Evolving Voice and Audio Requirements for Smartphones

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Tensilica At a Glance

Business Model – Semiconductor IP Licensing

• 160+ Licensees worldwide, >500M units/year
• Licensed by 8 of the top 12 semiconductor manufacturers
• Designed into 7 of the top 12 Smartphone manufacturers’ products
• #1 and #2 DTV system companies
• #1 auto infotainment semiconductor company

Market Focus

• Mobile wireless and home entertainment segments
  • Baseband PHY DSPs & Audio DSPs

• Plus … customized dataplane solutions for >20 other markets
  • Printers, cameras, network infrastructure/access, storage. & more
Voice Performance Demands Increase

Voice requirements outpace Moore’s Law and battery technology

200 MHz today on an optimized audio/voice DSP for narrow band voice codecs and basic noise suppression

600+ MHz in 2-3 years

- AMR WB becomes the dominant voice codec
  - 16 KHz vs traditional 4-8 KHz voice codecs
- Deployment of Super wideband codecs in VoIP
  - 24 kHz Skype SILK codec
- Improved noise suppression and multi-mic beam forming algorithms require more DSP horsepower
- Adaptive processing on the receive side of a call
Speech Quality Becoming More Important

Growing speech trends
- Voice/video conferencing in Skype, Face Time, Fring
- Voice recognition and search
  - Far talk – voice search while looking at the phone
- Speech to text
  - Clean voice signal on the phone improves cloud processing
- Improved speakerphone quality in noisy environments
Audio Entertainment Requirements Escalate

- Smartphones will directly support multi-channel entertainment
  - Netflix, Amazon, etc. streaming content
  - Content stored on Flash memory

- Gaming will support up to 32 streams for immersive play
  - Lower latency is a key requirement

- Audio post processing complexity increases
  - Volume boost
  - Effects processing for bass, treble boost, dynamic equalization
  - Stereo sound stage widening
  - 5.1 channel virtualization
Gaming Performance Demands Increase

Today

Future

- Margin
- RTOS
- Post Processing
- Noise Suppression - AEC
- Audio codecs
- Voice codecs
# Codecs in Use Today and Tomorrow in Smartphones

## Today

<table>
<thead>
<tr>
<th>Audio Codecs</th>
<th>Pre &amp; Post Processing / MIDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP3</td>
<td>AM3D</td>
</tr>
<tr>
<td>AAC-LC</td>
<td>QSound</td>
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<tr>
<td>aacPLus v1</td>
<td>SRS</td>
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<td>BSAC (Korea)</td>
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<td>Ogg Vorbis</td>
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<td>WMA</td>
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<tr>
<td>Real Audio</td>
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<tr>
<td>AMR WB+</td>
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<tr>
<td>Ogg Vorbis</td>
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<tr>
<td>Voice Codecs</td>
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<tr>
<td>AMR Narrowband</td>
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<tr>
<td>AMR Wideband</td>
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<td>EVRC</td>
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<tr>
<td>Bluetooth SBC</td>
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<td>G.711</td>
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<td>G.723.1</td>
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<td>G.726</td>
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<td>iLBC</td>
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## Tomorrow

### Audio Codecs

<table>
<thead>
<tr>
<th>Dolby Mobile</th>
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<tbody>
<tr>
<td>Dolby Digital Decoder AC-3</td>
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<tr>
<td>Dolby Digital Plus</td>
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<tr>
<td>Dolby True HD</td>
</tr>
<tr>
<td>Dolby Pro Logic II/IIx</td>
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<tr>
<td>DTS Surround Sensation</td>
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<tr>
<td>DTS Core</td>
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<tr>
<td>DTS-HD Hi Resolution</td>
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<tr>
<td>DTS Express</td>
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<tr>
<td>DTS-HD Master Audio</td>
</tr>
<tr>
<td>AAC-LC Decoder, 7.1</td>
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<tr>
<td>aacPLus v1 Decoder, 7.1</td>
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<tr>
<td>HD Radio</td>
</tr>
<tr>
<td>DAB</td>
</tr>
<tr>
<td>DAB+</td>
</tr>
<tr>
<td>DRM (Digital Radio Mondiale)</td>
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<tr>
<td>XM – Sirius Radio</td>
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</tbody>
</table>

### Voice Codecs

<table>
<thead>
<tr>
<th>AMR-WB</th>
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<tbody>
<tr>
<td>Skype SILK</td>
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</tbody>
</table>

### Pre Processing

More sophisticated noise suppression, AEC
Apps Processor Host CPU Isn’t Power Efficient for Audio and Voice

The default implementation is to run audio and voice functions on the ARM host CPU
- EX: Android media framework targets all audio and voice to the ARM CPU

However ARM Cortex plus NEON is not the most power efficient architecture for voice and audio
- The architecture is general purpose for control with signal processing assist
  - Not optimized for audio and voice functions
  - Includes significant overhead (gates, power) unrelated to audio & voice
- >14x the power vs an optimized audio DSP based on benchmarking
Audio and Voice Offload Trends

- Smartphone Apps Processor: offload signal processing intensive functions to dedicated task-specific processors
  - TI OMAP
  - Qualcomm Snapdragon
  - Marvell Armada

- Alternative smartphone architectures offload voice and audio to:
  - DAC/ADC (H/W codec) with integrated DSP
    - EX: Wolfson Microelectronics
  - Power Management IC – PMIC with integrated DSP
HiFi Audio Conceptual Approach

**Ease of Programming**
- All audio and voice codecs are written in C
- Simplifies maintenance of existing codecs and development of new codecs
- Minimizes time to port special audio algorithms or proprietary audio software (SOC supplier or System OEMs)

**Control and DSP Capabilities**
- Optimized Instruction Set for DSP Processing of Audio and VoIP
- Excellent target for control applications
  - Built on a 32-bit RISC architecture

**Configurability and Extensibility**
- Complete flexibility to add/configure caches and local memories
- Option to add interfaces via ports and queues
- Custom instructions can be added with full compiler support
HiFi 2 Audio/Voice DSP ISA

- DSP instruction set optimized for Audio & Voice
  - Dual 24-bit MACs for higher quality audio

- Can be added to any Tensilica Processor

- Supports all Audio / Voice Codecs
  - DTS-HD, DTS, Dolby 7.1, …

- Fully C programmable with efficiency of assembly code
  - MP3 at 5.7 MHz

- More than 40 HiFi licensees across a wide range of products
  - Portable audio
  - Cell phones
  - DVC / DSC / PVR multimedia chips
  - Blu-ray Disc players
  - Digital terrestrial and satellite radio
HiFi Audio DSP Instruction Formats

- The HiFi Audio DSP employs a 2-issue VLIW architecture
- Delivers ultra-low power with minimum clock rate requirements while reducing code size

<table>
<thead>
<tr>
<th>Dual Issue 64-bit or Single Issue 24/16-bit Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation 1</td>
</tr>
<tr>
<td>Operation 0</td>
</tr>
<tr>
<td>Slot 1</td>
</tr>
<tr>
<td>Slot 0</td>
</tr>
</tbody>
</table>

- Multiply and Audio ALU Instructions
- Base ISA operations
- Load/store operation
- Huffman coding instructions

HiFi 2 Audio Instructions
Base/HiFi 2 Audio Instructions
Base LX Instructions
HiFi Audio DSP Block Diagram

Q Audio Register File (4 x 56 bits)

24 bits

P Audio Register File (8 x 48 Bits)

Base Register File

Register Mux

Operation Slot 1

Audio ALU

Add/Sub

X

X

Slot 1 Audio Functions

Operation Slot 0

Slot 0 Audio Functions

Variable-Length Encode/Decode

Base ALU

Load/Store Unit

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HiFi EP Overview

- Built on the proven HiFi 2 audio DSP architecture
  - Superset of HiFi 2
  - Supports all HiFi 2 codec binaries

- Includes a 32x24 MAC
  - Improved DTS Master Audio performance - ~35% lower MHz vs. HiFi 2

- Improved cache mechanism for high memory latency designs

- Additional instructions for general DSP support

- Improved performance provides:
  - More MHz headroom for additional customer specific S/W
  - Lower MHz for high-precision proprietary audio technologies
  - Reduced power => lower packaging and thermal management costs
Lowest Power Audio
Retaining Flexibility of Pure C/C++ Coding

All codecs are ported using only C and C intrinsic functions for Audio DSP instructions

No assembly coding
MP3 Decode

- 0.45 mW for real-time MP3 decode @ 5.7 MHz
  - 66 µW/MHz dynamic power running MP3 decode, gate-level simulation with post-layout RC
  - 69 µW leakage power
  - 65 LP process, typical operating conditions

- Core area: 0.202 mm² – logic area for a power-optimized Xtensa with HiFi 2
## Sample of HiFi Enabled Products

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
<th>Chip Supplier</th>
<th>Shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxee</td>
<td>Digital Media Player</td>
<td>Intel</td>
<td>Now</td>
</tr>
<tr>
<td>Denon</td>
<td>AV Receiver</td>
<td>Samsung</td>
<td>Now</td>
</tr>
<tr>
<td>JVC</td>
<td>Car Radio</td>
<td>NXP</td>
<td>Now</td>
</tr>
<tr>
<td>LG</td>
<td>DTV</td>
<td>LG</td>
<td>Q3 2011</td>
</tr>
<tr>
<td>Logitech</td>
<td>Google TV STB</td>
<td>Intel</td>
<td>Now</td>
</tr>
<tr>
<td>Tier 1 Smartphone OEMs</td>
<td>Smartphone</td>
<td>Wolfson, others</td>
<td>Q3 2011</td>
</tr>
<tr>
<td>Samsung</td>
<td>Blu-ray Disc DTV</td>
<td>Samsung</td>
<td>Now</td>
</tr>
<tr>
<td>Sony</td>
<td>Blu-ray Disc Google TV</td>
<td>Intel</td>
<td>Now</td>
</tr>
</tbody>
</table>
Summary

- Voice and audio requirements increasing faster than silicon and battery performance

- Host apps processor isn’t keeping up with the demands in a low power footprint

- Offloading voice and audio is imperative for the best user experience

- Rich and constantly evolving codec and special effects SW modules required
Backup
Over 80 HiFi Audio DSP Codecs & Audio/Voice Enhancement Packages

Stereo Audio
- AAC
- HE-AAC
- HE-AAC Plus
- MP3
- FLAC
- WMA 9
- WMA 10 Pro
- REAL Audio 8, 9, 10
- Ogg Vorbis
- AMR WB+
- SBC Bluetooth
- BSAC
- DAB
- DAB+
- DRM

Multi-Channel
- AAC
- HE-AAC
- WMA Pro
- FLAC
- Dolby MS10
- Dolby Digital AC-3
- Dolby Digital Plus
- DDCE
- Dolby True HD
- Dolby Pro Logic II/IIX
- DTS-HD (Master Audio)
- DTS Express
- DTS Transcoder
- DTS Neo:6
- DTS Broadcast
- DTS DMP

Voice
- G.711
- G.723.1
- G.726
- G.729AB
- AMR-NB
- AMR-WB
- GSM-HR
- GSM-FR
- GSM-EFR
- AEC
- LEC

Enhancement
- AM3D
  - Diesel Power
  - Zirene
- QSoud
  - microQ
  - mQSynth
  - mQ3D
  - MQFX
  - QVoice
- SRS
  - SRS Studio Sound HD
  - SRS TruSurround
  - SRS TruVolume
  - SRS TruDialog
  - SRS TruTools
  - SRS WOW XT
  - SRS Tru Gaming

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Audio Codec API

API features
- Generic C API is common throughout all codec libraries
- Each library has a single entry point that supports a set of generic API commands
- Easy to replace one codec library with another
- Fully re-entrant to support concurrent processing of multiple audio streams
- Run in parallel multiple instances of the same codec or different codecs

Codec Deliverables
- Codec library (in object or source code)
- Sample application (source code)
- Programmer’s Guide including a common section covering the standard API and a section describing the codec-specific features and parameters

Integration
- DTS-HD Master Audio Player Application
- Multi-Codec Multi-Stream App Note
- Dolby MS10 Player Application
Tensilica Focus
Bringing efficient programmability to the dataplane

Dataplane Processing Unit

Strengths
Control-oriented, Software Development

CPU

Strengths
Task-specific, Differentiating, Direct point-to-point interfaces.

Custom Logic

Strengths
SIMD, VLIW, Stream processing

DSP

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Programmability in the Dataplane

What is the Dataplane?

Data Plane
“Compute & Throughput”
Requiring:
• Control and DSP
• Performance
• Throughput
• Connectivity
• Low Power

“DPU”
Dataplane Processing Unit

Control Plane
“Applications and Operating Systems”

What is the Dataplane?

Tools for the Dataplane

- Video
- Audio
- Baseband DSP
- Bband
- Security
- Protocol processing

Analog

Memory

Main Applications

Memory
Comprehensive Development Flow
Unique, Patented, Automated

Single, Integrated Development Environment

Reference
Source
C/C++
Proprietary

Predefined
Define
Processor
(optional)
Customize

Auto Create
DPU
(in minutes)

Full Software
Development Tools
Evaluate &
Produce
Models, RTL
and EDA scripts

Integrates with industry standard flows
Market Focus
Mobile Wireless & Home Entertainment

Mobile Wireless
- SmartPhone
- Base Station
- Wireless

Home Entertainment
- DTV
- Blu-ray
- Receiver
- STB

Additional Technologies
- Digital Cameras
- Auto InfoTainment
- Games
- Network Access
- Printers
- Storage
- Network Infrastructure
- PC Graphics
Market Focus
Mobile Wireless & Home Entertainment

Showing some of our publically announced customers, many others are unannounced.
Product Focus
All Based Upon a Common Platform

**HiFi**
Audio/Voice
- Encode/Decode, Pre/Post Processing

**ConnX**
Baseband
- 3G/4G/WiMax, Infrastructure & Terminals

**Diamond**
Controllers
- Small, Low Power, Deeply Embedded Control

**Xtensa**
- Video, Imaging, Networking, Storage, Security

**Consulting Services**

**DPU Technology Foundation**
Xtensa Architecture, Development Tools, 3rd Party Ecosystem
Product Focus
Sampling of 160+ Customers

HiFi
Audio/Voice

ConnX
Baseband

Diamond + Xtensa

DPU Technology Foundation
Xtensa Architecture, Development Tools, 3rd Party Ecosystem
Introducing New Family for LTE Advanced

ConnX BBE64 – The highest performance, most efficient DSP family ever for demanding infrastructure equipment and user equipment

ConnX BBE64-128 for infrastructure performance

ConnX BBE64-UE for user equipment
Testimonials

Tier 1 Companies Confirm Our Benefits

• “Tensilica’s DPUs helped us pack the LTE functions in a small and power-efficient footprint, and they contributed greatly to the efficient implementation and first-time silicon success of our LTE chip.”

• “We also achieved a faster time to market and gained post-silicon flexibility due to programmability without sacrificing power or area efficiency.”

Toshio Miki
Associated Senior Vice President & Managing Director of Communication Device Development Department of NTT DOCOMO

• “We conducted a thorough review and evaluation of licensable DSP IP cores before selecting Tensilica.”

• “Tensilica’s unique ability to combine world-class DSP capability with the flexibility and customization of the Xtensa DPUs gives HiSilicon the opportunity to strongly differentiate our products.”

• “We feel this will give us a strong competitive advantage.”

Teresa He
Vice President of HiSilicon Huawei’s silicon arm
## DSP Computation Requirements of LTE Advanced

<table>
<thead>
<tr>
<th>Application</th>
<th>LTE (designs completing today)</th>
<th>LTE-Advanced (designs starting)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User Equipment</strong></td>
<td>• 2x2 MIMO</td>
<td>• 2x2 MIMO</td>
</tr>
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<td></td>
<td>• 150Mbs Peak</td>
<td>• 1Gbs Peak</td>
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<tr>
<td></td>
<td>• 20MHz Bandwidth</td>
<td>• 100MHz Bandwidth</td>
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<tr>
<td></td>
<td><strong>ConnX BBE16</strong></td>
<td><strong>ConnX BBE64</strong></td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td><strong>5 x performance increase</strong></td>
<td><strong>ConnX BBE64-UE</strong></td>
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<tr>
<td></td>
<td>• 2x2 MIMO</td>
<td>• 4x4 MIMO</td>
</tr>
<tr>
<td></td>
<td>• 150Mbs Peak</td>
<td>• 1Gbs Peak</td>
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<tr>
<td></td>
<td>• 20MHz Bandwidth</td>
<td>• 100MHz Bandwidth</td>
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<tr>
<td></td>
<td><strong>10~15 x performance increase</strong></td>
<td>• Iterative Receivers</td>
</tr>
<tr>
<td></td>
<td><strong>ConnX BBE16</strong></td>
<td><strong>ConnX BBE64-128</strong></td>
</tr>
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A range of solutions is required to meet the needs of LTE Advanced