Insight, Analysis, and Advice on Signal Processing Technology

Choosing a Processor: Benchmarks and Beyond
(S043)

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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

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?

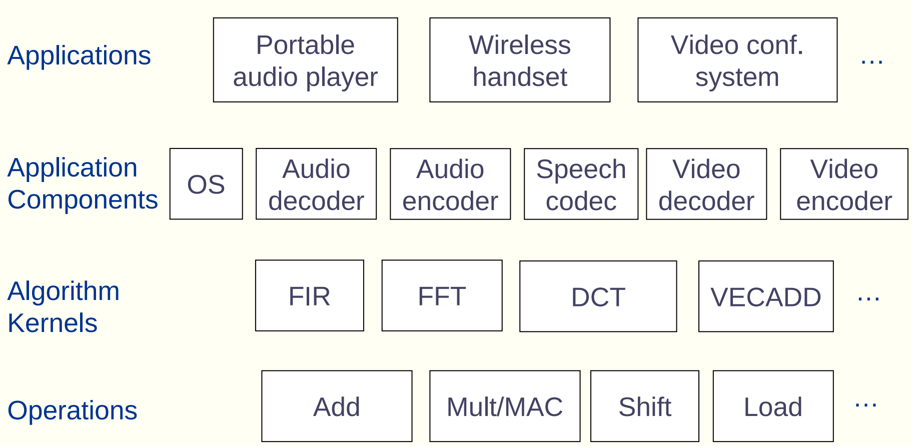
Assess key processor metrics accurately, e.g.,

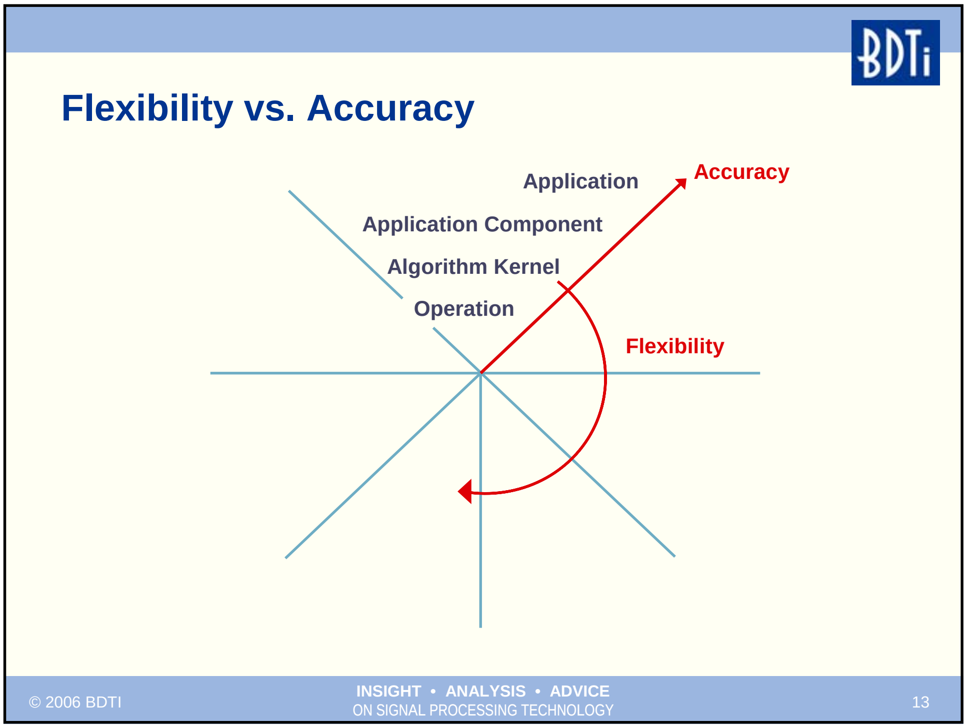
- Speed (*not* cycle counts!)
- Cost efficiency
- Energy efficiency (*not* power consumption!)
- Memory efficiency

Use limited engineering resources effectively

Compare performance across a wide range of architectures, applications

Typical Application Decomposition




Flexibility vs. Accuracy
Application
Accuracy
Application Component
Algorithm Kernel
Operation
Flexibility
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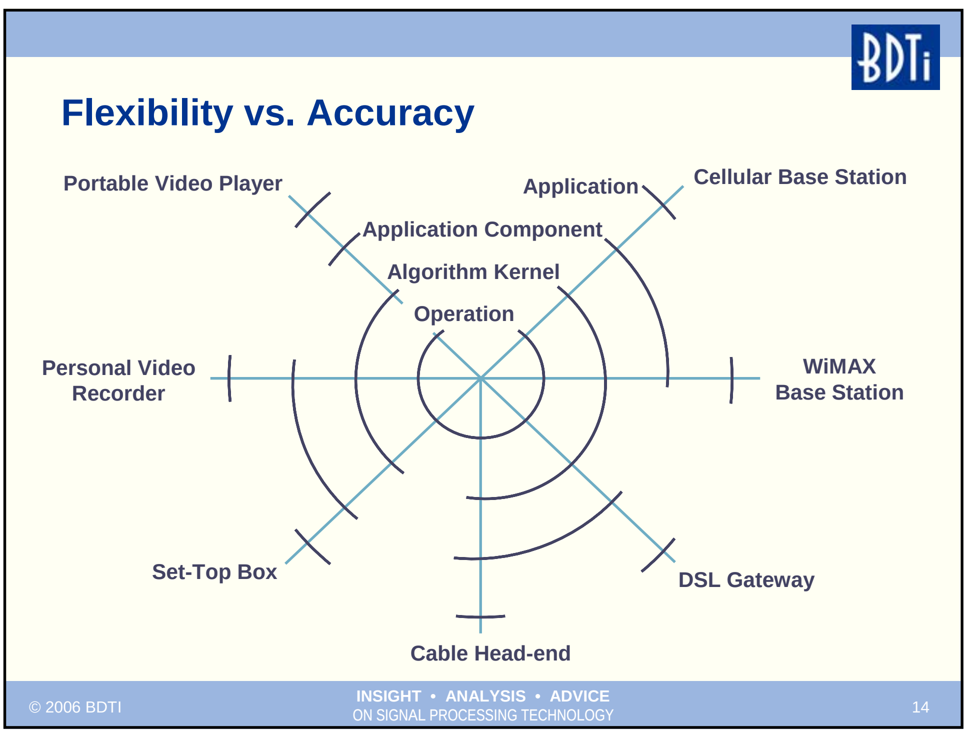
Flexibility vs. Accuracy
Portable Video Player
Application
Cellular Base Station
Application Component
Algorithm Kernel
Operation
Personal Video
Recorder
WiMAX
Base Station
Set-Top Box
DSL Gateway
Cable Head-end
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What's Wrong with MMACS?

MMACS approximates performance on some signal processing algorithms like FIR filters, but:

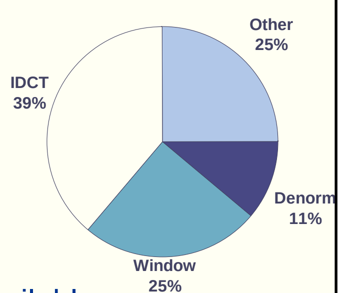
- It ignores other operations required to sustain repeated MACs
- It ignores memory bandwidth bottlenecks
- Many important signal processing algorithms don't use MACs!

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™



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

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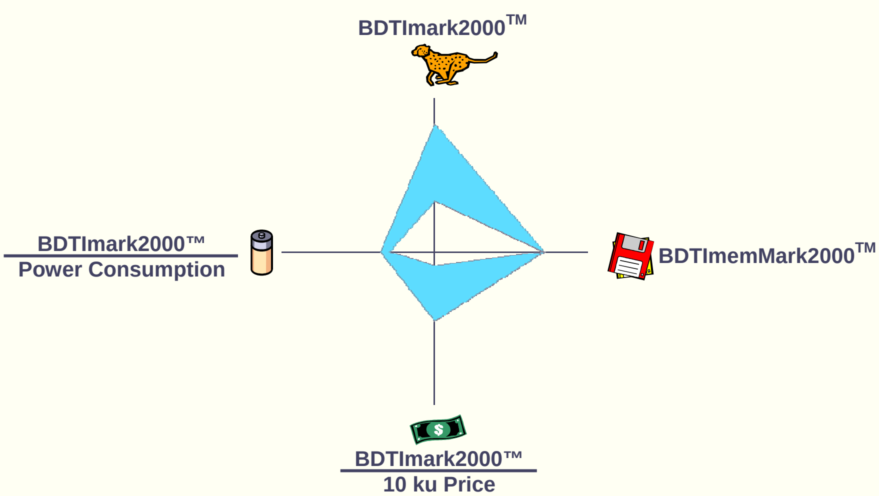
Benchmark Results

Example: 'C64x Family



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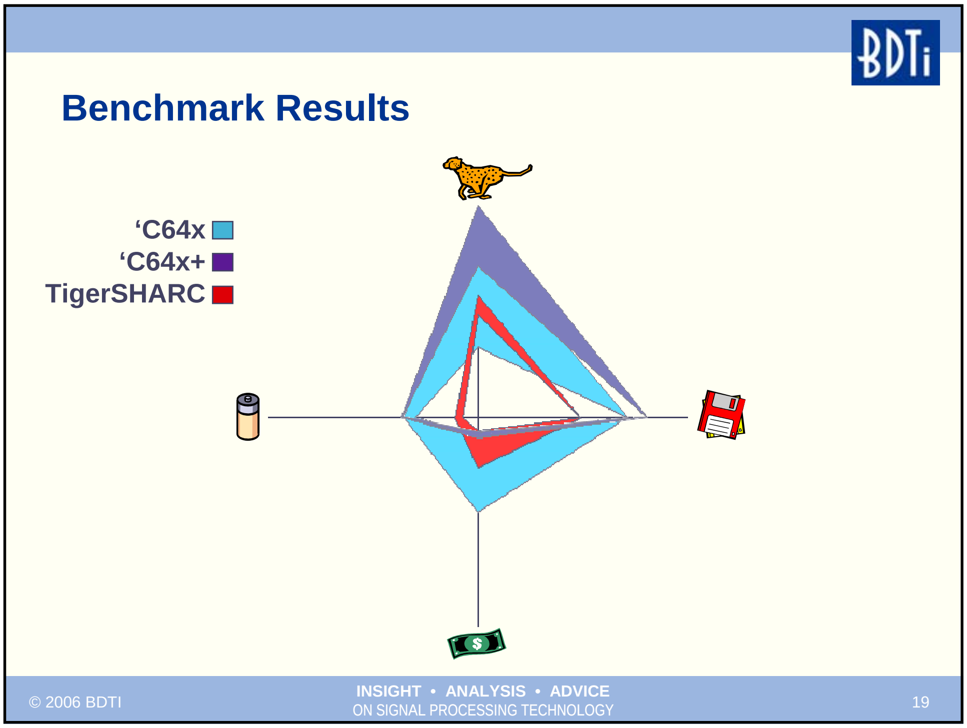
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Benchmark Results
'C64x
'C64x+
TigerSHARC
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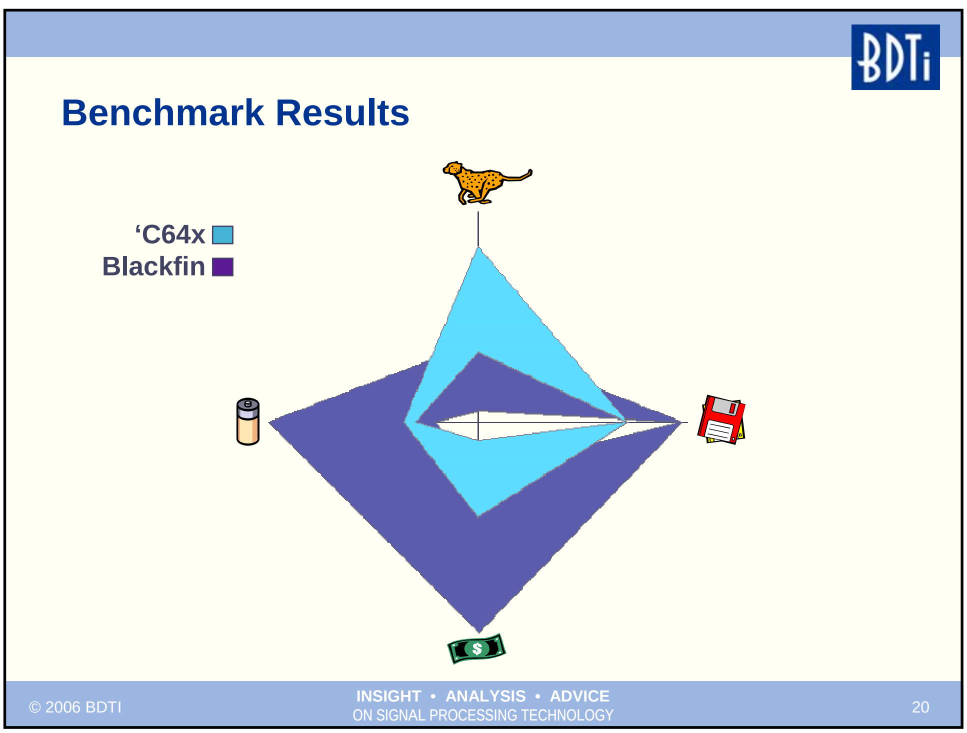
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Benchmark Results
'C64x
Blackfin
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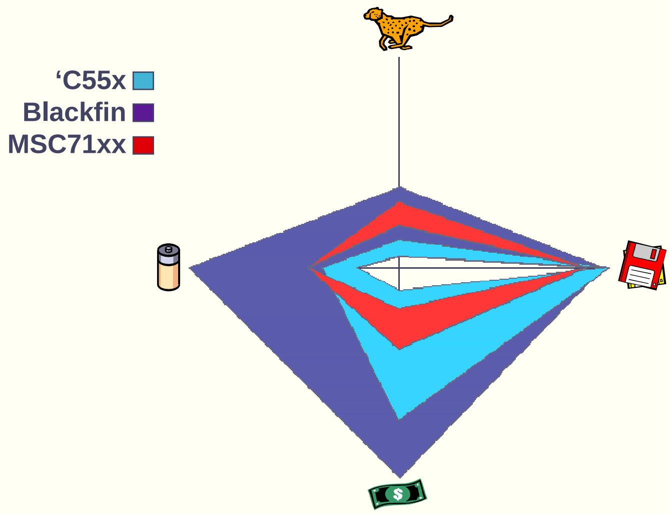
Benchmark Results



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

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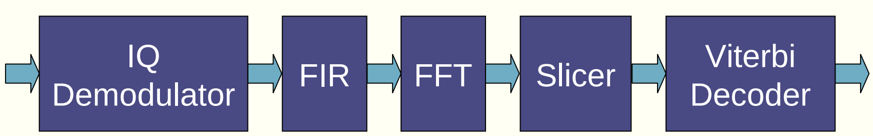
Example Application Component Benchmark

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



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BDTI Communications Benchmark™

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

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

BDTI Communications Benchmark™

Estimated Engineering Effort (for an Optimized Implementation)

	Typical DSP	Typical FPGA*
With Block Libraries	1-2 weeks	~40 weeks
Without Block Libraries	8-10 weeks	???

*Assumes traditional HDL design flow

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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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

BDTI's Methodology

Standardization:
- Operating points
- Test streams
- Metrics

Certification (independent verification):
- Functionality
- Performance

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

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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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 loose sight of non-performance considerations

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