlas bus
- Phased antenna arrays
- True Diversity Reception
HPSDR Standalone Server

For those with no antennas…

Phil, VK6APH and John G0ORX/N6LYT are working on adding a softcore CPU to the FPGA on Metis

- GHPSDR3 Server runs inside the FPGA
- No PC required
- Ethernet-based server
Firmware Update

- Update for Alex filter control
  - Requires new firmware for all boards
  - New command types in data stream

- More flexible Alex filter selection
  - Automatically selects filters based on frequency by default
  - PC Software can manually override automatic selection

- Maintains compatibility with all existing software
Latest Firmware revisions under Beta test:

- Ozy/Magister - V2.0
- Metis - V1.5
- Mercury - V3.0
- Penelope/PennyLane - V1.5

**Status:**

Project leader: Phil, VK6APH
Scheduled for release by 18 September 2011
Kiss Konsole (KK) has been unified by George, K9TRV
- Unifies Ethernet and USB code
- Will be basis of future versions of KK from now on

cuSDR by Hermann, DL3HVH
- written in C++/C instead fo C#
- uses Qt interface
Thank you!

Project information at: www.openhpsdr.org

Interest list at: www.hamsdr.com

Boards available at: www.tapr.org
www.iQuadLabs.com