Insight, Analysis, and Advice on Signal Processing Technology

Processors for Consumer Audio/Video Applications

(Class CSD-620)

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Outline

- **Motivation and scope**
- Challenges
- Application requirements
- Processor architecture options
- Selection methodology
- Conclusions

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Motivation

- Technology creates new opportunities, e.g.,
  - Broadband Internet enables video on demand
  - Product convergence: cellphone+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 and cost
- Range of processor options is large and rapidly changing, making selection difficult

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Scope

- Processor selection for consumer media products with varying features:
  - Application a mix of audio, video, or still image
    - MP3 players, voice recorders, cell phones
    - Still or video cameras, set-top boxes
  - Using streaming or stored content
  - Battery or line powered, portable or fixed
  - Cost constrained
  - Input/output quality varies by application
    - E.g., lower quality audio for voice recorder, high quality audio for MP3 or DTS playback

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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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Player/DRM Requirements

- Manages other application sub-modules (e.g., codecs), provides user interface
- Processing requirements: 1's–10's MIPS
- Good tools are critical
- Processor features that benefit compilers are useful, e.g.,
  - Orthogonal instruction set
  - Large, linear address spaces
  - Flexible data type support
- I/O bandwidth requirements depend on:
  - Application features, peripheral mix
  - Software architecture

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Audio and Video Codec Requirements

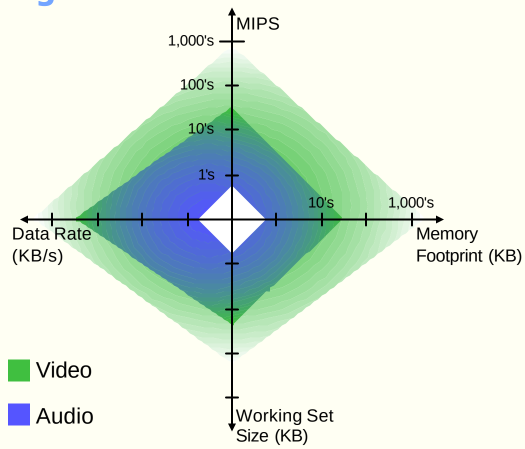
Including Post-Processing

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 AVC, WMV9, DivX ...
- Alpha blending, scaling
- Lower precision (≤16 bits)
- High throughput



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I/O Requirements

- Processors must support multiple I/O interface standards both internal and external
  - Basic in-system serial & parallel (CCD, I2S, SPI, “host port”)
  - Storage ports (glueless SDRAM, ATA, flash)
  - External connectivity (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 co-processors reduce load on core processor

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Development Effort and Cost

- Development effort affected by many factors
  - Programming model complexity
    - More powerful processor → more complex model
    - More complex model → increased development effort
    - Don't overlook complexity of intelligent I/O
  - Availability of off-the-shelf software components
    - Codecs
    - OSs
    - Device drivers
  - Reference designs
  - Quality of tools
    - Maturity, capability of development tools
    - Support for I/O in debug
- The right choice of processor can reduce development effort and cost

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Video Processor Types

Processor Type	Chips	IP
PC CPU	✓	
RISC CPU	✓	✓
DSP (generic or specialized)	✓	✓
Media processor, heterogeneous multiprocessor	✓	
Customizable processor		✓
ASIP		✓
Reconfigurable processor	✓	✓
FPGA	✓	
Fixed-function engines	✓	✓
ASSP (incorporating one or more processor types)	✓	

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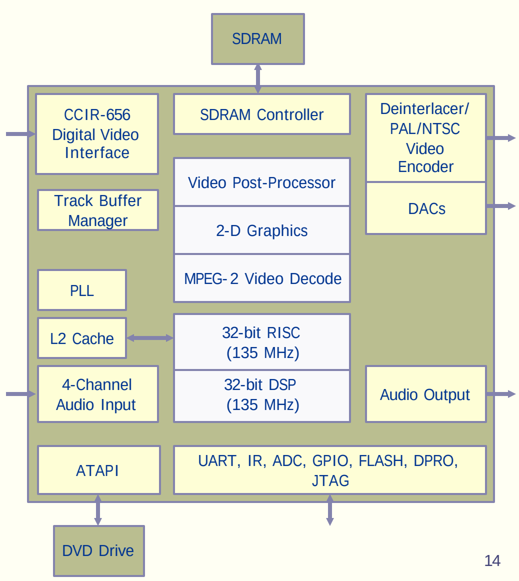
Example ASSP

Zoran Vaddis 5R

- Includes 135 MHz, 32-bit RISC core, and 135 MHz, 32-bit DSP core
- DSP core can handle audio processing in software
- Fixed-function hardware provides real-time MPEG-2 video decode (D1 @ 30 fps), image processing, 2-D & 3-D graphics
- Price not provided



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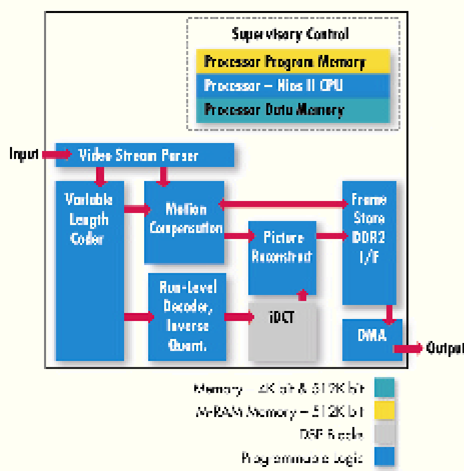
ASSPs
Strengths and Weaknesses

- ⬆ Often very well matched to the application
  - ⬆ SoCs with extensive integration
  - ⬆ 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

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 $120 in (qty 1k)
  - Pin-compatible HardCopy II structured ASIC starts at $15 (qty 100K)



FPGAs
Strengths and Weaknesses

- ⬆ Massive performance gains over instruction set processors on some DSP tasks
  - ⬆ Adjust data widths throughout algorithm
  - ⬆ Huge throughput, cost/performance advantages over DSP, 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 signal-processing applications not proven

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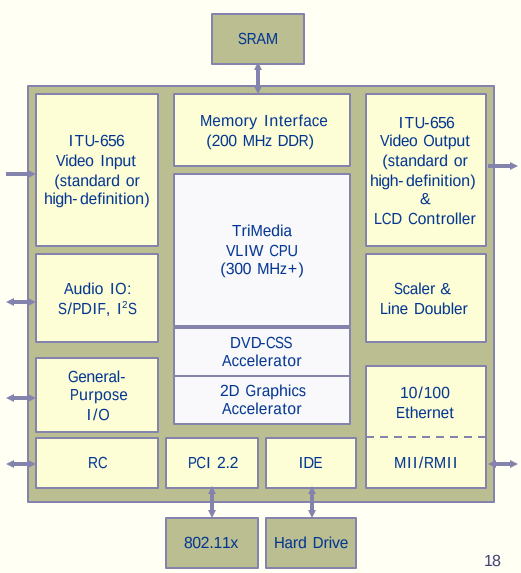
Example Media Processor
Philips PNX1500

- General-purpose 300 MHz five-way VLIW
- On-chip L1 data, instruction caches, and L2 data cache
- Media-specific interfaces, co-processors, instructions
- C/C++ programming model
- MPEG-4 decode (simple profile, CIF, 30 fps): 45 MHz
- MPEG-4 D1 video + audio encoding in real time
- Price <$20, qty >100k



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Media Processors

Strengths and Weaknesses

- ⬆ Higher performance than most DSPs, GPPs
  - ⬆ VLIW, huge register sets, wide SIMD typical
  - ⬆ High performance peripherals, co-processors
- ⬇ Very complex programming models
- ⬆ Better support for media processing in development tools, infrastructure, compared to GPPs
- ⬇ Application performance compiler-dependent
  - ⬇ Compilers can be poor quality
- ➡ Maturing technology—but roadmaps unclear
  - ⬇ 3rd party support weaker than other processor types
- ⬆ Development cost, risk, lower than ASIC, FPGA

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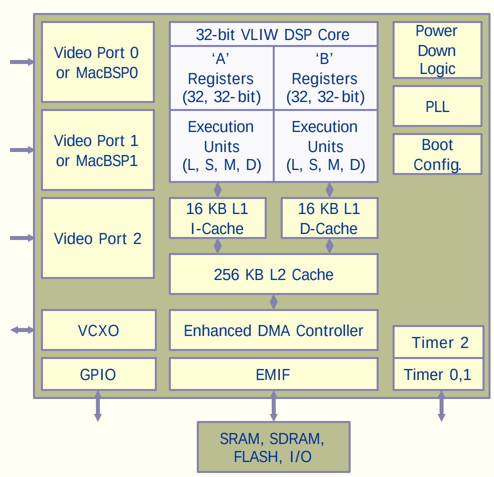
Example DSP Processor

Texas Instruments TMS320DM642

- 720 MHz, 32-bit VLIW DSP processor
- 64, 32-bit general-purpose registers
- 8- and 16-bit SIMD
- Large L1/L2 caches
- High integration
- BDTImark2000™ score: 6570
- MPEG-2 decode (D1 @ 30 fps) under 150 MHz
- Price $60, qty 10k



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DSP Processors

Strengths and Weaknesses

- ↑ Performance, efficiency on media applications vs. general-purpose processors
- ↓ But not as strong as customized solutions, and may not be adequate for demanding tasks
- ↑ Media-oriented development tools, infrastructure
- ↓ Tools not as sophisticated as those available for general-purpose processors
  - ↓ Often, poor compiler quality
- ↑ Stable, mature technology and vendors
- ↑ Third-party audio/video application software available
  - ↓ Support for non-DSP software not as strong as, e.g., RISC
- ↑ Relatively low development cost, risk

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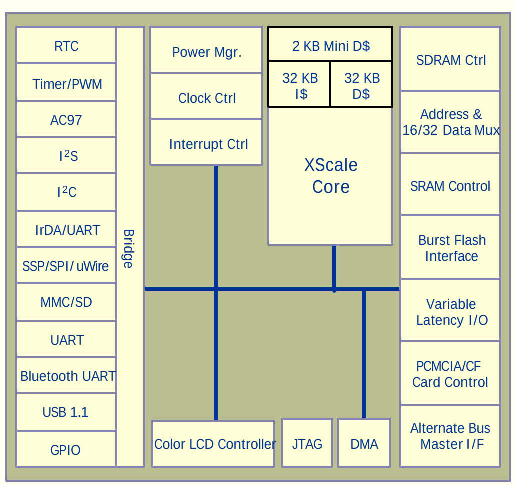
Example Embedded RISC CPU

Intel PXA255

- 400 MHz, 32-bit RISC with modest DSP extensions
- BDTImark2000™ score: 930
- MPEG-4 decode (simple profile, CIF @ 30 fps) 200 MHz
- 16-bit SIMD, 32-bit data types benefit media apps
- Predicated instruction execution good for control
- Good development tool support, optimized DSP software available (e.g., Intel IPP), good OS options
- Price $35, qty 10k (2004 pricing)



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Embedded RISC CPUs

Strengths and Weaknesses

- Can have adequate performance on media applications
  - Often less efficient that DSPs and media processors
- Dynamic features complicate programming
  - Complicates optimization & ensuring real-time
- Sometimes, convoluted programming model
- 32-bit GPPs better targets for non-media tasks
  - E.g., TCP/IP network stacks
- Multi-vendor architectures more common
- Good tools, but generally weak on support for media application development
- Very good third-party OS, software component support
- Compatibility more common
- High integration parts increasingly common

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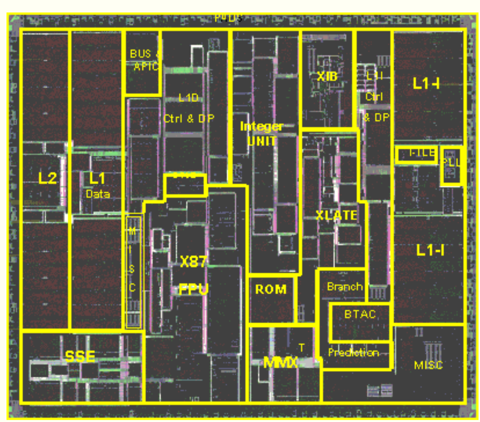
Example PC CPU

VIA Technologies C3

- 1 GHz x86 compatible
- Moderate power consumption, cost
- SSE support for media applications, supports fixed-, floating-point types
- Access to massive x86 3^{rd}-party software, tools base
- Familiar to software, hardware developers
- MPEG-4 decode (D1, 30 fps) using 35% of CPU, when using VIA CN400 chipset
- CPU: $70, chipset: $23 (qty 10k)



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PC CPUs (GPPs)

Strengths and Weaknesses

- ⬆ Can handle complex media processing tasks
  - ⬆ May be as fast or faster than DSPs…
  - ⬇ … but cost & power consumption typically higher
- ⬇ Dynamic features complicate optimization, real-time design
- ⬇ Generally weak on integration
- ⬆ Many options for OS, 3rd party application software
- ⬆ Easier migration of PC applications
- ⬆ Excellent targets for non-signal-processing tasks
  - ⬆ E.g., protocol stacks
- ⬆ Compatibility, multi-vendor architectures common
- ⬆ Development tools mature, powerful
  - ⬇ But typically lack features useful for media application development

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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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Processor Selection Criteria

Signal-Processing-Centric Concerns

- Performance on relevant audio/video tasks
  - Speed
  - Memory bandwidth: on-chip, off-chip
  - Execution-time predictability
    - Dynamic features confound determinism
  - Energy consumption
  - Fixed-point vs. floating-point
    - Floating-point less important for video
  - Data word size(s)
- Memory usage

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Processor Selection Criteria
Signal-Processing-Centric Concerns

- On-chip integration
  - Memory, peripherals, I/O interfaces, coprocessors
- Development effort, risk
  - Media-oriented tools, infrastructure
  - Programming model complexity
  - Application software components
  - Reference designs
  - Tools, support (vendor, 3rd party)
    - Accurate cycle-count and memory profiling
    - Visibility into cache, pipeline
  - Features useful for integration, real-time testing
    - E.g., on-chip debug support

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Processor Selection Criteria
General Concerns

- Cost
- Packaging options
- Roadmap
  - Availability; reliability of supply
    - Multi-vendor architectures a plus
  - New spins, new architectures, compatibility
  - Core version available?
- Special requirements
  - Variable-voltage operation

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Assessing Performance

- Use results from relevant application modules
  - More accurate than kernel benchmark mapping—if available
  - Use caution! The data may be misleading or incomplete
- Use kernel benchmarks & application profiles
  - Useful when application data isn't available
  - Use kernel benchmark results to predict application module performance
- Use care with either approach
  - Hazards include data types, multitasking effects …

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Assessing Performance, continued

- Core CPU performance isn't enough
  - Must also consider memory sizes and bandwidths
  - I/O bandwidths and overheads: data movement can be very costly
- Impact of software partitioning in multi-processor systems
  - Must refine software architecture to predict performance
- Dynamic features complicate performance prediction
- Assessing energy efficiency can be very difficult

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Development Considerations

- Language support
  - Quality of C compiler; availability of C++ compiler
  - Support for assembly language optimization
- Software availability
  - Media processing components
  - Player, device drivers, operating system
- Hardware/software reference designs
- Debug/development benefit from tools with:
  - Peripheral and multi-processor simulation
  - Non-intrusive, real-time debug
- Compatibility, developer familiarity

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Availability and Roadmap

- Risk
  - Is the chip available in volume today?
  - Are there second sources of the chip or compatible chips?
  - What does the errata list look like?
- Roadmap
  - What is the vendor's commitment to evolving the chip? E.g., improved integration, reduce cost
  - What is the vendor's roadmap for next-generation chips? Compatibility?
  - What is your confidence that the vendor will execute on its roadmap?

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Conclusions

- Choosing a processor for a consumer media product is easy
- Choosing the best processor for your particular product is hard
  - Vast range of options
  - Many complex, competing criteria to consider
  - Poor information
  - Fast changing requirements and options
  - Limited time and resources

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Conclusions, cont.

- 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
  - Resource-hungry algorithms, cost-constrained processors, many variables
- Development-related considerations are key
- Appropriate integration is essential to low system cost

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Trends: Processors

- Consumer media applications are becoming a major focus of processor vendors
  - Expect more competitors, more options
- Technology, competition pushes performance up; price and power consumption down
  - Enabling new types of products, new levels of functionality
  - But not all processors are well matched to media processing workloads
- Increasing architectural complexity
  - Many heterogeneous multiprocessors
- Integration increasing
- Development infrastructure is a key differentiator

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Trends: Development

- Products are becoming more complex
  - Stereo receiver vs. home media center
- Processors are becoming more complex
- Algorithms are becoming more demanding
  - Nobody knows which ones will dominate
- Optimization continues to be essential
- Huge processor-to-processor differences in development infrastructure
  - Support for media applications
  - Off-the-shelf, optimized software components increasingly important

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For More Information…
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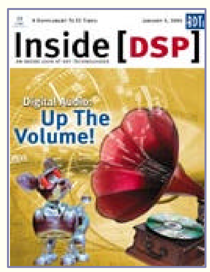

Inside [DSP] newsletter and quarterly reports

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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