Insight, Analysis, and Advice on Signal Processing Technology

Selecting Processors for Video Applications
(ESC-324)

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

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

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.

 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 5

Video Processor Types

Processor Type	*Chips*	*IP Cores*
PC CPU	✓	
Embedded RISC CPU	✓	✓
Application processor	✓	
DSP (generic or specialized)	✓	✓
Media processor	✓	✓
Heterogeneous multiprocessor	✓	
Customizable processor		✓
ASIP		✓
Reconfigurable processor	✓	
FPGA	✓	
Fixed-function engine	✓	✓
ASSP (incorporating one or more processor types)	✓	
Massively parallel multi-core embedded processors	✓	✓

 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 6

Outline

Motivation and scope

Selection criteria and methodology

Benchmarking options

Processor architecture options

Conclusions

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.

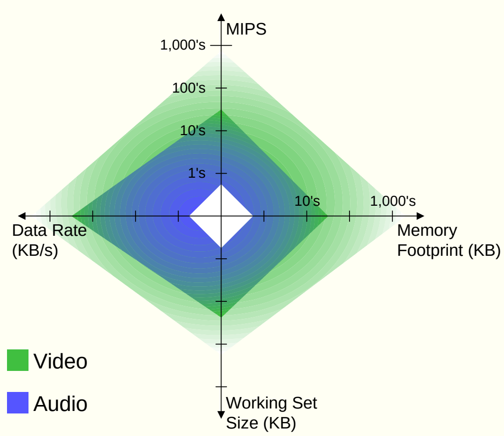
Processor Selection Criteria
Performance Considerations

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



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

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

 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 15

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

 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 16

Outline

Motivation and scope

Selection criteria and methodology

Benchmarking options

Processor architecture options

Conclusions

Benchmarking Options

Applications	Portable video player	Video conf. system	Surveillance system	. . .		
Application Components	OS	Video decoder	Video encoder	Speech codec	Audio decoder	Audio encoder
Algorithm Kernels	Motion Estimation	FFT	Deblocking	VECADD	. . .	
Operations	Add	Mult/MAC	Shift	Load	. . .	

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:

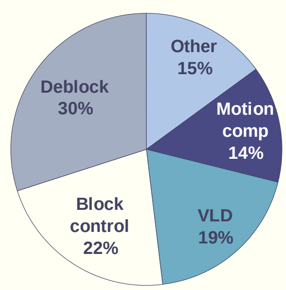
```
mac d12,d8,d0  mac d13,d8,d1  mac d14,d8,d2
mac d15,d8,d3  move.4f(r2)+,d12:d13:d14:d15
move.4f (r0)-,d8:d9:d10:d11
```

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

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

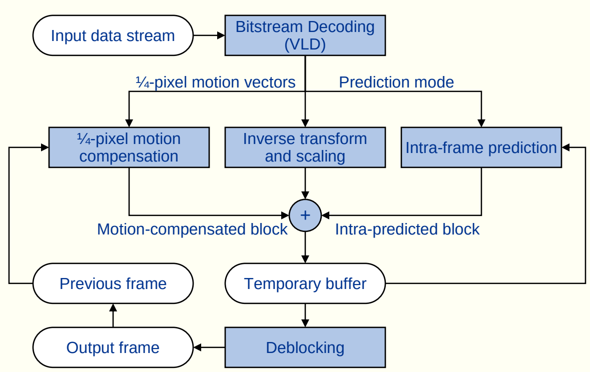
Larger workload vs. kernel benchmarks
- ⬆ Allows comparison of broader range of architectures
- ⬆ Simplifies programming rules
- ⬇ May be harder to implement than a set of kernel benchmarks

Can benchmark the entire system
- ➡ Capture effects of memory size, bandwidth, etc.
- ⬇ Does not capture effects of combining multiple tasks

INSIGHT • ANALYSIS • ADVICE
ON SIGNAL PROCESSING TECHNOLOGY
21

Modeling a Video Decoder
Example Application Component Benchmark

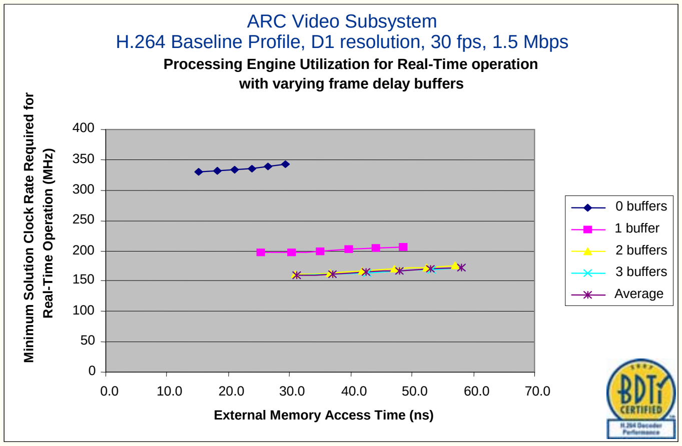
Key goals:
- Represent the application workload
- Standardize the workload
- Simplify implementation
- Represent real application development approaches



BDTI Video Decoder Benchmark

INSIGHT • ANALYSIS • ADVICE
ON SIGNAL PROCESSING TECHNOLOGY
22

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



© 2007 BDTI | INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY | 23

Outline

Motivation and scope

Selection criteria and methodology

Benchmarking options

Processor architecture options

Conclusions

© 2007 BDTI | INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY | 24

Video Processor Types

Processor Type	***Chips***	***IP Cores***
PC CPU	✓	
Embedded RISC CPU	✓	✓
Application processor	✓	
DSP (generic or specialized)	✓	✓
Media processor	✓	✓
Heterogeneous multiprocessor	✓	
Customizable processor		✓
ASIP		✓
Reconfigurable processor	✓	
FPGA	✓	
Fixed-function engine	✓	✓
ASSP (incorporating one or more processor types)	✓	
Massively parallel multi-core embedded processors	✓	✓

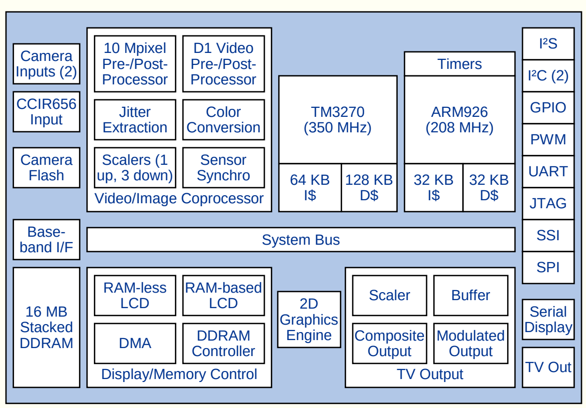
Example Application Processor
NXP PNX4103

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

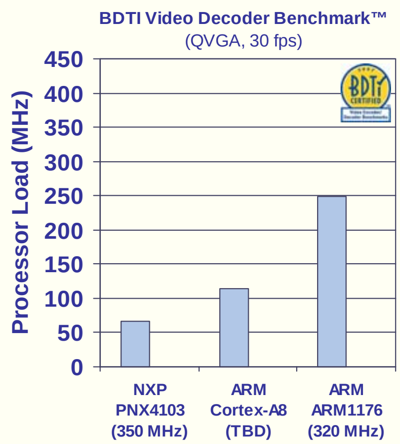
Accelerators for pre-, post-processing

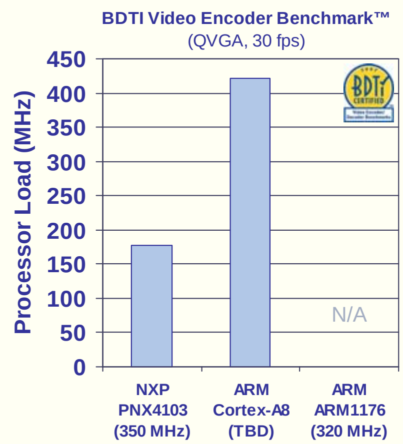
TM3270 performance for video (BDTI-certified benchmark results):
- BDTI Decoder, 30 fps
  - QVGA: ~67 MHz
  - D1: ~290 MHz
- BDTI Encoder, 30 fps
  - QVGA: ~175 MHz

Price not disclosed



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

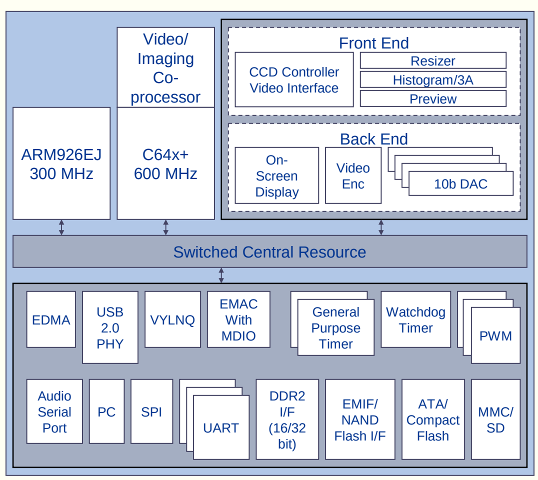
Accelerators for video encoding

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

 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 31

Example FPGA
Altera Stratix II EP2S15

Includes specialized fixed-function blocks:
- Multipliers
- PLLs
- Memory blocks
- High-speed I/O

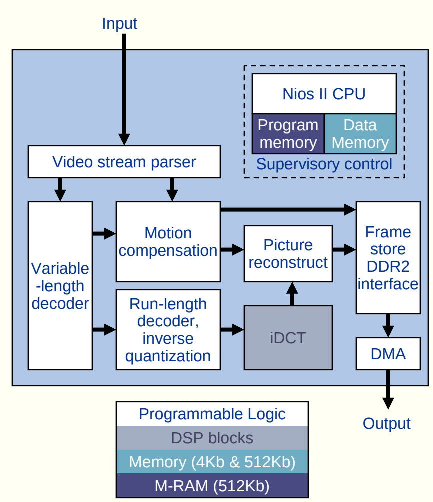
Supports Nios II RISC “soft core”

Performance for video:

(Uncertified results)

Real-time MPEG-2 decode (1080p @ 30 fps): 133 MHz
- Requires ~65% of device

Price $35, qty 10k



 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 32

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

 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 33

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

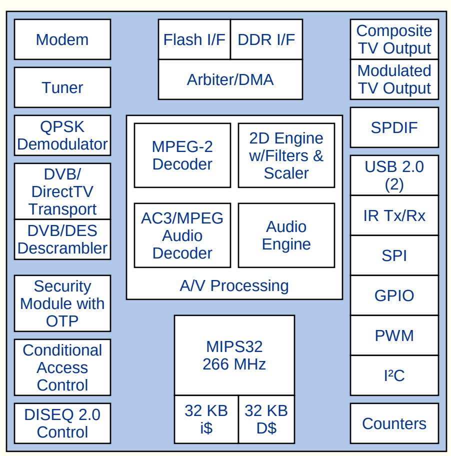
Includes 266 MHz MIPS32 core

On-chip integration
- Video, audio DACs
- USB, GPIO, I²C, SPI

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

Support for third-party OSs, tool chains

Price not provided



 INSIGHT • ANALYSIS • ADVICE ON SIGNAL PROCESSING TECHNOLOGY 34

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

Outline

Motivation and scope

Selection criteria and methodology

Benchmarking options

Processor architecture options

Conclusions

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

4i2i	Video IP cores
Agere Systems	DSPs
Altera	FPGAs, Hardcopy ASICs
Ambric	Massively-parallel processors
Analog Devices	Media processors, DSPs
ARC	Configurable CPU/DSP cores, platforms
ARM	General-purpose CPU cores
Broadcom	ASSPs
Ceva	DSP cores, subsystems
Chips & Media	Video IP cores, ASSPs
Freescale	Media processors, Application processors
Hantro	Hardwired video codecs
Imagination Tech.	Video IP cores
Intel	CPUs

INSIGHT • ANALYSIS • ADVICE
ON SIGNAL PROCESSING TECHNOLOGY
39

Example Video Processor Vendors

LSI Logic	ASSPs
MIPS	General-purpose CPU cores
Mobilic	Media processors
NXP Semiconductors	Media processors, Application processors
PixSil Technology	Media processors, Video IP soft cores
Samsung Semiconductor	ASSPs
Sandbridge Technologies	Multi-core DSPs
Sarnoff	Video IP cores
Siano Mobile Silicon	ASSPs
STMicroelectronics	ASSPs
Telegent Systems	Application processors
Tensilica	Configurable CPU/DSP cores, subsystems
Texas Instruments	Media processors, DSPs, Application processors

INSIGHT • ANALYSIS • ADVICE
ON SIGNAL PROCESSING TECHNOLOGY
40

Example Video Processor Vendors

Videantis	Video IP cores
Xilinx	FPGAs
Zoran	ASSPs

For More Information…
www.BDTI.com

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