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**: 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](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!