High Performance Software Defined Radio

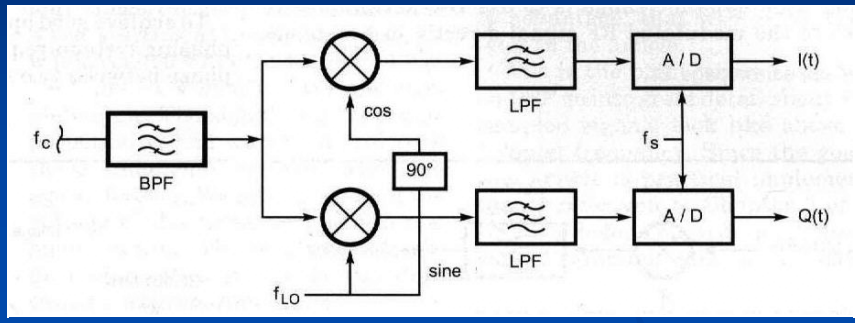
– An Open Source Design –

Lyle Johnson, KK7P

Microhams Digital Conference, 2007

SDR: What Is It?

- Software Defined Radio (SDR) means a radio whose primary functions are defined by software.
  - Not just PC control (CAT)
  - Based on Digital Signal Processing (DSP)



- SDR software can usually be changed or updated by the operator.
  - Ten Tec products since Pegasus (e.g., Jupiter, Argonaut V, Orion)
  - Most other brands don't allow this
- To satisfy our charter for Self Education and Advancing the Radio Art, SDR software is preferably Open Source
  - dTTsp from N4Hy and AB2KT primary example
    - Core of PowerSDR
    - Basis of most work done in HPSDR project
  - LinRAD, GNURadio, Pic-A-Star, DSP-10, EMRFD 18 MHz Project, etc.
- Other SDR software is freely available but not open source
  - Rocky, KGKSDR, Winrad
  - Spectravue is closed but has open-source interfaces to allow 3rd party plug-in and expansion

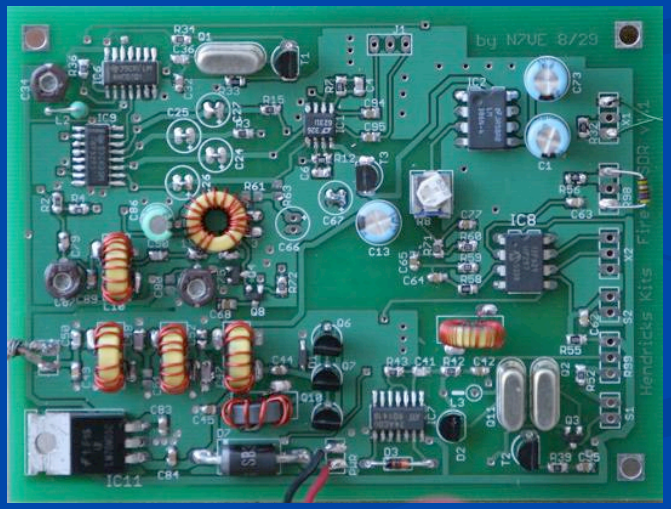
SDR: Examples

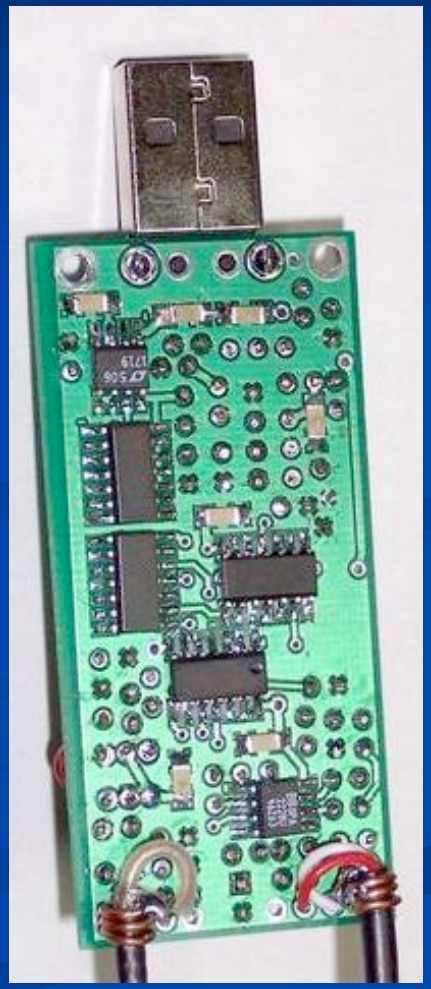
- W7PUA's DSP-10 is a superb example of SDR
  - Based on embedded DSP
  - Open Source
  - See QST 9/99 – 11/99 or EMRFD
  - http://www.proaxis.com/~boblark/dsp10.htm

- Flex Radio's SDR-1000 is first commercial Amateur SDR
  - Flex makes proprietary hardware
    - K5SDR Introduced QSD/QSE
    - QEX July 2002 1st of 4 Part Article
  - Community writes application code
    - Originally by Flex
    - Flex now only writes GUI and Drivers
  - $1500
  - http://www.flex-radio.com/

SDR: More Examples

- Tony Park's Softrock Series
  - QSD for Rx, QSE for Tx
  - $20 for Rx (1 or 2 band)
  - $40 for Tx/Rx (1W, 1 or 2 band)
  - http://groups.yahoo.com/group/softrock40/
- Hendricks QRP Kits
  - Firefly Xcvr
    - QSD Rx
    - Tx not SDR
  - $65 (1 band, CW)

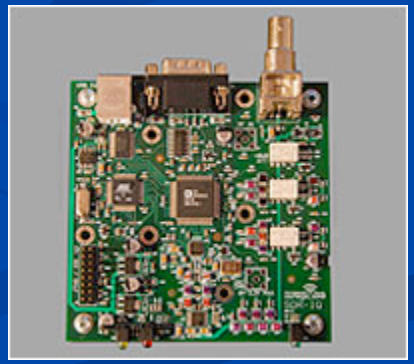




  - http://www.qrpkits.com/firefly.html

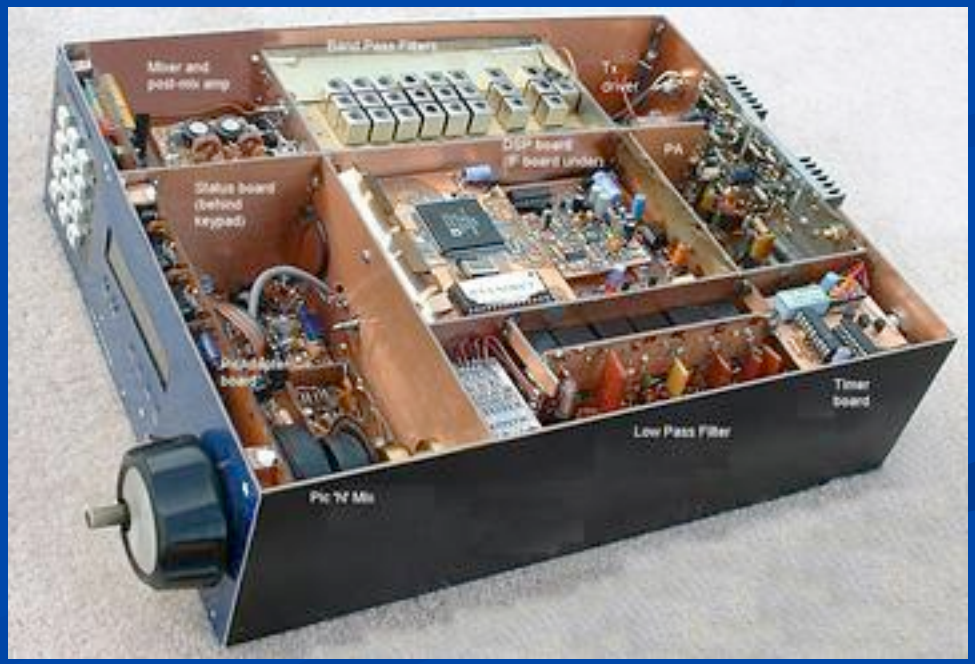
SDR: More Examples

- RFSpace
  - SDR-14 Spectrum Analyzer
    - 14-bit ADC @ 65 MHz
    - $1099
  - SDR-IQ
    - Similar, $450
  - Both Products use single USB Interface
  - http://www.rfspace.com/products.html

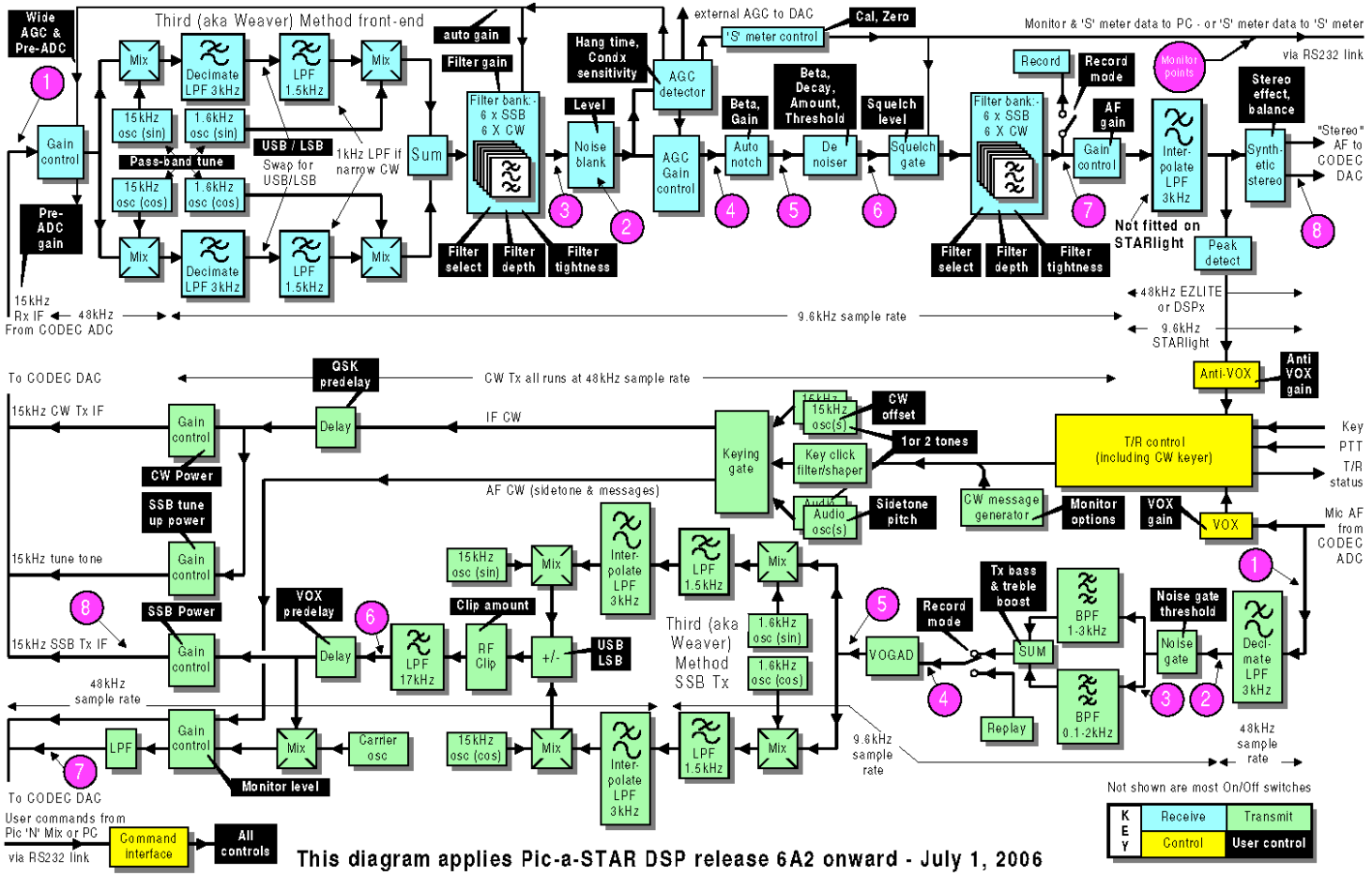


SDR: Pic A Star HF Transceiver

- Design by G3XJP
- Based on 16-bit Embedded DSP
  - Original DSP code derived from DSP10
- Published in RadCom 2002-2004
    - Chapter in Latest RSGB Handbook
- http://uk.groups.yahoo.com/group/picastar



SDR: DSP Code inside Pic A Star



This diagram applies Pic-a-STAR DSP release 6A2 onward - July 1, 2006

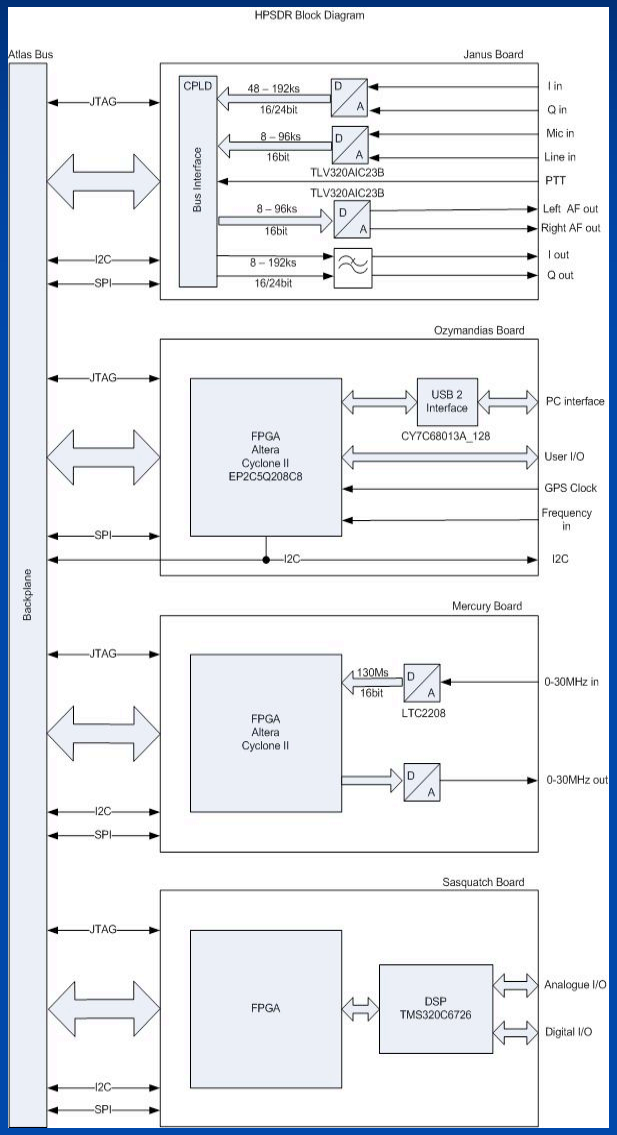
SDR: Grassroots Action!

- Hams are traditionally experimenters.
- A group was formed spontaneously in late 2005 to play around with FPGAs in the context of SDR.
  - FPGA – Lots of parts in one chip
- In a matter of months, HPSDR was formed
  - High Priced SDR?

HPSDR: What's It All About?

- The High Performance Software Defined Radio (HPSDR) is an All-Volunteer Project to Create Hardware and Software Modules for Experimentation and Advancing the Radio Art.
- The designs are Open Source.
  - Software
  - Hardware
  - Programmable Logic (FPGA, CPLD)
- Translation: A Bunch of Geeks Having a Good Time.

HPSDR: What Is It, Really?



- Standalone SDR
  - No PC Required
- Control of SDR-1000
- Superior Quality Sound Card
  - Delta 44, Presonus (Exit Stage Left)
- Spectrum Analyzer (cf. SDR-14)
- USB Interface
- Multiple Plug-In Modules

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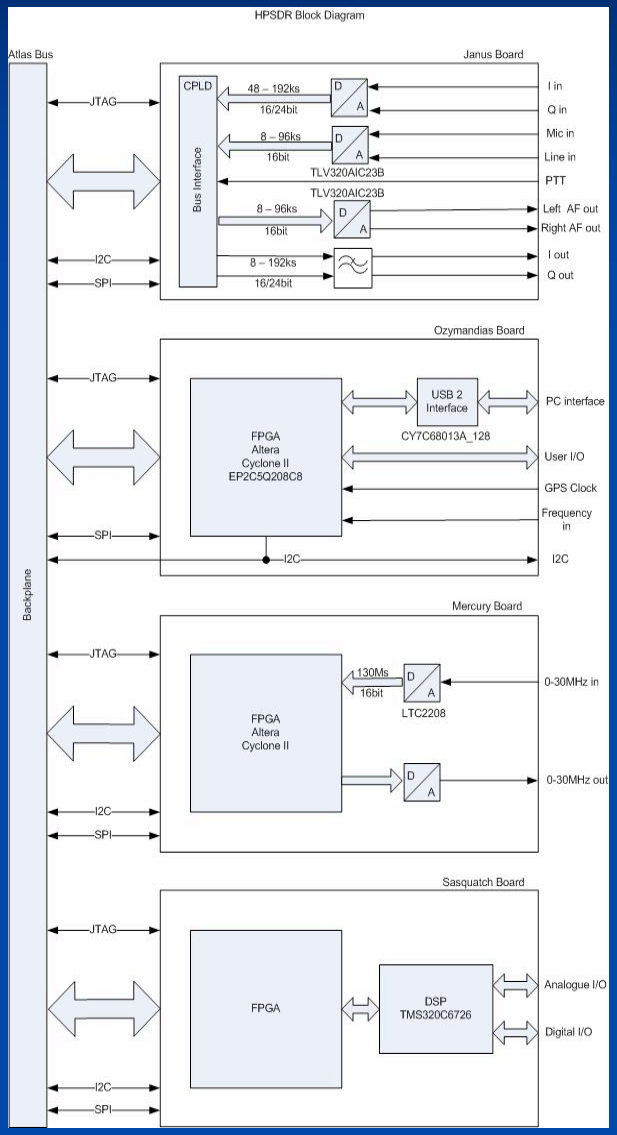

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- Or, like the Accountant said when asked what 2+2 equals, "What would **you** like it to be?"

HPSDR: What's It Do?

- Initially, a High-Performance Sound Card for QSD and QSE Radios.
  - SDR-1000
  - SoftRock Series
  - FireFly
  - Homebrew
- It Will Soon Add Features Like the SDR-14
  - Digitize the Entire HF Band in Real Time
  - Spectrum Analyzer
  - Incredibly Flexible Receiver

Open Source Hardware?

- Many Hams are Familiar with the Gnu Public License for Software
  - The source code is freely available to anyone who asks
  - Any changes you make must be made freely available to anyone who asks – you can't alter it and make it "proprietary"
- We are Providing the Hardware and Logic Designs Under Similar Provisions
  - The designs are freely available to anyone who asks
  - Any changes you make must be freely available to anyone who asks – you can't alter it and make it "proprietary"

Open Source Hardware – Part Deaux?

- TAPR Open Hardware License (OHL) and Noncommercial Hardware License (NHL)
  - The design materials are freely available to anyone who asks
  - Any changes you make must be made freely available to anyone who asks – you can't alter it and make it "proprietary"
- Public Comment Period until March 7, 2007. The designs are freely available to anyone who asks
  - http://www.tapr.org/ohl.html?PHPSESSID=a44a3e7b07c1ba861f7232d46beb96a7

HPSDR: How Is It Designed?

- Community Discussions
  - http://hpsdr.org
  - Wiki: http://hpsdr.org/wiki/index.php?title=HpsdrWiki:Community_Portal
  - Email Reflector/Discussion Group
- Someone Proposes a Project and Leads It
  - They get to be called the Designer
  - Community Discusses It
  - Designer Designs It
  - Design is Reviewed
    - Comments Evaluated

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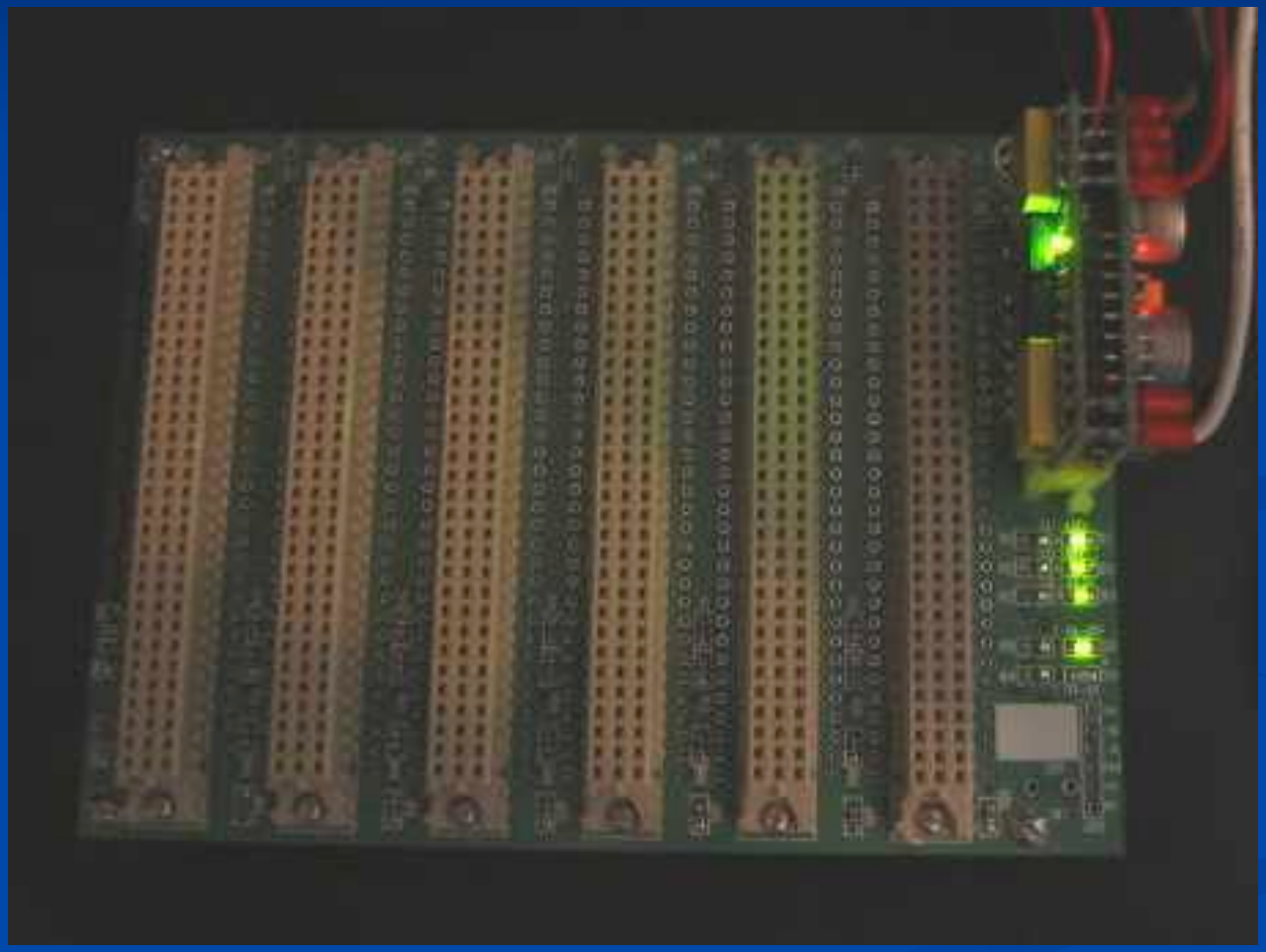
    - Comments Evaluated
    - Re-Design Until Designer Says, "Enough, Already!"

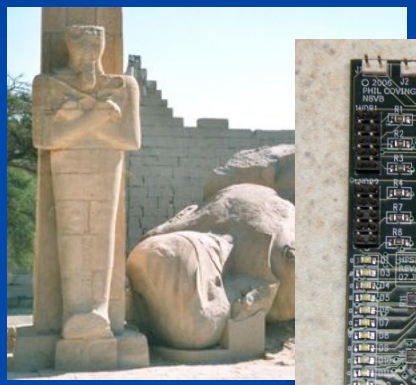
ATLAS – Foundation

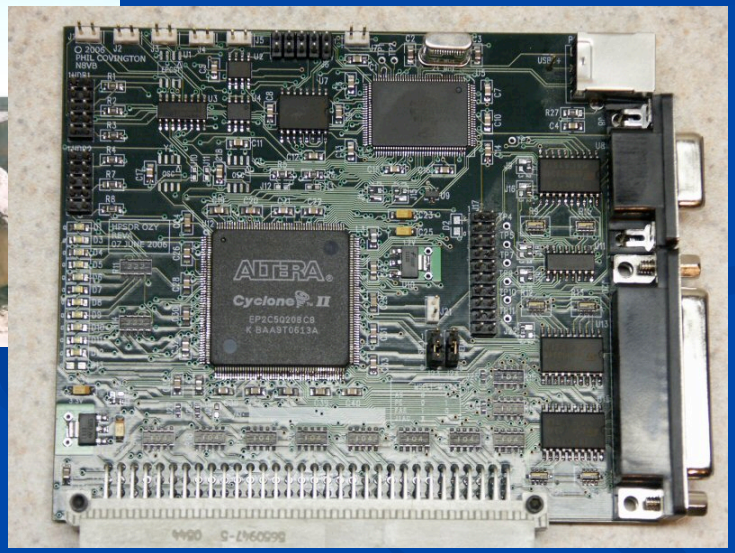


- ATLAS is a passive backplane that all other modules plug into.
- ATX 20 pin Power Connector
  - Recycle that Old PC
- DIN 41612 96-pin Connectors
- First Module
  - No Software!
  - But is it SDR?
- Designer: N8VB

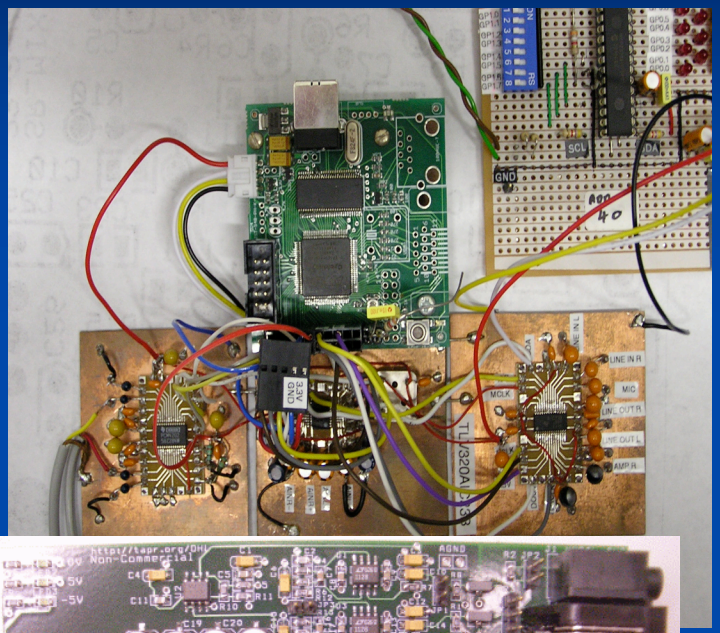
Ozymandias – Ruler

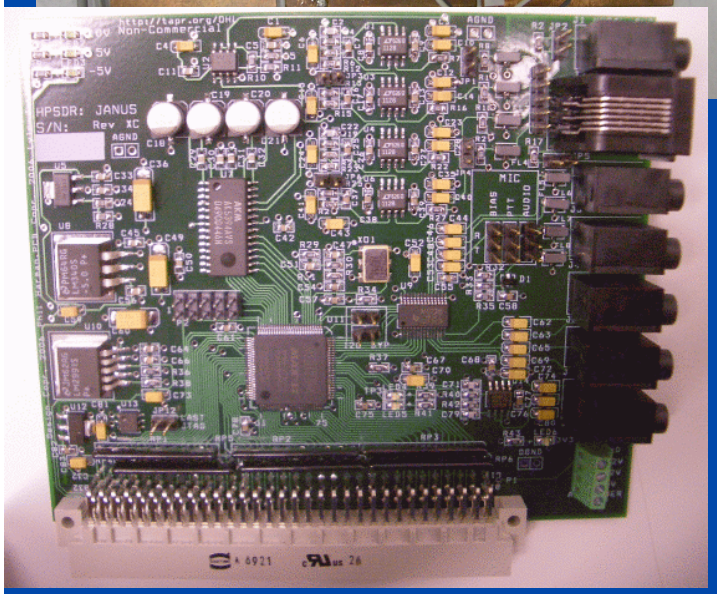
- Ozymandias was a King in Ancient Times.
- OZY is the Module that Controls the Initial HPSDR Systems.
- USB 2.0 PC Interface
  - Cypress FX2 Controller
  - 8051 Processor Core
  - 35 Megabytes/Second
- Altera Cyclone II FPGA
  - User Definable Logic
- Loosely based on:
  - Xylo (http://www.fpga4fun.com)
  - USRP (http://www.comsec.com/wiki?UniversalSoftwareRadioPeripheral)
- Designer: N8VB





Janus – Having It Both Ways

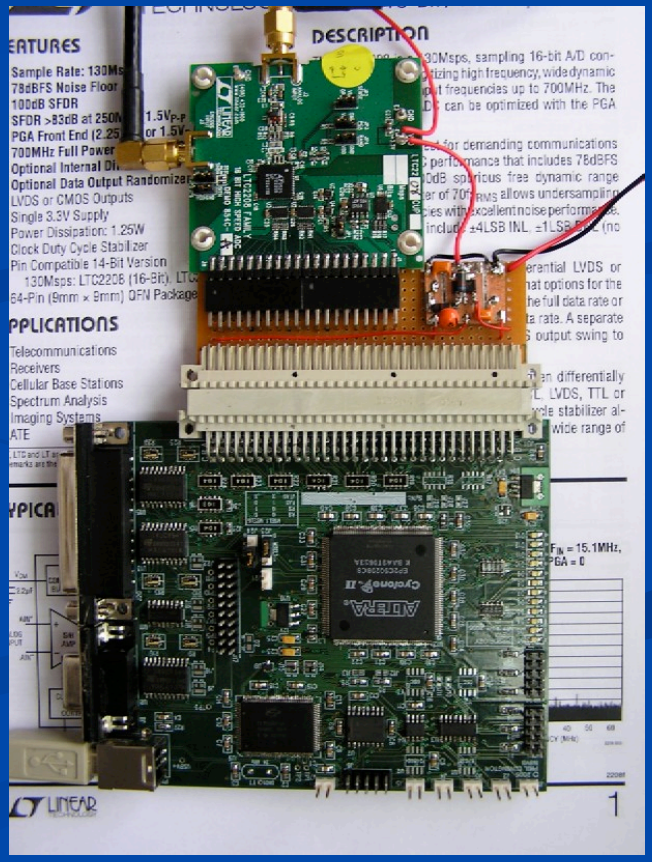




- Analog -> Digital
  - Very High Performance
  - QSD
- Digital -> Analog
  - QSE
- Full Duplex
- International Design Team
  - Phil, VK6APH (Hardware, Verilog)
  - Bill, KD5TFD (Software)
  - Support from KK7P, N8VB

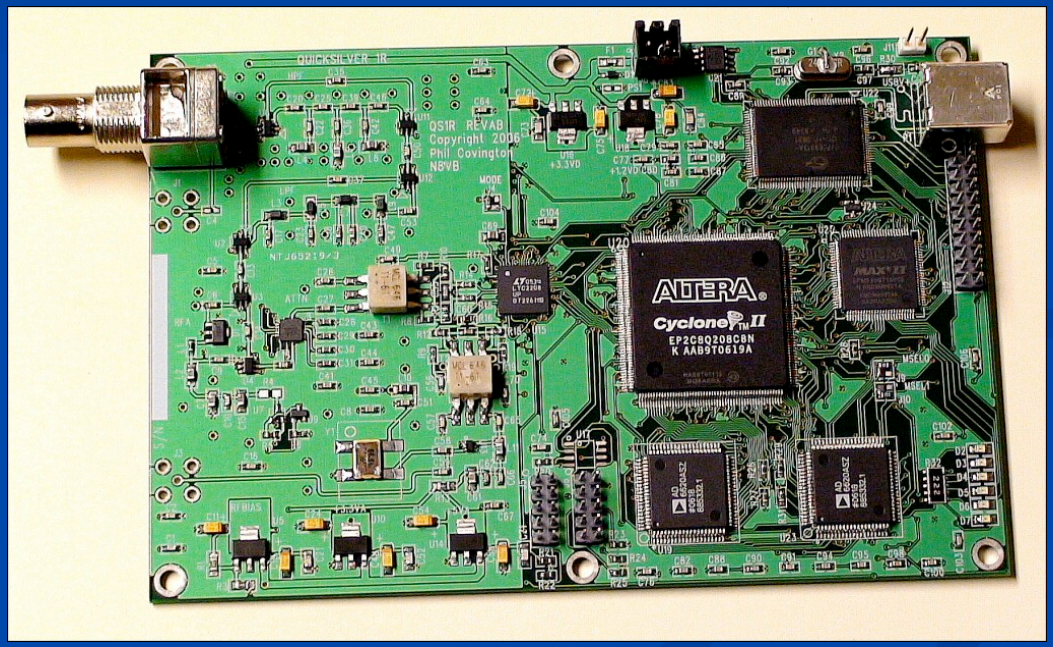
Mercury – That Dude is Fast!

- 16-bit ADC Running at 130 MHz!
  - Linear Technology LTC2208 ADC
  - Sample entire HF Spectrum in Real Time
- Cyclone II FPGA
  - Digital Down Converter
    - Typical Bandwidth Reduction to 200 kHz
  - User Defined Features
- USB
  - On-board FX2
- Prototype measures:
  - Max Input Signal +9 dBm
  - MDS (500 Hz BW) -120 dBm
- Designers: N8VB and VK6APH



QuickSilver

- Mercury Core
- USB
  - Single Board
- Not HPSDR Project
  - Yet?
- Designer: N8VB

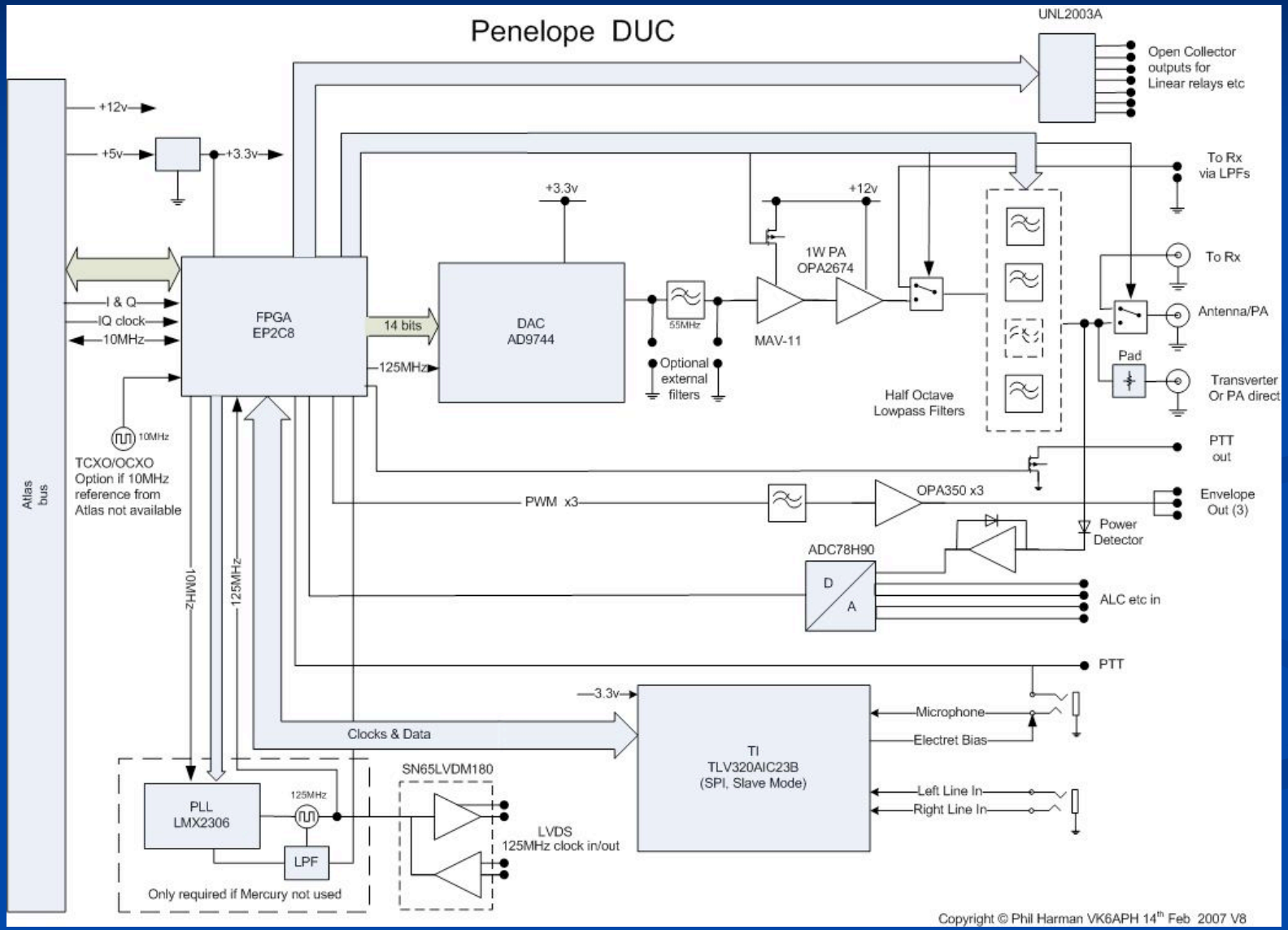


- http://groups.google.com/group/quicksilver-sdr-support

Penelope – Digital Xmtr

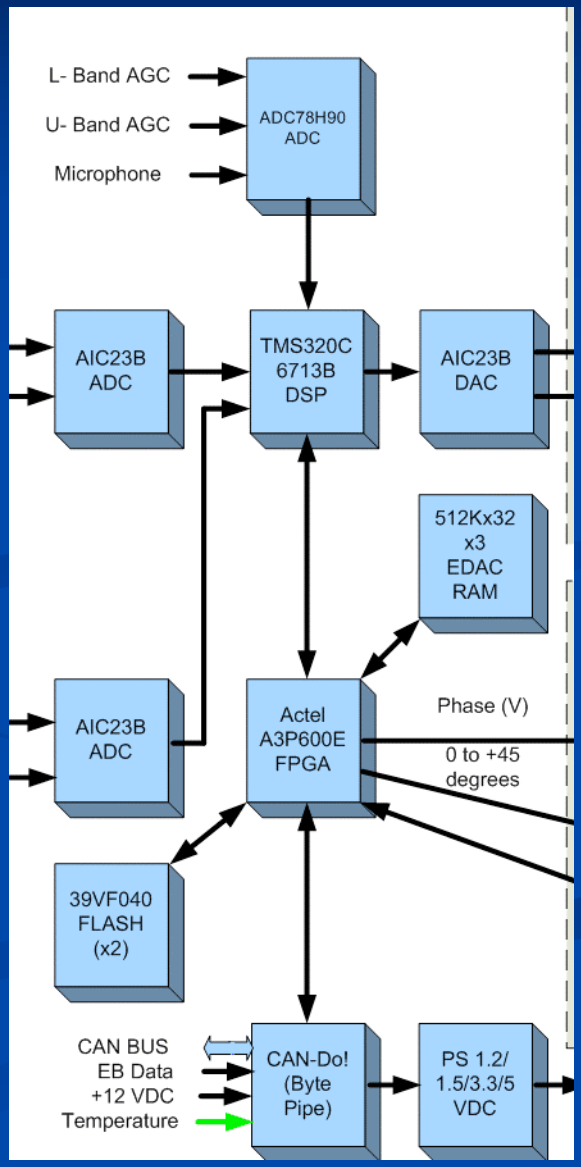
- 16-bit DAC Running at 130 MHz!
  - Analog Devices AD9744
  - 1.8 – 54 MHz for Amateur Use
- Cyclone II FPGA
  - Digital Up Converter
  - All Modes
- USB
  - Via OZY
- Prototype measures:
  - 0.5W to 1W Output
- Designers: N8VB, VK6APH w/help from KK7P

Penelope – Not Howard!



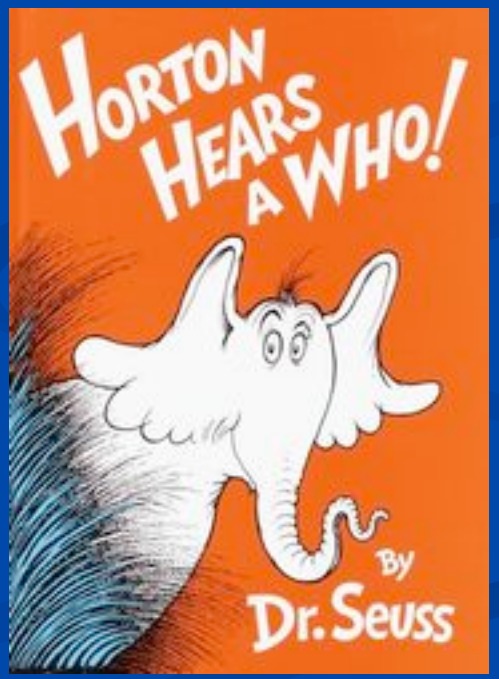
Sasquatch – Big and Bad

- Based on AMSAT SDX Core
- High Performance Floating Point DSP
  - TI TMS320C6726
  - Don't Need No Stinkin' PC
- Flash Memory
  - No Other Controller Required
  - Standalone Applications
- Analog and Digital I/O
  - Analog For QSD/QSE
  - Digital for EER
- FPGA
  - Envelope Elimination and Restoration (EER)
  - HELAPS to AMSATters
  - Super High Efficiency Transmitters
- Designer: KK7P



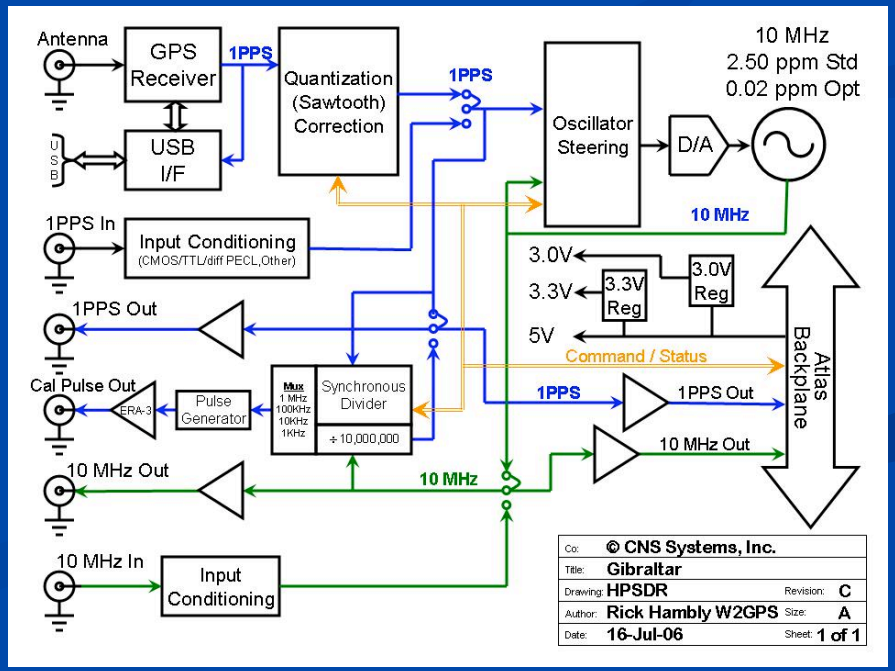
HORTON – It Pays to Listen

- Receiver Module
- Integrates ADC of Janus with QSD
  - More Likely ISD
- So far, just a proposal



Gibraltar – Stable as a Rock

- System Reference Oscillator
  - 10 MHz Output
  - Additional Frequencies Simultaneously
  - Ovenized Oscillator
- GPS Disciplined
  - Long Term Accuracy
- Pending OHL
- Designer: Rick, W2GPS



Proteus – Have It Your Way!

- Module with:
  - IC Footprints
  - Power Supply Regulators
  - ATLAS Bus Connector

- Breadboard for Prototyping Your Designs

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  - Power Supply Regulators
  - ATLAS Bus Connector

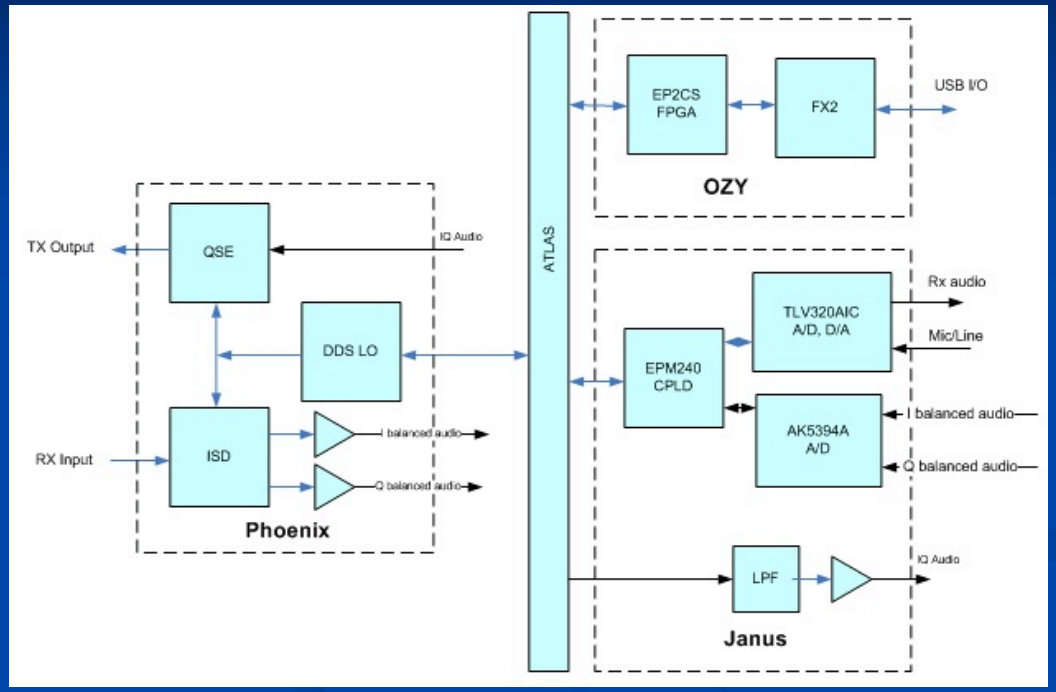
- Breadboard for Prototyping Your Designs
  - This means **YOU**
  - It's All About Having Fun

Pinocchio – The Extender

- ATLAS-based Extender
- Allows Probing and Troubleshooting While Operating
- Designer: KK7P

Phoenix: SDR Reborn

- QSD Rx
- QSE Tx
- Synthesizer
  - DDS?
  - PLL?
- Quick Path to On-the-Air
- Alternative to Penelope/Mercury
  - Uses Janus for ADC/DAC
- Designer: Ray, WB6TPU



Odyssey – Handheld SDR

- QSD/QSE at 10.7 MHz
  - Easy-to-Use IF Processor
- dsPIC33 for DSP Functions
- PIC24 for Other Control
- VIDEO CAPTURE CARD!
- First Application is SuitSat-2
- Designers:
  - Joe, N9WXU
  - Steve, N7HPR
  - Frank, AB2KT
  - Bob, N4HY
  - Lou, W5DID

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Is this what Homer had in mind when he wrote "The Odyssey"

HPSDR: Where to Get Modules

- TAPR Volunteers are Making Boards Available
  - Bare Boards
  - Kits
  - Assembled/Tested Boards
- Available Now:
  - ATLAS
  - Pinocchio
- Accepting Orders:
  - Janus
  - Ozy
- Followed by:
  - Mercury
  - Penelope
  - ???

HPSDR: Your Radio

- This is a Community Effort
- Designed by Hams in the Traditional Amateur Spirit
  - Time and Talent Freely Given
  - Anyone Can Participate
  - Everyone Can Learn
  - International Participation
- Support Especially from The Usual Suspects
  - AMSAT
    - $1,000,000 of Shared Development Tool Licenses
  - TAPR
    - Development Funds
    - Board Distribution

HPSDR

THANK YOU!

Questions?