Presentation Goals

By the end of this workshop, you should know:

• What to consider when choosing a processor
• How to make the selection process manageable
• How to use benchmarks
• Benchmark results for TI processors and selected competitors
Choosing a Processor: Benchmarks and Beyond

Outline

Processor selection criteria
  • Processor selection methodology
Processor benchmarking approaches
  • Sample benchmark results
Benchmarking hardware+software solutions
Conclusions

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
Processor Selection Criteria

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

Packaging options
- Sizes
- Temperature ranges
- Ease of manufacture

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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Why Do Benchmarks Matter?

Assess key processor metrics accurately, e.g.,
- Speed \(\textit{(not cycle counts!)}\)
- Cost efficiency
- Energy efficiency \(\textit{(not power consumption!)}\)
- Memory efficiency

Use limited engineering resources effectively

Compare performance across a wide range of architectures, applications

Typical Application Decomposition

<table>
<thead>
<tr>
<th>Applications</th>
<th>Portable audio 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>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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Choosing a Processor: Benchmarks and Beyond

Flexibility vs. Accuracy

Operation
Algorithm Kernel
Application Component
Application

Accuracy

Flexibility

Flexible vs. Accuracy

Flexibility vs. Accuracy

Portable Video Player
Application Component
Application
Cellular Base Station

Cable Head-end
DSL Gateway
WiMAX Base Station
Set-Top Box
DSL Gateway

Personal Video Recorder

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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 PXA260

- 200 MHz ‘C5510: 400 MMACS and 1,200 million bytes/sec
- 400 MHz PXA260: 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 DSP Kernel Benchmarks™, BDTI Video Kernel Benchmarks™
Choosing a Processor: Benchmarks and Beyond

Example: BDTI DSP Kernel Benchmarks™

- Hand optimized
  - Reflects common coding practice
  - Accurate representation of architecture capability
  - Moderate level of effort
- Detailed programming rules
  - Ensures fair comparison between architectures
  - Complicates programming
- Large base of results available for comparison
  - Nearly 100 architectures already benchmarked
  - Provides easy means for quick and accurate analysis

Benchmark Results

Example: ‘C64x Family

BDTImark2000™

Power Consumption

BDTImemMark2000™

10 ku Price

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Benchmark Results

'C64x
'C64x+
TigerSHARC

Benchmark Results

'C64x
Blackfin
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Benchmark Results

Typical Application Decomposition

Applications
- Portable audio player
- Wireless handset
- 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
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 Application Component Benchmark

BDTI Communications Benchmark™ (OFDM) is based on a simplified 10 Mbps OFDM receiver
- Closely resembles a real-world task
- Simplified to enable optimized implementations
- Constrained to ensure consistent, reasonable implementation practices
Choosing a Processor: Benchmarks and Beyond

BDTI Communications Benchmark™

<table>
<thead>
<tr>
<th></th>
<th>Freescale MSC7110 (200 MHz)</th>
<th>TI 'C6410 (400 MHz)</th>
<th>Altera Stratix 1S20-6</th>
<th>Altera Stratix 1S80-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit rate</td>
<td>5.6 Mbit/s</td>
<td>12 Mbit/s</td>
<td>800 Mbit/s</td>
<td>2400 Mbit/s</td>
</tr>
<tr>
<td>Cost (1 ku)</td>
<td>$14</td>
<td>$18</td>
<td>$120</td>
<td>$600</td>
</tr>
<tr>
<td>Cost per Mbit/s</td>
<td>$2.50</td>
<td>$1.45</td>
<td>$0.15</td>
<td>$0.25</td>
</tr>
</tbody>
</table>

From BDTI’s report *FPGAs for DSP* and unpublished benchmarks.

BDTI Communications Benchmark™

Estimated Engineering Effort (for an Optimized Implementation)

<table>
<thead>
<tr>
<th></th>
<th>Typical DSP</th>
<th>Typical FPGA*&lt;sup&gt;*&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Block Libraries</td>
<td>1-2 weeks</td>
<td>~40 weeks</td>
</tr>
<tr>
<td>Without Block Libraries</td>
<td>8-10 weeks</td>
<td>???</td>
</tr>
</tbody>
</table>

*Assumes traditional HDL design flow
Choosing a Processor: Benchmarks and Beyond

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 H.264 Decoder Solution Certification™
- … 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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Choosing a Processor: Benchmarks and Beyond

The Problem with “Solutions”

Vendors increasingly offer HW + SW “solutions”
But solution performance claims are very difficult to use and compare…

“Hantro’s H.264 player for series 60 handsets is based on the 6100 software decoder and PlayEngine middleware. Running on the Nokia 7610 handset, full screen video (208x176 resolution) at 15 frames per second can be achieved.”

“We’re shipping today, running a 90-MHz processor and delivering 20-frame per second QCIF video, which is a very acceptable level.” – Agere

“H.264 player on 600 MHz Blackfin, CIF (360 x 240) at 30 fps: 111 MHz” – ADI

Application Code as a Benchmark

◆ Actual application code can give the most accurate and relevant measure of performance
◆ Usually impractical to implement application code solely for benchmarking purposes
◆ Vendor’s data is often difficult to interpret
  ◆ Varying configurations and conditions
  ◆ Varying performance metrics
  ◆ Inability to quickly distinguish real solutions from vaporware
Choosing a Processor: Benchmarks and Beyond

### BDTI’s Methodology

<table>
<thead>
<tr>
<th><strong>Standardization:</strong></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Operating points</td>
<td></td>
</tr>
<tr>
<td>• Test streams</td>
<td></td>
</tr>
<tr>
<td>• Metrics</td>
<td></td>
</tr>
</tbody>
</table>

**Certification (independent verification):**

- Functionality
- Performance

**Benefits:**

- Meaningful, comparable performance data
- Real solutions distinguished from vaporware

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### BDTI H.264 Decoder Solution Certification™

**Primary Operating Point:**

- Baseline profile, level 1.3
- D1 resolution (720 × 480)
- 30 frames per second
- 2 Mbit/second bitstream

**Secondary Operating Points are used to provide a complete performance picture**

**Metrics:**

- CPU use (MHz, % loading)
- Memory bandwidth use (Mbit/second, % loading)
- Energy consumption (mJ/frame)
- Cost or die area ($ or mm²)
- Program and data memory use (Mbytes)

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Choosing a Processor: Benchmarks and Beyond

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Conclusions

Know what to look for in a processor
- Clearly define the application requirements
- Consider all the processor options
- Be alert for incomplete or misleading information

Use a hierarchical approach to pick a processor
- Develop a hierarchy of requirements
- Start with critical criteria; iteratively narrow the field
- Expect to make trade-offs
Conclusions

Benchmarks are invaluable, if you…
- Choose the right benchmarking approach for the task at hand
  - Different approaches make different trade-offs
- Consider all the relevant metrics
- Beware the many benchmarking pitfalls
- Don’t lose sight of non-performance considerations

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
comp dsp FAQ

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