Introducing the HiFi Audio DSP

The most popular DSP IP core

- Greater than 40 licensees
  - More licenses than any other audio DSP IP core

Widest range of audio, voice & enhancement software

- Over 80 software packages ported to this architecture

A drop-in solution that’s also configurable

- So you can customize it for your application

The most efficient, lowest power audio IP core

- Dual 24-bit MAC architecture
- Lowest power MP3 decode in the industry
Advantages of the HiFi Audio DSP

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 the Xtensa 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 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 Master Audio performance - ~35% lower MHz vs. HiFi 2
- Improved post processing performance vs. HiFi 2

Improved cache mechanism for high memory latency designs

Additional instructions

- For improved noise reduction/cancellation
- 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
Range of HiFi Audio DSP Applications
Hundreds of Millions of Products Shipped with HiFi Audio

HiFi 2
- Mobile Phones
- Consumer Portable
- Residential Gateway

HiFi EP
- STB
- Automotive Entertainment
- Home Audio
- Blu-ray Disc Player

Typically Higher Precision/Performance Requirements

Copyright © 2011, Tensilica, Inc.
HiFi Audio Applications

Announced Customers

*Used by Many of the Top Semiconductor Companies*

- Mobile Phones
- Automotive Entertainment
- Consumer Portable Electronics
- STB, AVR & Blu-ray Disc players
- DTV
- Intel
- AMD
- NXP
- iBiquity
- SONY
- Samsung
- LG
- Tensilica
- Wolfson
- HiFi Audio Applications

Announced Customers: Fujitsu, AMD, NXP, iBiquity, SONY, Samsung, LG, Tensilica, Wolfson.
## 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><strong>Boxee</strong></td>
<td>Digital Media Player</td>
<td>Intel</td>
<td>Now</td>
</tr>
<tr>
<td><strong>Denon</strong></td>
<td>AV Receiver</td>
<td>Samsung</td>
<td>Now</td>
</tr>
<tr>
<td><strong>JVC</strong></td>
<td>Car Radio</td>
<td>NXP</td>
<td>Now</td>
</tr>
<tr>
<td><strong>LG</strong></td>
<td>DTV</td>
<td>LG</td>
<td>Now</td>
</tr>
<tr>
<td><strong>Logitech</strong></td>
<td>Google TV STB</td>
<td>Intel</td>
<td>Now</td>
</tr>
<tr>
<td><strong>Tier 1 Smartphone OEM</strong></td>
<td>Smartphone</td>
<td>Wolfson, others</td>
<td>Now</td>
</tr>
<tr>
<td><strong>Samsung</strong></td>
<td>Blu-ray Disc DTV</td>
<td>Samsung</td>
<td>Now</td>
</tr>
<tr>
<td><strong>Sony</strong></td>
<td>Blu-ray Disc Google TV</td>
<td>Intel</td>
<td>Now</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Codec</th>
<th>Average MHz</th>
<th>Measurement Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>HiFi 2 MP3 Decoder</td>
<td>5.7</td>
<td>44.1 kHz / 128 kbps (stereo)</td>
</tr>
<tr>
<td>HiFi 2 MP3 Encoder</td>
<td>26</td>
<td>44.1 kHz / 128 kbps (stereo)</td>
</tr>
<tr>
<td>HiFi 2 AAC-LC Decoder</td>
<td>8.1</td>
<td>48 kHz / 128 kbps (stereo)</td>
</tr>
<tr>
<td>HiFi 2 AAC-LC Encoder</td>
<td>37.8</td>
<td>44.1 kHz / 128 kbps (stereo)</td>
</tr>
<tr>
<td>HiFi 2 WMA Decoder</td>
<td>10.3</td>
<td>44.1 kHz / 128 kbps (stereo)</td>
</tr>
</tbody>
</table>

Lowest Power MP3 in the Industry

Real-time MP3 decode power @ 5.7 MHz

Example Power = 0.45 mW

66 μW/MHz dynamic power running MP3 decode, gate-level simulation with post-layout RC. 69 μW leakage power. 65 LP process, Typ Op. Cond; Core Area: 0.202 mm2 – logic area for a power-optimized Xtensa w/ HiFi 2
Over 80 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
- Audyssey
- Dynamic Volume
- Dynamic EQ
- QSound
- microQ
- mQSynth
- mQ3D
- MQFX
- QVoice
- SRS
- SRS Studio Sound HD
- SRS TruSurround
- SRS TruVolume
- SRS TruDialog
- SRS TruTools
- SRS WOW XT
- SRS Tru Gaming
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
DTS Master Audio
- Required for Blu-ray Disc
- First certified IP core

DTS Broadcast and DTS DMP (Digital Media Player)
- Enables streaming and file based decode of DTS content
- Targeted at DTV, STB, DMP
- DMP is certified
- DTS Broadcast is certified
  - HiFi is the first and currently only IP core certified for these standards

DTS LBR for Primary Audio
- Supports streaming video services such as Cinema Now

DTS Neural Audio
- Targeted at automotive and home entertainment
Dolby Labs

Available today

- Dolby Digital AC-3
- Dolby Digital Consumer Encoder
- Dolby Digital Plus
- TrueHD
- Dolby Pro Logic II/IIx
- MS10
- Dolby Mobile 3+ Targets smartphones, tablets

MS11

- Next generation multi-standard broadcast decoder

Dolby Volume

Working with Dolby to port PCEE4 to HiFi
HiFi Supports All Digital Terrestrial and Satellite Radio Audio Standards

- HD Radio - Available now from iBiquity Digital
- DAB - Available now with the HiFi 2 MP3 decoder
- DAB+ - Available now from Tensilica, Certified by Dolby
- DRM (Digital Radio Mondiale) - Available now from Tensilica
- XM Satellite - Available from XM Satellite
- T-DMB (BSAC audio) – Available now
- ISDB – Available now with AAC, HE-AAC decoders
## Post Processing Partners

<table>
<thead>
<tr>
<th>Product</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>StudioSound HD, TruSurround HD4</td>
<td>DTV, STB, DMP</td>
</tr>
<tr>
<td>WOW XT, TruGaming</td>
<td>Mobile (3D, stereo expansion, bass &amp; treble boost)</td>
</tr>
<tr>
<td>Dynamic Volume</td>
<td>DTV, STB, Automotive</td>
</tr>
<tr>
<td>microQ mQFX</td>
<td>Mobile (3D, stereo expansion, bass &amp; treble boost)</td>
</tr>
<tr>
<td>QVoice</td>
<td>Mobile (noise suppression, voice clarity)</td>
</tr>
<tr>
<td>Diesel Power Zirene</td>
<td>Mobile (3D, stereo expansion, bass &amp; treble boost)</td>
</tr>
</tbody>
</table>
Tensilica HiFi Audio

for
Blu-ray Disc Players and DTV / STB
Blu-ray Disc Audio
The Most Demanding Consumer Audio System

- Primary Audio Decode
- Secondary Audio Decode
- PCM Input
- 5.1 Channel Encode (Dolby, DTS)
- SRC
- Mix
- SRC
- Mix
- S/PDIF out
- HDMI out

Copyright © 2011, Tensilica, Inc.
HiFi EP Reduces BD MHz Required by 155 MHz
(100 cycle latency, worst case performance on Blu-ray Disc)

<table>
<thead>
<tr>
<th>Audio Function</th>
<th>HiFi 2 100 cycle latency, 48KB D$, 16KB I$, 64 B cache line, 5 stage</th>
<th>HiFi EP 100 cycle latency, 48KB D$, 16KB I$, 64 B cache line, 5 stage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary audio:</strong> DTS Master Audio 24.5 Mbps 5.1 192 kHz</td>
<td>175 MHz</td>
<td>160 MHz</td>
</tr>
<tr>
<td><strong>Secondary audio:</strong> DTS-LBR (DTS Express) 256 kbps 5.1 48 kHz Decoding</td>
<td>63 MHz</td>
<td>68 MHz</td>
</tr>
<tr>
<td>DTS Transcode, Upsample, downsample, mixing, others</td>
<td>124 MHz</td>
<td>152 MHz</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>362 MHz</td>
<td>380 MHz</td>
</tr>
</tbody>
</table>
Global Digital TV Broadcast Standards

Terrestrial Broadcast Specifications

AAC (MPEG-2)
HE-AAC (MPEG-4)
Dolby Digital
Dolby Digital Plus
HE-AAC and Dolby Digital Plus
DMB/T
Undecided
Dolby MS10 Multistream Decoder

Dolby Digital
Dolby Digital Plus
Dolby Pulse
HE-AAC
AAC

Transcode
Decode

Dolby Digital Bitstream (unmixed)
To S/PDIF and/or HDMI

2-Channel PCM
To Analog and/or S/PDIF, HDMI

2-Channel PCM Mixer For Audio Description

Mixing metadata
To analog and/or S/PDIF, HDMI (mixed)

Dolby’s most flexible and full-featured codec solution

Full Dolby metadata support

Fully supports: Dolby Digital, Dolby Digital Plus, Dolby Pulse, and any AAC-based stream including HE-AACv2

Includes legacy support for SDIF connections via Dolby Digital Encoded for transcoding streams to Dolby Digital 5.1
## HiFi 2 and EP MS10 Performance (MHz)
(Worst Case Conditions with 5.1 Channel Associated Data)

<table>
<thead>
<tr>
<th>Audio Function</th>
<th>HiFi 2 Ideal memory, 5 stage</th>
<th>HiFi EP Ideal memory, 5 stage</th>
<th>HiFi 2 100 cycle memory latency, 16KB D$, 8KB I$, 64 B cache line, 5 stage</th>
<th>HiFi EP 100 cycle memory latency, 16KB D$, 8KB I$, 64 B cache line, 5 stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main audio: HE-AAC 5.1 ch.</td>
<td>73.5 MHz</td>
<td>73.5 MHz</td>
<td>138 MHz</td>
<td>117 MHz</td>
</tr>
<tr>
<td>Associated audio: HE-AAC 5.1 ch.</td>
<td>73.5 MHz</td>
<td>73.5 MHz</td>
<td>138 MHz</td>
<td>117 MHz</td>
</tr>
<tr>
<td>Dolby Digital Encoding</td>
<td>49 MHz</td>
<td>49 MHz</td>
<td>71 MHz</td>
<td>62 MHz</td>
</tr>
<tr>
<td>Downmix and Post Processing</td>
<td>27 MHz</td>
<td>27 MHz</td>
<td>50 MHz</td>
<td>49 MHz</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>223 MHz</strong></td>
<td><strong>223 MHz</strong></td>
<td><strong>398 MHz</strong></td>
<td><strong>340 MHz</strong></td>
</tr>
</tbody>
</table>
Tensilica HiFi Audio

for
Mobile / Portable / Automotive Applications
Voice Performance Demands
In Smartphones

200 MHz today

- 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

Copyright © 2011, Tensilica, Inc.
Speech Quality Becoming More Important

- Voice/video conferencing in Skype, Face Time, Fring
- Voice recognition and search
- Speech to text
- 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

MHz

Today Future

- Margin
- RTOS
- Post Processing
- Noise Suppression - AEC
- Audio codecs
- Voice codecs
## Codecs in Use 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>
</tr>
<tr>
<td>aacPlus v1</td>
<td>SRS</td>
</tr>
<tr>
<td>aacPlus v2</td>
<td></td>
</tr>
<tr>
<td>BSAC (Korea)</td>
<td></td>
</tr>
<tr>
<td>Ogg Vorbis</td>
<td></td>
</tr>
<tr>
<td>WMA</td>
<td></td>
</tr>
<tr>
<td>Real Audio</td>
<td></td>
</tr>
<tr>
<td>AMR WB+</td>
<td></td>
</tr>
<tr>
<td>Ogg Vorbis</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Voice Codecs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AMR Narrowband</td>
<td></td>
</tr>
<tr>
<td>AMR Wideband</td>
<td></td>
</tr>
<tr>
<td>EVRC</td>
<td></td>
</tr>
<tr>
<td>Bluetooth SBC</td>
<td></td>
</tr>
<tr>
<td>G.711</td>
<td></td>
</tr>
<tr>
<td>G.723.1</td>
<td></td>
</tr>
<tr>
<td>G.726</td>
<td></td>
</tr>
<tr>
<td>G.729AB</td>
<td></td>
</tr>
<tr>
<td>iLBC</td>
<td></td>
</tr>
</tbody>
</table>

### Tomorrow

<table>
<thead>
<tr>
<th>Audio Codecs</th>
<th>Voice Codecs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolby Mobile</td>
<td>AMR-WB</td>
</tr>
<tr>
<td>Dolby Digital Decoder AC-3</td>
<td>Skype SILK</td>
</tr>
<tr>
<td>Dolby Digital Plus</td>
<td></td>
</tr>
<tr>
<td>Dolby True HD</td>
<td>Pre Processing</td>
</tr>
<tr>
<td>Dolby Pro Logic II/IIx</td>
<td>More sophisticated noise suppression, AEC</td>
</tr>
<tr>
<td>DTS Surround Sensation</td>
<td></td>
</tr>
<tr>
<td>DTS Core</td>
<td>DTS-HD Hi Resolution</td>
</tr>
<tr>
<td>DTS Express</td>
<td>DTS-HD Master Audio</td>
</tr>
<tr>
<td>DTS-HD Master Audio</td>
<td>AAC-LC Decoder, 7.1</td>
</tr>
<tr>
<td>aacPlus v1 Decoder, 7.1</td>
<td></td>
</tr>
<tr>
<td>HD Radio</td>
<td>DAB</td>
</tr>
<tr>
<td>DAB+</td>
<td>DAB+</td>
</tr>
<tr>
<td>DRM (Digital Radio Mondiale)</td>
<td>XM – Sirius Radio</td>
</tr>
</tbody>
</table>

Pre & Post 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 functions 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
- >15x the power vs an optimized audio DSP based on benchmarking
ARM Cortex A Series Not Efficient for Smartphone Digital Audio/Voice Signal Processing

Cortex A8 series processors: bigger size/power

- Requires 2 to 3.2x MHz vs. HiFi 2/EP
- Consumes 10.4 to 16.6x power vs. HiFi 2/EP
- Size is 9.4x area vs. HiFi 2/EP

Cortex M4 has only a 3-stage pipeline

- Will not scale to support demanding use cases for voice, audio entertainment and gaming

Lack of full suite of audio codecs
Trend: Smartphone Audio and Voice Offload

Apps processor offloads to dedicated task-specific processors

- Intel Moorestown
- Marvell Armada
- Qualcomm Snapdragon
- TI OMAP

Other architectures offload voice and audio to:

- DAC/ADC (HW codec) with integrated DSP
  - Ex: Wolfson Microelectronics
- Power management IC – PMIC with integrated DSP
Working to Lower Power in Android Platforms

- Tunneling of audio codecs (full offload to the DSP)
- DSP accelerated audio effects
- DSP based mixing and volume control
- DRM offload to the DSP
- Compliance with EU regulations for sound pressure level
Why Tensilica HiFi Audio DSPs?

Widest set of high-performance codecs available now for fast TTM

- All programming uses C/C++

The smallest, lowest power audio processor for home/automotive

DSP optimality plus general RISC CPU flexibility

- Multi-channel → Stereo audio, and voice codecs, run on same CPU/DSP
- Rich set of audio DSP instructions blended with core Xtensa RISC architecture
- Xtensa general purpose CPU horsepower available for other tasks
- Robust, complete software development toolchain

HiFi provides the best in class MACs/mW/mm²/$