Implementing Embedded Streaming Media: 10 Secrets of Success

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- Formats and Standards for Streaming Audio and Video
- Hardware Considerations
- Software Considerations
- Additional Considerations
- Conclusions

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INTRODUCTION

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Challenges of Implementing Streaming Media Products

- Evolving technologies
  - Chips, communications standards
  - Compression formats, rights management
- Competitive market
  - Many players, big and small
  - Overlap between similar applications
- Many complex design considerations
  - Quality and feature selection
  - Cost and time-to-market constraints

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Characteristics of (Strict) Streaming Media

- Media carried in packets
- Packets may arrive out of order
- Packets may not arrive at all!
- Network or some intermediary *not designed to carry data reliably in real-time*
- Starts playing before the entire audio/video clip is downloaded

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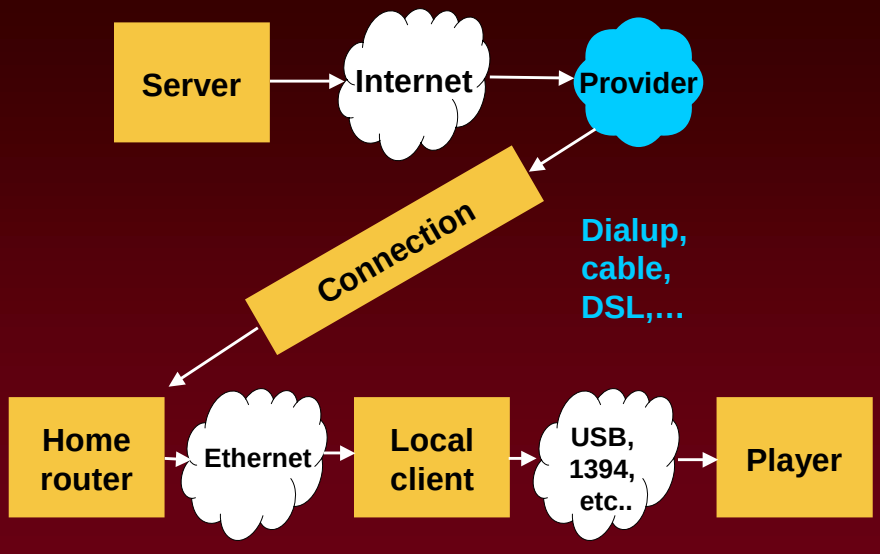
Typical Big Picture (Expanded)



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APPLICATIONS

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Internet Applications

- Audio via Internet becoming ubiquitous
- Video via Internet gaining popularity
- Communications products incorporating streaming media
  - E.g., Nokia 9210 Communicator
- By 2003, 50% of Internet access may be via non-PC devices (CEMA)
- Streaming audio may displace traditional radio

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Set-Top Boxes

- Devices providing interface to cable, other services
- New applications emerging
- Today, categories overlap:
  - Home theater functions
  - Direct broadcast satellite
  - Internet terminals
  - Digital recorder (TiVo)
  - Interactive TV
  - Music

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Game Consoles

- Game consoles:
  - Stand-alone units
  - Display via TV set
  - Fast CPU
  - Graphics co-processors
  - Storage options
- Consoles & PCs require similar audio functions
- Consoles now support DVD playback
- Broadband communications ports will enable streaming media applications in future consoles

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Other Consumer Applications

- DAB – Digital Audio Broadcast
- DBS – Direct Broadcast Satellite
- Digital camcorders
- Home theatre
- Home audio
- Car audio
- In-flight audio/video
- Kitchen appliances (!)

from Hifi.com

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FORMATS AND STANDARDS FOR STREAMING AUDIO AND VIDEO

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Secret for Success #1:

Select appropriate algorithm(s)

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Selecting an Algorithm

- Compatibility with existing content
- Audio/video quality
- Bitrates supported
  - Match network/broadcast bandwidth?
- Resource requirements
  - CPU cycles, memory use
- Cost considerations
  - Licensing fees, royalties
  - Development effort
- May want to support multiple formats

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Video Quality

- Display parameters
  - Frame resolution (pixels per frame)
  - Color resolution (# of possible colors)
  - Frame rate (frames per second)
- Visible compression artifacts
  - "Blocking" artifacts
  - Gibbs effect: blurring/shimmer around objects
  - "Ringing" artifacts
- Viewing tests are important

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Audio Quality

- Speech quality
  - Is speech intelligible?
  - Can speaker be identified?
  - Is speech natural?
- Music / streaming media quality
  - "CD-quality": 16 bits, 44.1 kHz
  - Misused term
- Listening tests are important

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MPEG Family

- Moving Pictures Experts Group
- Moving pictures + associated audio
- MPEG-1, MPEG-2, MPEG-4
  - MPEG-2 is the most popular video compression technique today
- Ongoing standardization effort (MPEG-7)

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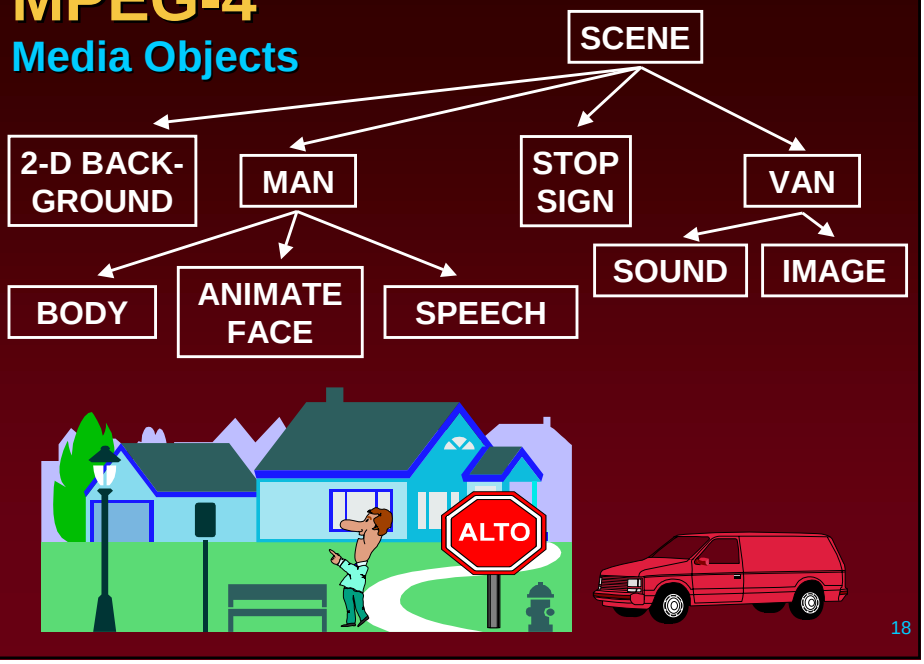
MPEG-4

Media Objects



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Other Video Algorithms

- Ligos Indeo
  - Scalable bitstreams:
    - Low-quality preview
    - High-quality, high bandwidth version
- RealNetworks RealVideo 8
  - Bitrates from 20 kbps to 0.5 Mbps
  - Frame rate is adjusted according to content and target bandwidth
- MJPEG, Cinepak

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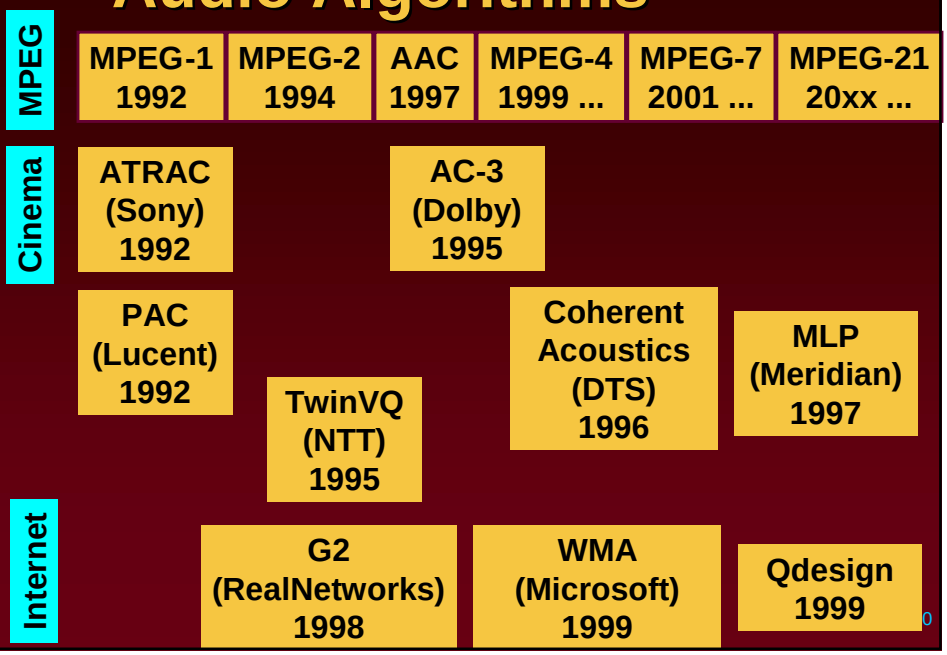
Audio Algorithms



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Audio Algorithms

- MPEG-1/2 (MP3 = MPEG-1/2, Layer 3)
- MPEG-2 AAC (Advanced Audio Coding)
  - 8 - 96 kHz sample rate, up to 48 channels
- MPEG-4
  - Uses different compression methods for different types of audio signals
- RealNetworks RealAudio 8
  - Frames interleaved across several transmission packets
  - RealNetworks' algorithms + ATRAC
- Sony ATRAC, Dolby AC-3, Microsoft WMA

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Secret for Success #2:

In-depth understanding of algorithm(s) is necessary

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HARDWARE CONSIDERATIONS

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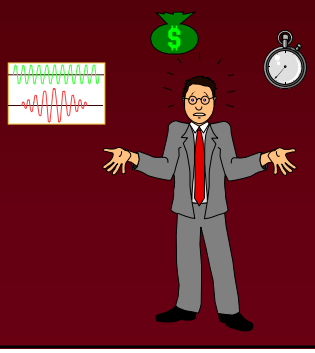
Selecting a Processor
...Or Evaluating an Existing One

- Performance Considerations
- Cost Considerations
- Development Considerations



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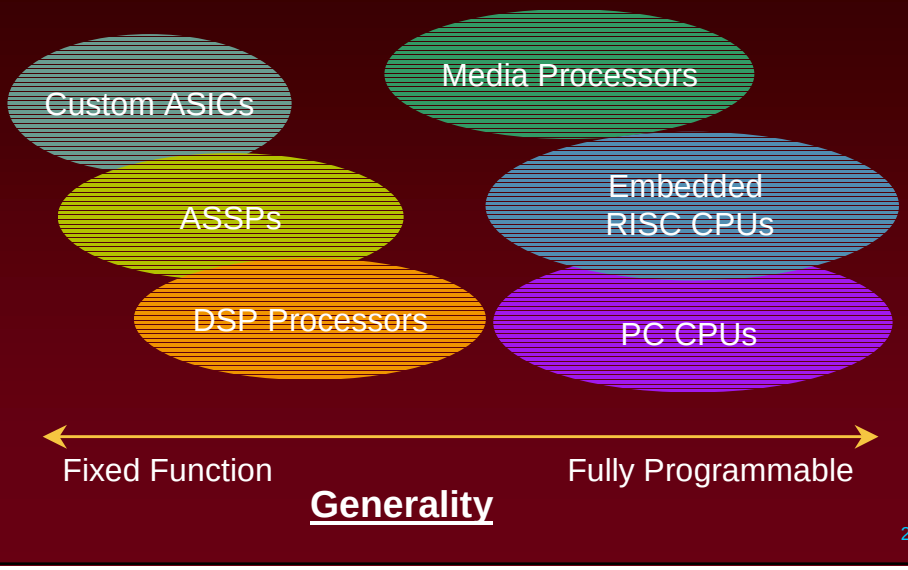
Processor Categories



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Arithmetic Formats

	Fixed point	Floating point
Cost	Cheap	Expensive
Ease of use	Tricky	Easy
Dynamic range	Same as precision	Set by exponent: 1500 dB for single-precision IEEE
Precision	16 bit: 1 part in 64 K 24 bit: 1 part in 16 M	Equal to mantissa precision (24 bit for IEEE signal precision)

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Secret for Success #3:

Match the processor to the algorithm(s)

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Performance Considerations

- **Architectural features**
  - **DSP arithmetic operations**
  - **Data bandwidth, DSP addressing modes**
  - **Cache size**
  - **Bit-field manipulation**
  - **Control operation efficiency**
  - **I/O efficiency (e.g., interrupt handling)**
- **Numeric fidelity**
  - **Data type(s)**
  - **Saturation, rounding, scaling, block floating-point**
- **Power consumption**

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Resource Requirements

- Video requirements depend on:
  - Image size(s) supported by application
  - Desired frame rate
  - Encoding practices
- Real-time MPEG-2 video decode:
  - Example stream: DVD
    - 720x480 pixels, 30 fps
  - On a VLIW media processor:
    - ~80% of a 166 MHz TriMedia TM32 core
- Memory requirements vary from 100s of kbytes to several Mbytes

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Resource Requirements

- Real-time MP3 decode example:
  - On a 24-bit DSP:
    - ~20 MIPS on a Motorola DSP56307
    - ~56 Kbytes total program + data memory
- Real-time Real G2 decode example:
  - On an embedded CPU:
    - ~27 MIPS on an NEC VR5432
    - ~48 Kbytes total program + data memory

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Resource Requirements

- Don’t forget other functions:
  - Player application
  - Sample rate conversion, color space conversion
  - Tone controls
  - Rights management, I/O, …

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Secret for Success #4:

Integration lowers costs and simplifies hardware design

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Hardware Integration

- Chip cost vs. system cost
- Hardware system components
  - Memory
    - On-chip memory
    - Specialized external memory interfaces
  - I/O
    - Appropriate interfaces (e.g., I^2S)
    - On-chip peripherals
- Off-the-shelf device or custom SoC?

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SOFTWARE CONSIDERATIONS

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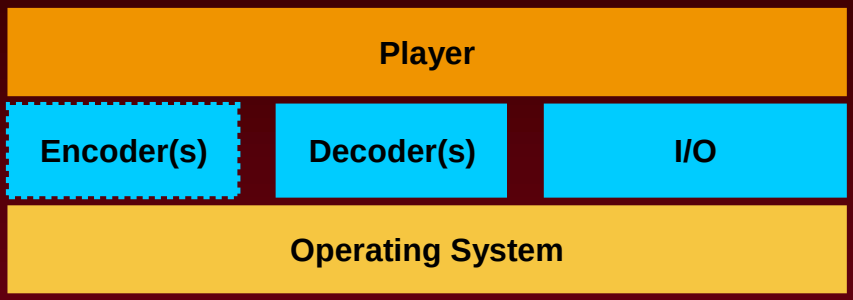
Software Architecture



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Secret for Success #5:

No use reinventing the wheel: utilize available software modules

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Operating Systems

- Provide real-time scheduling, task switching, inter-task communication, file system, (maybe) network stack
- Off-shelf candidates
  - Wind River VxWorks (set-top boxes)
  - Symbian EPOC (wireless)
  - Palm PalmOS (PDAs)
  - Microsoft WinCE (PDAs)
  - iObjects Dadio (portable players)
  - Embedded Linux (set-top boxes)

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I/O Management Software

- Management of DAC, USB port, etc.
  - Interrupt service routines (ISRs)
  - DMA management
  - Buffering
- Network stack
  - IP, TCP, UDP, RTSP, RTP, ...
- Possible sources:
  - OS vendor
  - Processor vendor
  - Third parties

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Player Software

- Responsible for
  - GUI
  - File management (if stored files available)
  - Play, stop, pause, fast-forward, rewind, …
  - Error detection, correction
- Makes calls to decoder, encoder
- Maintains synchronization of audio and video
- Communicates with network

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Secret for Success #6:

Create a usable and complete software development environment

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Development Considerations

- Software
  - Components, modules, applications
- Architecture
  - Complexity, data type(s)
  - Compatibility
- Tools
  - Compiler
    - Robustness, efficiency
  - Debugger, IDE, development boards, OS
  - Version control
- Support
  - From vendor, third parties, consultants

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DSP Software Development

- Not like other kinds of SW development. Why?

  - Resource-hungry, complex algorithms
  - Severe cost limitations
  - Numeric fidelity
  - Hard real-time constraints
  - Time-to-market constraints
- Optimization is essential

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Where to Start?

- Standard specifications
- Reference implementation
- Optimized implementation(s)
  - From algorithm vendor
  - From chip vendor
  - From third party developers
- Published papers
  - Often describe optimizations, pitfalls, etc.
- Independent software developers
  - May have valuable experience, expertise, and methodology

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Secret for Success #7:

Watch out for outdated or erroneous code, specifications, and documentation

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Some Pitfalls to Avoid

- Be wary of publicly available source code
  - May be outdated and/or lack features
  - Audio/video quality may be low
- Be wary of "reference" code
  - May be extremely inefficient
  - May be based on floating-point math
- Be wary of the published spec
  - May be outdated or incomplete
- Be sure to get all errata sheets and updates for spec (and for chip)

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Secret for Success #8:

Focus optimization effort where it will be most effective

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Software Optimization

- Divide and conquer
  - Profile of algorithm execution by function
  - Estimate optimization gain per function
  - Estimate optimization effort per function
- Optimization techniques
  - Algorithm transformation/modification
  - Processor-independent software optimization
  - Processor-specific optimization

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Optimization Techniques
Algorithm Transformations

- Re-arrange block diagram
  - E.g., down-mix in frequency domain
- Coupling channel
  - E.g., re-calculate vs. store in memory
- Truncate where you can
- Recast or factor iMDCT
- Recast Huffman coding
  - Binary search tree?
  - ROM lookup tables?

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Optimization Techniques
Processor-Independent Optimization

- Strength reduction
  - Avoid costly operations:

```
int i, k, x[N];
…
for (i=0; i<N; i++)
  x[i] /= k;
```

```
int i, k, x[N], oneoverk;
…
oneoverk = (1<<12)/k;
for (i=0; i<N; i++)
  x[i] = (x[i]*oneoverk)>>12;
```

- Function in-lining
- Recycle otherwise idle buffers

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Optimization Techniques
Processor-Specific Optimization

- Code optimizations
  - Loop unrolling
  - Change memory map
  - Use specialized instructions
    - 'C54xx instruction to count 1s, 0s
    - Tricks with bit counter
- Hardware optimizations
  - Customize instructions
  - Accelerators and co-processors

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ADDITIONAL CONSIDERATIONS

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Secret for Success #9:

Plan out the testing of the implementation in advance

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Testing

- Presents technical challenges
  - Vast amounts of data
  - Development platform limitations
- Audio/video quality
  - Objective measures, subjective tests
  - Varies with type of content
- Modes
  - Sample rates, frame sizes, compression
- Real-time
  - Data-dependent execution time
  - Dynamic processor features

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Secret for Success #10:

Give the software “room to grow”

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Future-proofing

- Standards & algorithms are evolving
  - New algorithms tend to consume more CPU power and memory than older ones
- Security technology still under development
- Products may need to be field-upgradeable
  - Must support new software downloads
  - Must provide sufficient CPU power and memory for future algorithms

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CONCLUSIONS

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Conclusions

- Streaming media applications promise to revolutionize communication and entertainment
- Key technologies exist today
  - Broadband connections
  - Algorithms and protocols
  - Inexpensive microprocessors
  - Accessible content & server networks

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Conclusions

- Streaming media product design and implementation are extremely challenging
  - Hardware challenges
    - Processor selection
    - Cost limitations
  - Software challenges
    - Demanding algorithms
    - Optimization
    - Testing
  - Audio/video quality requirements
  - Time-to-market

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Resources

- **BDTI**
  - **www.BDTI.com**
  - ***Digital Audio: Applications, Algorithms, and Implementation***
  - ***Buyer's Guide to DSP Processors***
- **MicroDesign Resources**
  - **www.MDRonline.com**
  - ***Microprocessor Report***
  - ***Embedded Processor Watch***
- **Forward Concepts**
  - **www.fwdconcepts.com**
  - ***The Convergence of Audio***
  - ***Beyond MP3***