



*The Engine of SOC Design*

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

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**November 28, 2007**

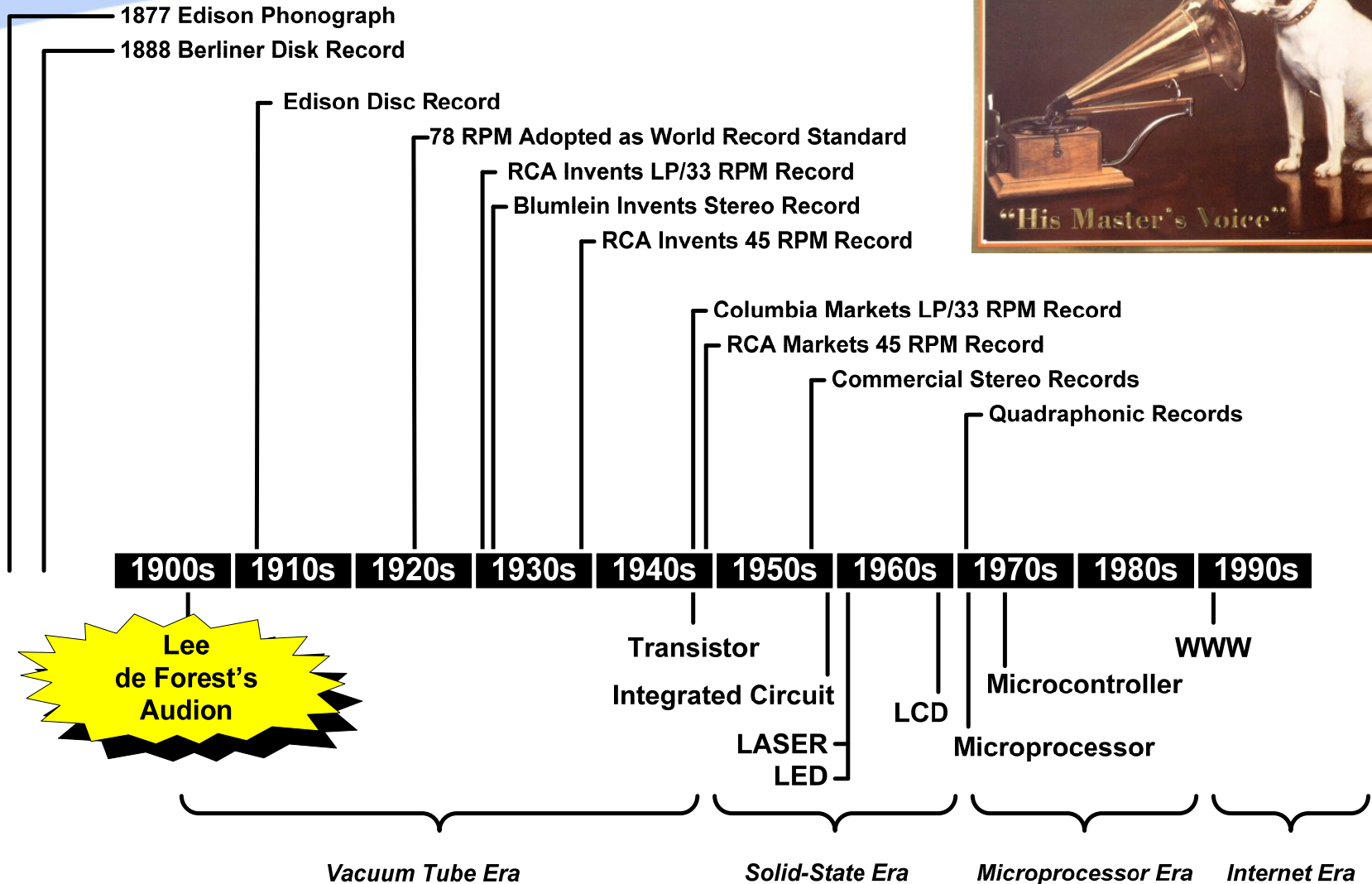


# Why Listen to This Web Seminar?

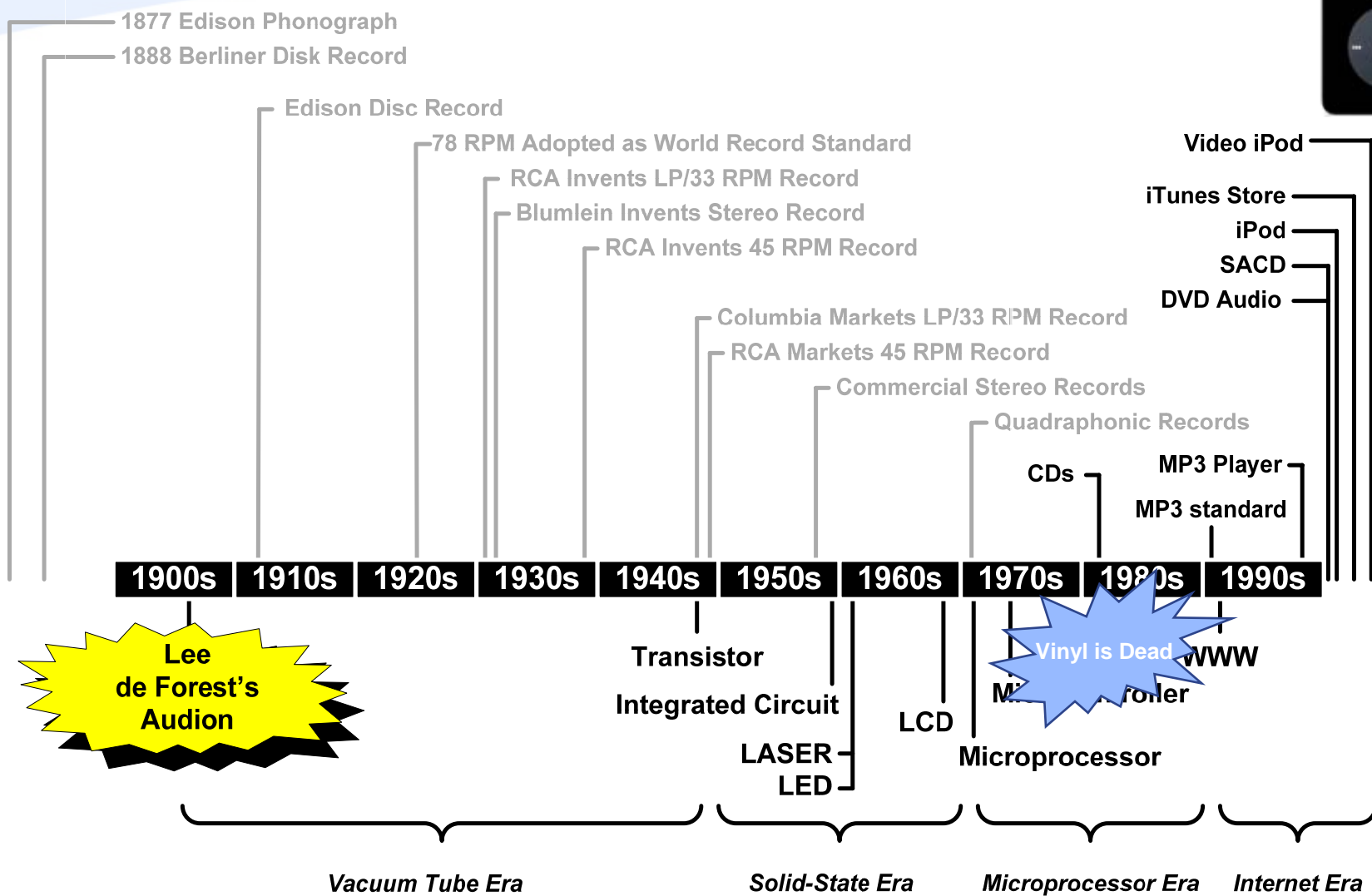
- **Learn about digital audio subsystem alternatives for SOC design**
  - Advantages and disadvantages for each alternative
  - Tradeoffs
- **Learn about key decision factors for choosing one alternative over another**
- **Learn about energy consequences of digital audio implementation choices**

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

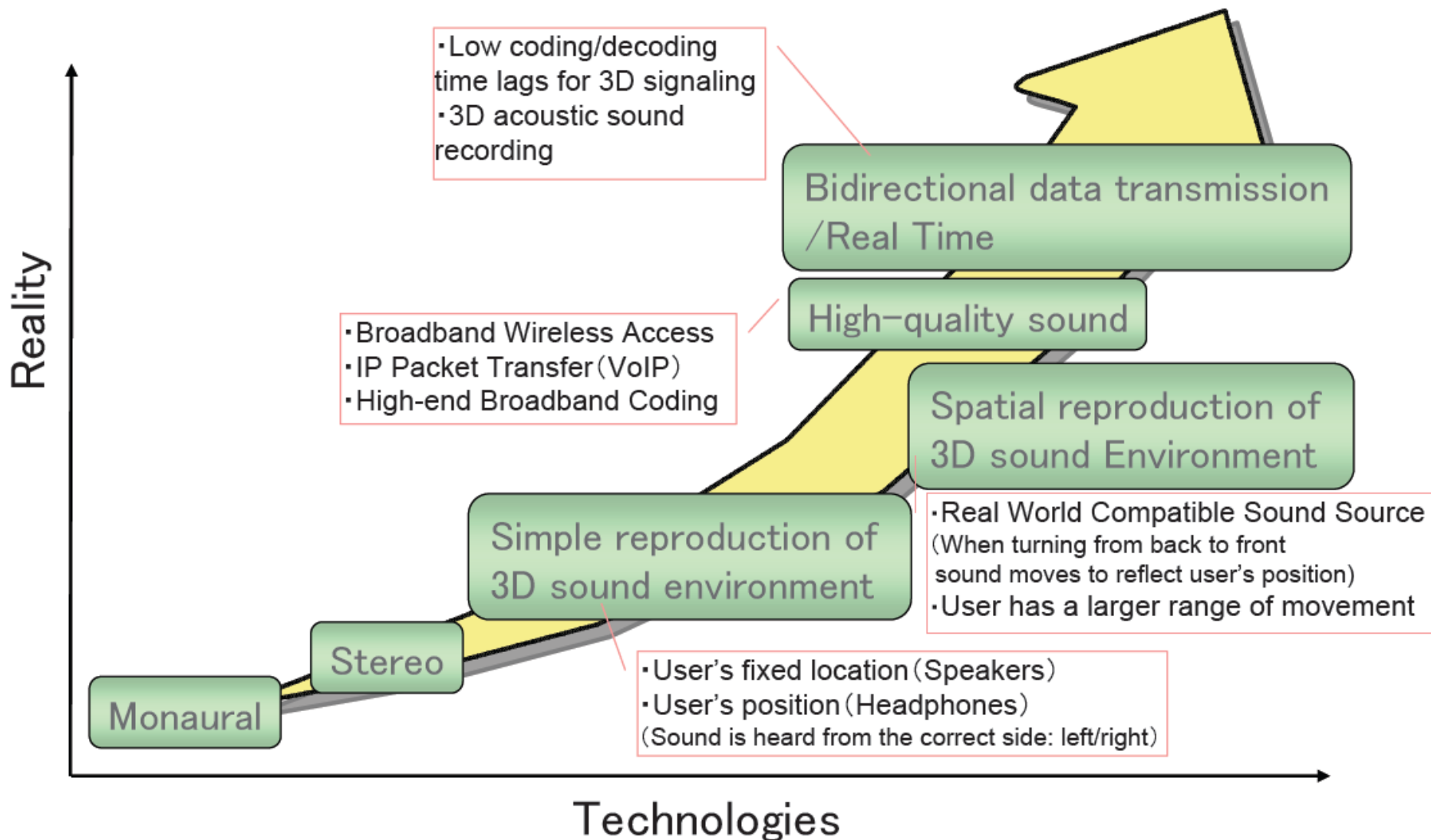
# A Brief History of Audio



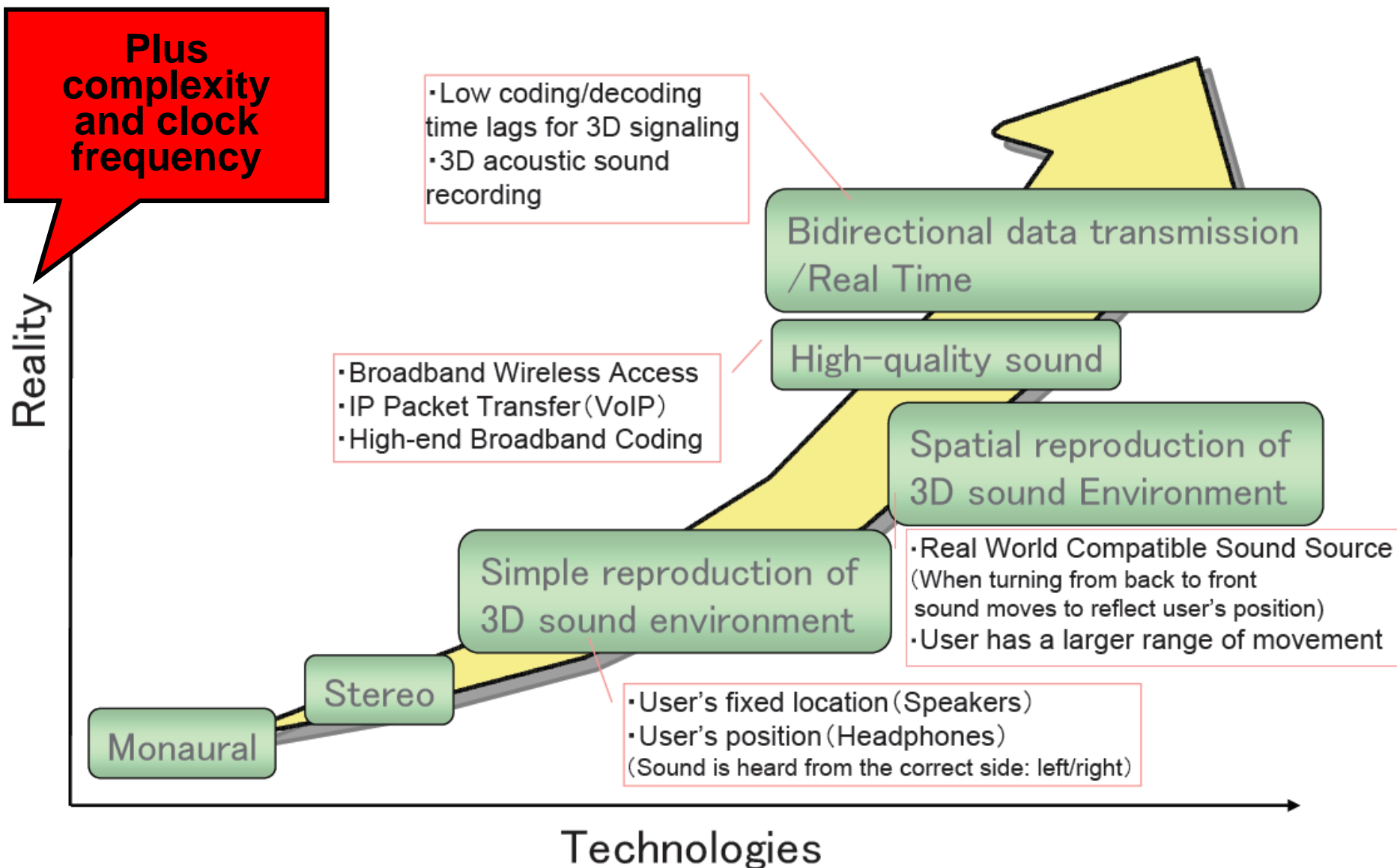
# The Era of Digital Audio



# Evolving Audio Capability



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# Digital Audio Applications



# Digital Audio Applications

- **Digital Audio Applications and Products**
  - Cell Phones

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    - PMPs
    - MP3 players

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    - DVD and HDTV
    - Blu-ray
    - HD DVD

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  - They require more processing power
  - Codec vendors introduce more advanced codecs regularly
- **Large number of digital audio codecs now in use**



# Many Digital Audio Codecs, Here are a Few

<b>Dolby Digital (AC3) Decoder 5.1 channel</b>
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<b>DTS – HD 5.1 channel Decoder</b>
<b>DTS – HD 7.1 channel Decoder</b>
<b>DTS – HS Master Audio 7.1 channel Decoder</b>
<b>MP3 Decoder (128 Kbps, 44.1 kHz)</b>
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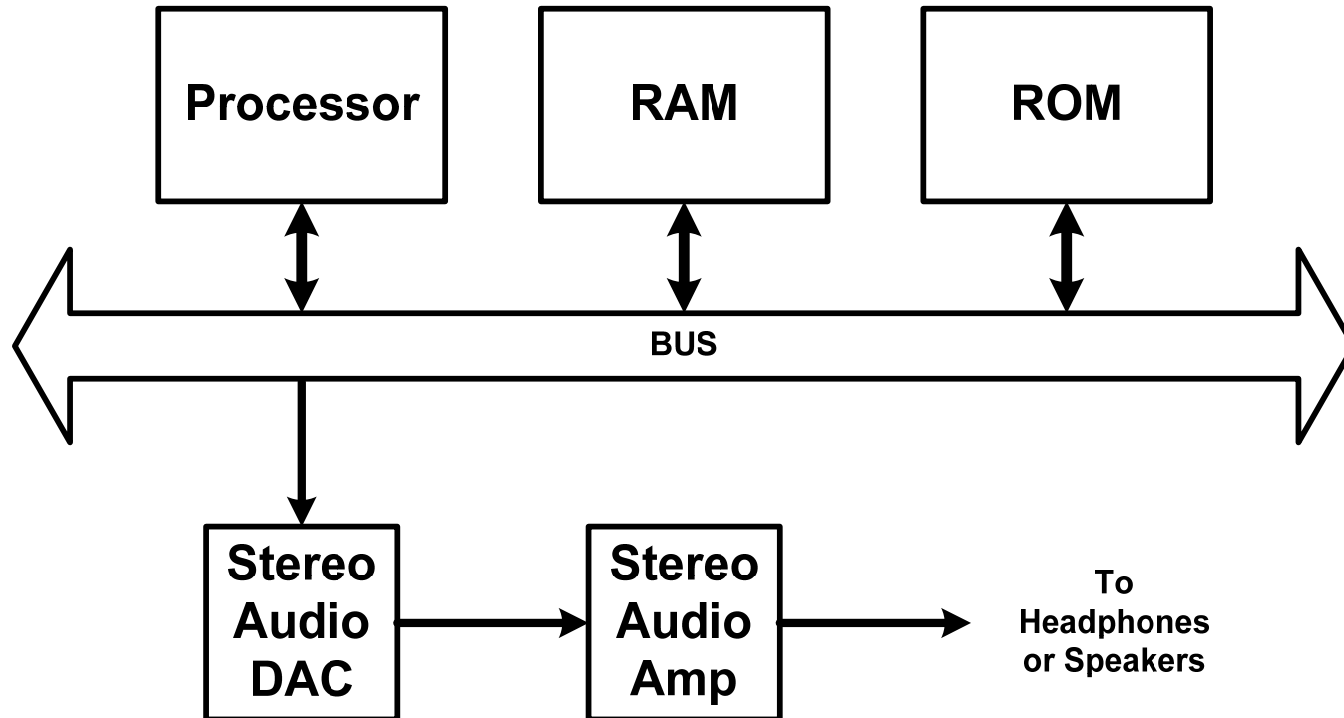
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<b>G.729AB Speech Codec (8 Kbps)</b>



# 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)



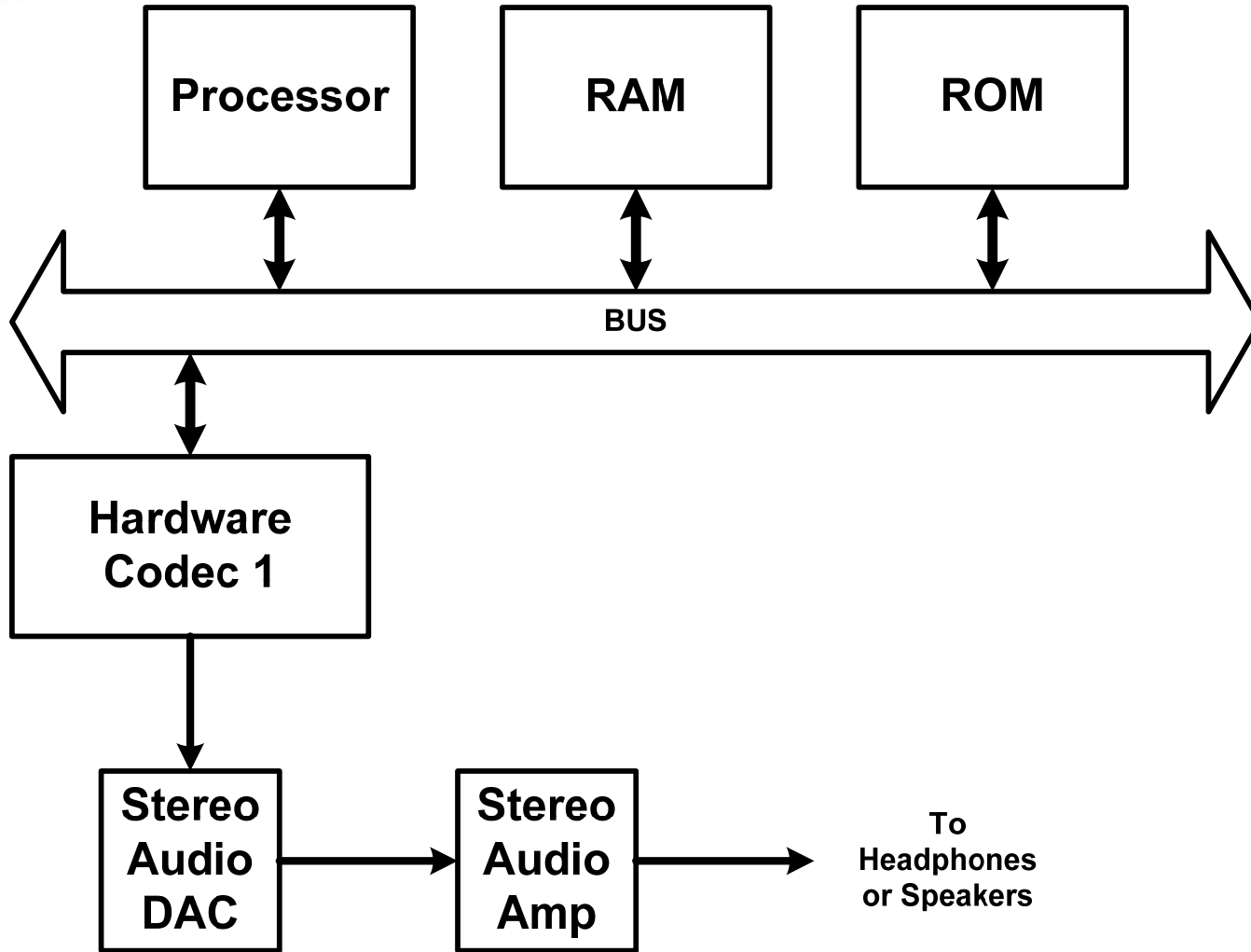
# General-Purpose Processor Core – Advantages and Disadvantages

## ■ Advantages

- Probably one on the chip anyway
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## ■ Disadvantages

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





# Hardware Codec – Advantages and Disadvantages

- **Advantages**
  - Small on-die area
  - Low power

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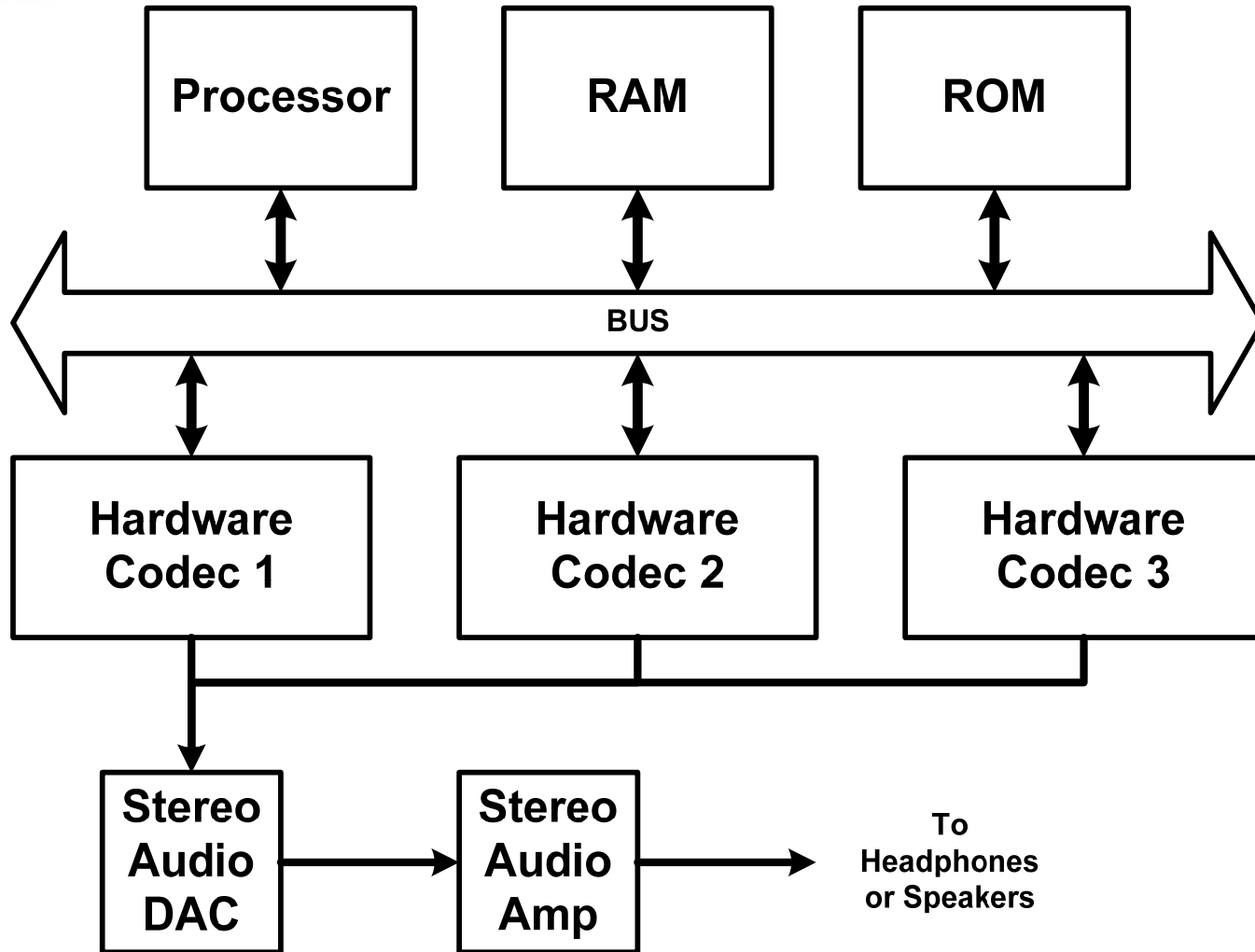
- **Advantages**

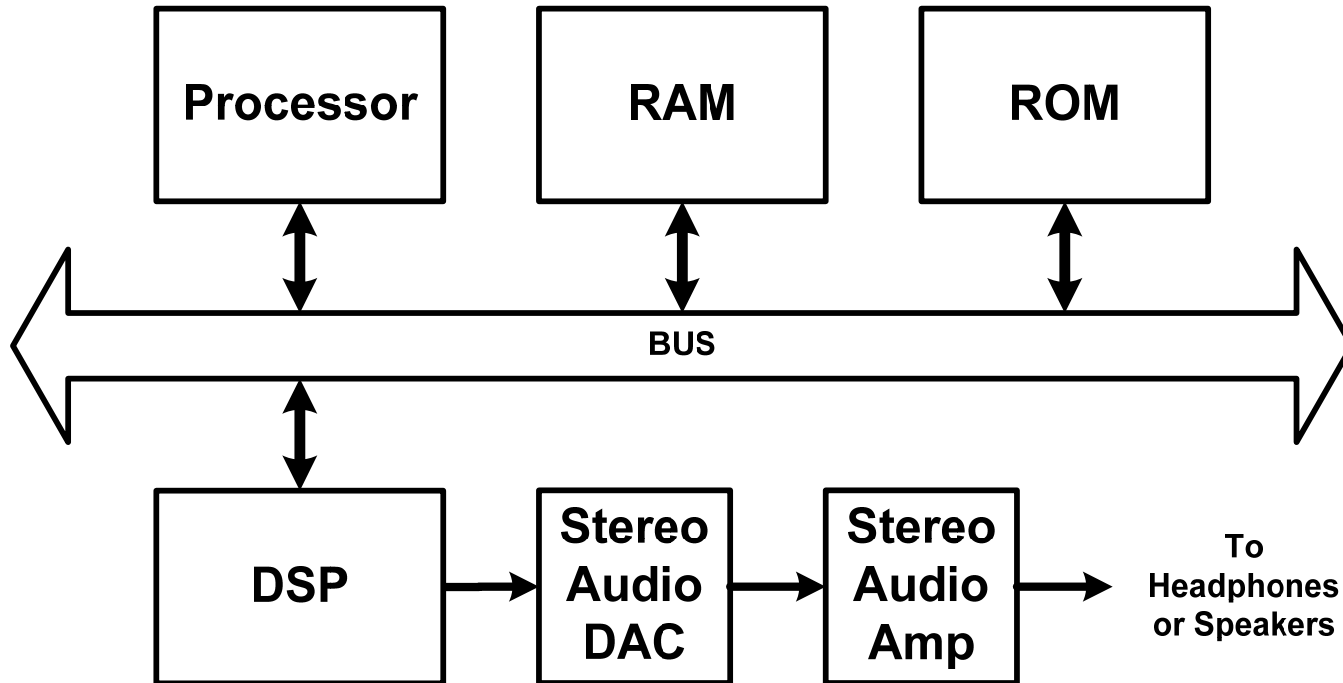
- Small on-die area
- Low power

- **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 – Advantages and Disadvantages

## ▪ **Advantages**

- Integral multiplier helps lower the clock rate, vs. general-purpose processor
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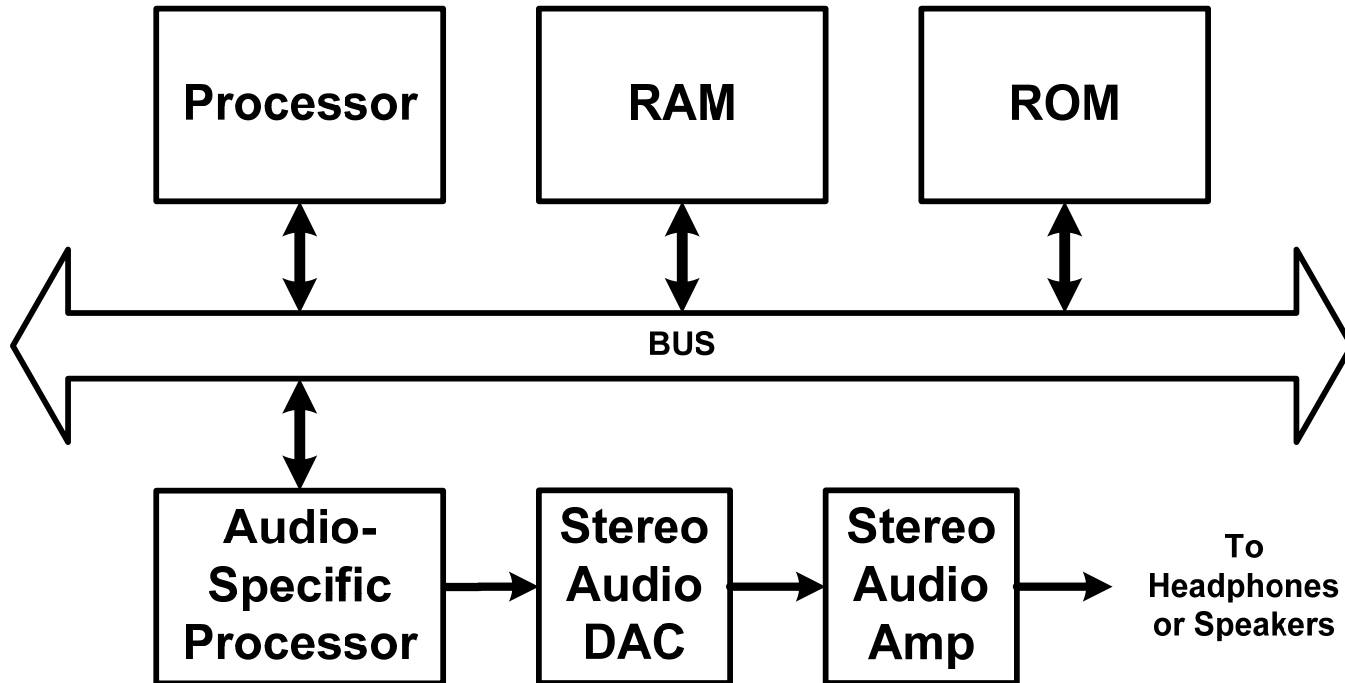
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## ▪ **Disadvantages**

- 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 high fidelity audio
- 32-bit DSPs do not improve fidelity (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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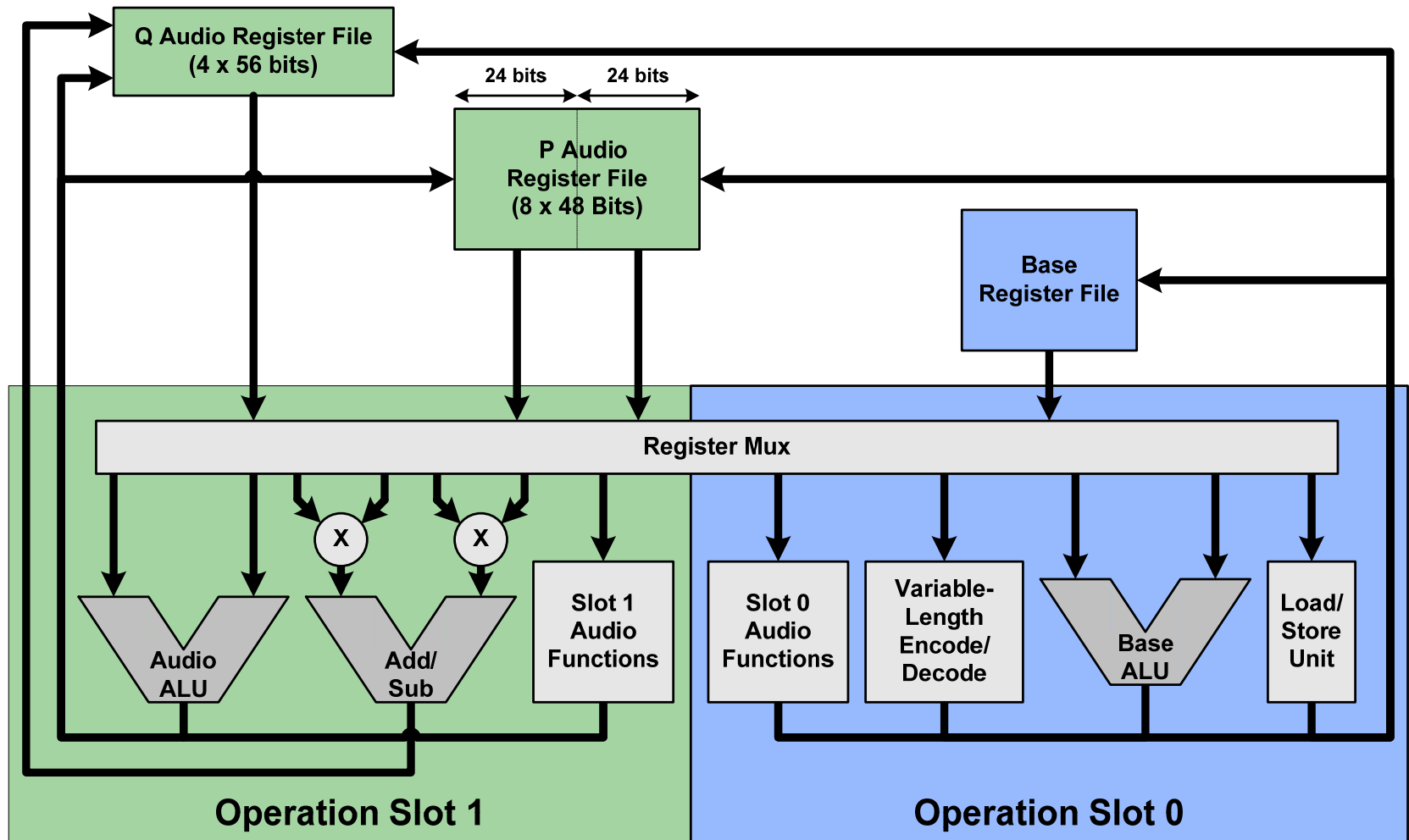
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- **Wide audio-specific registers**
  - Handles stereo 24-bit/channel data samples as a native data type
- **300 audio-specific instructions**
- **Comprehensive and growing set of digital audio codecs**



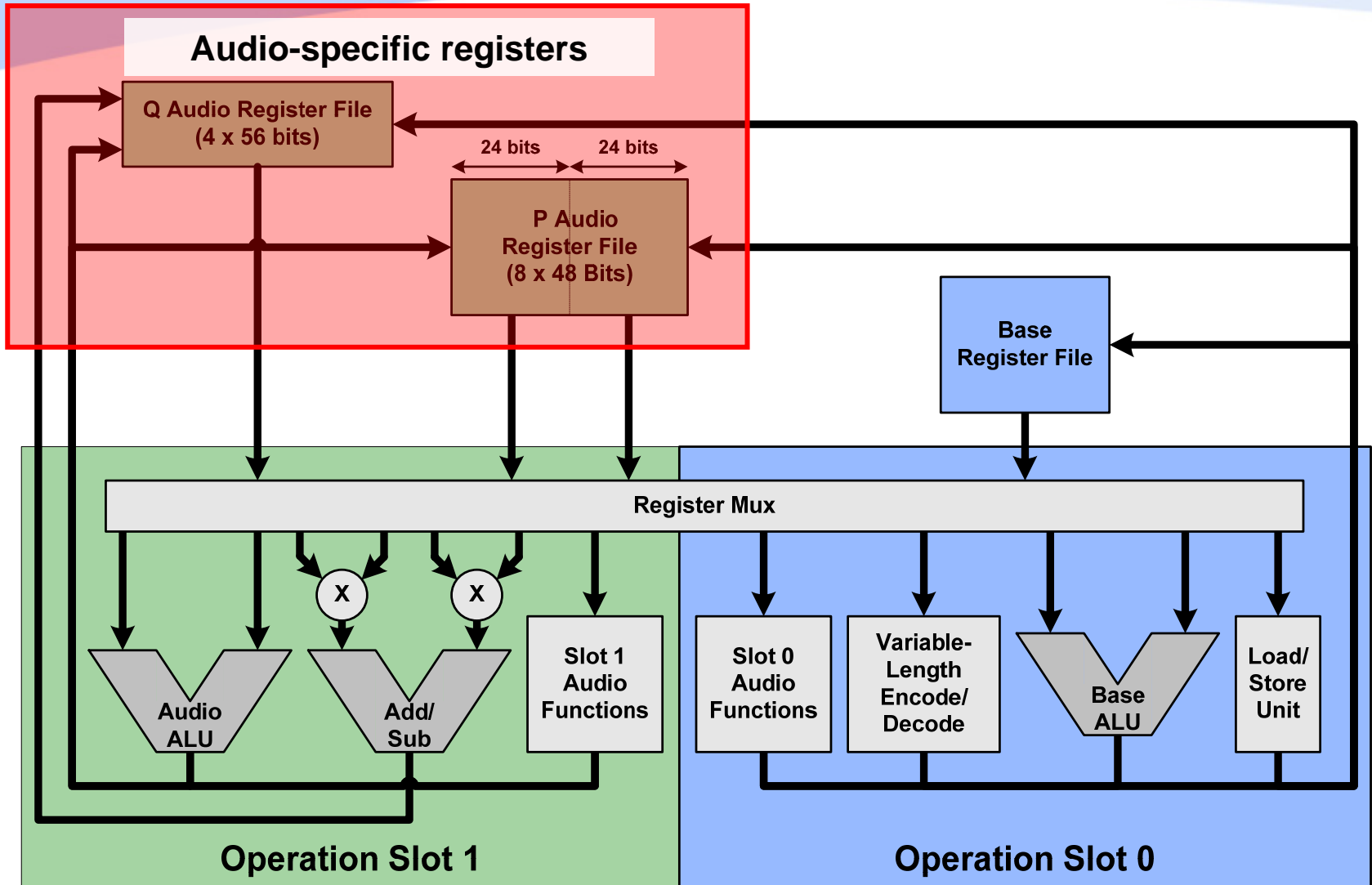
# Tensilica's Diamond 330HiFi Audio Engine Processor Core

- **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

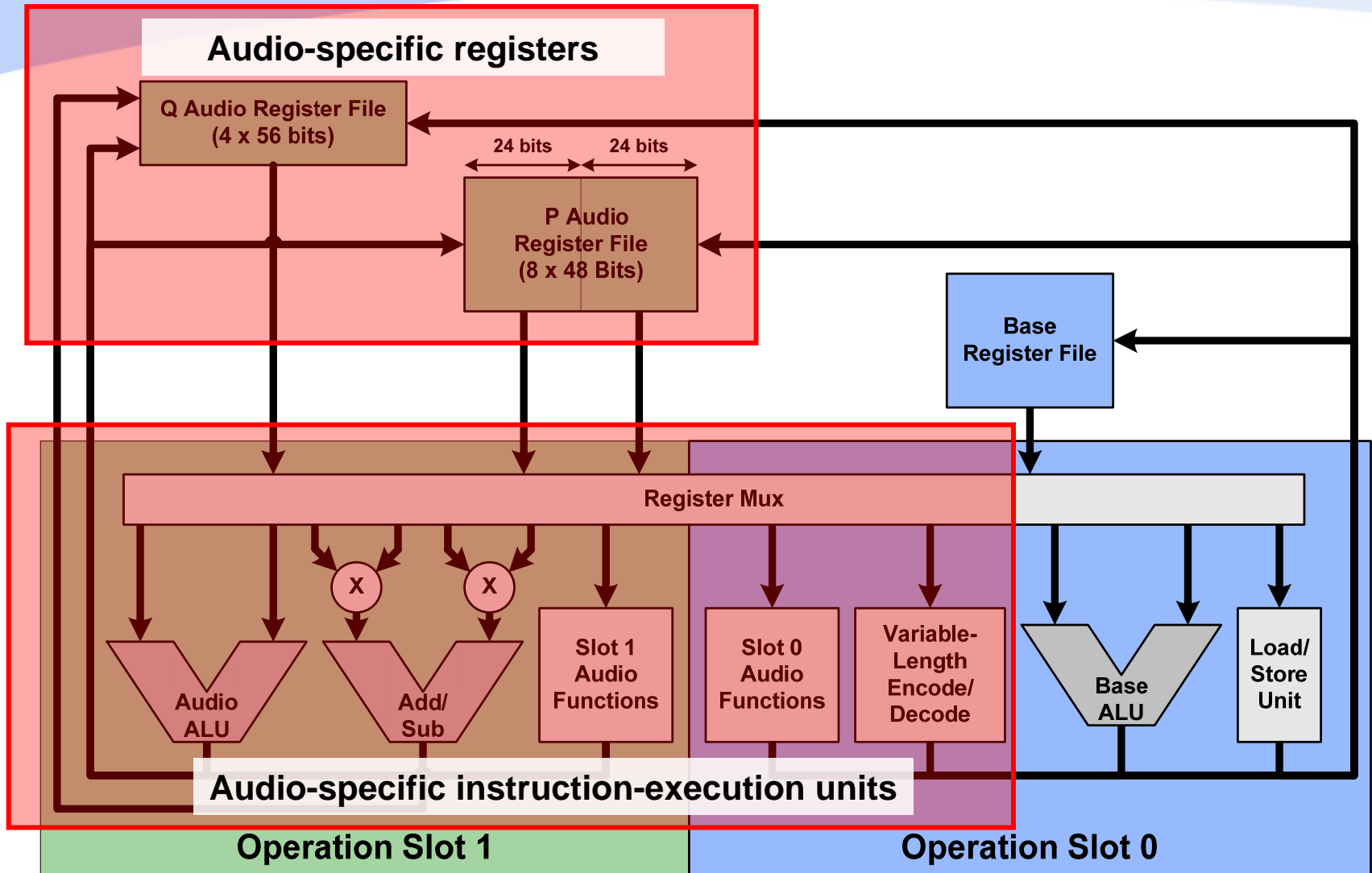
# Diamond 330 HiFi Audio Engine Block Diagram



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# Tensilica HiFi 2 Audio Engine Instruction Groups

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

**~ 300 Audio-Specific Instructions**



# The HiFi 2 Audio Engine (recap)

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



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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 Home Entertainment Codec Set

	Clock Rate (MHz)
Dolby Digital (AC3) Decoder 5.1 channel	27.3
Dolby Digital (AC3) Consumer Encoder (DDCE) 2 ch	19
Dolby Digital Compatible Output (DDCO) 5.1 ch	60
Dolby Digital Plus Consumer Decoder, 7.1 channel	63
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)	25.7
MP3 Encoder (320 Kbps, 44.1 kHz)	30.2
MPEG-4 aacPlus v2 Decoder (64 Kbps, 48 kHz)	21.7
MPEG-4 aacPlus v2 Encoder (48 Kbps, 48 kHz)	21.8
MPEG-4 aacPlus v1 Decoder (64 Kbps, 48 kHz)	20.6
MPEG-4 aacPlus v1 Decoder (128 Kbps, 48 kHz)	20.8
MPEG-4 aacPlus v1 Encoder (64 Kbps, 48 kHz)	46.9

	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)	11.4
MPEG 2/4 AAC LC Encoder (128 Kbps, 48 kHz)	37.8
MPEG 2/4 AAC LC Encoder (320 Kbps, 48 kHz)	43.9
BSAC Decoder (64 kbps, 44.1 kHz)	25
Ogg Vorbis Decoder (128 Kbps, 44.1 kHz)	12.3
Ogg Vorbis 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, 44.1 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)	34.6
G.729AB Speech Codec (8 Kbps)	13.7

\* As of 11/28/07

# 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





# 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
- **For low-power applications, consider a second processor for audio effects**
  - Allows very low-power operation for simple playback
  - Long battery life during playback



# Notes on Memory: Local vs. Cache

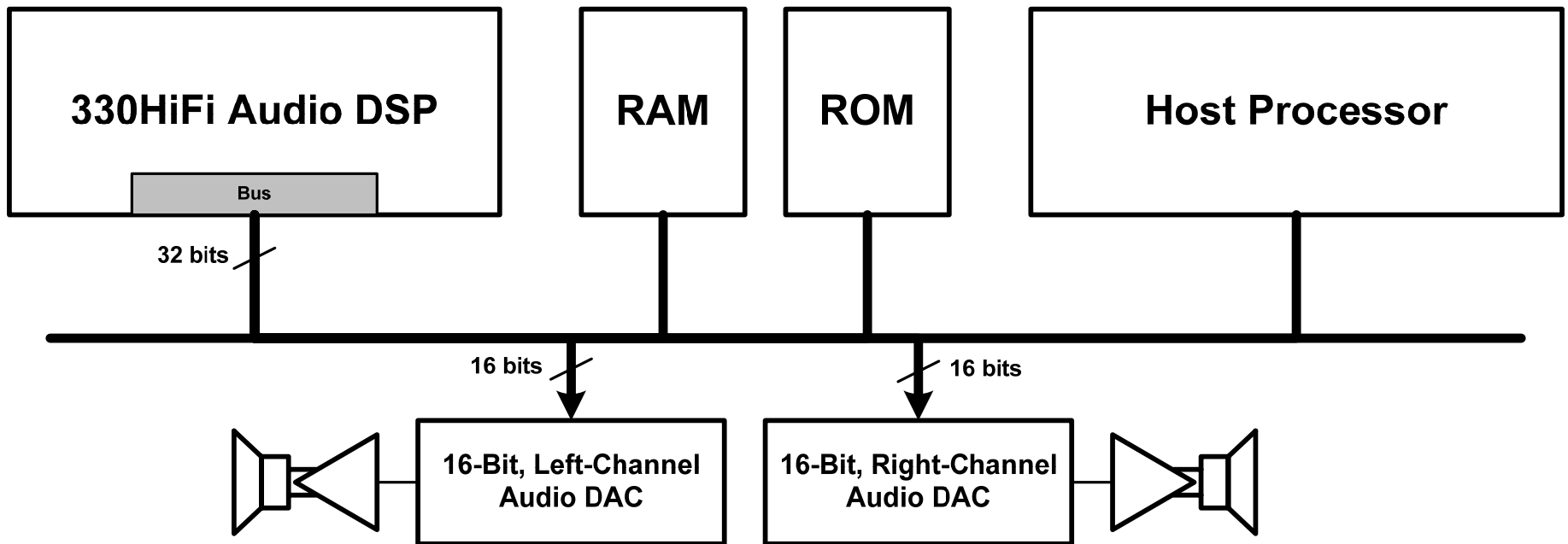
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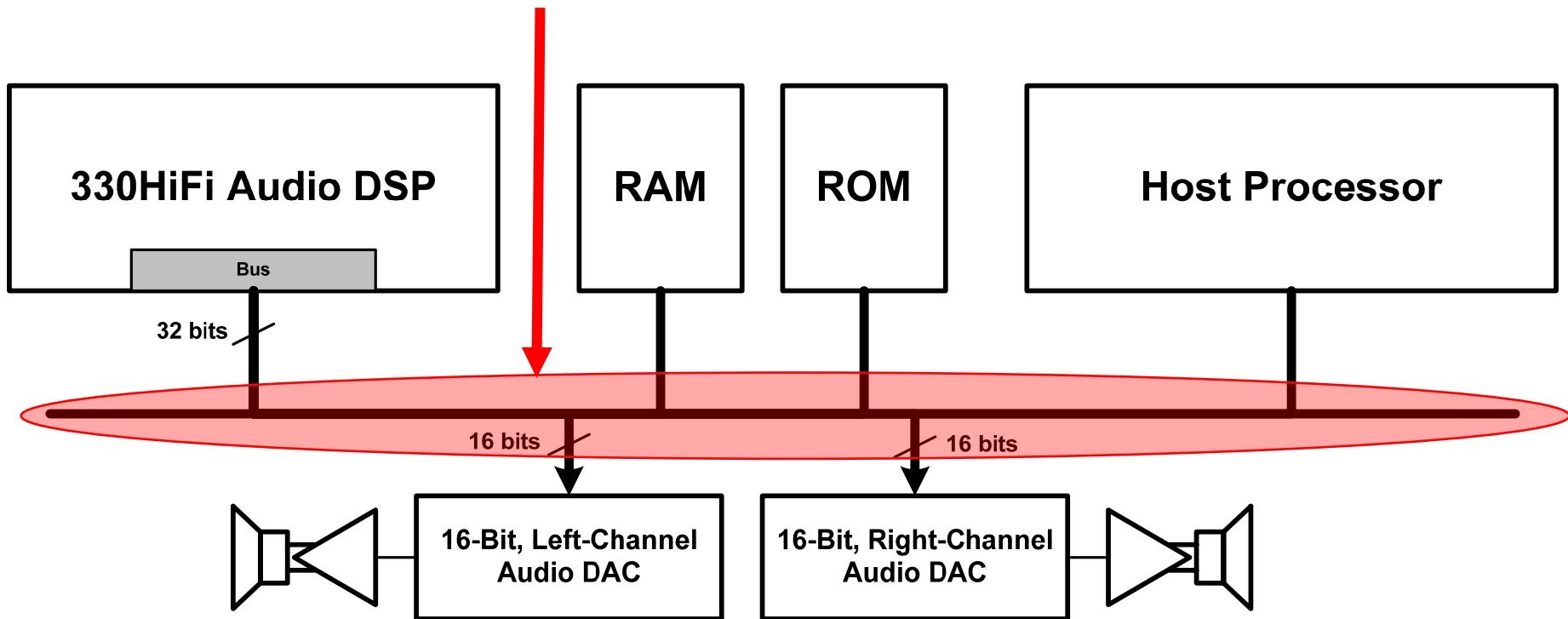
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- **Xtensa LX2**
  - Configurable with or without caches, with or without local memory
- **Diamond 330HiFi**
  - Has caches, but they can be disabled if desired

# Diamond 330HiFi on the Bus

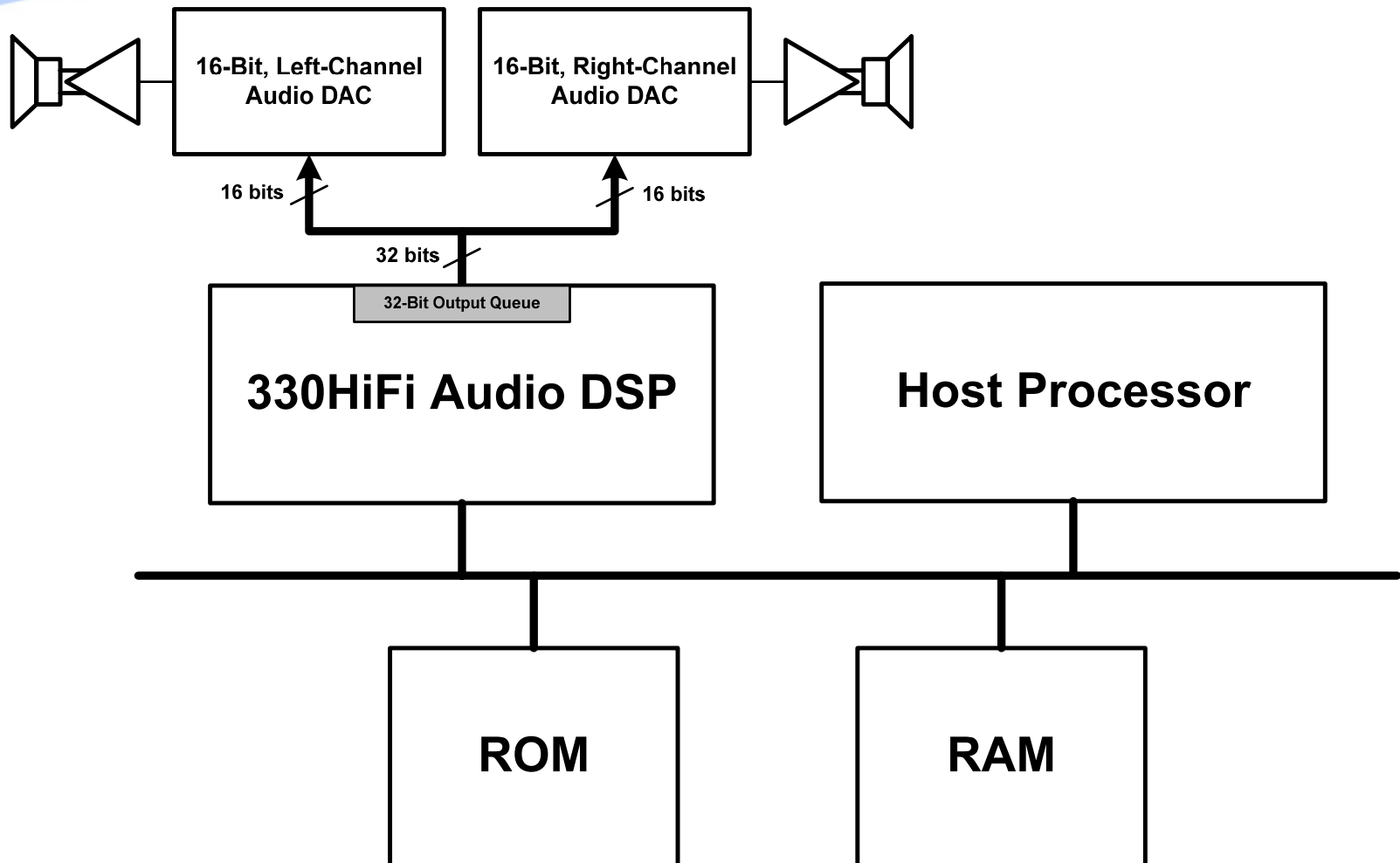


# Diamond 330HiFi on the Bus

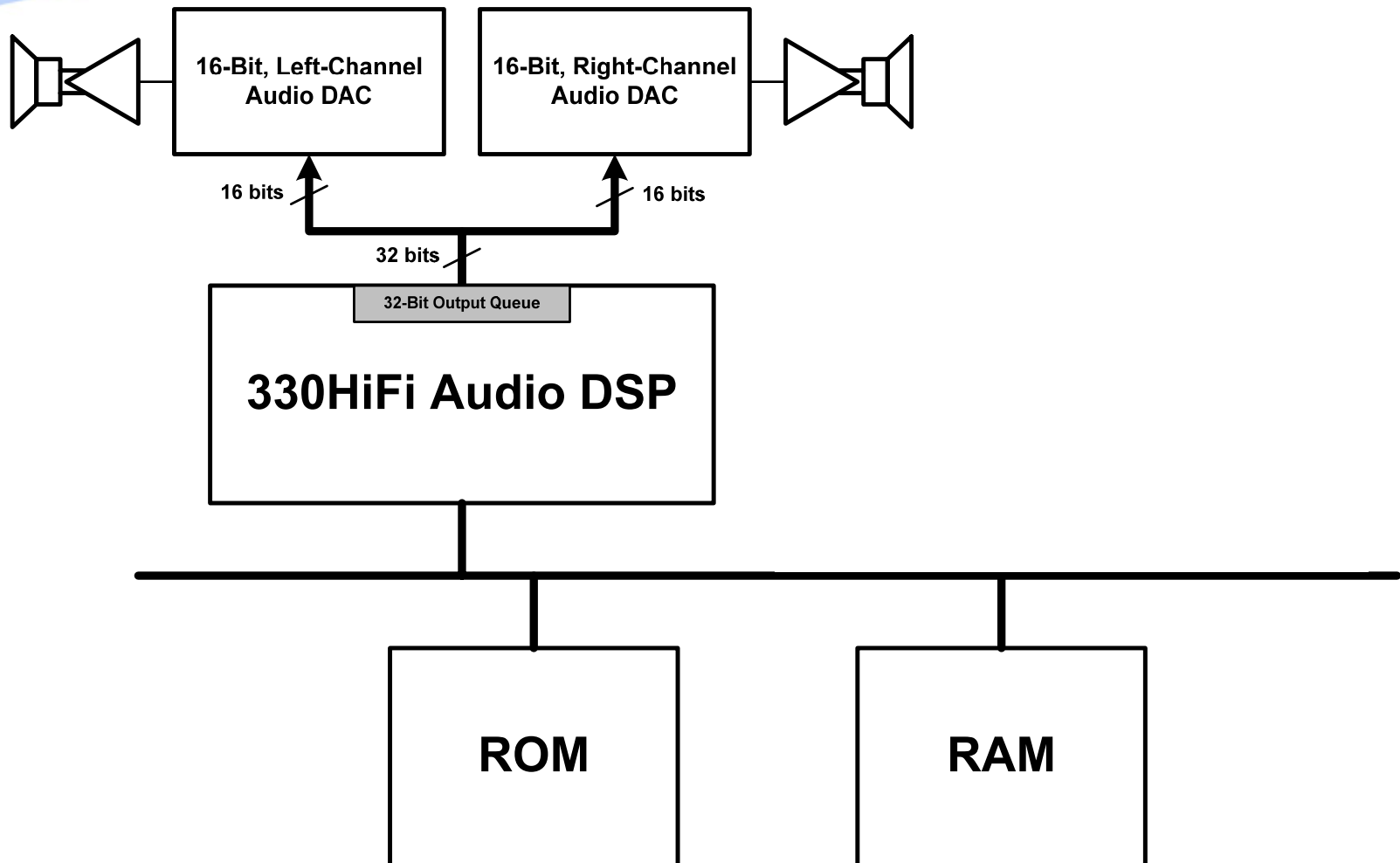
**Bottleneck**



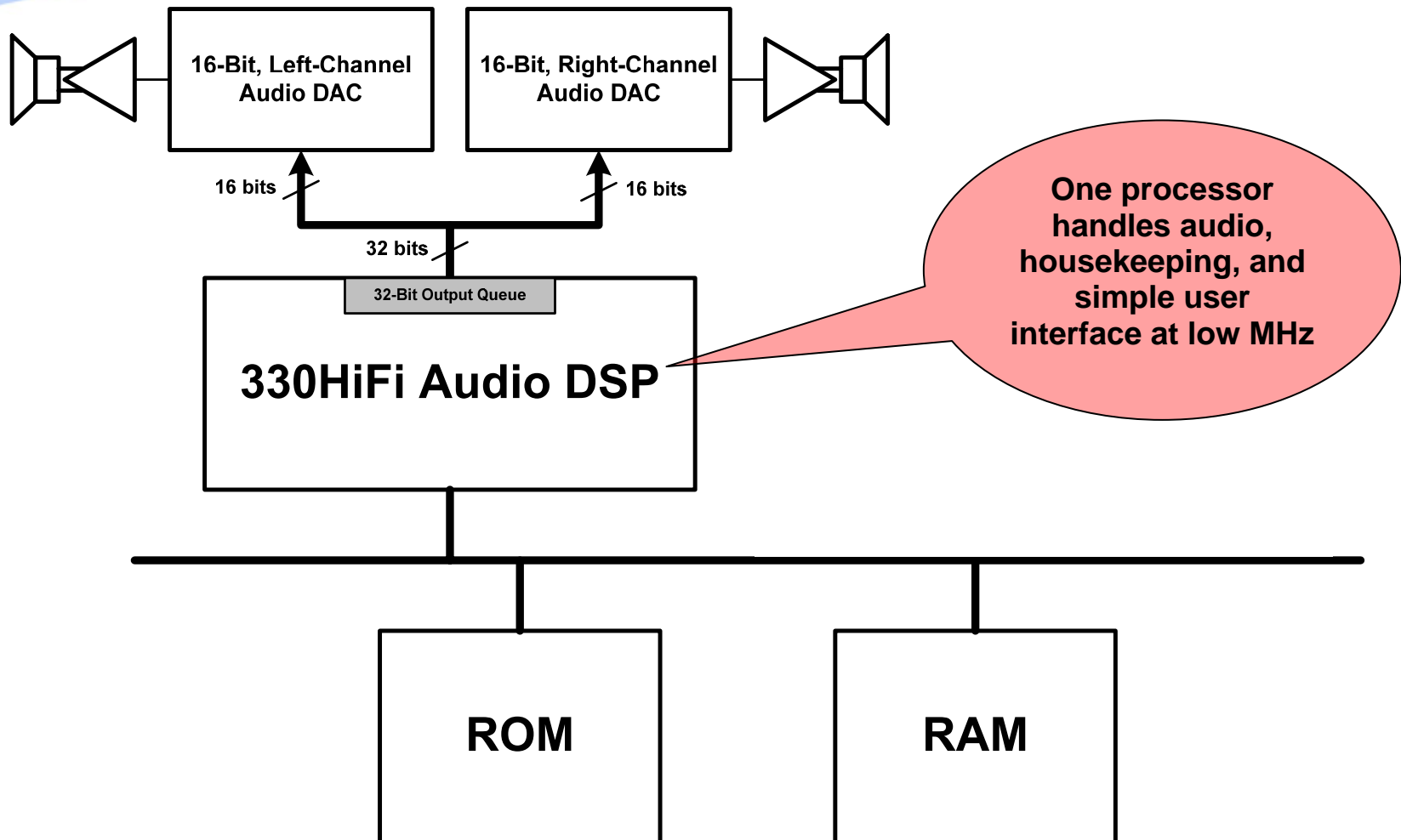
# Diamond 330HiFi using Output Queue Keep Audio Traffic Off of the Bus



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

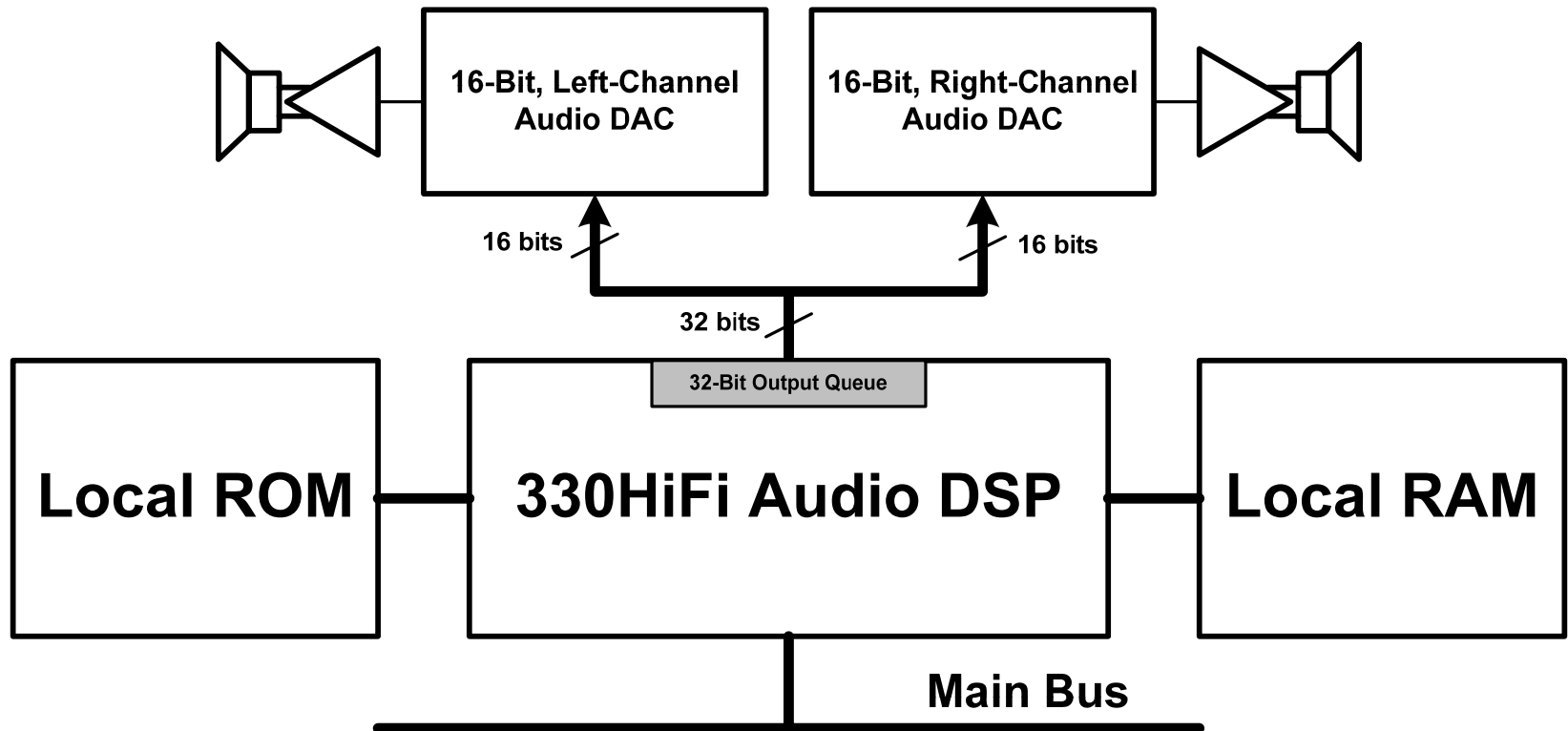


# Many Systems Only Need One Processor (Get Rid of the Host)



One processor handles audio, housekeeping, and simple user interface at low MHz

# Move Audio Processor Memory to Local Interconnect



- ✓ **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](http://www.tensilica.com)**