Processors for Consumer Video Applications

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Outline

• Motivation and scope
  • Challenges
  • Application requirements
  • Processor architecture options
  • Selection methodology
  • Conclusions

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Motivation

- Technology creates new opportunities, e.g.,
  - Broadband Internet enables video on demand
  - Product convergence: cellphone+video camera, digital still+video camera
- “Right” processor key to product success
  - Supports, enables desired product features
  - Heavily influences product cost, power consumption, performance (end user experience)
  - Can simplify development effort and cost
- Range of processor options is large and rapidly changing, making selection difficult

Scope

- Processor selection for consumer video products with varying features:
  - Application a mix of video and audio, still image, ...
    - Portable media players, cell phones, still or video cameras, set-top boxes, security, ...
  - Using streaming or stored content
  - Battery or line powered, portable or fixed
  - Cost constrained
  - Input/output quality varies by application
    - E.g., lower quality video for cell phone, high quality video for set-top box
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Processor Selection Challenges

The fundamental problem:

- Many processors and types of processors to choose from
- Complex processors, applications
- Multiple standards to support
- Many important selection criteria to consider
- Unpredictable changes in processor options, application requirements
- Poor information, complex analysis
- Limited time and resources for selection

The wrong choice can be fatal for a product development effort
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Player/ DRM Requirements

• Manages other application sub-modules (e.g., codecs), provides user interface
• Processing requirements: 1’s-10’s MIPS
• Good tools are critical
• Processor features that benefit compilers are useful, e.g.,
  • Orthogonal instruction set
  • Large, linear address spaces
  • Flexible data type support
• I/O bandwidth requirements depend on:
  • Application features, peripheral mix
  • Software architecture
Audio and Video Codec Requirements

**Audio: less demanding**
- MP3, MPEG-4 AAC, DTS, RA10 ...
- Sample rate conversion, equalization
- Higher precision (>16 bits)
- Low throughput

**Video: more demanding**
- MPEG-2, MPEG-4, H.264, WMV9, DivX ...
- Alpha blending, scaling
- Lower precision (≤16 bits)
- High throughput

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I/O Requirements

- Processors must support multiple I/O interface standards
  - Basic in-system serial & parallel (CCD, I2S, SPI, “host port”)
  - Storage ports (glueless SDRAM, ATA, flash)
  - External connectivity (Ethernet, USB, 1394, wireless)

- Support for high transfer rates
  - Video data rates range from 100’s—1000’s KB/s

- Autonomous, intelligent I/O
  - E.g., programmable communications coprocessors reduce load on core processor
Development Effort, Cost and Risk

- Development effort, cost, risk affected by many factors
  - Programming model complexity
    - More powerful processor → more complex model
    - More complex model → increased development effort
  - Don't overlook complexity of intelligent I/O
  - Availability of off-the-shelf software components
    - Codecs
    - OSs
    - Reference designs
    - Quality of tools
      - Maturity, capability of development tools
  - Device drivers
  - Frameworks
  - Support for I/O in debug

- The right choice of processor can reduce development effort, cost and risk

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## Video Processor Types

<table>
<thead>
<tr>
<th>Processor Type</th>
<th>Chips</th>
<th>IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC CPU</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Embedded RISC CPU</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Application processor</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>DSP (generic or specialized)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Media processor, heterogeneous multiprocessor</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Customizable processor</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>ASIP</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Reconfigurable processor</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FPGA</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Fixed-function engine</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ASSP (incorporating one or more processor types)</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

## ASSPs

### Strengths and Weaknesses

- Often very well matched to the application
  - SoCs with extensive integration
  - Architecture tuned for the application
  - Can yield excellent performance, cost, energy efficiency
- Ease of use
  - Reduce system development costs
  - Reduce required implementation expertise
- Often inflexible
- Limited differentiation opportunities for system designer
- Usually single-source
- Roadmap often unclear
Example FPGA
Altera Stratix II EP2S15

- Includes specialized fixed-function blocks:
  - Multipliers
  - PLLs
  - Memory blocks
  - High-speed I/O
- Supports Nios II RISC “soft core”
- Real-time MPEG-2 decode (1080p @ 30 fps): 133 MHz
  - Requires ~65% of device
- Price $28, qty 10k
  - Pin-compatible HardCopy II structured ASIC starts at $15, qty 100k

FPGAs
Strengths and Weaknesses

- Massive performance gains over instruction set processors on some video tasks
- Huge throughput, cost/performance advantages over DSPs, general-purpose processors in some applications
- Architectural flexibility can yield efficiency
  - Adjust data widths throughout algorithm
  - Parallelism where you need it; distributed storage
  - Dynamic reconfigurability?
- High development effort compared to instruction-set processors
  - Complex design flow is unfamiliar to most signal-processing engineers
  - Suitability for single-channel, low-power, cost-sensitive applications not proven
Example Media Processor
Philips PNX1500

- General-purpose 300 MHz five-way VLIW
- On-chip L1 data, instruction caches, and L2 data cache
- Media-specific interfaces, co-processors, instructions
- C/C++ programming model
- MPEG-4 decode (simple profile, CIF, 30 fps): 45 MHz
- MPEG-4 D1 video + audio encoding in real time
- Price $15, qty 100k

Media Processors
Strengths and Weaknesses

- Higher performance than most DSPs, GPPs
  - High performance peripherals, coprocessors
  - Very complex programming models
- Better support for video processing in development tools, infrastructure, compared to GPPs
- Application performance compiler-dependent
  - Compilers can be poor quality
- Maturing technology—but roadmaps unclear
  - 3rd party support weaker than other processor types
- Development cost, risk, lower than ASIC, FPGA
**Example DSP Processor**

**Texas Instruments TMS320DM641**

- 600 MHz, 32-bit VLIW DSP processor
- 64, 32-bit general-purpose registers
- 8- and 16-bit SIMD
- Large L1/L2 caches
- High integration
- BDTImark2000™ score: 5480
- MPEG-2 decode (D1 @ 30 fps) under 150 MHz
- Price $30, qty 10k

**DSP Processors**

**Strengths and Weaknesses**

- Performance, efficiency on video applications vs. general-purpose processors
- But not as strong as customized solutions, and may not be adequate for demanding tasks
- Media-oriented development tools, infrastructure
- Tools not as sophisticated as those available for general-purpose processors
  - Often, poor compiler quality
- Stable, mature technology and vendors
- Third-party audio/video application software available
  - Support for non-DSP software not as strong as, e.g., GPPs
- Relatively low development cost, risk
Example Application Processor

Freescale i.MX21

- Based on a 266 MHz ARM9E
- Accelerators for MPEG-4 and H.263 encode and decode, video pre-/post-processing
- Strong emphasis on energy-saving design
  - Accelerators
  - Active well biasing
- BDTIsimMark2000 score: 550
- MPEG-4 decode (CIF @ 30 fps): ~5 MHz
- Good development tools, optimized DSP software available, good OS options
- Price $17, qty 10k

Application Processors

Strengths and Weaknesses

- Adequate performance for portable video
  - Typically less powerful than other types of processors
- Emphasis on energy efficiency
- Programming model may be simple or complex
- 32-bit GPP core is a good target for non-media tasks
  - E.g., TCP/IP network stacks
- Good tools, but generally weak on support for video application development
- Very good third-party OS, software component support
- Compatibility good for ARM core
  - But generally use proprietary video processing hardware
- High integration
**Example PC CPU**

**VIA Technologies C3**

- 1 GHz x86 compatible
- Moderate power consumption, cost
- SSE support for video applications, supports fixed-, floating-point types
- Access to massive x86 3rd-party software, tools base
- Familiar to software, hardware developers
- MPEG-4 decode (D1, 30 fps) using 35% of CPU, when using VIA CN400 chipset
- CPU: $70, chipset: $23 (qty 10k)

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**PC CPUs (GPPs)**

**Strengths and Weaknesses**

- Can handle complex video processing tasks
- May be as fast or faster than DSPs...
- ... but cost & power consumption typically higher
- Dynamic features complicate optimization, real-time design
- Generally weak on integration
- Many options for OS, 3rd party application software
- Easier migration of PC applications
- Excellent targets for non-signal-processing tasks
  - E.g., protocol stacks
- Compatibility, multi-vendor architectures common
- Development tools mature, powerful
- But typically lack features useful for video application development
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Processor Selection Methodology

Use a hierarchical approach to make the problem manageable:
- Determine selection criteria
- Prioritize or assign weights to selection criteria
- Use critical criteria to eliminate obviously unsuitable choices
  - Begin with classes of processors
- Evaluate and rank candidates
- Weigh trade-offs among non-critical criteria
- Iterate as necessary
  - Refine criteria and analysis of candidates
Processor Selection Criteria
Signal-Processing-Centric Concerns

• Performance on relevant audio/video tasks
  • Speed
  • Memory bandwidth: on-chip, off-chip
  • Energy consumption
  • Execution-time predictability
    • Dynamic features confound optimization
  • Data word size(s)
• Memory usage

Processor Selection Criteria
Signal-Processing-Centric Concerns

• On-chip integration
  • Memory, peripherals, I/O interfaces, coprocessors
• Development effort, risk
  • Media-oriented tools, infrastructure
  • Programming model complexity
  • Application software components
  • Reference designs
  • Tools, support (vendor, 3rd party)
    • Accurate cycle-count and memory profiling
    • Visibility into cache, pipeline
    • Features useful for integration, real-time testing
      • E.g., on-chip debug support
Processor Selection Criteria

General Concerns

- Cost
- Packaging options
- Roadmap
  - Availability; reliability of supply
    - Multi-vendor architectures a plus
  - New spins, new architectures, compatibility
  - Core version available?
- Special requirements
  - Variable-voltage operation

Development Considerations

- Language support
  - Quality of C compiler; availability of C++ compiler
  - Support for assembly language optimization
- Software availability
  - Video processing components
  - Player, device drivers, operating system
  - Hardware/software reference designs
- Debug/development benefit from tools with:
  - Peripheral and multi-processor simulation
  - Non-intrusive, real-time debug
  - Compatibility, developer familiarity

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Availability and Roadmap

• Risk
  • Is the chip available in volume today?
  • Are there second sources of the chip or compatible chips?
  • What does the errata list look like?

• Roadmap
  • What is the vendor’s commitment to evolving the chip? E.g., improved integration, reduce cost
  • What is the vendor’s roadmap for next-generation chips? Compatibility?
  • What is your confidence that the vendor will execute on its roadmap?

Benchmarking Approaches

Applications
- Portable video player
- Set-top box
- Video conf. system
...

Application Components
- OS
- Audio decoder
- Audio encoder
- Speech codec
- Video decoder
- Video encoder

Algorithm Kernels
- FIR
- FFT
- DCT
- VECADD
...

Operations
- Add
- Mult/MAC
- Shift
- Load
...
What’s Wrong with MMACS?

MMACS approximates performance on some signal processing algorithms like FIR filters, but:
- It ignores other operations required to sustain repeated MACs
- It ignores memory bandwidth bottlenecks
- Many important signal processing algorithms don’t use MACs!

Example: ‘C5510 and PXA255
- 200 MHz ‘C5510: 400 MMACS and 1,200 million bytes/sec
- 400 MHz PXA255: 800 MMACS and 1,600 million bytes/sec
- These two processors have comparable signal processing speed!

Algorithm Kernels

- Computationally intensive portions of signal processing applications
  - FFTs, filters, bit unpack, ...
- Strong predictors of performance
  - Do not measure system-level performance or OS overhead
- Modest programming effort
- Results for common kernels widely available
- Difficult to apply to multi-core processors, hardware accelerators, FPGAs, etc.
- Examples: BDTI Benchmarks™, BDTI Video Kernels™
Application Components

Model a key signal processing task
† Often representative of overall workload
† Easier to implement than a full application
↓ Less general than a set of kernel benchmarks
Larger workload vs. kernel benchmarks
† Allows comparison of different types of architectures
† Simplifies programming rules
Can benchmark the entire system
  • Capture effects of memory size, bandwidth, etc.
↓ Does not capture effects of combining multiple tasks
Example: BDTI Video Benchmarks™

Full Application Benchmarks

† Potential for highly accurate results
↓ Results useful only for specific application (or highly similar applications)
↓ Applications tend to be ill-defined
† May be able to use existing application code as a benchmark ...
  • Example: BDTI Solution Certification service
↓ ... but costly and time-consuming to implement a new application
↓ For processors, similar results via simpler approaches
  • But this is not true for all implementation technologies
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Conclusions

• Choosing a processor for a consumer video product is easy
• Choosing the best processor for your particular product is hard
  • Vast range of options
  • Many complex, competing criteria to consider
  • Poor information
  • Fast changing requirements and options
  • Limited time and resources
Conclusions, cont.

• Use a hierarchical approach
  • Develop a well-defined hierarchy of product requirements
  • Start with the critical criteria and iteratively narrow the field
  • Expect to make trade-offs
• Assessing performance is a challenge
  • Resource-hungry algorithms, cost-constrained processors, many variables
• Development-related considerations are key
  • Appropriate integration is essential to low system cost

Trends: Processors

• Consumer video applications are becoming a major focus of processor vendors
  • Expect more competitors, more options
• Technology, competition pushes performance up; price and power consumption down
  • Enabling new types of products, new levels of functionality
  • But not all processors are well matched to video processing workloads
• Increasing architectural complexity
  • Many heterogeneous multiprocessors
• Integration increasing
  • Development infrastructure is a key differentiator
Trends: Development

- Systems are becoming more complex
- Processors are becoming more complex
- Algorithms are becoming more demanding
- Optimization continues to be essential
- Huge processor-to-processor differences in development infrastructure
  - Support for video applications
  - Off-the-shelf, optimized software components increasingly important

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