



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

OpenHPSPDR 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





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

OpenHPSPDR Boards, cont'd

- ❑ **LPU:** Linear Power Unit
- ❑ **Pandora:** OpenHPSPDR Chassis
- ❑ **Alexiaries:** LP/HP Filter Set
- ❑ **Pennywhistle:** 20W PA

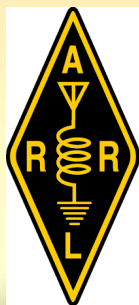


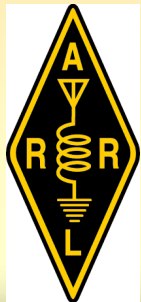
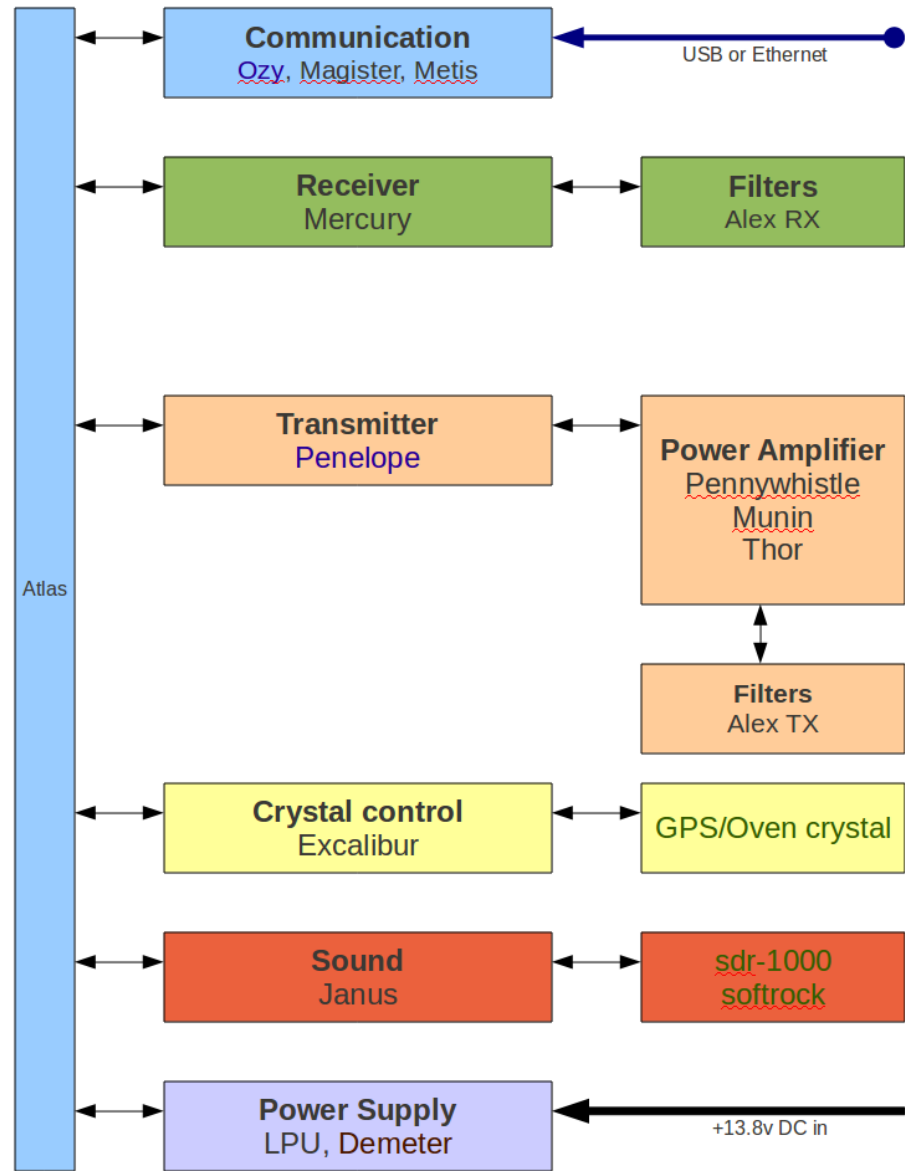


The Boards

OpenHPSDR Boards, Useful Additions

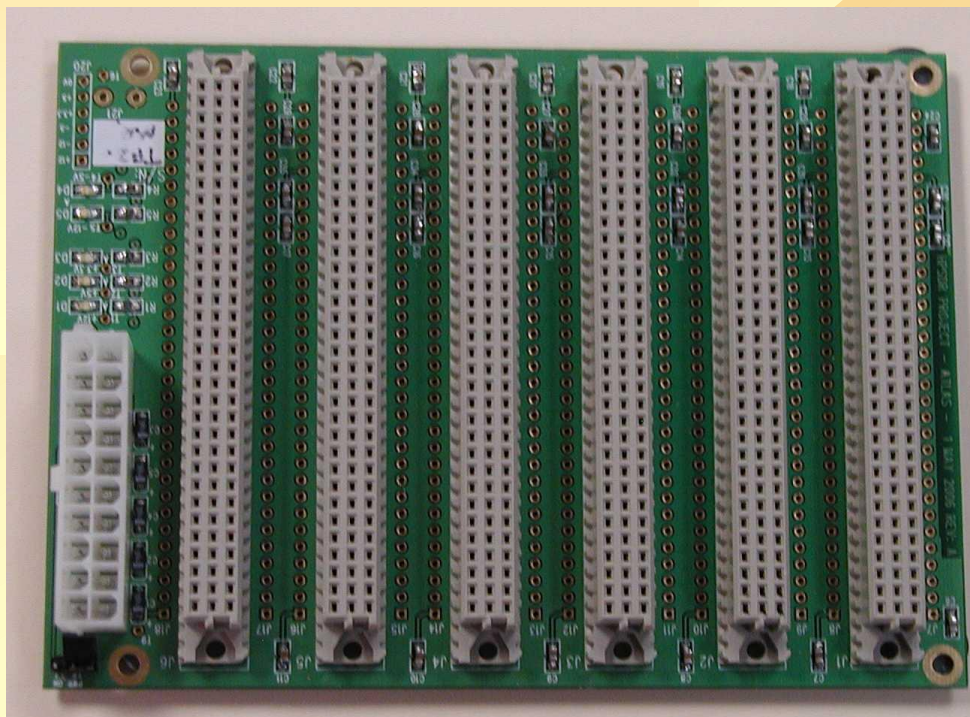
- ❑ **Janus:** Baseband A/D and D/A
- ❑ **Pinocchio:** The Extender
- ❑ **Excalibur:** 10MHz reference
- ❑ **DJ8AY:** Atlas 3-slot backplane
- ❑ **DJ8AY:** Antenna Switch and 6M LNA







Atlas Backplane



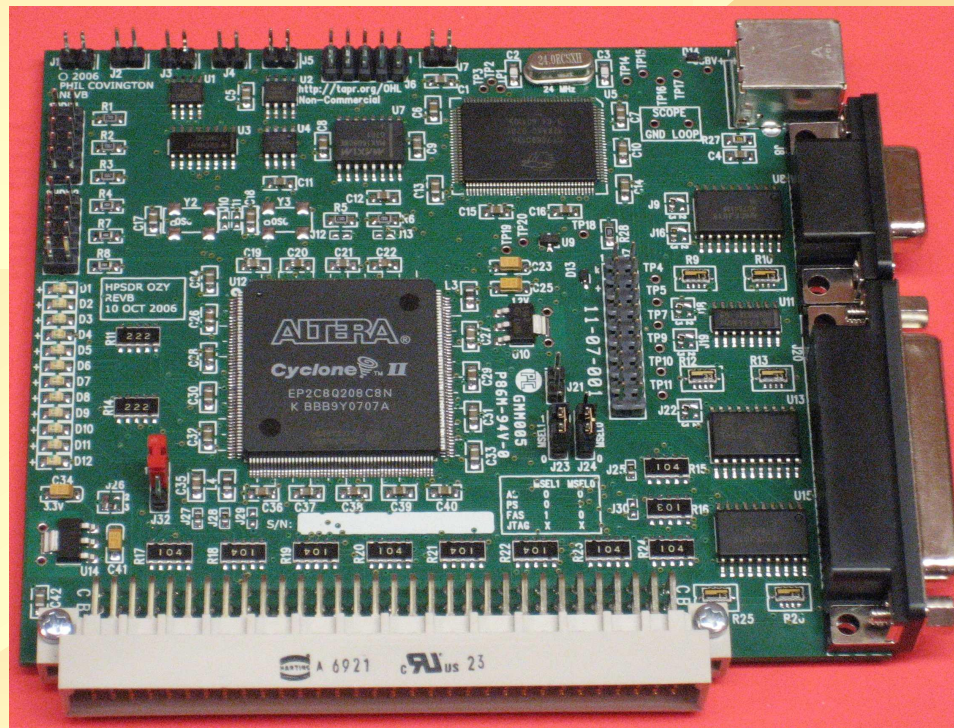
Status: Kits available from TAPR





Ozymandias USB Gateway

USB interface to Atlas bus with parallel I/O



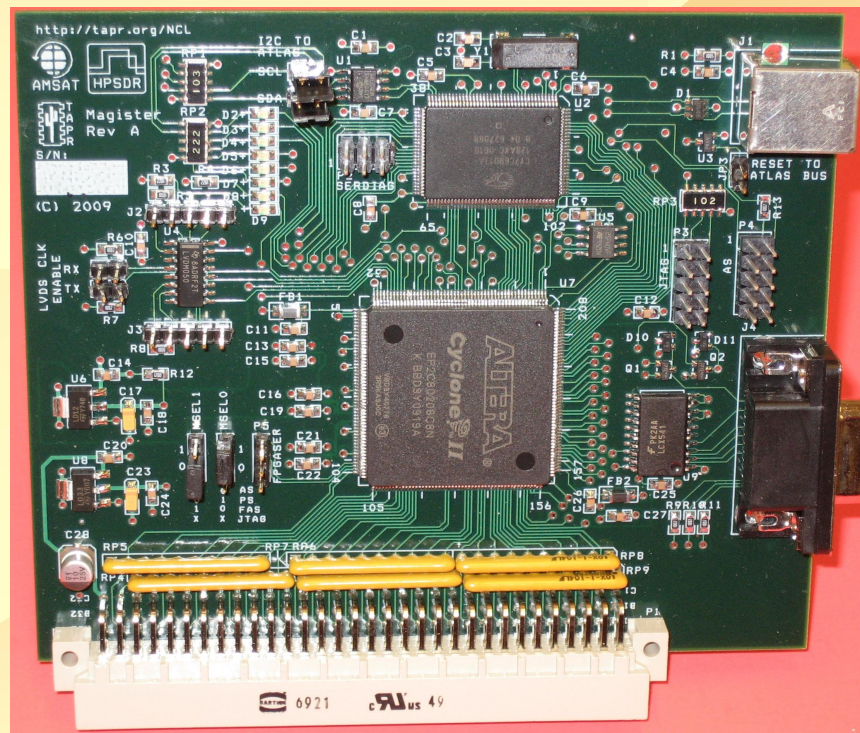
Status: superseded by Magister





Magister USB Gateway

USB interface to Atlas bus



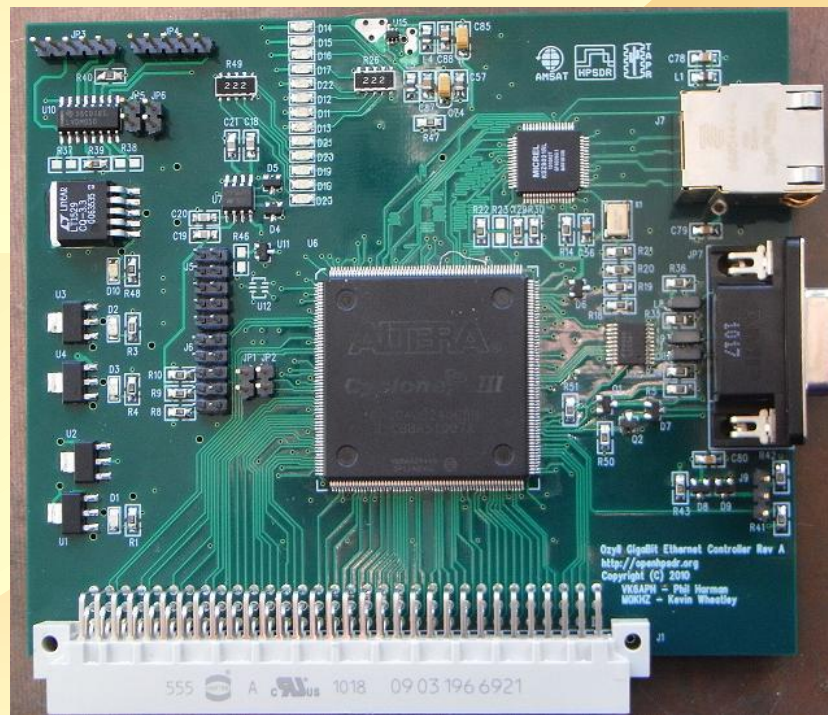
Status: Available from iQuadLabs





Metis Gigabit Ethernet Interface

Gigabit Ethernet interface to Atlas bus



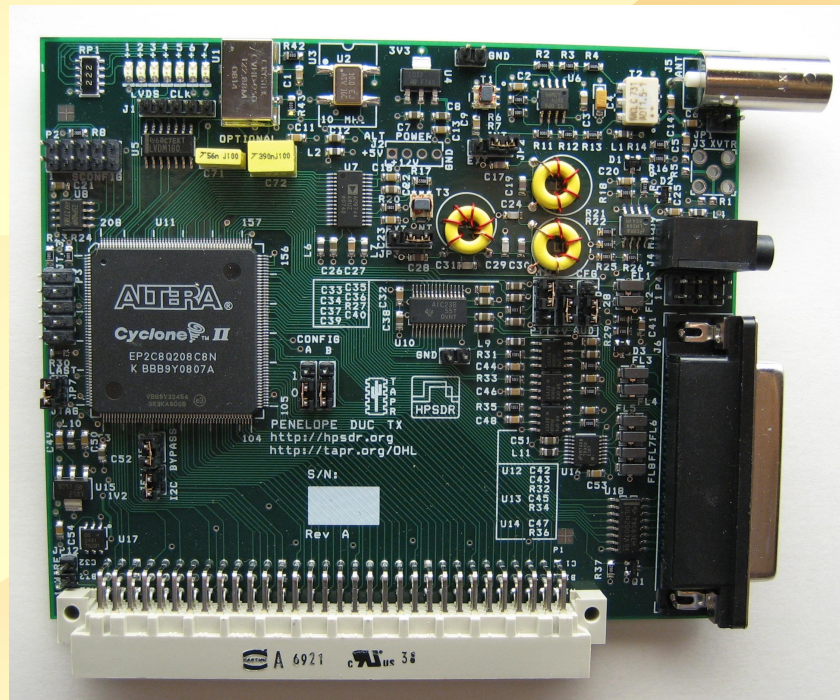
Status: Available from TAPR





Penelope Transmitter/Exciter

Digital Up Conversion (DUC) 1/2 W transmitter/exciter



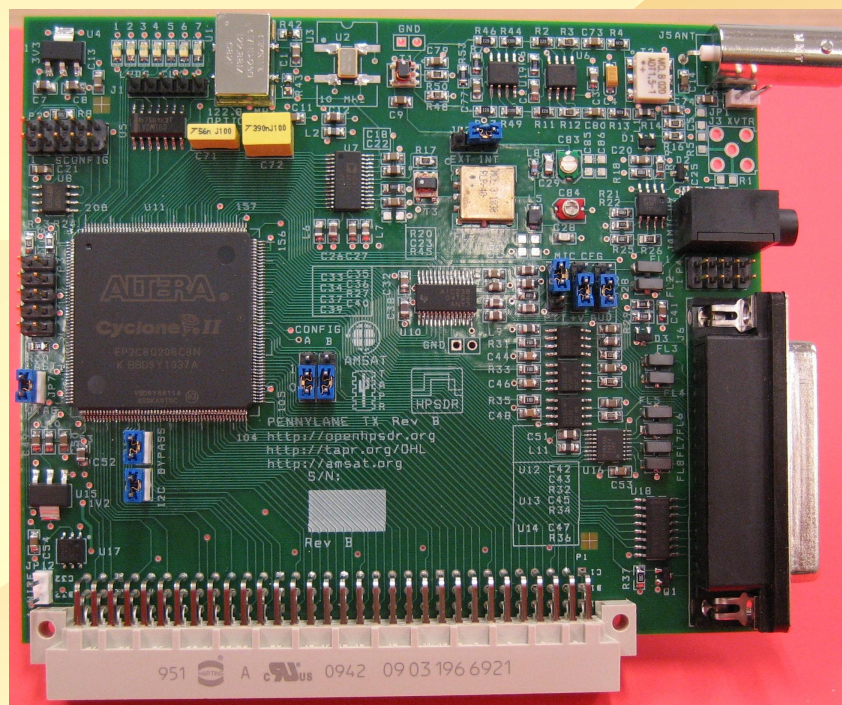
Status: superseded by Pennylane





Pennylane Transmitter/Exciter

Digital Up Conversion (DUC) 1/2 W transmitter/exciter



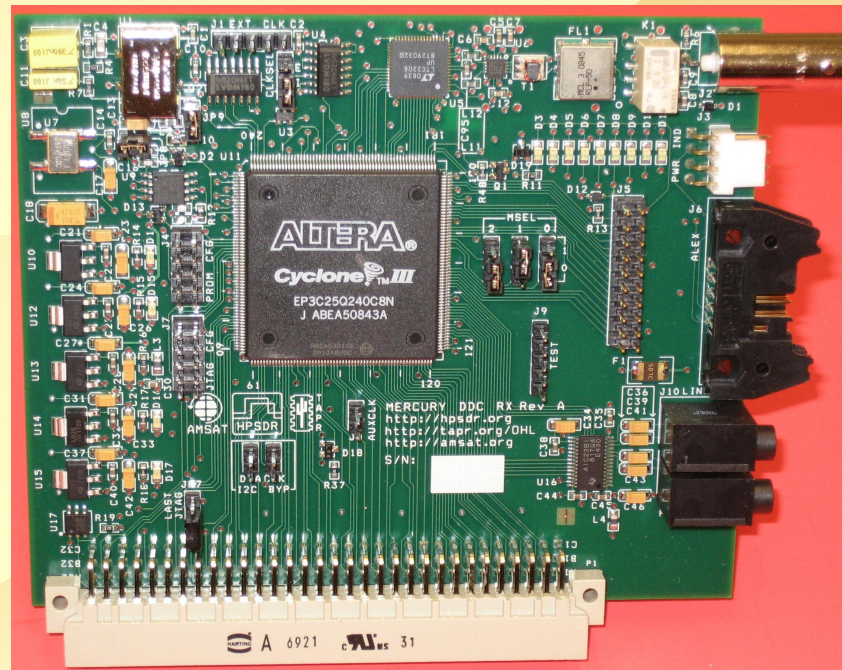
Status: Available from iQuadLabs





Mercury Direct Sampling Receiver

0-65MHz direct sampling receiver



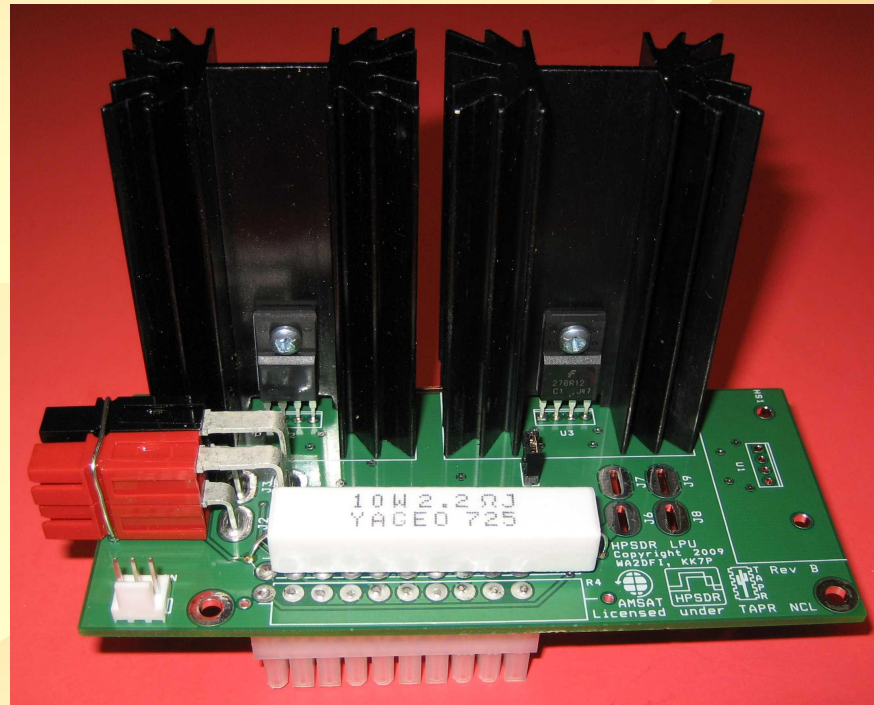
Status: Available from iQuadLabs





LPU

Linear Power Unit



Status: Kits available from TAPR





Pandora Enclosure

OpenHPSPDR Chassis



Status: Available from TAPR





Alexiares RF Bandpass Filters

Alex Quick Features

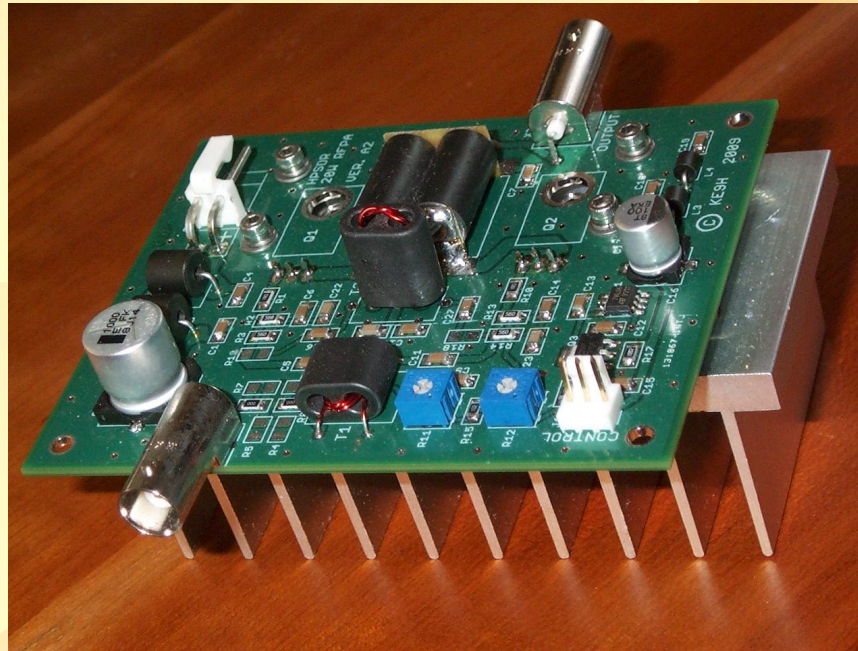
- ❑ Two board set
 - ❑ RX-HPF High-Pass Filter board
 - ❑ TX-LPF Low-Pass filter board
- ❑ 160mm x 100mm boards fit into standard Euroboard housing
- ❑ SPI bus controlled (from Mercury or other SPI)
- ❑ Power requirement: nominal +12V @ 180mA maximum
- ❑ Can operate stand-alone for other applications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





Pennywhistle 20W PA

20W Power Amplifier



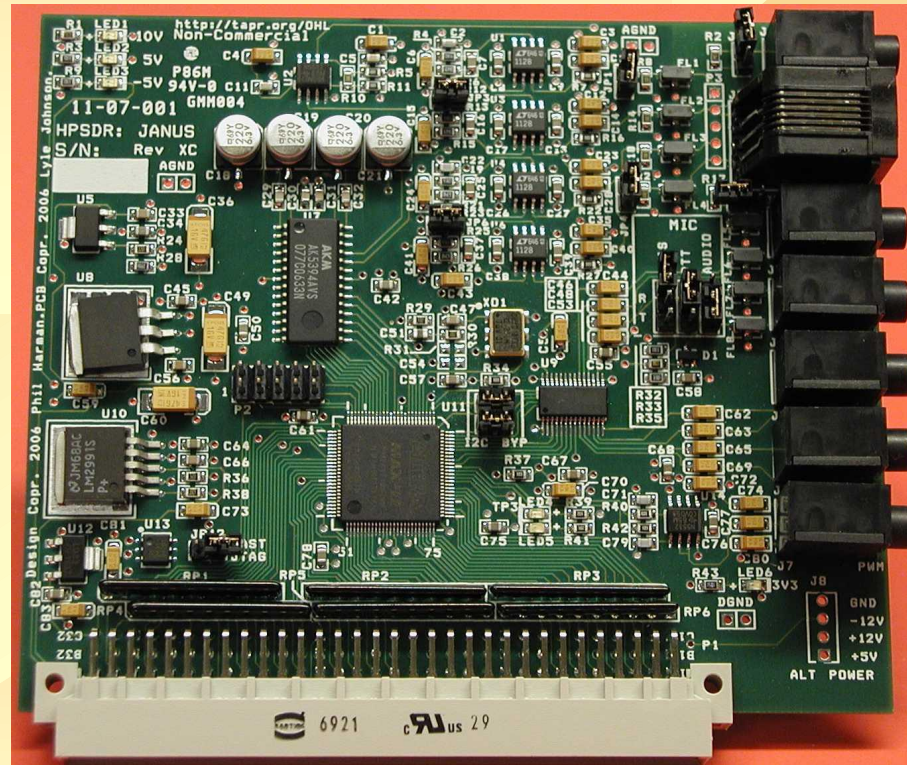
Status: Kits available from TAPR





Janus A/D – D/A Converter

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

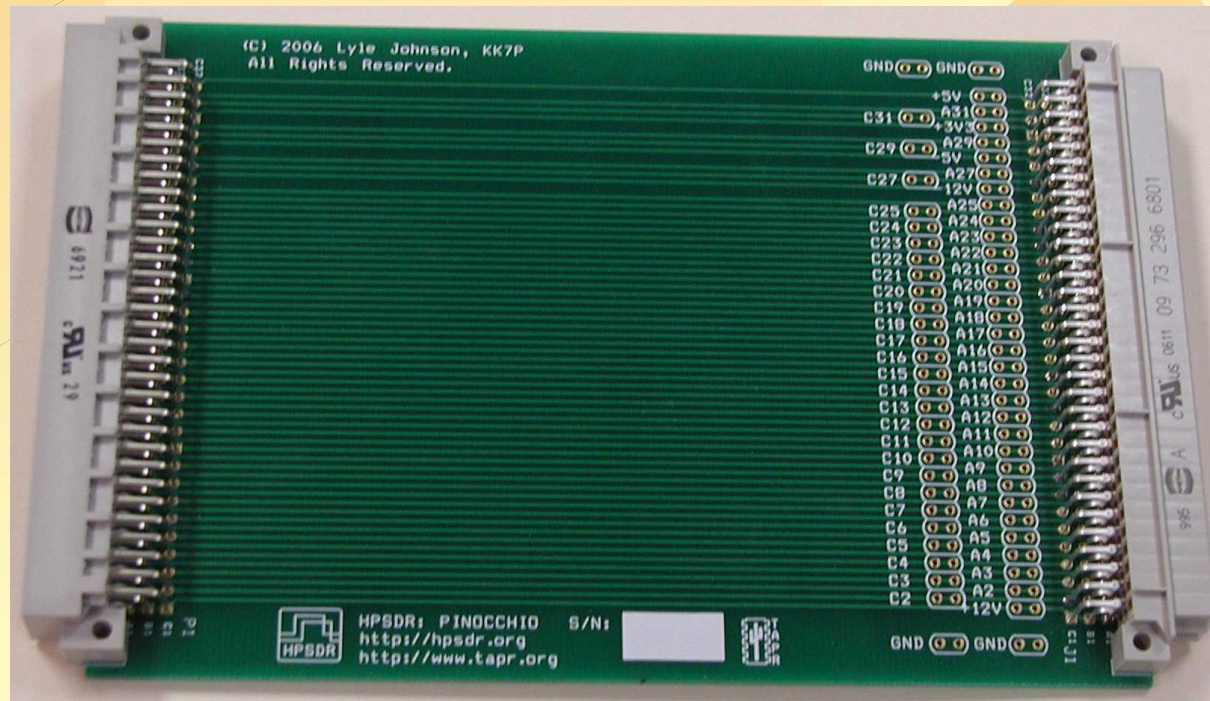


Status: Available from TAPR





Pinocchio Extender



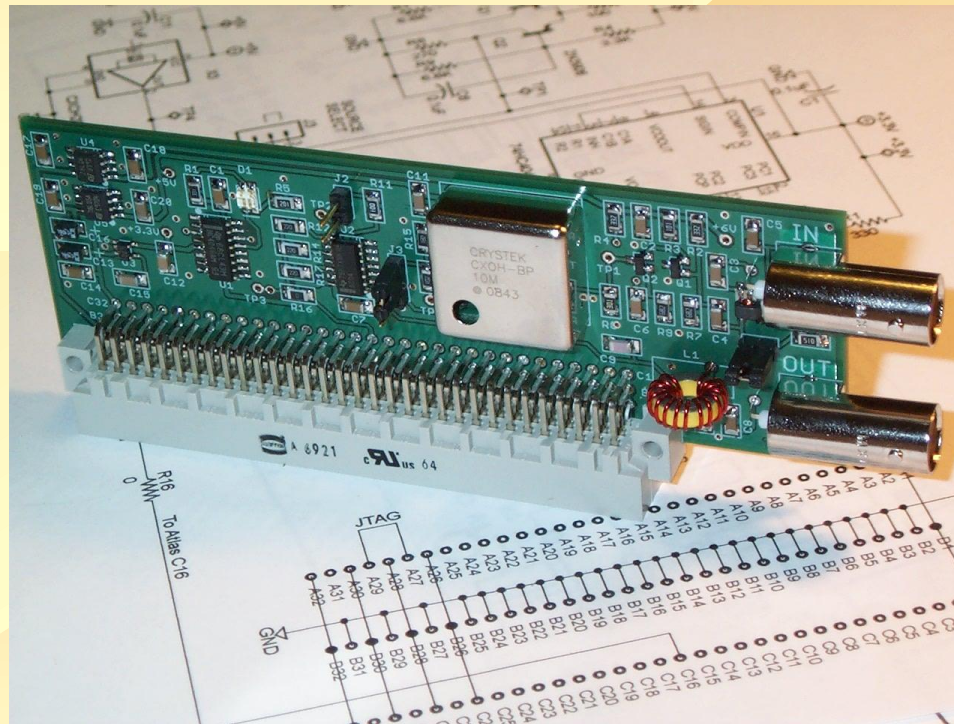
Status: Kits available from TAPR





Excalibur 10MHz Reference

10MHz Clock Reference



Status: Kits available from TAPR





DJ8AY OpenHPSDR boards

OpenHPSDR Boards available from DJ8AY

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

For availability, contact:

Gerd Loch DJ8AY

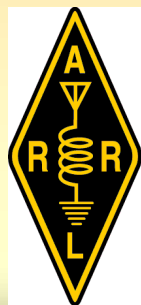
g.loch@nt-electronics.de





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

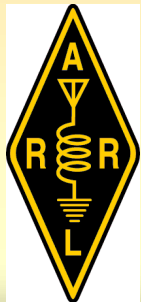




Hermes

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





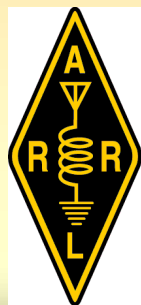
Hermes

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:

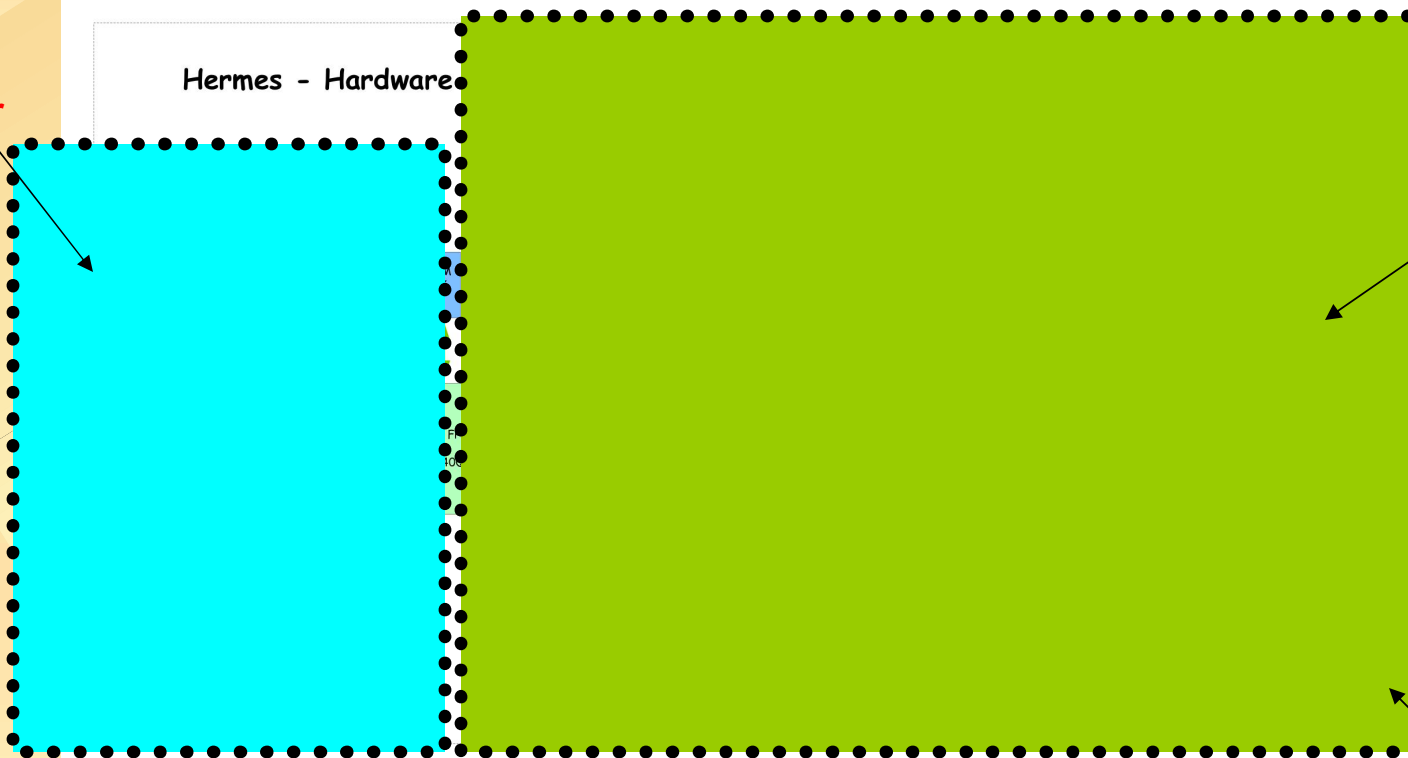
Second GiG-E prototype (A-4) built and tested. All spur issues resolved. Pre-production build underway.



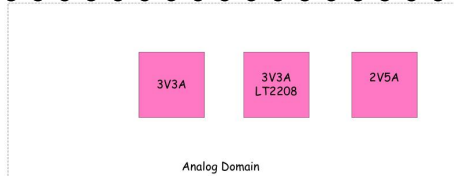
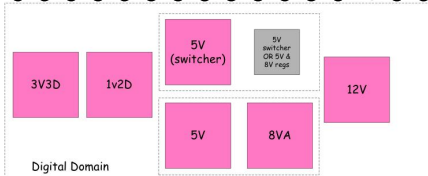


Hermes

Metis
Magister



Penny Lane
Penelope



Hermes
a DDC and DUC
transceiver



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Released under TAPR noncommercial Hardware licence
<http://www.tapr.org/ncl>

Version : 1.7

Mercury

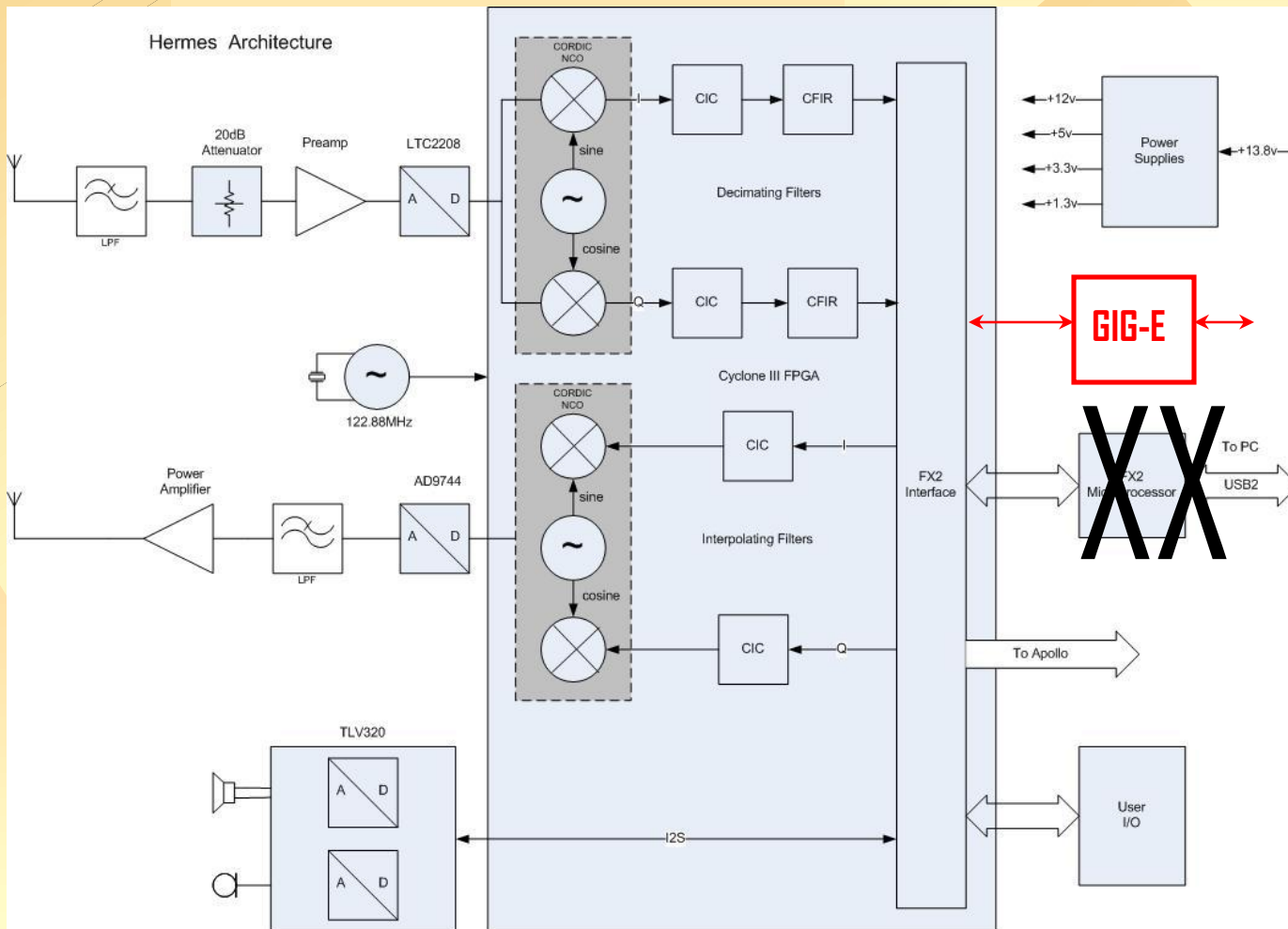


Hermes DUC/DDC Transceiver

© 2011 Scotty Cowling WA2DFI



Hermes



Hermes DUC/DDC Transceiver Architecture

© 2011 Scotty Cowling WA2DFI





Hermes

Single-board DUC/DDC Transceiver



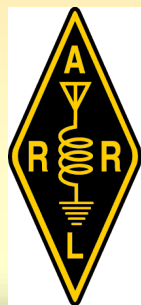
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Hermes Companion

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.





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

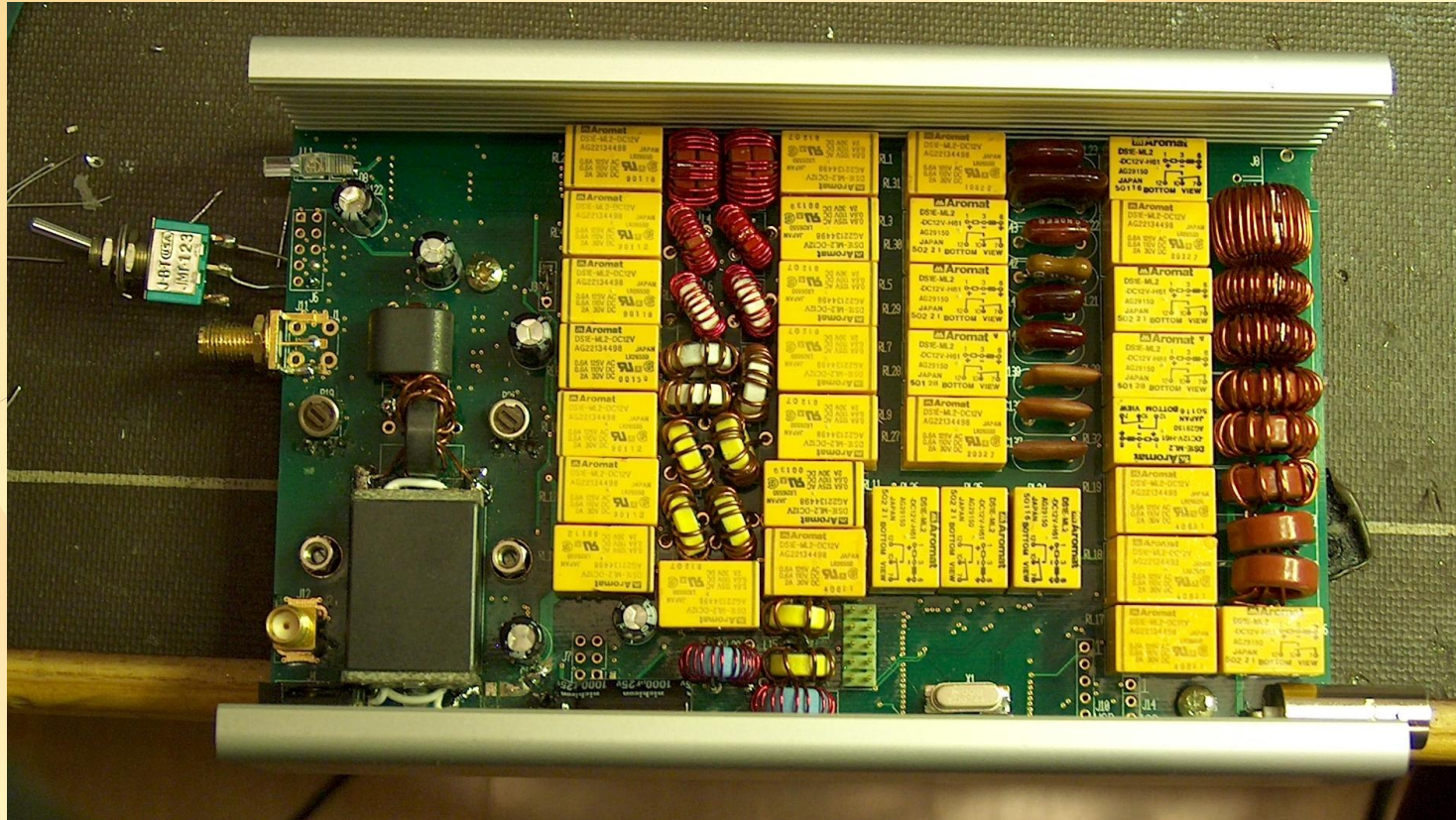
Project leader Kjell, LA2NI

Planned for release slightly after Hermes





Apollo 15W PA-LPF-ATU





openHPSDR-in-a-box

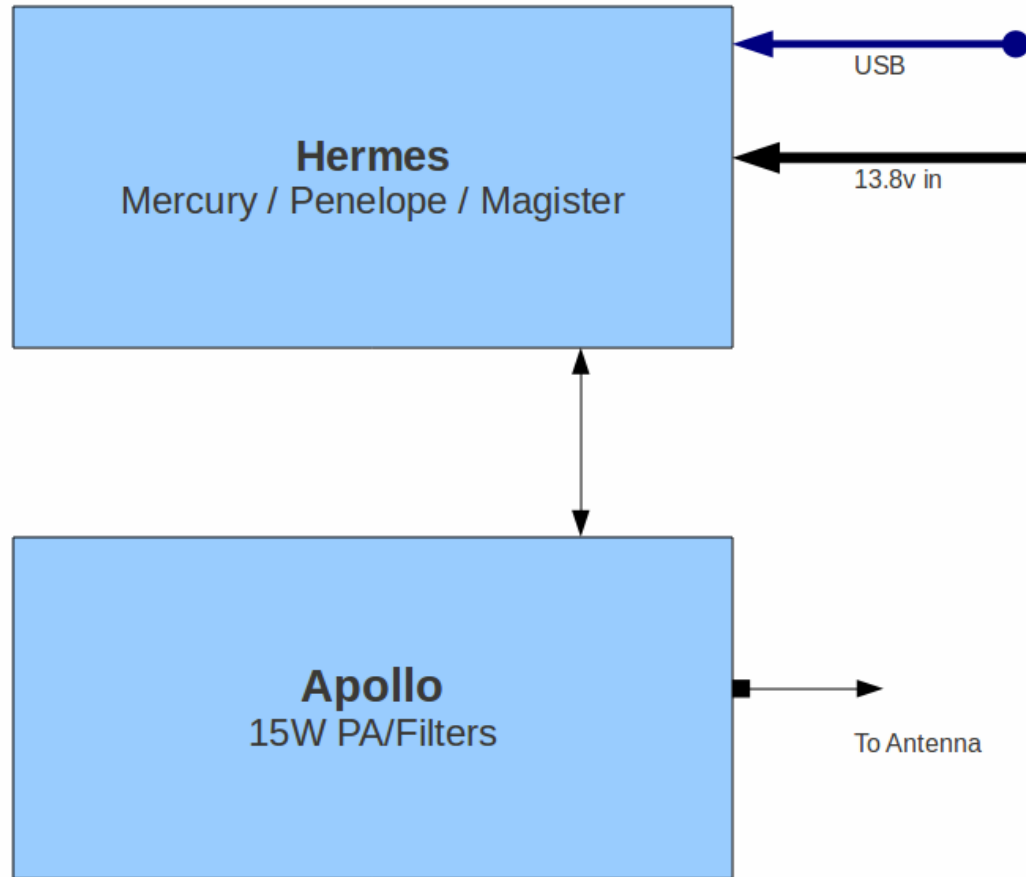
Well, almost!

Hermes and Apollo share a standard enclosure

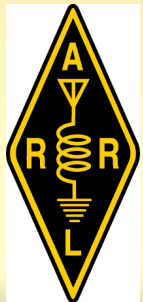
This is the smaller Alpha-2 build form factor

(100mm x 160mm)





Simplified Block Diagram





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 . 10M
 - ❑ 102W on 6M
- ❑ 500mW drive for full output. can be driven by Penelope/Pennylane

Status:

Alpha unit built and under test

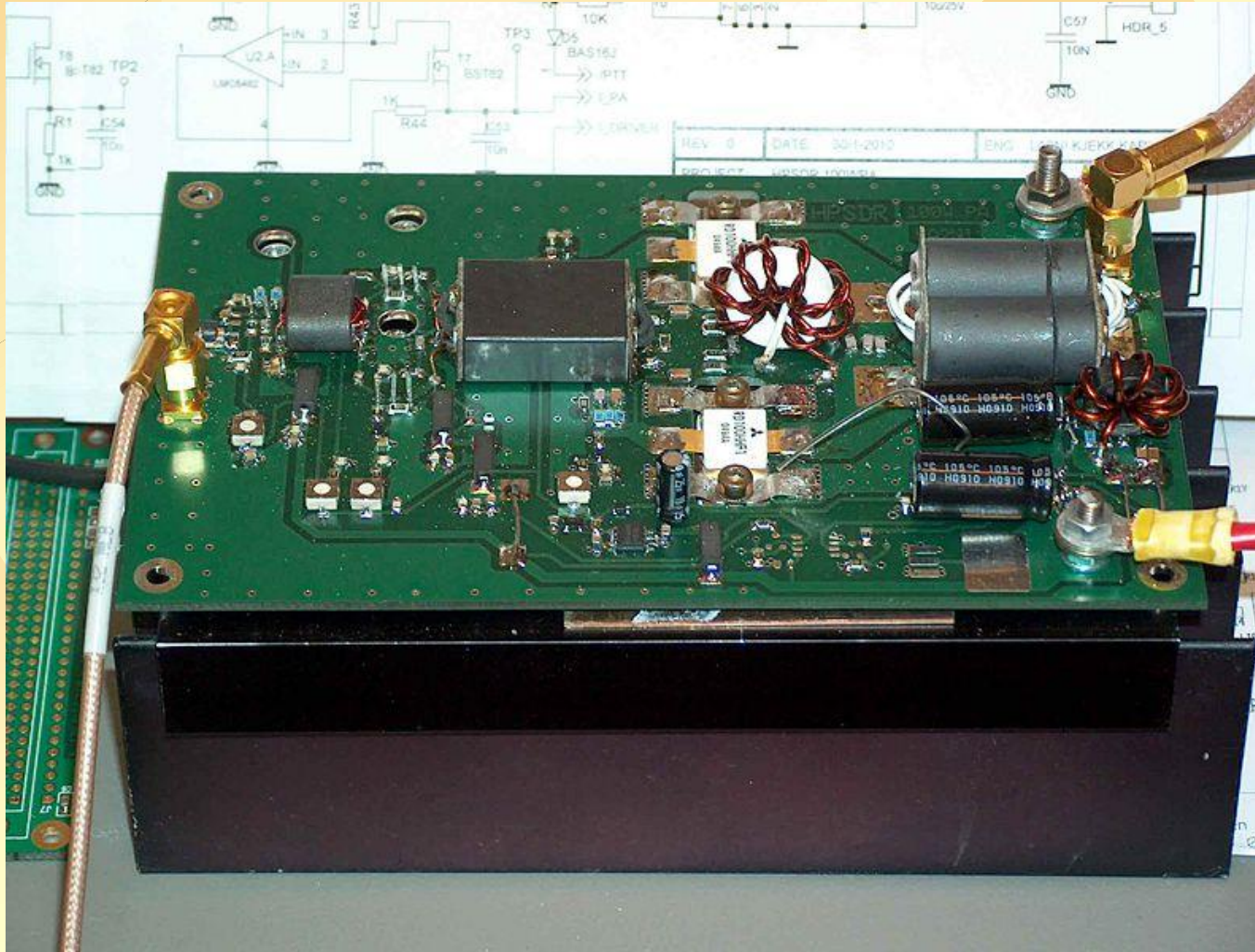
Project leader Kjell, LA2NI

Availability TBD





Munin 100W PA





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

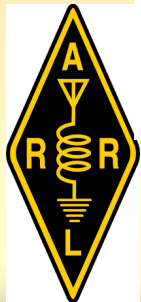
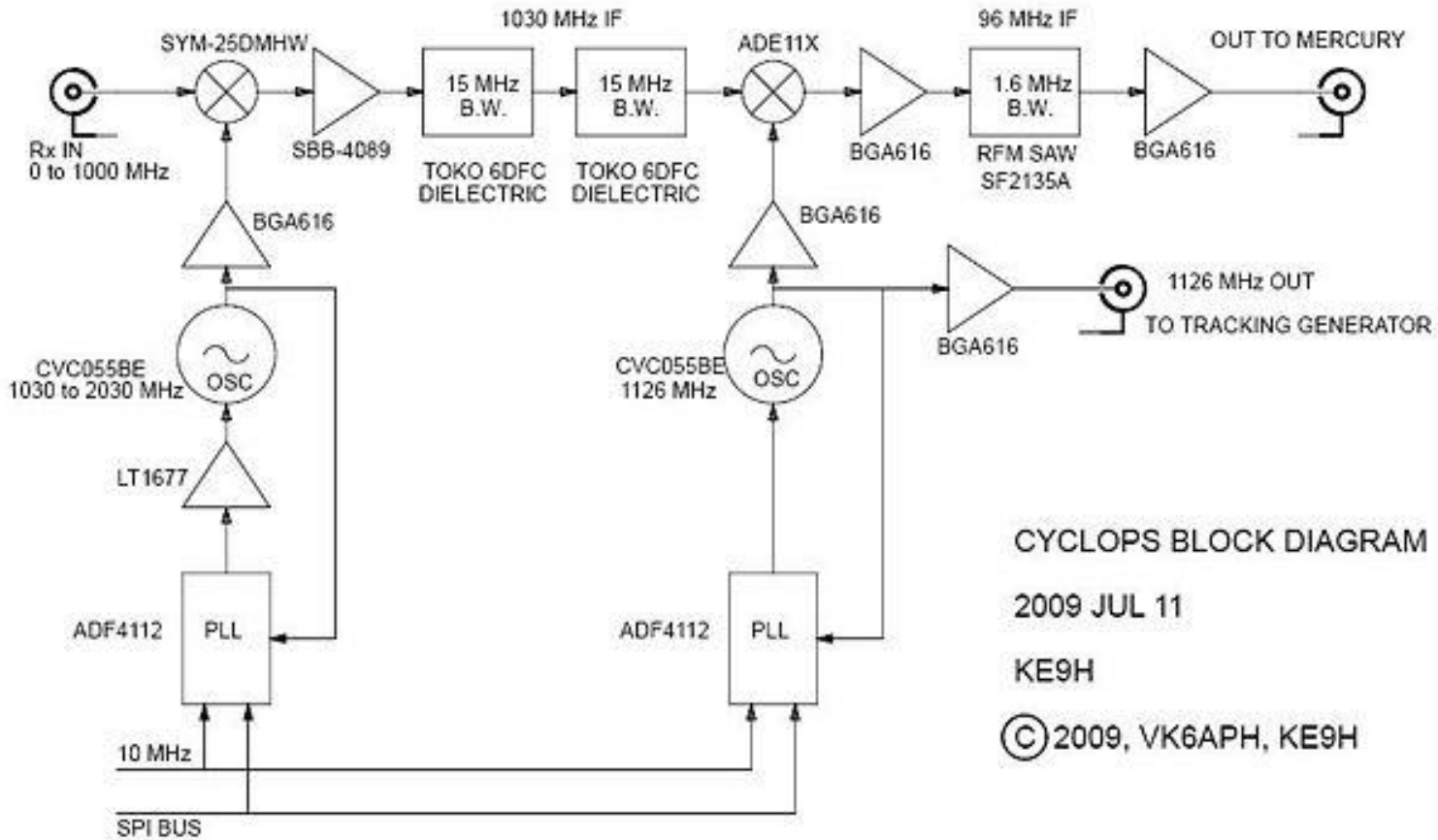
Status:

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

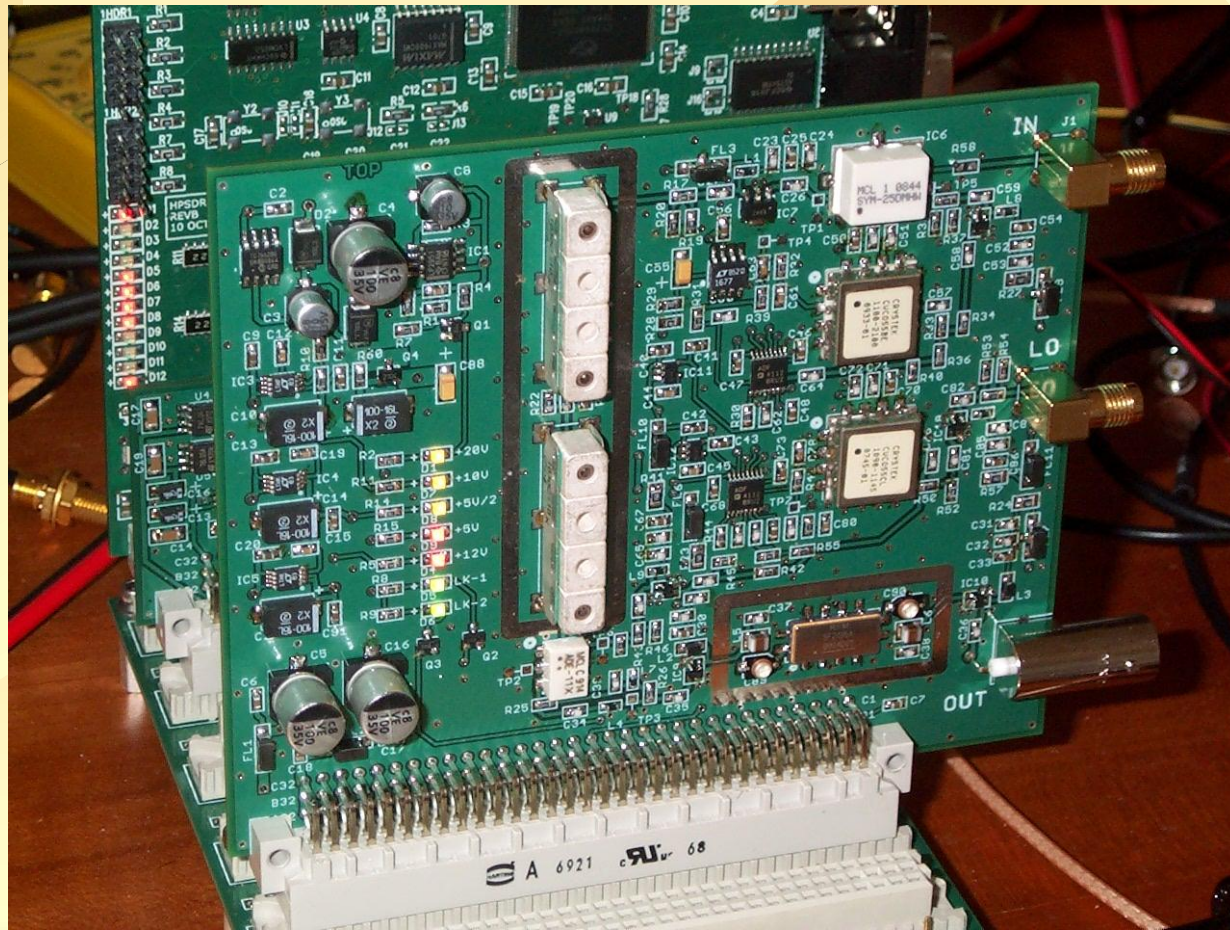




Cyclops

1GHz Spectrum Analyzer

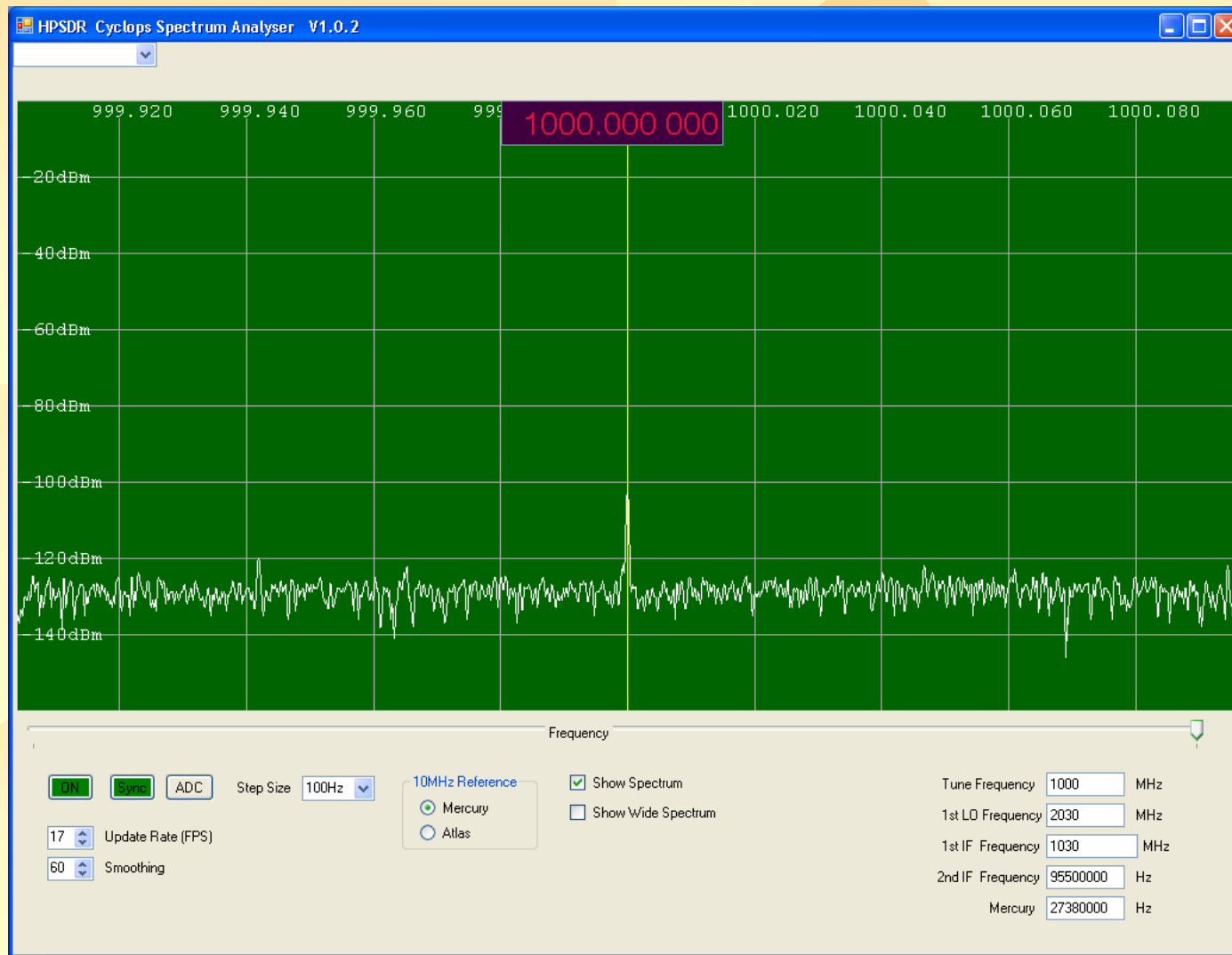
Cyclops
Alpha-1
Build





Cyclops

**Cyclops
Screen
Shot:
1uV @ 1GHz**





New & Improved Cyclops

4 GHz Spectrum Analyzer

- ❑ Project re-activated
- ❑ New devices available to extend range beyond 4 GHz
- ❑ Evaluating ADF4350 synthesizer, DC . 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, VK3OIE 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

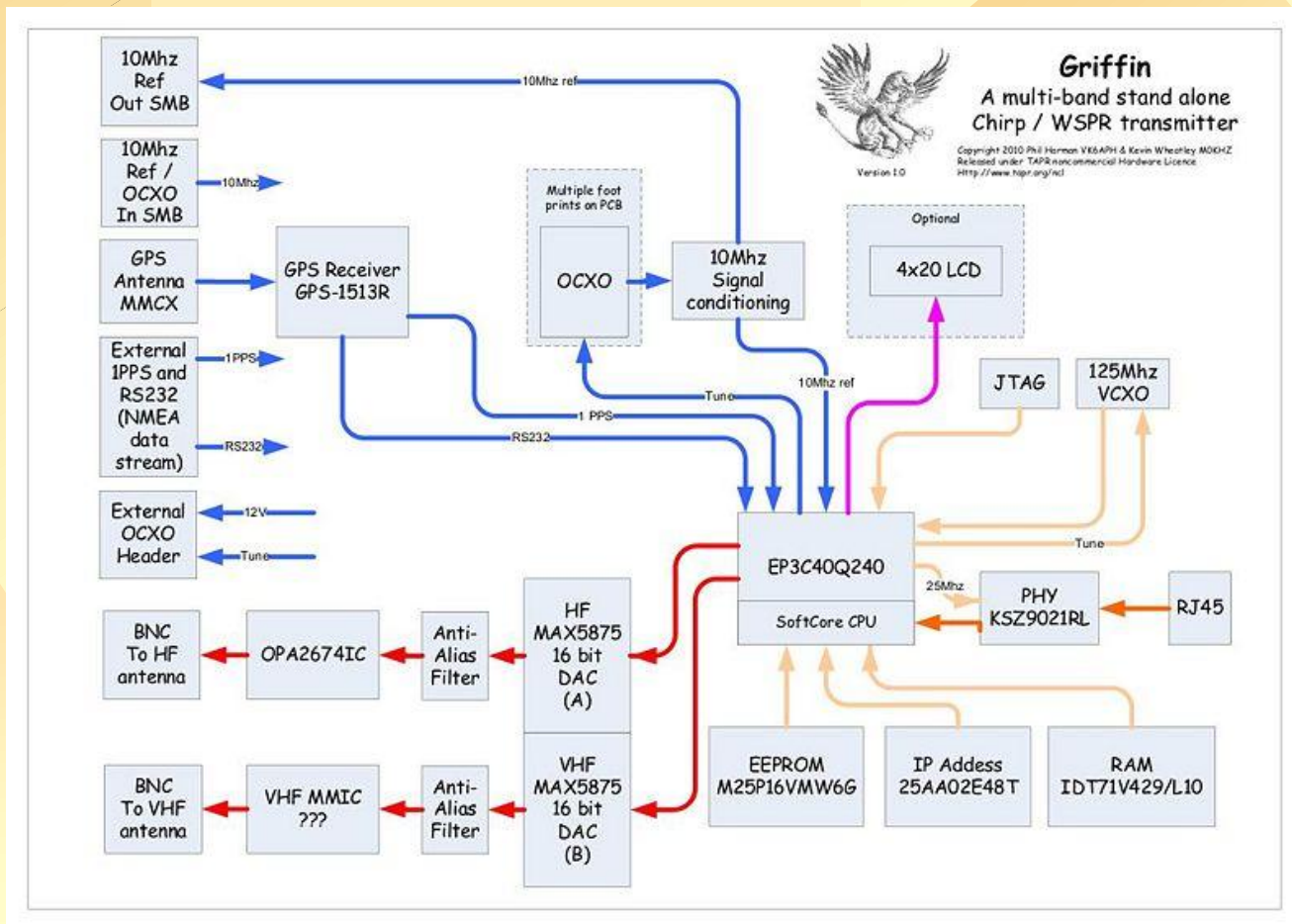
Currently under development





Griffin

HF/VHF Beacon Exciter

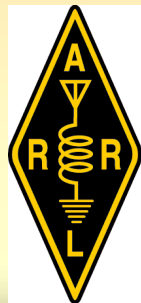




Multiple Receivers, F/W

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

The screenshot shows a Linux desktop environment with a space-themed wallpaper. Four JMonitor windows are open, each displaying a different radio receiver's status. The system monitor on the right shows various system metrics.

Window Title	Band	Filter	DSP	Mode	AGC	AFGain
JMonitor: 24.192.100.58	3.6	9	+20	+60	0.780000	AM
JMonitor: 24.192.100.58	7.00	7.02	7.04	7.06	7.040600	LSB
JMonitor: 24.192.100.58	9.96	9.98	10.00	10.02	10.000000	AM
JMonitor: 24.192.100.58	14.14	14.16	14.18	14.20	14.185000	USB

System Monitor (sidesostat) metrics:

- 25% siderostat
- 22% CPU0
- 32% CPU1
- 49K CPU2
- 123K CPU3
- 123K Disk
- 4M Mem





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

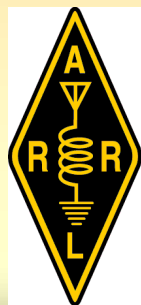
- ❑ GHPSDR3 Server runs inside the FPGA
- ❑ No PC required
- ❑ Ethernet-based server





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





Firmware Update

- ❑ 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





Token Software Page

('cuz Jeremy sez I hafta...)

- ❑ 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, DL3HVV
 - ❑ written in C++/C instead fo C#
 - ❑ uses Qt interface





Token Software Picture

cuSDR
from
Hermann
DL3HVH





Thank you!

Project information at: www.openhpsdr.org

Interest list at: www.hamsdr.com

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

