



# Choices in Embedded DSP for SDR

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# Overview

- Should I Walk Out Now?
- What is an SDR?
- Primary Hardware Architectures for SDR
- Main Approaches to Implementation
- Choices in Embedded DSP
- Summary

# SDR: Who Cares?

- This Talk is Aimed at Two Groups
- Experimenters
  - Write/Modify Code
  - Build Hardware
  - Explore and Apply Component-Level Technology
- Operators
  - De-Mystify SDR
  - Understand Difference Between DSP and SDR

# SDR: What Is It?

- SDR: **S**oftware **D**efined **R**adio
- Software Implements the **Modes**
  - AM, FM, SSB, CW, Synchronous AM, ...
- Software Implements the **Features**
  - VOX, QSK, Equalizers, ...
- Software Enforces the **Limits**
  - Tx Frequency, Power, ...
- Software Allows **Generalized Hardware**

# SDR: What Is It?

- SDR **Does Not** Mean PC-Based
- SDR **Does** Mean **Digital Signal Processing**
  - But DSP **Does Not** Mean SDR
  - Might Just be Audio Filters (FT1000, TS480, IC706)
- SDR Implies Ability to Change Software
  - We **Expect Upgradability** by the User
  - New Features/Modes by Means of Updates
  - Internet Distribution
  - Software/Firmware Distinction is a Red Herring

# SDR Architectures

- Direct Digital Sampling
  - SDR-14, SDR-IQ, Perseus, QS1R, Mercury (Receivers)
  - Penelope (Transmitter)
  - ADAT-200A, Hermes/Apollo (Transceiver)
- Direct Conversion To Baseband (Audio)
  - Flex Products
  - SoftRock Series
- Superhet With Bandpass (Roofing) Filters
  - Elecraft K3, Ten Tec Orion, Yaesu FT5000, ...
  - DSP-10, Pic-A-Star
- All Possible with PC or “Embedded” DSP
  - Embedded Simply Means Contained Within the Product

# SDR Architectures: Receiver

- Holy Grail is an ADC at the Antenna Jack
  - Convert to Digital As Soon as Possible
  - Needs Really Fast ADC and Blazingly Fast DSP
    - Anti-Aliasing Requires a Front End Filter
    - Blazingly Fast DSP in Software Defined Hardware (FPGA)
- Otherwise Signal Must Be Down Converted
  - Quadrature Oscillator/Mixer to Baseband
  - Traditional Front End to Low IF



# SDR Architectures: Transmitter

- Conceptual Goal is a DAC at the Antenna Jack
  - Convert from Digital As Late as Possible
  - Needs Really Fast DAC and Blazingly Fast DSP
    - Reconstruction Filter Required
    - Blazingly Fast DSP Can be Done in Hardware (FPGA)
- Otherwise Signal Must Be Up Converted
  - Quadrature Oscillator/Mixer from Baseband
  - Traditional IF to Operating Frequency Signal Conversion



# To PC or Not to PC

- PC-Based SDR Designs are Suitable for Fixed (and Sometimes Portable) Use
  - Sunlight Readable PC Screens are Rare
  - Mouse Somewhat Impractical for Mobile Operation
- PC-Based Radio is Sharing the PC's CPU and OS
  - Drivers and Upgrade Support
  - Latency
    - Block Processing vs Per-Sample Processing
    - Other Programs and Processes (DPC)
- Common Examples of PC-Based Designs
  - Flex, MicroTelecom, RF Space, SRL-LLC
  - OpenHPSDR

# Embedded DSP

- Low Power (500 mW vs 50-200W for a PC)
- Low Cost
- Simple, Fast, Intended for Real Time Applications
  - No GUI-Based, Cycle-Stealing OS
- **All** the DSP's Power is Available for the SDR
  - A 75 MHz DSP Can Often Keep Up With a 2 GHz PC
  - Imagine What a 600 MHz DSP Can Do!
    - Is This “Less's Law” ?
- Let's Take a Closer Look

# DSP Choices

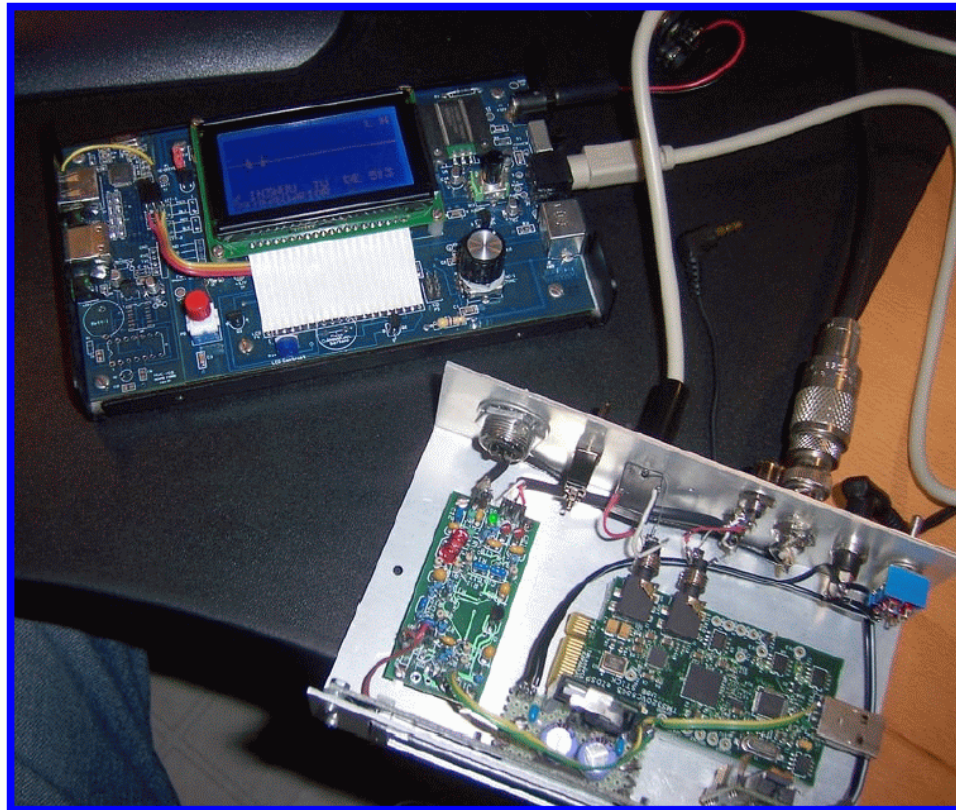
- DSP Chips Are Available in a Wide Range of Computational Power and Speed
- Low End: 16 bit Fixed Point
  - Fixed Point Just Means the Math is Harder
    - dsPIC: 40 MIPs
    - Analog Devices Blackfin: 400 MIPs
    - TI TMS320VC5500 Series: 100-400 MIPs
- High End: 32 bit Floating Point
  - Analog Devices SHARC
  - TI TMS320VC674x

# Low End DSP Possibilities

- Icom IC-7000 (Operators)
  - Analog Devices Blackfin: 400 MIPs
- SoftRock (Experimenters)
  - PC Based, so not Embedded DSP
  - But Wait, There's More...
- Midnight Design's NUE-SDR (Experimenters **and** Operators)
  - TI 16-bit "USB Stick" Eval Board: \$49
  - Uses SoftRock 6.3 RxTx!



# NUE-SDR Pre-Prototype



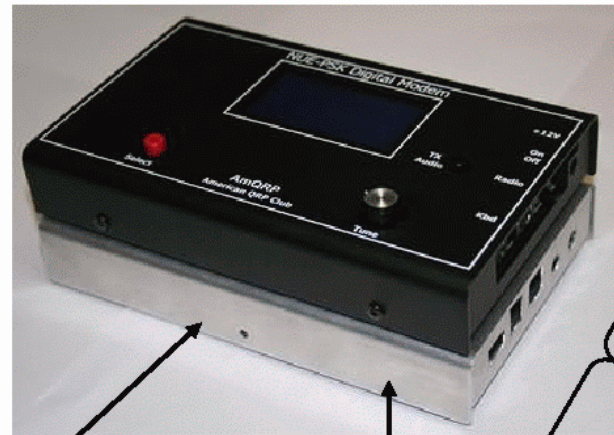
**NUE-PSK Digital Modem (upper left)**

Spectrum display of SDR output displays band activity

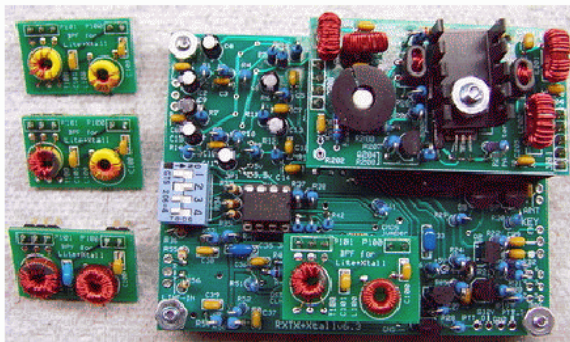
**Prototype Clocking, Tuning and HF Modem (lower right)**

SoftRock (left), eZDSP starter kit running NUE-SDR v0.5 software and Si570 Controller & Frequency Generator on front panel

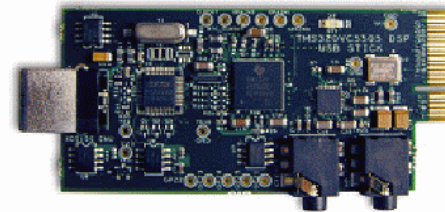
# NUE-SDR Prototype



Optional add-on  
NUE-SDR transceiver



Softrock RXTX 6.3



eZDSP USB Stick

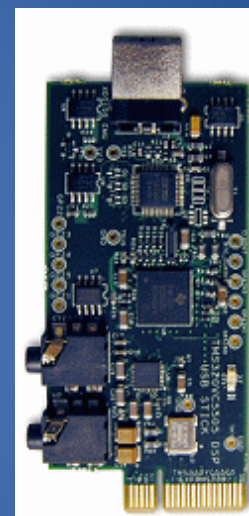
# Development Tools for Low End DSP

- dsPIC
  - MPLAB IDE (free download from Microchip)
  - C Compiler (free download from Microchip)
  - ICD-3 Debugger (about \$150)
- Blackfin
  - Analog Devices Tools: \$3,500 (oops...)



# Development Tools for Low End

- TI TMS320VC55xx
  - TMDX5505EZDSP Eval Board: \$49
    - Includes USB Debugger/Loader
    - Includes Stereo Audio I/O
    - Embeddable in Projects (e.g., NUE-SDR)
  - TMDX5515EZDSP Eval Board: \$79
    - Higher Performance, More Features
  - Full Code Composer Tool Suite
    - Free Download
    - Fully Functional if Eval Board Attached
      - Otherwise \$1,995 and up



# High End DSP Possibilities

- Suitable for High Performance Radios
  - Huge Dynamic Range
  - Fast: 1.2 **Billion** Floating Point Operations/Sec
    - Bill Gates, Steve Jobs nor Linus Torvalds get any of those cycles!
- Today's High Performance Transceivers Use 32-Bit Floating Point DSP (or PCs)
  - But Not All are SDRs (e.g., Field Upgradeable, Software-Defined Features)

# High End DSP Chips

- Analog Devices SHARC Series
- Used in (Operators):
  - Ten Tec Orion
  - ADAT-200A
- Expensive Development Tools (Experimenters)
  - \$3,500 SW
  - Emulator/Debugger...
  - Oops...

# High End DSP Chips

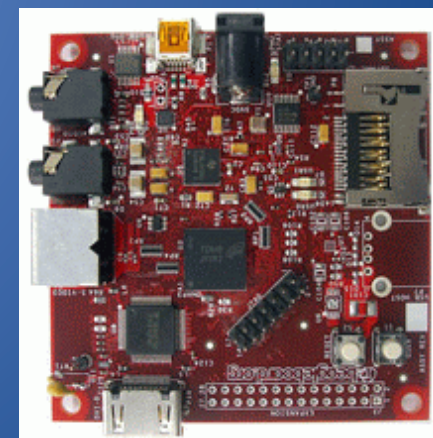
- TI TMS320VC674x Series
  - Up to 1.2 Billion Floating Point Operations/Sec
  - Low Power (under 1 watt)
- Development Tools (Experimenters)
  - Free if Using \$99 Debugger
    - Cheap Enough for Hams!
  - \$1,995 if Using Higher End Debugger/Emulator

# Yet Another Approach

- TI's OMAP (Experimenters)
- OMAP is a 300 MHz ARM Plus a 300 MHz DSP
  - Inexpensive
  - Low Power
  - Widely Used in Cell Phones!
- Latest Chips use 674x DSP Core
- ARM Can Run Linux for UI and Background
  - DSP Unencumbered by OS
- Uses Standard TI Toolchain or Linux

# Beagleboard (Experimenters)

- Open Design based on OMAP 3530
- \$149 from Digikey
- Can be Embedded in Project
- Runs Linux, Gnome, Android, Symbian, QNX, Windows Embedded, ...
  - Can be Crippled Just Like a PC 😊
- <http://beagleboard.org> for details





# Embedded DSP for SDR Summary

- SDR Can be PC or Non-PC Based
- SDR is Mainstream in Amateur Radio Today
- SDR Means DSP
  - But DSP Does Not Mean SDR
- SDR Is a Wonderful Learning Opportunity
  - An Experimenter's Paradise!



Embedded DSP Choices for SDR

**THANK YOU!**