Processors for Consumer Video Applications

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Outline

Motivation and scope
Selection methodology
Benchmarking options
Processor architecture options
Conclusions

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Motivation

Technology creates new opportunities
- 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, cost, and risk

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
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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Processor Selection Criteria

Performance on relevant tasks
- Speed
- Numeric fidelity
  - Fixed-point vs. floating-point
  - Data word size(s)
- Execution-time predictability
  - Dynamic features confound determinism
- Energy consumption
- Memory bandwidth: on-chip, off-chip
- Memory usage

Audio and Video Codec Requirements
Including Post-processing

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
Processor Selection Criteria

Cost
On-chip integration
• Coprocessors
• Memory
• I/O interfaces
• Other peripherals

Packaging options
• Sizes
• Temperature ranges
• Ease of manufacture

I/O Requirements

Processors must support multiple I/O interface types and standards
• Basic in-system serial & parallel (e.g., CCD, I²S, SPI, “host port”)
• Storage ports (e.g., glueless SDRAM, ATA, flash)
• External connectivity (e.g., 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
Availability and Roadmap

Risk
- Availability; reliability of supply
  - Multi-vendor architectures a plus
- What does the errata list look like?

Roadmap
- Vendor commitment to evolving the chip, e.g., improved integration, reduced cost
- Roadmap for next-generation architectures
- Compatibility of future parts
- What is your confidence that the vendor will execute on its roadmap?

Development Considerations

Programming model complexity
Developer familiarity
Compatibility
Tools (vendor, 3rd party)
- Accurate cycle-count and memory profiling
- Visibility into cache, pipeline

Debug/development benefit from tools with:
- Peripheral and multi-processor simulation
- Non-intrusive, real-time debug
Development Considerations

Language support
- Quality of C compiler; availability of C++ compiler
- Support for assembly language optimization

Software availability
- Signal processing components
- Device drivers and other general-purpose software
- Operating systems

Hardware/software reference designs

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
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- **Benchmarking options**
- Processor architecture options
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### Benchmarking Options

<table>
<thead>
<tr>
<th>Applications</th>
<th>Portable video player</th>
<th>Wireless handset</th>
<th>Video conf. system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Components</td>
<td>OS</td>
<td>Audio decoder</td>
<td>Audio encoder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speech codec</td>
<td>Video decoder</td>
</tr>
<tr>
<td>Algorithm Kernels</td>
<td>FIR</td>
<td>FFT</td>
<td>DCT</td>
</tr>
<tr>
<td>Operations</td>
<td>Add</td>
<td>Mult/MAC</td>
<td>Shift</td>
</tr>
</tbody>
</table>

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Avoiding the Extremes

MIPS (millions of instructions per second) and MFLOPS (millions of floating-point operations per second) are easy to measure…

• …but “instructions” and “operations” are poorly defined, making the results useless

DSP16410 single instruction:
\[ A0 = A0 + P0 + P1 \quad P0 = Xh \times Yh \quad P1 = Xl \times Yl \quad Y = *R0++ \quad X = *PT0++ \]

TMS320DM64x single instruction:
\[ \text{ADD} \quad A0, A3, A0 \]

Full-application benchmarks can have very accurate results…

• …but they are impractical to implement

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 Video Kernel Benchmarks™, BDTI DSP Kernel Benchmarks™
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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 Encoder and Decoder Benchmarks™

Model modern video compression standards
- Subset of functions, modes
- Motion estimation algorithm specified by BDTI

Capture 70%-90% of typical workload
Much easier to implement than a full codec
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**Video Processor Types**

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<tr>
<th>Processor Type</th>
<th>Chips</th>
<th>IP Cores</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</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>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>
Example Application Processor
Philips PNX4103

Two cores:
- 208 MHz ARM9E
- 350 MHz 5-issue VLIW TM3270 media processor

Accelerators for pre-, post-processing
BDTIsimMark2000 score: 430 (ARM only)

TM3270 performance:
- H.264 MP decode (D1 @ 30 fps): ~210 MHz
- MPEG-4 ASP decode (D1 @ 30 fps): ~100 MHz

Price not disclosed

PNX4103 Benchmark Results

Benchmarks run on the TM3270, a 350 MHz, 5-issue VLIW core.
No external memory was required for this benchmark.
Results measured via simulator.
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
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 Media Processor
Texas Instruments TMS320DM6446

Two cores:
- 300 MHz ARM9E
- 600 MHz 8-issue VLIW DSP core

Accelerators for video encoding
BDTImark2000™ score: 6590 (‘C64x+ only)

Maximum performance:
- H.264 MP encode and decode D1: @ 30 fps
- MPEG-4 SP encode and decode: 720p @ 30 fps

Price $35, qty 10k

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
    - 3rd party SW support weaker than other processor types
    - Vendor-provided SW support can be strong
  - Application performance compiler-dependent
    - Compilers can be poor quality
  - Maturing technology—but roadmaps unclear
  - Development cost, risk, lower than ASIC, FPGA
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 ASSP

Broadcom BCM7312

Targets set-top boxes for digital satellite TV

Fixed-function hardware:
- MPEG-2 video decode (D1 @ 30 fps)
- Audio decoding
- 2D graphics

Includes 266 MHz MIPS32 core

Application-specific integration
- RF tuner and demodulator
- Satellite descramblers
- Access control hardware

Price not provided

ASSPs

Strengths and Weaknesses

- Often very well matched to the application
  - SoCs with extensive integration
  - Typically paired with extensive application-specific software
  - 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
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Trends

Growing markets attract new competitors
• Not all processors are well suited for video
Technology, competition push performance up; price and power consumption down
• Enabling new products, new functionality
Algorithms becoming more demanding
Applications becoming more complex
Processors becoming more complex
• Many heterogeneous multiprocessors
• Integration increasing
Development infrastructure increasingly important
• Support for video applications
• Off-the-shelf software
Conclusions

Choosing the best processor is hard
- Fast changing requirements and options
- Vast range of options
- Many complex, competing criteria to consider
- Poor information
- Limited time and resources

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

For More Information...
www.BDTI.com

Inside DSP newsletter and quarterly reports
Benchmark scores for dozens of processors
Pocket Guide to Processors for DSP
  - Basic stats on over 40 processors
Articles, white papers, and presentation slides
  - Processor architectures and performance
  - Signal processing applications
  - Signal processing software optimization
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