Selecting Processors for Video Applications

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Jeff Bier
Berkeley Design Technology, Inc.
Berkeley, California USA
+1 (510) 665-1600
info@BDTI.com
http://www.BDTI.com

Outline

Motivation and scope
Selection criteria and methodology
Benchmarking options
Processor architecture options
Conclusions

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Selecting Processors for Video Applications

Motivation

Digital video applications are multiplying
- New types of video-centric products; e.g., Slingbox
- Analog to digital migration; e.g., surveillance
- Video as a “feature”; e.g., cell phone, sewing machine

The right processor is key to product success
- Enables desired product features
- Heavily influences product cost, power consumption, performance (end user experience)
- Can ease or worsen development effort, cost, and risk

Range of processor options is large and rapidly changing, making selection difficult

Scope

Processor selection for video products with varying features:
- Cost- and/or energy-constrained
- Input/output quality varies by application
  - E.g., lower quality video for cell phone, high quality video for set-top box
- Using streaming or stored content
- Based on off-the-shelf or custom algorithms
Selecting Processors for Video Applications

Processor Selection Challenges

The fundamental problem:
- Many processors, types to choose from
- Complex processors
- Complex, diverse 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.

Video Processor Types

<table>
<thead>
<tr>
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<th>Chips</th>
<th>IP Cores</th>
</tr>
</thead>
<tbody>
<tr>
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<td>✔</td>
<td></td>
</tr>
<tr>
<td>Embedded RISC CPU</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Application processor</td>
<td>✔</td>
<td></td>
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<tr>
<td>DSP (generic or specialized)</td>
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Processor Selection Criteria
The Big Picture

• Performance considerations
  • Critical because video applications are computationally demanding
• Cost, on-chip integration
  • Requirements for video applications (I/O, for instance) can be quite different from requirements for other applications
• Availability and roadmap
  • Important for managing risk
• Development considerations
  • Especially critical for consumer video products because of the intense time-to-market pressures
• Other considerations
  • Packaging options to meet size constraints, etc.
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Processor Selection Criteria
Performance Considerations

Performance on relevant tasks
• Speed
• Numeric fidelity
  • Data word size(s)
• Execution-time predictability
  • Dynamic features confound determinism
• Energy consumption
  • Affected by off-chip memory accesses, etc.
• Memory
  • Memory bandwidth provided: on-chip, off-chip
  • External memory performance required
  • Memory usage efficiency

Performance Requirements

Audio: less demanding
• MP3, WMA, ...
• Sample rate conversion, equalization
• Higher precision (>16 bits)
• Low throughput

Video: more demanding
• MPEG-2, MPEG-4, H.264, WMV9, DivX, …
• Deinterlacing, scaling
• Lower precision (≤16 bits)
• High throughput
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Cost and Integration

Cost of chip
On-chip integration
  • Host processor
  • Memory
  • Peripherals
  • I/O interfaces
Packaging options
  • Package sizes, types
  • Temperature ranges

On-chip Integration Considerations

I/O Requirements

Support for multiple I/O interface types and standards
  • Basic in-system serial and parallel
    • e.g. ITU 656, I²S, SPI, host port
  • Memory Interfaces
    • e.g. glueless DDR DRAM, ATA, flash
  • External connectivity
    • e.g. Ethernet, USB, FireWire
Support for high transfer rates
  • Video data rates range from 100’s to 1000’s KB/s
Support for autonomous, intelligent I/O
  • E.g., programmable communications coprocessors reduce load on core processor
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Processor Selection Criteria
Availability and Roadmap Considerations

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

Roadmap – risk for your future designs
- 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?

Processor Selection Criteria
Development Considerations

Programming model complexity
- Single- vs. multi-core
  - Heterogeneous vs. homogeneous
- Instruction set architecture
- Microarchitecture

Developer familiarity

Compatibility
Tools (vendor, third party)
- Support for software optimization, including assembly language
- Accurate profiling: multiple levels, multiple metrics
  - E.g., visibility into buses, caches, pipeline
- Debug/development benefit from tools with:
  - Peripheral and multi-processor simulation
  - Non-intrusive, real-time debug
- Compilers: Languages supported; efficiency
Other Development Considerations
Software, Reference Designs

Off-the-shelf software availability
- External and internal
- Vendor and third-party
- Software reference designs
- Video processing components
  - E.g., codecs, post-processing blocks
- Video kernels
- Device drivers and other general-purpose software
- Operating systems

Hardware 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 and refine as necessary
  - Refine criteria
  - Refine analysis of candidates
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**Benchmarking options**
Processor architecture options
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Benchmarking Options

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<tr>
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<th>Portable video player</th>
<th>Video conf. system</th>
<th>Surveillance system</th>
</tr>
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<tbody>
<tr>
<td>Application Components</td>
<td>OS</td>
<td>Video decoder</td>
<td>Video encoder</td>
</tr>
<tr>
<td>Algorithm Kernels</td>
<td>Motion Estimation</td>
<td>FFT</td>
<td>Deblocking</td>
</tr>
<tr>
<td>Operations</td>
<td>Add</td>
<td>Multi/MAC</td>
<td>Shift</td>
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</table>
Avoiding the Extremes

- Operation-level benchmarks
  - e.g. MIPS (millions of instructions/sec) and MFLOPS (millions of floating-point operations/sec)
  - Easy to measure...
  - ...but “instructions” and “operations” are poorly defined, making the results useless

SC1400 single instruction:
mac d12,d8,d0  mac d13,d8,d1  mac d14,d8,d2
mac d15,d8,d3  move.4f(r2)+,d12:d13:d14:d15
move.4f (r0)~,d8:d9:d10:d11
ARM11 single instruction:
ADD tmp, dinc, #3*NumOfPoints

- Full-application benchmarks
  - Can have very accurate results...
  - ...but they are impractical to implement

Algorithm Kernel Benchmarks

Approximate the application workload
- Computationally intensive portions of signal processing apps: DCT, image resize, etc.
- Strong predictors of performance
  - But do not measure system-level performance or OS overhead
- Modest programming effort
- Results for common kernels widely available

Reasonably general
- One kernel set may be applicable across a range of applications
- Difficult to apply to multi-core processors, hardware accelerators, FPGAs, etc.

Example: BDTI Video Kernel Benchmarks
Selecting Processors for Video Applications

Application Component Benchmarks

Model a key video 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 broader range of architectures
- Simplifies programming rules
- May be harder to implement than a set of kernel benchmarks

Can benchmark the entire system

- Capture effects of memory size, bandwidth, etc.
- Does not capture effects of combining multiple tasks

Modeling a Video Decoder

Example Application Component Benchmark

Key goals:

- Represent the application workload
- Standardize the workload
- Simplify implementation
- Represent real application development approaches

[Diagram of the BDTI Video Decoder Benchmark]
Evaluating Off-the-Shelf Solutions
Example: BDTI Solution Certification of H.264 Video Decoder

ARC Video Subsystem
H.264 Baseline Profile, D1 resolution, 30 fps, 1.5 Mbps
Processing Engine Utilization for Real-Time operation
with varying frame delay buffers

External Memory Access Time (ns)

Minimum Solution Clock Rate Required for
Real-Time Operation (MHz)

0 buffers
1 buffer
2 buffers
3 buffers
Average

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Example Application Processor
NXP PNX4103

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

Accelerators for pre-, post-processing
- TM3270 performance for video (BDTI-certified benchmark results):
  - BDTI Decoder, 30 fps
    - QVGA: ~67 MHz
    - D1: ~290 MHz
  - BDTI Encoder, 30 fps
    - QVGA: ~175 MHz

Price not disclosed
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PNX4103 Video Processing Benchmark Results

Processor utilization results are peak figures. PNX4103 Benchmarks run on the TM3270, a 350 MHz, 5-issue VLIW core.

Application Processors
Strengths and Weaknesses

• Performance considerations
  • Adequate performance for portable video
  • But typically less powerful than other types of processors
  • Emphasis on energy efficiency
  • 32-bit GPP core is a good target for non-media tasks
    • E.g. TCP/IP stack, user interface

• On-chip integration
  • High level of integration

• Usually offered only to very high volume customers
Application Processors
Strengths and Weaknesses (Continued)

- Development considerations
  - Programming model may be simple or complex
  - Good tools, but generally weak on support for video application development
    - Programmability + tools = Flexibility
  - Sometimes very good third-party OS, software component support
  - Compatibility good with respect to ARM CPU core
    - But generally use proprietary video processing hardware

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:
(Uncertified results)
- 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

• Performance considerations
  - Higher performance than most DSPs, GPPs
  - High-performance peripherals, coprocessors
  - Application performance often very compiler-dependent
  - Compilers sometimes weak

• Availability and roadmap
  - Maturing technology, but roadmaps sometimes unclear

• Development, other considerations
  - Development cost, risk, lower than ASIC, FPGA
  - Balance between cost, energy efficiency and flexibility
    - More flexible than fixed-function hardware
    - More cost- and energy-efficient than most DSPs, GPPs
  - Programming models changing
    - Software provided, made accessible through API calls
    - Semi-programmable coprocessors
  - Better support for video processing in development tools, infrastructure,
    compared to GPPs, typical DSPs
  - Off-the-shelf software support can be strong

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”
Performance for video:
(Uncertified results)
Real-time MPEG-2 decode (1080p @ 30 fps): 133 MHz
- Requires ~65% of device
Price $35, qty 10k
FPGAs
Strengths and Weaknesses

• Performance considerations
  • Massive performance gains over instruction set processors on some video tasks
  • Huge throughput, cost/performance gains over processors in some applications
  • Architectural flexibility can yield efficiency
  • Suitability for single-channel, low-power, cost-sensitive applications not proven

• On-chip integration
  • Support for many electrical interface standards
  • Provide higher memory, I/O bandwidth than DSPs, GPPs, etc.
  • Flexible on-chip integration
    • But may have to roll your own

• Development, other considerations
  • High development effort compared to instruction-set processors
  • Can incorporate “hard” or “soft” processors, replace DSP-FPGA combination
  • Scalability with fewer design/development paradigm changes, compared to DSPs, GPPs, etc.
  • Greater “family breadth” (viz. throughput, price range) compared to processor families
  • Expanding array of IP libraries (video decoder blocks, etc.), reference designs

Example ASSP
Broadcom BCM7312

Targets set-top boxes for digital satellite TV

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

Includes 266 MHz MIPS32 core

On-chip integration
  • Video, audio DACs
  • USB, GPIO, PC, SPI

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

Support for third-party OSs, tool chains

Price not provided
ASSPs
Strengths and Weaknesses

• Performance considerations
  • Performance typically very well matched to the targeted application
  • SoCs with extensive integration
  • Typically paired with extensive application-specific software
  • Architecture tuned for the application
  • Can yield excellent performance, cost, energy efficiency

• Availability and roadmap
  • Roadmap often unclear

• Development, other considerations
  • Ease of use
    • Reduced system development costs
    • Reduced required implementation expertise
  • Often inflexible
  • Limited differentiation opportunities for system designer

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Trends

Market
- Growing markets attract new competitors
- Not all processors are well-suited for video
- Diverse applications have diverse requirements

Technology
- Technology, competition push performance up; price and power consumption down
  - Enabling new products, new functionality
- Algorithms becoming more demanding
- Applications becoming more complex
- Convergence is happening – at the system and chip levels
- Chips are becoming more complex
  - Many heterogeneous multiprocessors
  - Integration increasing

Development trends
- Development infrastructure becoming increasingly important
  - Support for video applications
  - Off-the-shelf software

Conclusions

Choosing the best processor is difficult
- 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
- Be an informed consumer of benchmark results
### Example Video Processor Vendors

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>4i2i</td>
<td>Video IP cores</td>
</tr>
<tr>
<td>Agere Systems</td>
<td>DSPs</td>
</tr>
<tr>
<td>Altera</td>
<td>FPGAs, Hardcopy ASICs</td>
</tr>
<tr>
<td>Ambric</td>
<td>Massively-parallel processors</td>
</tr>
<tr>
<td>Analog Devices</td>
<td>Media processors, DSPs</td>
</tr>
<tr>
<td>ARC</td>
<td>Configurable CPU/DSP cores, platforms</td>
</tr>
<tr>
<td>ARM</td>
<td>General-purpose CPU cores</td>
</tr>
<tr>
<td>Broadcom</td>
<td>ASSPs</td>
</tr>
<tr>
<td>Ceva</td>
<td>DSP cores, subsystems</td>
</tr>
<tr>
<td>Chips &amp; Media</td>
<td>Video IP cores, ASSPs</td>
</tr>
<tr>
<td>Freescale</td>
<td>Media processors, Application processors</td>
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<tr>
<td>Hantro</td>
<td>Hardwired video codecs</td>
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<td>Imagination Tech.</td>
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<td>NXP Semiconductors</td>
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<td>PixSil Technology</td>
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<td>Samsung Semiconductor</td>
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<tr>
<td>Sandbridge Technologies</td>
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For More Information...
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Inside [DSP] newsletter and website
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
  • Video applications
  • Video software development
comp.dsp FAQ