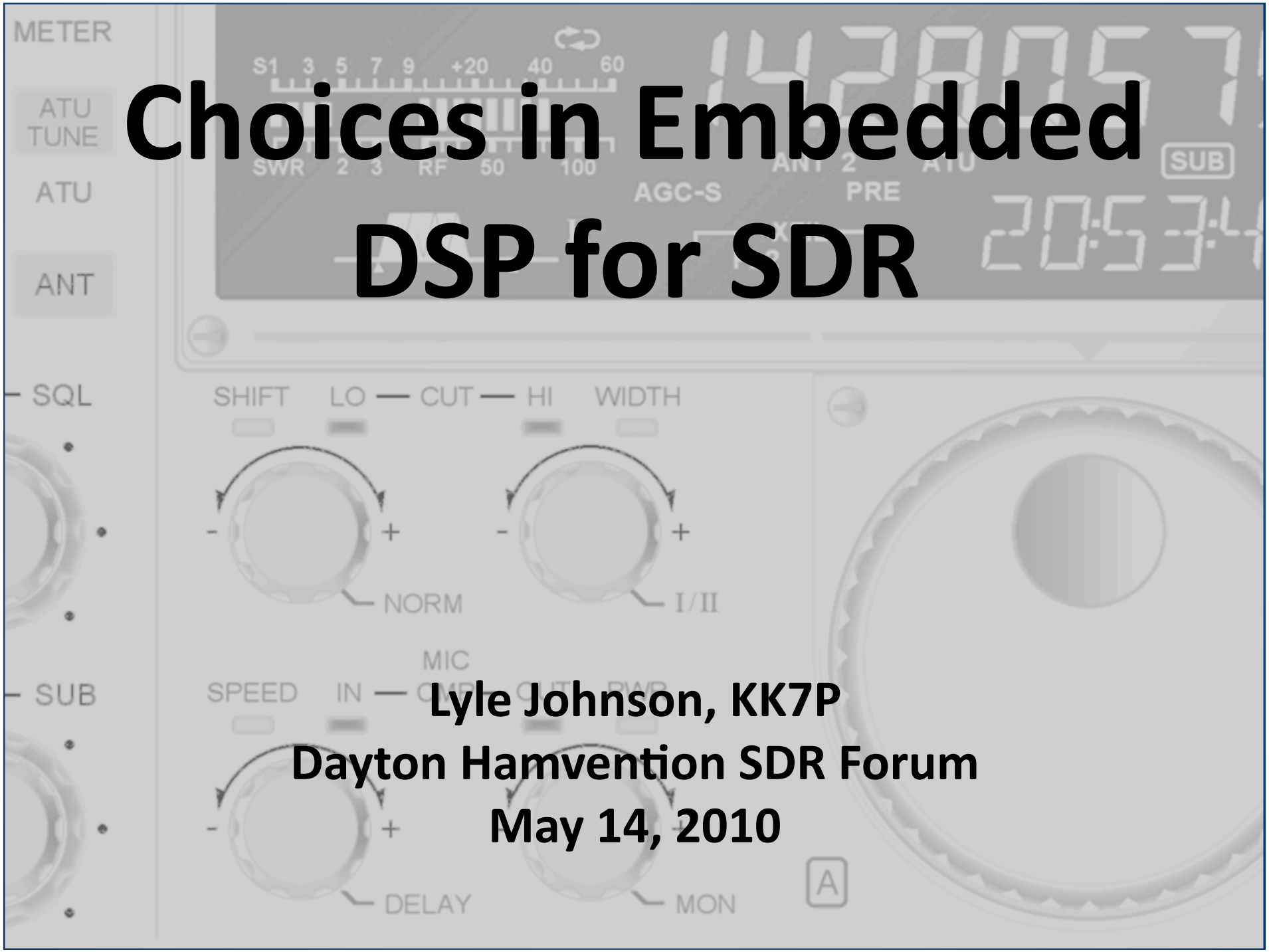

Choices in Embedded DSP for SDR

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Dayton Hamvention SDR Forum

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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: Software Defined Radio
- 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

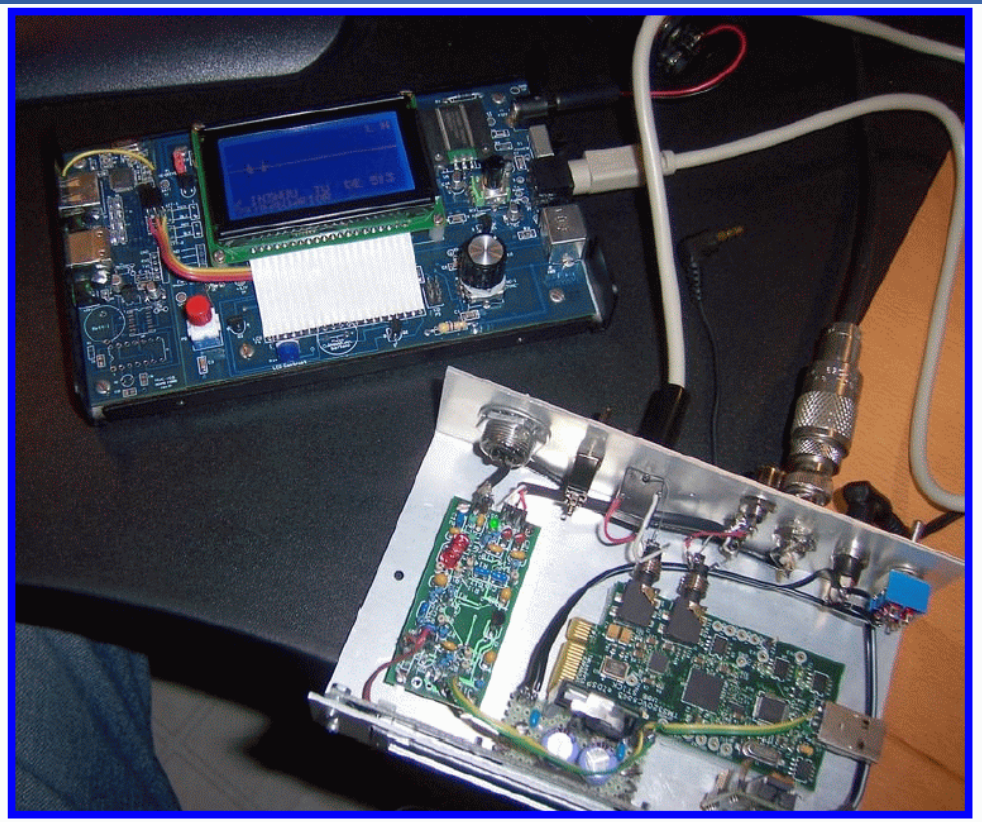
DSP Choices

- 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!

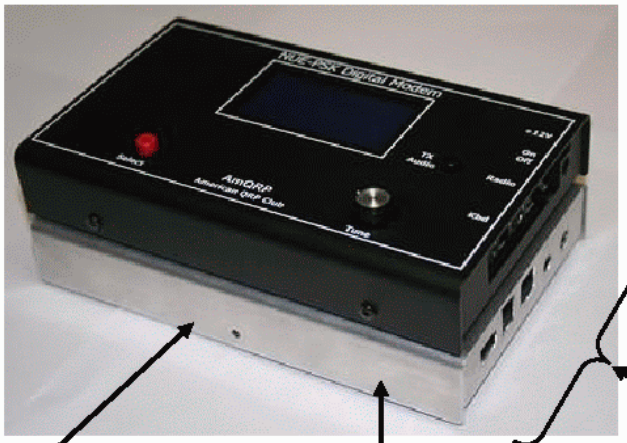
NUE-SDR Pre-Prototype



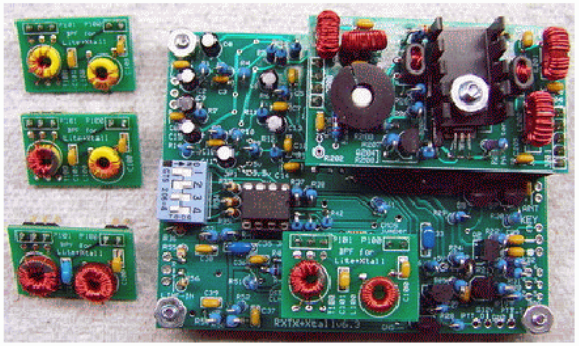
NUE-PSK Digital Modem (upper left)
Spectrum display of SDR output displays band activity

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

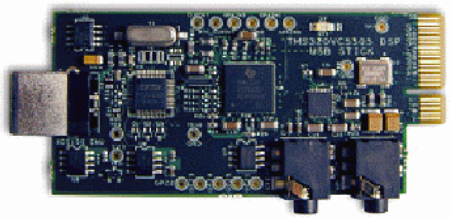
NUE-SDR Prototype



Optional add-on
NUE-SDR transceiver



Softrock RXTX 6.3



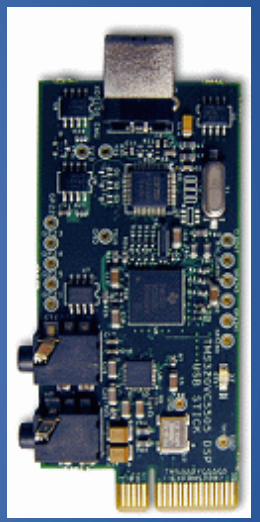
eZDSP USB Stick

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

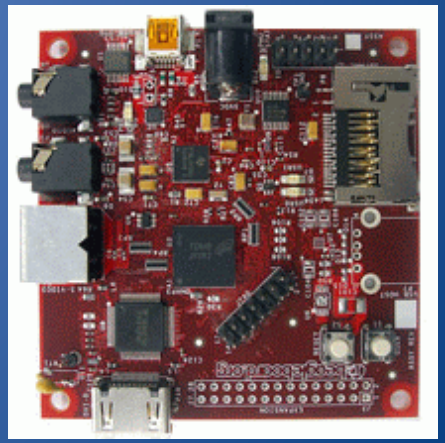
- TI TMS320VC674x Series
  - Up to 1.2 Billion Floating Point Operations/Sec
  - Low Power (under 1 watt)
- Development Tools (Experimenters)
  - Free if Using $99 Debugger
    - Cheap Enough for Hams!
  - $1,995 if Using Higher End Debugger/Emulator

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!