Low-Power, Low-Overhead, High-Fidelity Digital Sound for SOCs

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Why Listen to This Presentation?

- Learn about digital audio subsystem alternatives for SOC design
  - Advantages and disadvantages for each alternative
  - Tradeoffs
- Learn about key decision factors for choosing one alternative over another
- Learn about energy consequences of digital audio implementation choices

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Agenda

- Introduction to digital audio concepts
- Implementation choices for on-chip audio
- Implementation examples
- Concluding thoughts

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A Brief History of Audio

1877 Edison Phonograph
1888 Berliner Disk Record
Edison Disc Record
78 RPM Adopted as World Record Standard
RCA Invents LP/33 RPM Record
Blumlein Invents Stereo Record
RCA Invents 45 RPM Record
Columbia Markets LP/33 RPM Record
RCA Markets 45 RPM Record
Commercial Stereo Record
Quadraphon
CDs
MP3 Player
MP3 standard

1900s | 1910s | 1920s | 1930s | 1940s | 1950s | 1960s | 1970s | 1980s | 1990s

Lee de Forest's Audion
Transistor
Integrated Circuit
LASER
LED
LCD
Microcontroller
Microprocessor
WWW

Vacuum Tube Era
Solid-State Era
Microprocessor Era
Internet Era

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The Era of Digital Audio

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MP3 standard
Video iPod
iTunes Store
iPod
SACD
DVD Audio

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Digital Audio Applications

Digital Audio Applications

- Cell Phones

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- Cell Phones
- Personal Media Players
  - PMPs
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Introduction to Digital Audio

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  - They require more processing power too
  - Codec vendors introduce new codecs regularly

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- MP3 was the first widely used audio codec
- More advanced multi-channel audio codecs use increasingly sophisticated algorithms to improve fidelity
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  - Codec vendors introduce new codecs regularly
- Large number of digital audio codecs now in use

Many Digital Audio Codecs, Here are a Few

Dolby Digital (AC3) Decoder 5.1 channel
Dolby Digital (AC3) Consumer Encoder (DDCE)
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AMR Narrowband Speech Codec (5.15 Kbps)
AMR Wideband Speech Codec (8.85 Kbps)
G.729AB Speech Codec (8 Kbps)

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Notes:

Encode/Decode
Different Data Rates
Different Numbers of Channels

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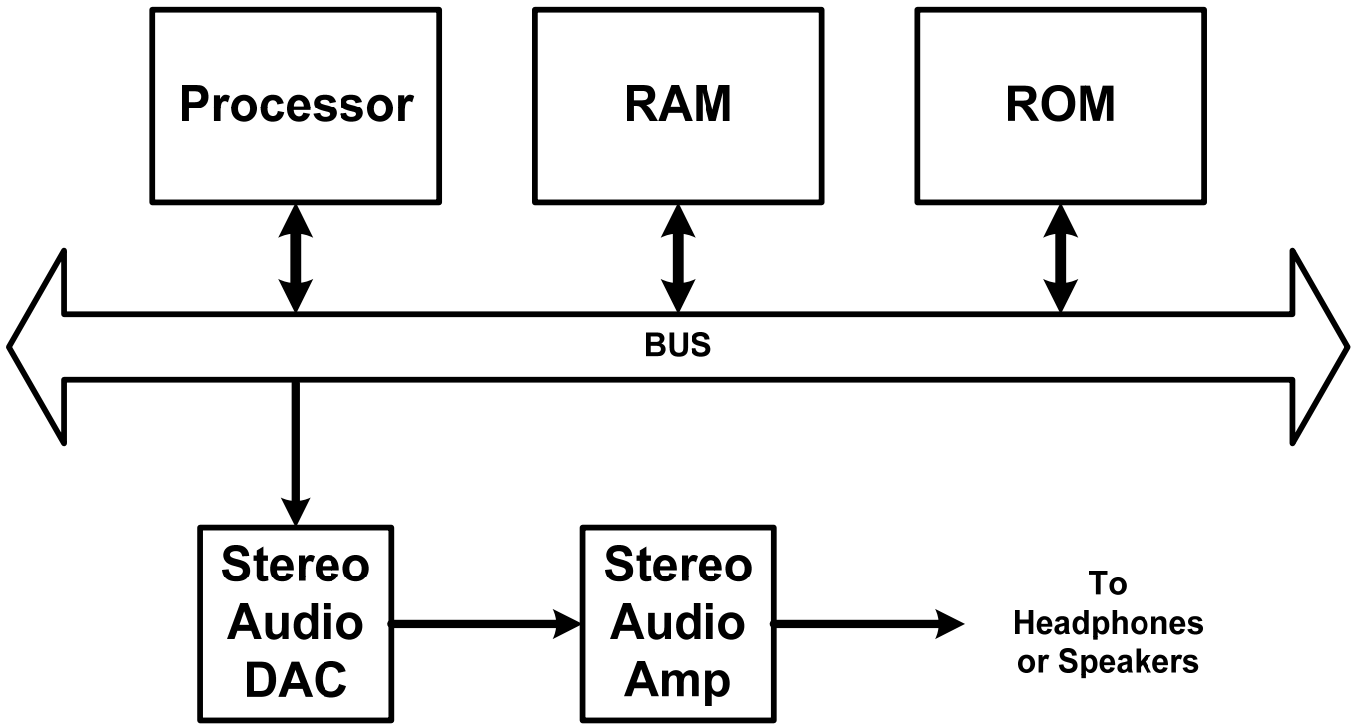
Digital Audio Implementation Choices

- General-purpose processor
- Hardware codecs
- DSP
- Audio-specific processor

General-Purpose Processor Core



General-Purpose Processor Core – Advantages and Disadvantages

- Advantages
  - Probably one on the chip anyway
  - Can implement multiple codecs for multi-purpose products using additional instruction memory
  - Accommodates new codecs (if the bandwidth is available)

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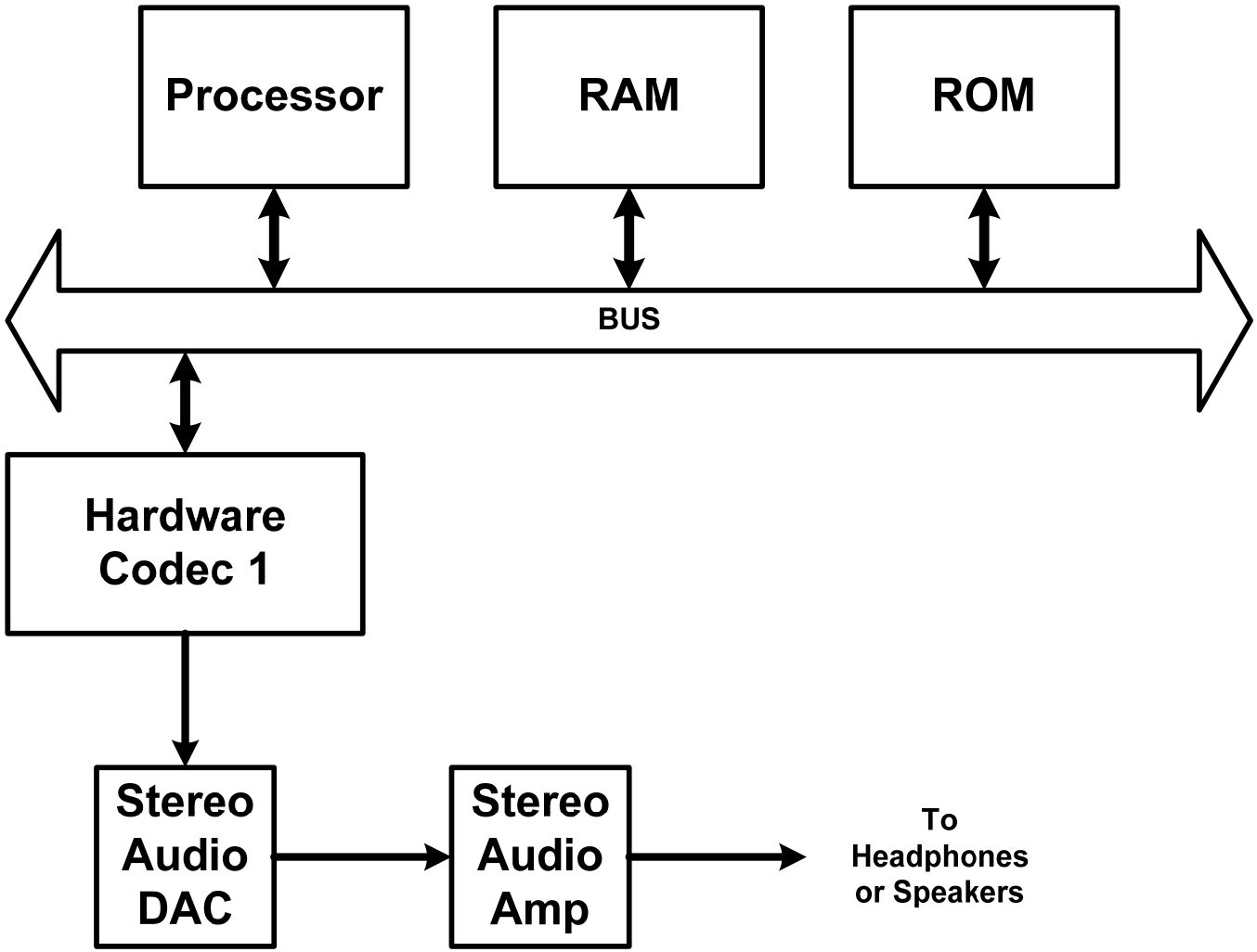
- Disadvantages
  - No audio glitches allowed and audio quality is sensitive to latency, so sharing one processor is problematic
  - Not optimized for audio, so clock rate and energy consumption will be higher

Hardware Codec



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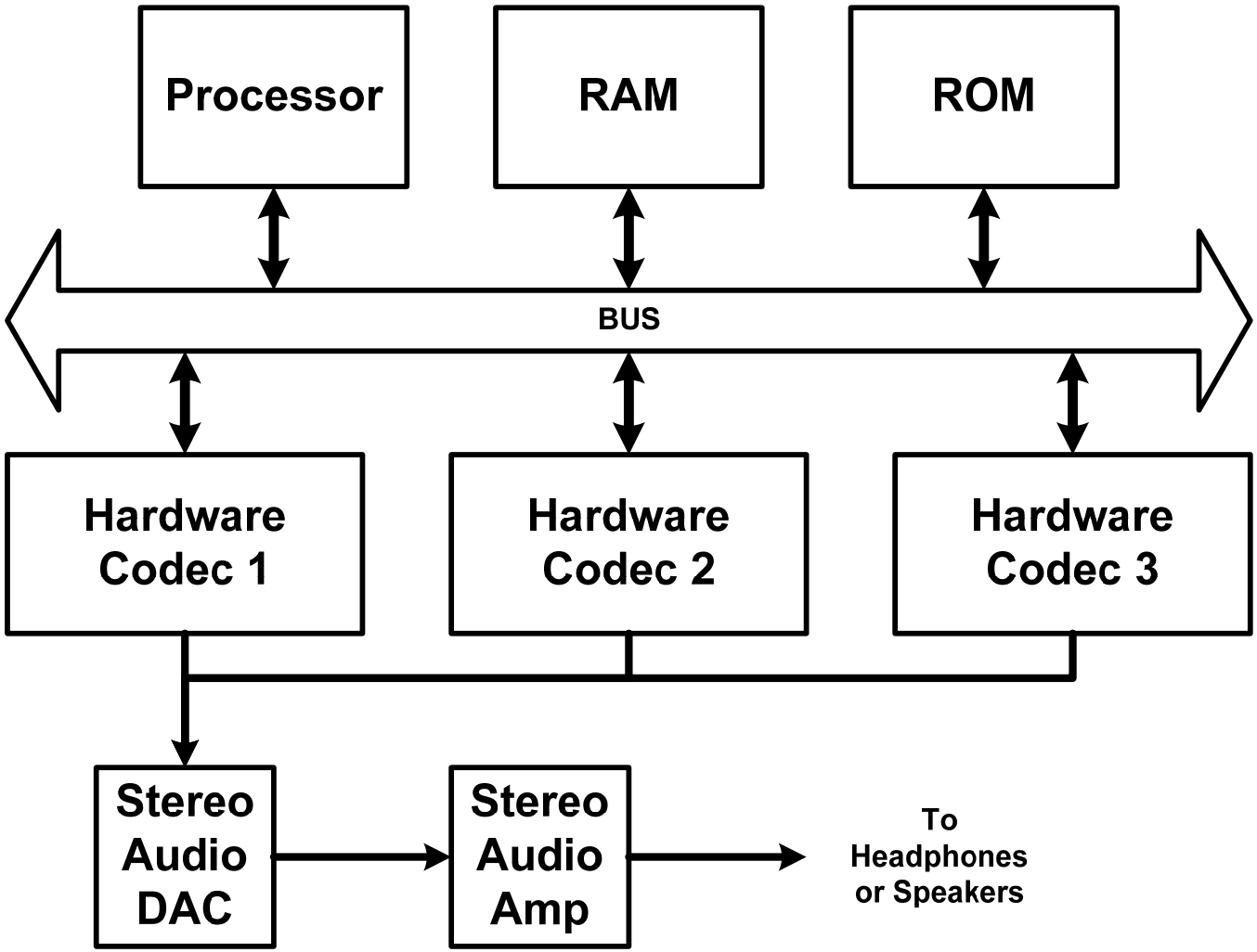
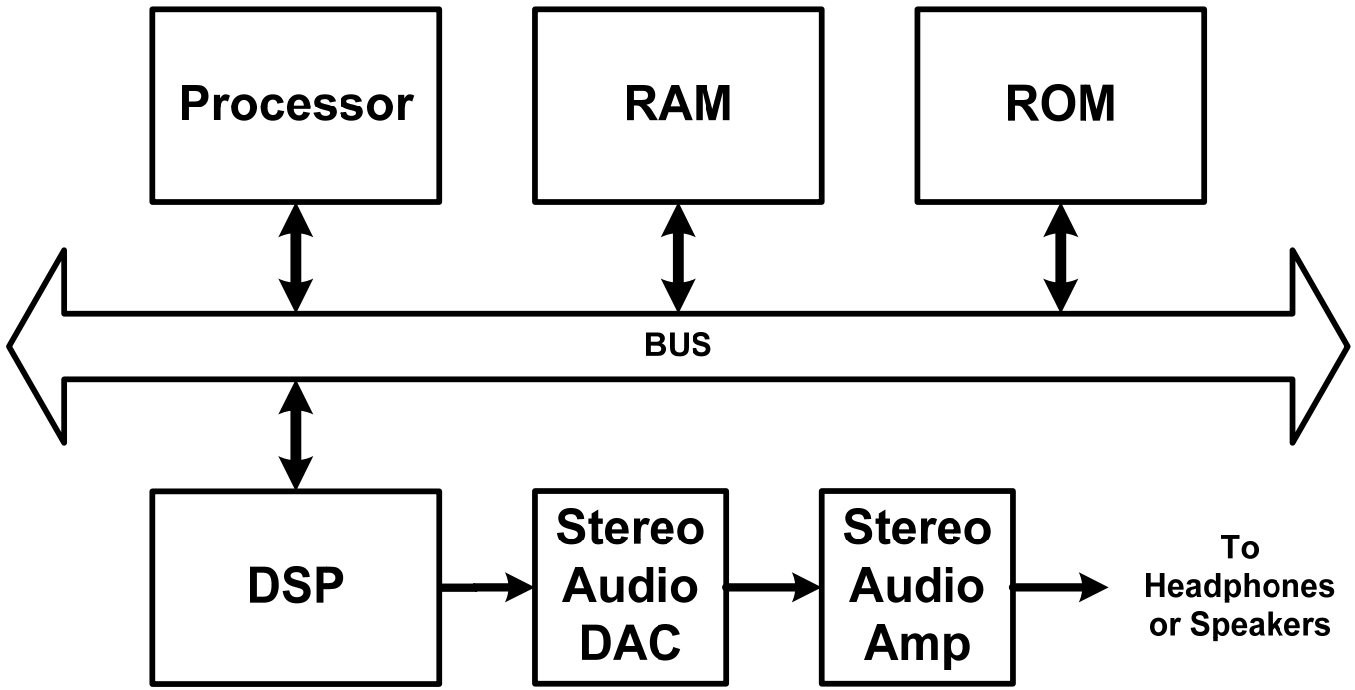
  - Low power
- Disadvantages
  - Die size grows with each new codec
  - Hard to change if…
    - There's a change in the codec spec
    - There's a bug
  - Impossible to change to accommodate a new codec
    - Must add additional hardware codecs

Multiple Hardware Codecs



DSP Core for Audio



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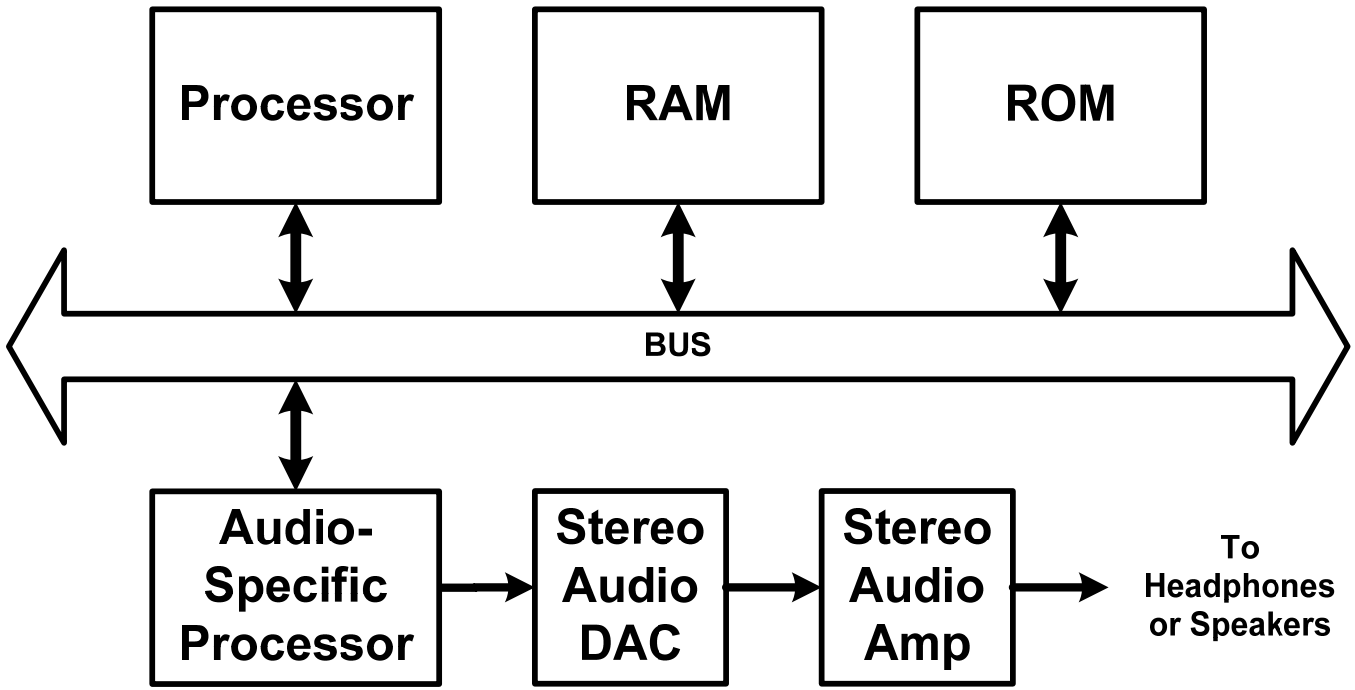
- Disadvantages
  - DSPs not good for general-purpose control
    - Need control processor and DSP
    - Task splitting and inter-processor communications are problematic
  - 16-bit DSPs not enough for good audio
  - 32-bit DSPs overkill (really need 24 bits)

Audio-Specific Processor Core



Audio-Specific Core – Advantages and Disadvantages

- Advantages
  - Instructions matched to the task of implementing digital audio codecs
    - Lowers the clock rate and energy consumption
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- Disadvantages
  - Not as familiar as the other alternatives

Anatomy of an Audio-Specific Processor: Tensilica's HiFi 2 Audio Engine

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- Exploits configurability and extensibility of Tensilica's Xtensa LX2 processor core

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  - Second generation set of audio extensions
  - Two hardware multipliers
  - Executes one or two operations per instruction
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- 300 audio-specific instructions
- Comprehensive and growing set of digital audio codecs

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Tensilica's Diamond 330HiFi Audio Engine

- Ready-made audio processor core
- Leverages HiFi 2 audio engine and HiFi codecs
- Adds 32-bit input and output queue interfaces to get ADC and DAC traffic off of the bus
  - Higher efficiency, lower power way to talk to peripherals

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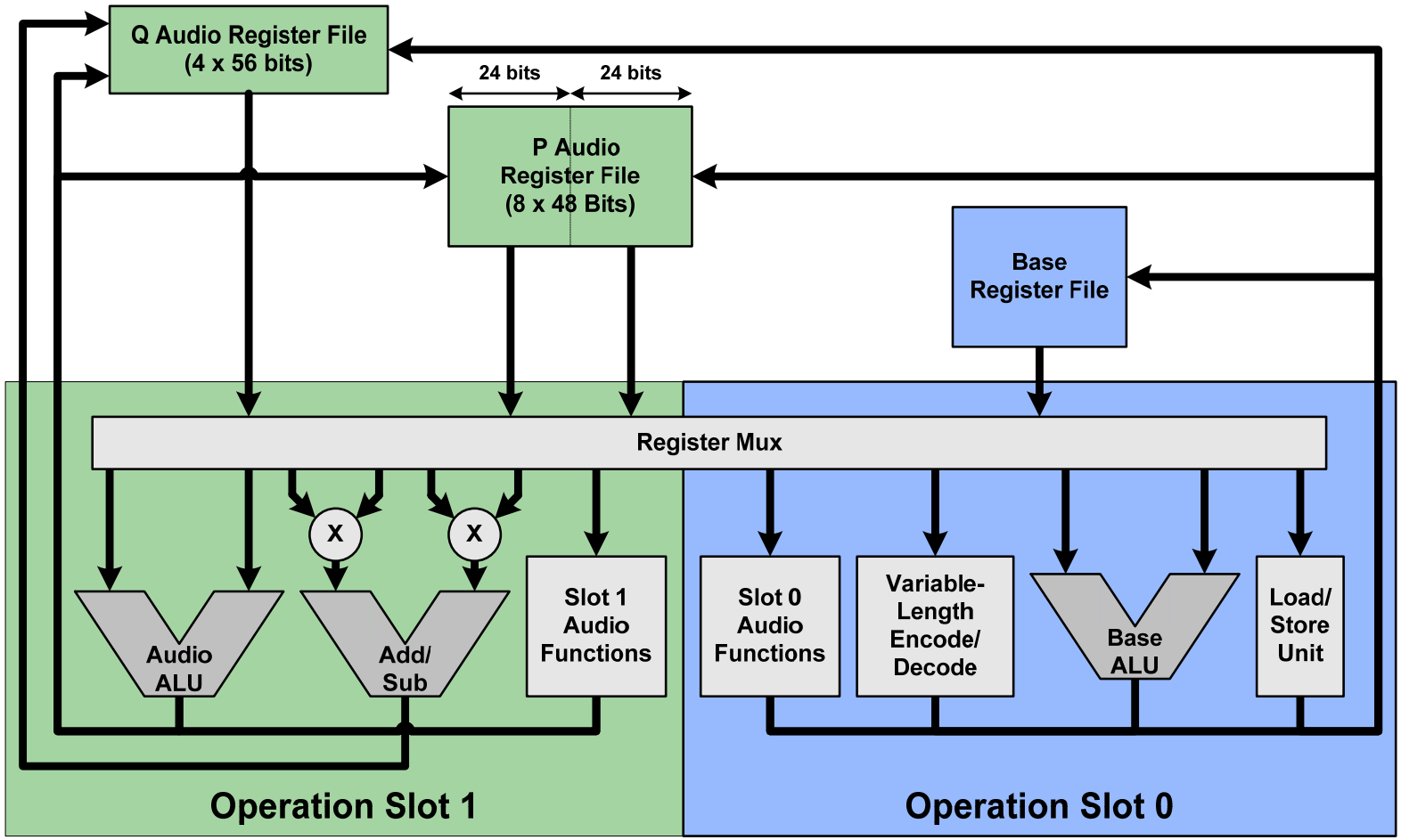
Diamond 330 HiFi Audio Engine Block Diagram



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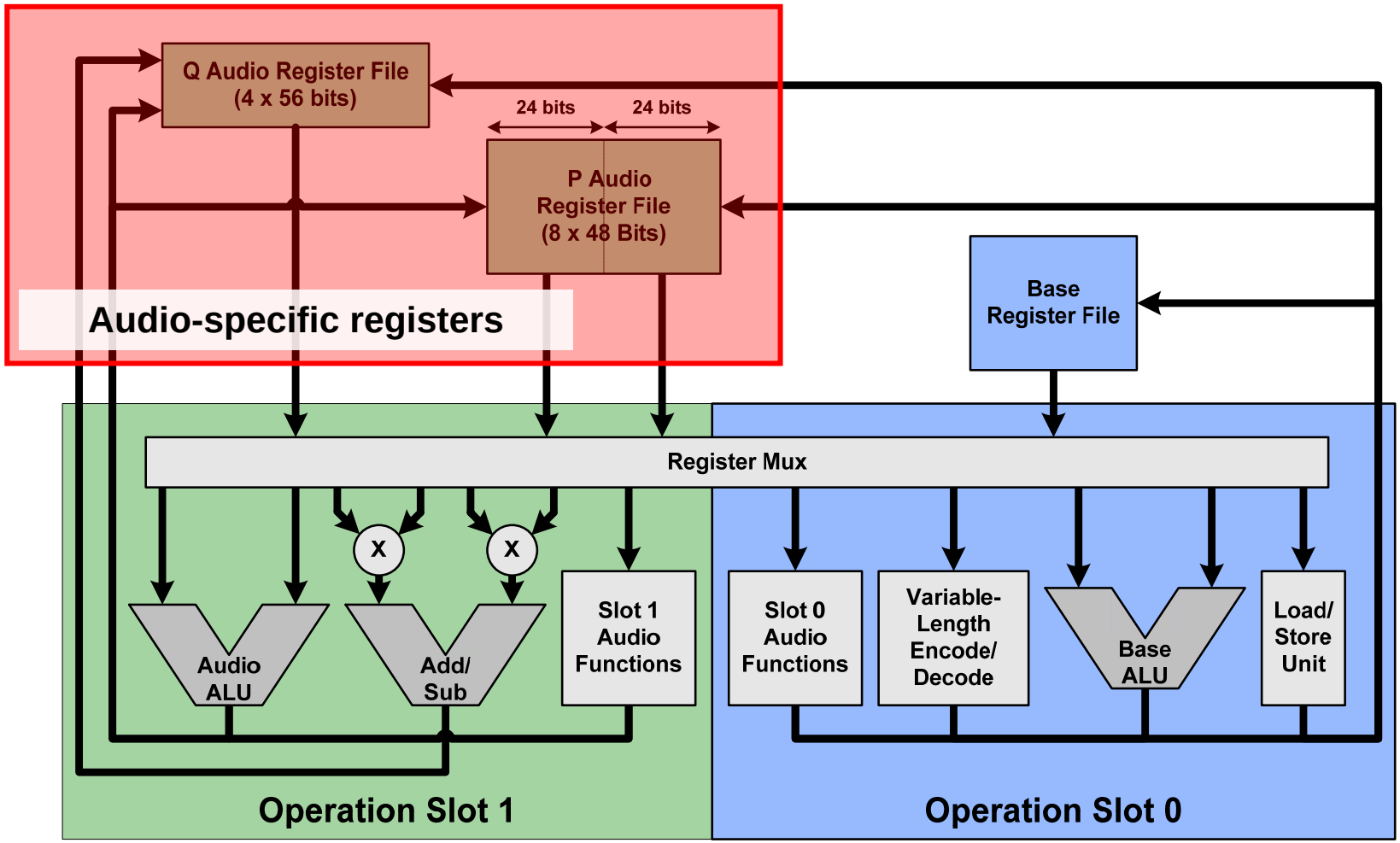

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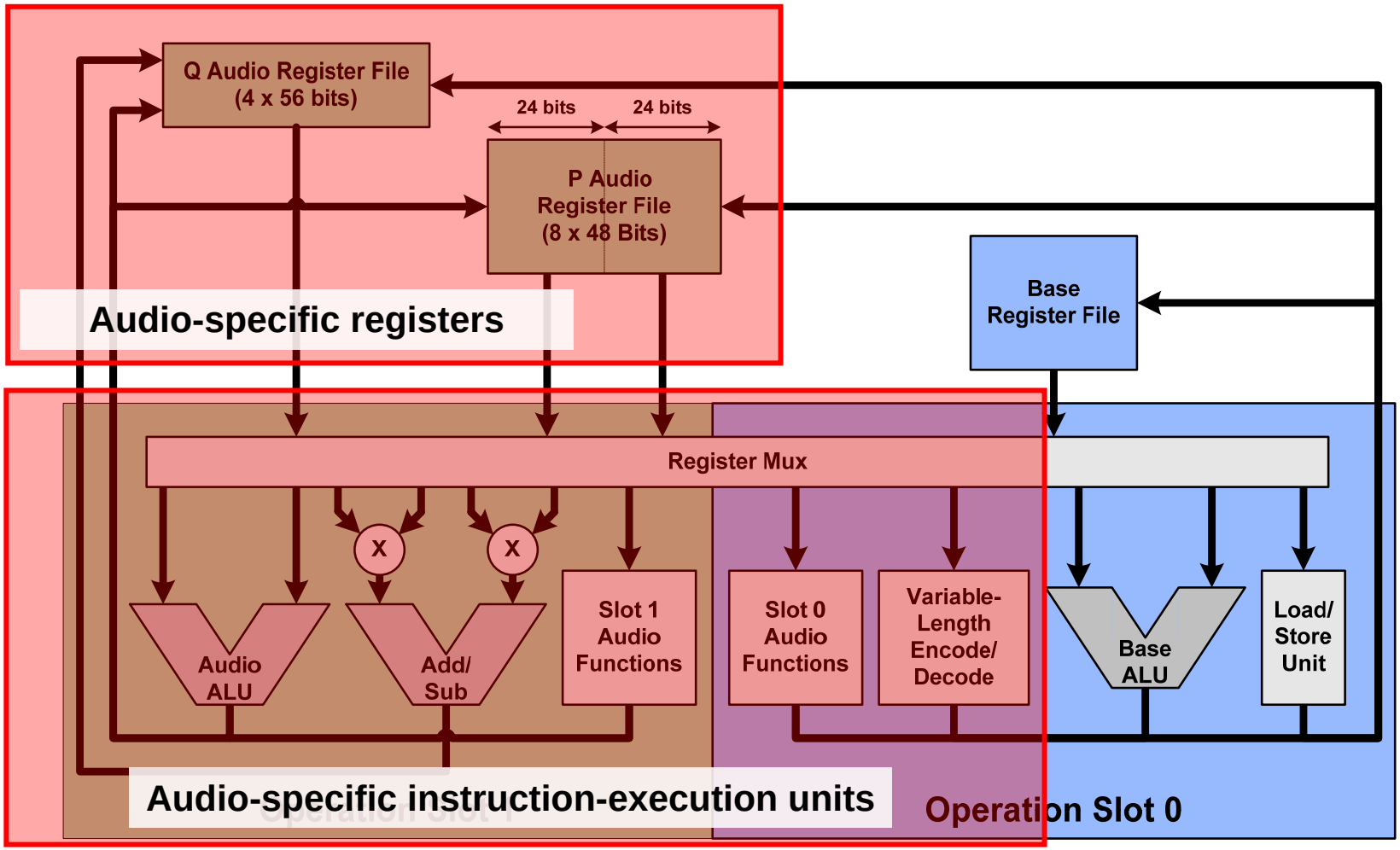

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Tensilica HiFi 2 Audio Engine Instruction Groups

Group	Operation
1	Loads and Stores
2	Single/Dual Multiply with 56-Bit Accumulator
3	Scalar and 2-Way SIMD ALU Operations
4	Variable/Immediate Shifts
5	Huffman Encode/Decode and Bit-Stream Support

~ 300 Audio-Specific Instructions

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The HiFi 2 Audio Engine (recap)

- Tensilica's configured Diamond 330HiFi processor core incorporates the HiFi 2 Audio Engine

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- Tensilica's configured Diamond 330HiFi processor core incorporates the HiFi 2 Audio Engine
- The HiFi 2 Audio Engine is available as an option for Tensilica's configurable Xtensa LX2 processor core

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The HiFi 2 Audio Engine (recap)

- Tensilica's configured Diamond 330HiFi processor core incorporates the HiFi 2 Audio Engine
- The HiFi 2 Audio Engine is available as an option for Tensilica's configurable Xtensa LX2 processor core
- All Tensilica digital-audio codecs run on both the Diamond 330HiFi processor core and the Xtensa LX2 processor core with the HiFi 2 Audio Engine option

Tensilica HiFi 2 and Diamond 330HiFi

Cellular Handset and Audio Entertainment Codec Set

	Clock Rate (MHz)
Dolby Digital (AC3) Decoder 5.1 channel	27.3
Dolby Digital (AC3) Consumer Encoder (DDCE)	30
Dolby Digital Plus Consumer Decoder, 7.1 channel	67
Dolby Digital Plus Decoder-Converter, 5.1 channel	43/52/70
MP3 Decoder (128 Kbps, 44.1 kHz)	5.7
MP3 Decoder (320 Kbps, 44.1 kHz)	6.9
MP3 Encoder (128 Kbps, 44.1 kHz)	26
MP3 Encoder (320 Kbps, 44.1 kHz)	30.2
MPEG-4 aacPlus v2 Decoder (48 Kbps, 48 kHz)	21.7
MPEG-4 aacPlus v2 Decoder (64 Kbps, 48 kHz)	21.9
MPEG-4 aacPlus v2 Encoder (48 Kbps, 48 kHz)	33.6
MPEG-4 aacPlus v2 Encoder (64 Kbps, 48 kHz)	34.2
MPEG-4 aacPlus v1 Decoder (64 Kbps, 48 kHz)	20.6
MPEG-4 aacPlus v1 Decoder (128 Kbps, 48 kHz)	20.9
MPEG-4 aacPlus v1 Encoder (64 Kbps, 48 kHz)	51.1
MPEG-4 aacPlus v1 Encoder (128 Kbps, 48 kHz)	52.8

	Clock Rate (MHz)
MPEG 2/4 AAC LC Decoder (128 Kbps, 48 kHz)	9.6
MPEG 2/4 AAC LC Decoder (320 Kbps, 48 kHz)	11.5
MPEG 2/4 AAC LC Encoder (128 Kbps, 48 kHz)	37.8
MPEG 2/4 AAC LC Encoder (320 Kbps, 48 kHz)	43.9
OggVorbis Decoder (128 Kbps, 44.1 kHz)	12.3
OggVorbis Decoder (320 Kbps, 44.1 kHz)	16.5
WMA Decoder (22 Kbps, 22 kHz)	12.4
WMA Decoder (128 Kbps, 44.1 kHz)	10.5
WMA Decoder (320 Kbps, 48 kHz)	14.9
WMA Encoder (128 Kbps, 44.1 kHz)	49
AMR Narrowband Speech Codec (5.15 Kbps)	17.9
AMR Wideband Speech Codec (8.85 Kbps)	37.2
G.729AB Speech Codec (8 Kbps)	13.7

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* As of 7/18/07

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Wide Adoption of Tensilica HiFi Digital Audio
The new standard in mobile audio, video, & DTV

Most top mobile handset makers ship Tensilica-based multimedia


Motorola KRZR


Motorola RIZR


Siemens SL75


Cingular 2125 (HTC)


Cingular 8125 (HTC)


Samsung SPH-V7800


Samsung SGH-910

LG Prada


Panasonic 705


LT1000 Korean T-DMB Standard


LG-LB1500


LD1200 DVB-H


LG-KD1200



LG-SB120


LG-LB1200


LG-KB1300

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Design for Portable Audio Applications

- Audio playback alone versus audio with enhancements and effects
  - Equalization, Bass Enhancement, 3D Audio, MIDI synthesis, etc.

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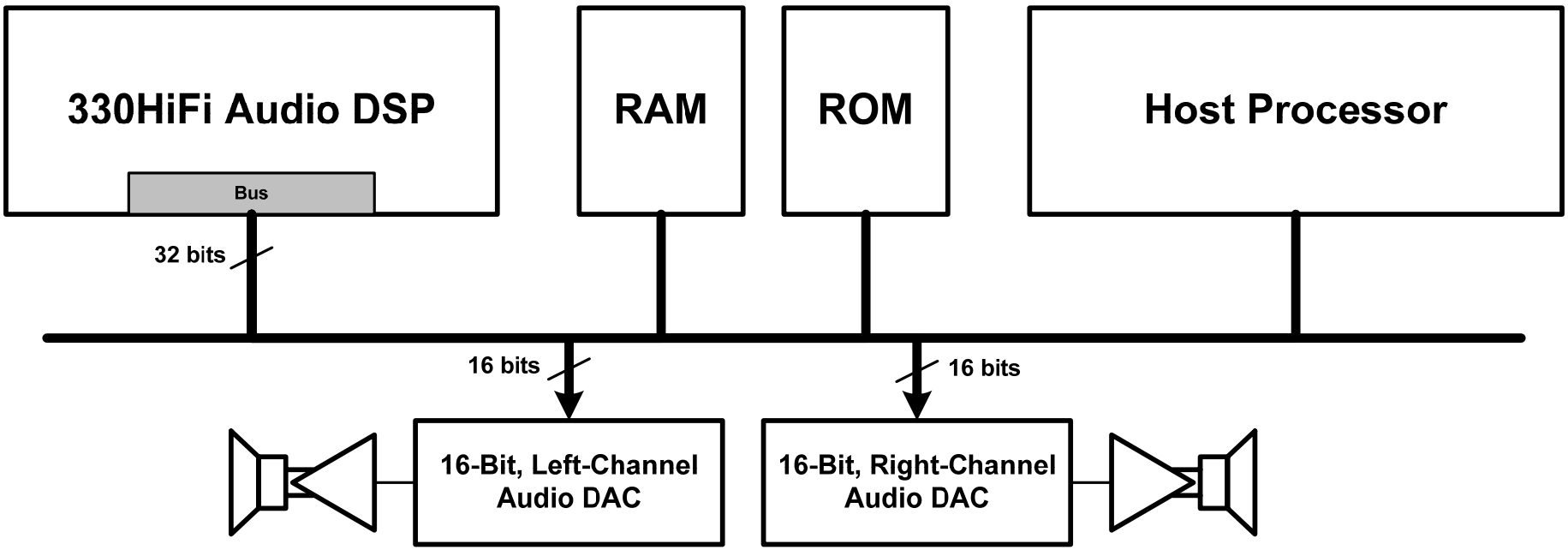
- Enhancements and effects may require an extra 100-200 MHz
  - May require synthesizing the audio processor for higher frequency operation
  - Makes the audio processor bigger and makes it dissipate more energy

Design for Portable Audio Applications

- Audio playback alone versus audio with enhancements and effects
  - Equalization, Bass Enhancement, 3D Audio, MIDI synthesis, etc.
- Enhancements and effects may require an extra 100-200 MHz
  - May require synthesizing the audio processor for higher frequency operation
  - Makes the audio processor bigger and makes it dissipate more energy
- For low-power applications, consider a second processor for audio effects
  - Allows very low-power operation for simple playback
  - Long battery life during playback

Diamond 330Hifi on the Bus



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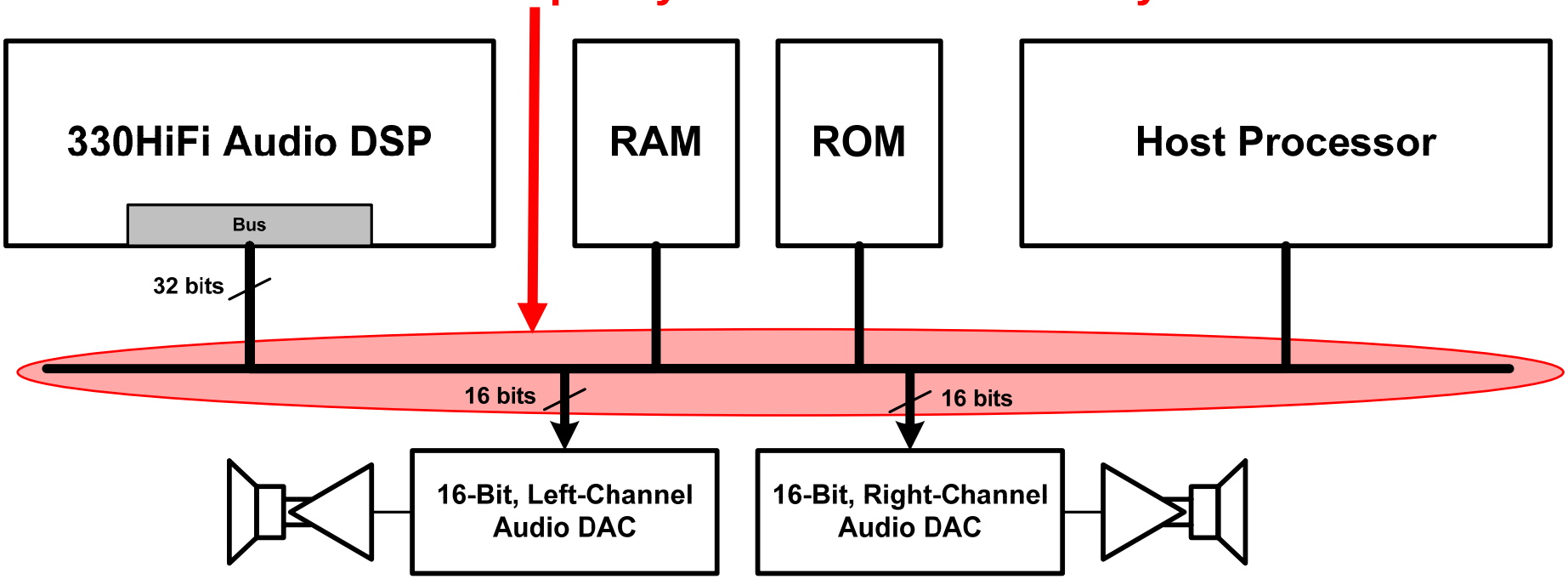
Diamond 330Hifi on the Bus

Potential Bottleneck, especially for 5.1- to 10.1-channel systems
Audio quality is sensitive to latency



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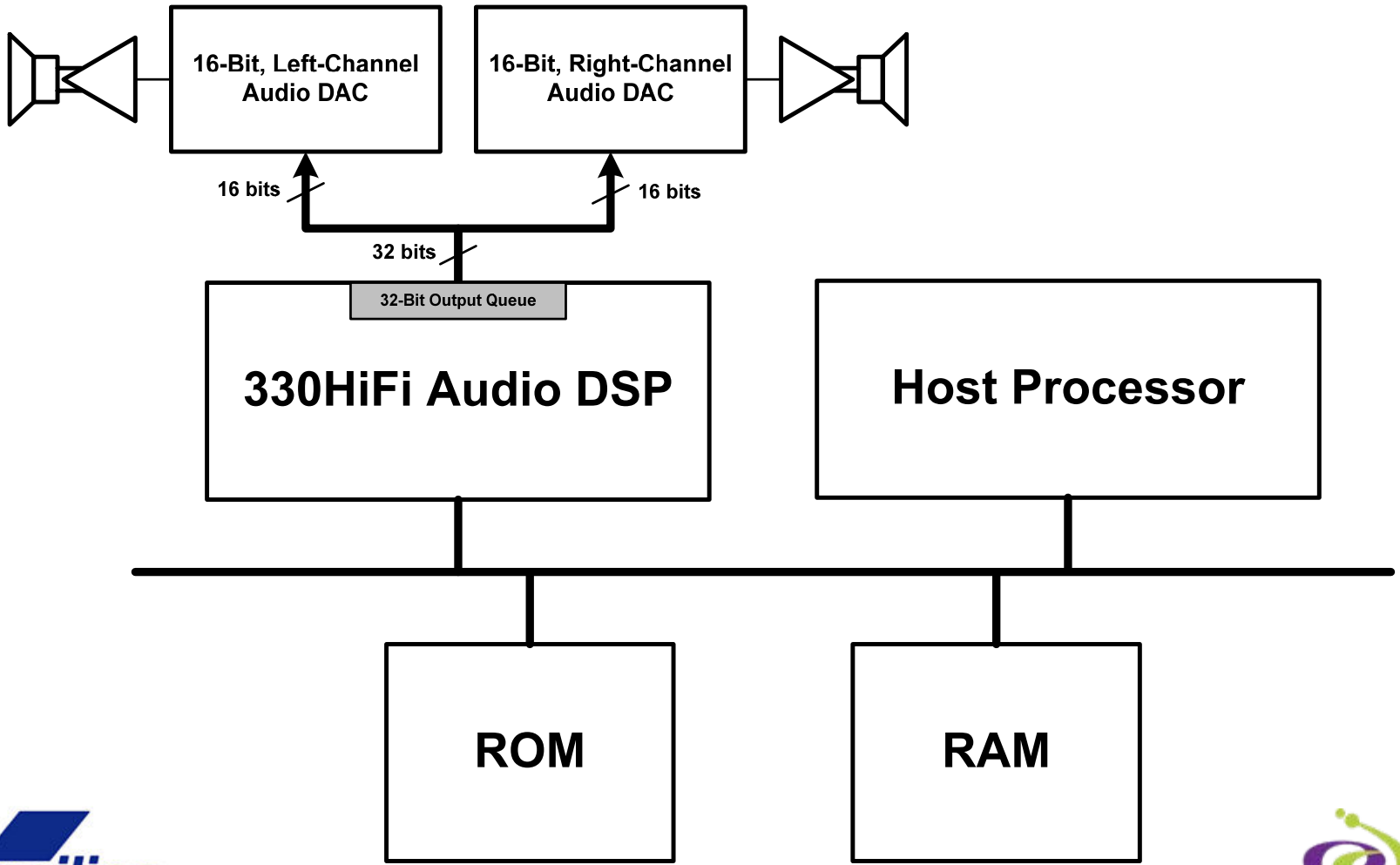
Diamond 330Hifi using Output Queue: Keep Audio Traffic Off the Bus



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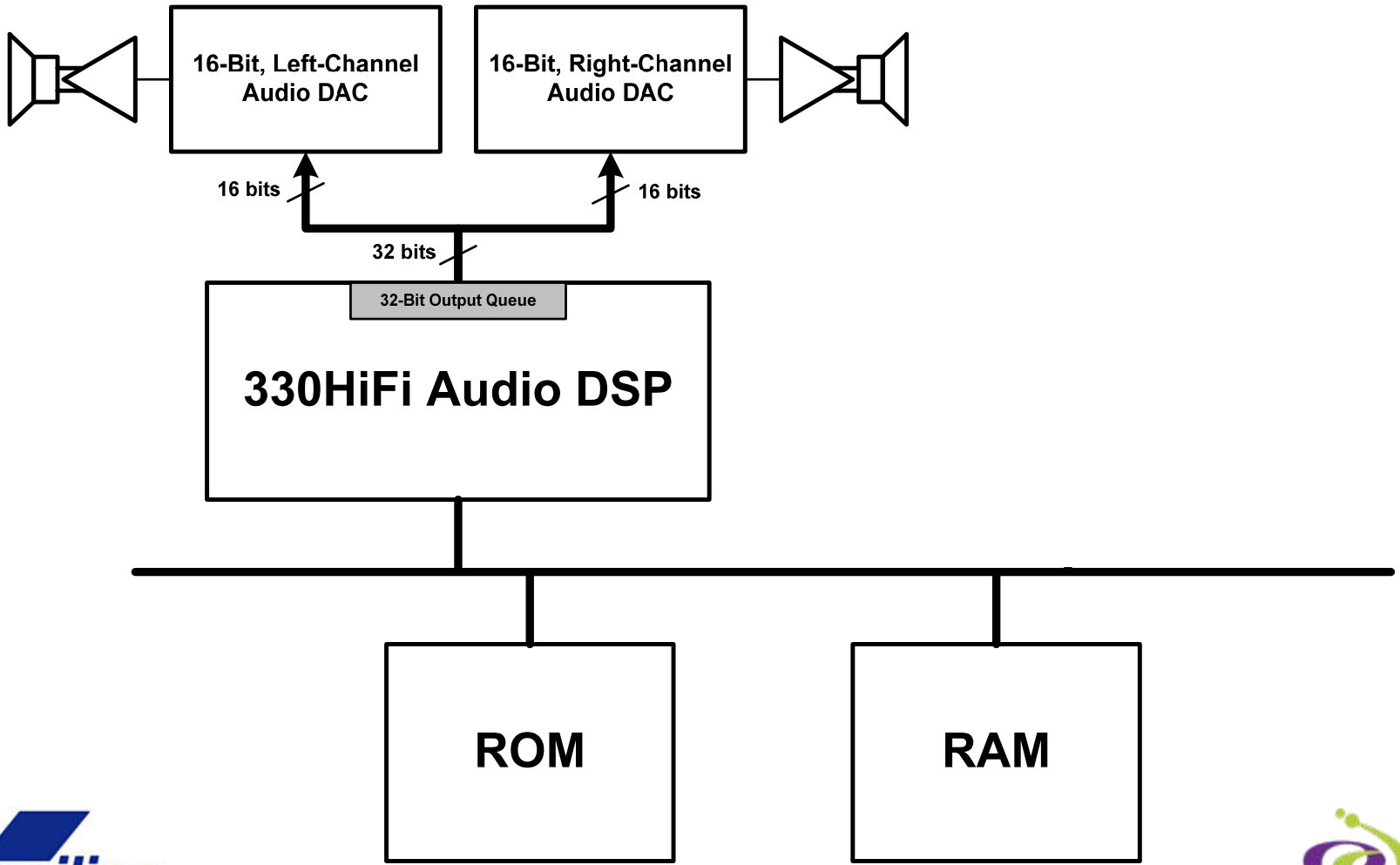
Many Systems Only Need One Processor (Get Rid of the Host)



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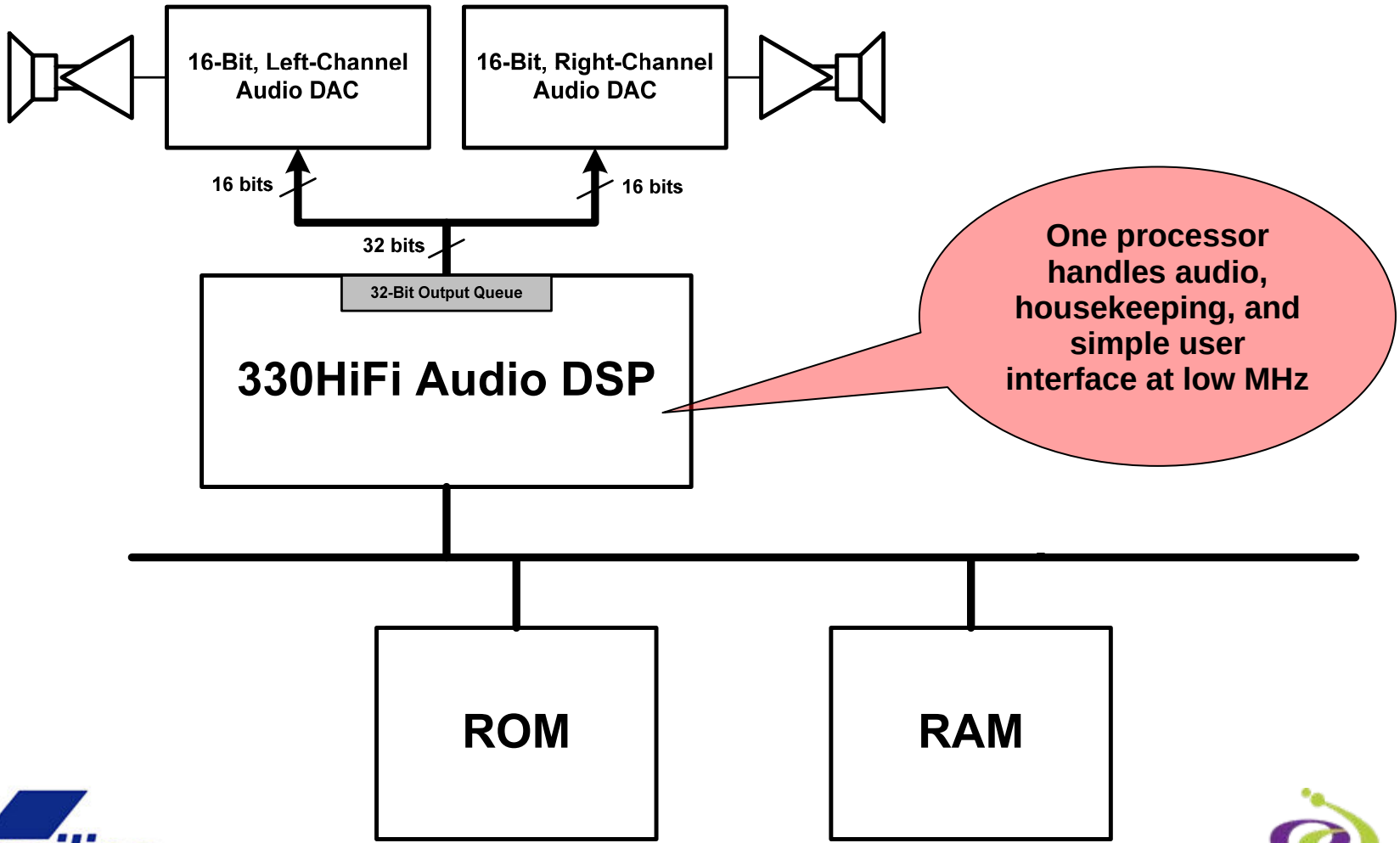

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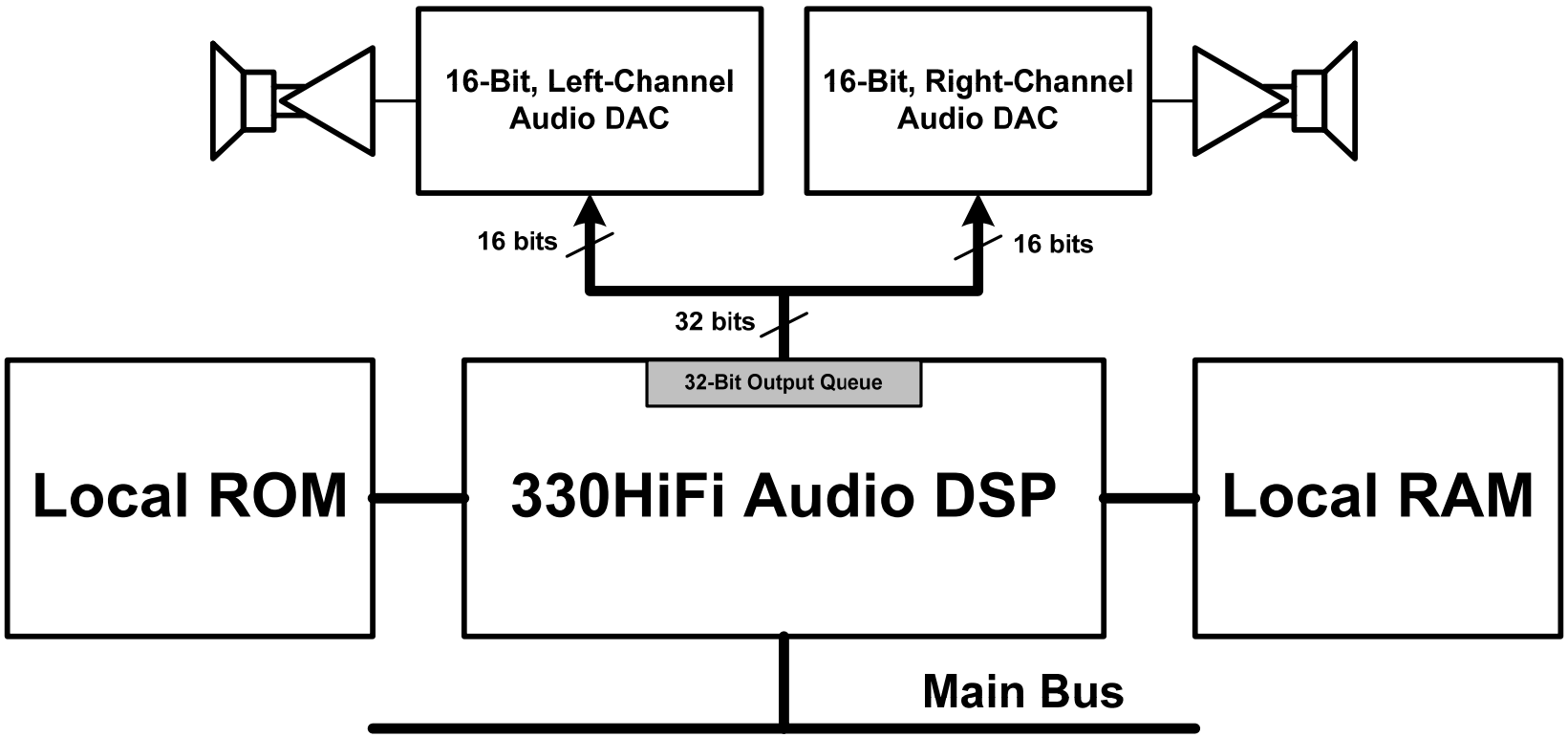
Move Audio Processor Memory to Local Interconnect



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Final Conclusions: Key Points

- ✓ Paths to low-power, on-chip digital audio
  - ✓ Low clock rate
  - ✓ Low Bus Traffic
  - ✓ Optimize use of local memory and cache
- ✓ Keep audio sample traffic off of the bus!!!
- ✓ Things to look for:
  - ✓ 24-bit audio processing ability
  - ✓ Comprehensive and growing codec set

Find out more at www.tensilica.com

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