Insight, Analysis, and Advice on Signal Processing Technology

Processors for Consumer Video Applications (CV-942)

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Outline

Motivation and scope
Selection methodology
Benchmarking options
Processor architecture options
Conclusions

Motivation

Technology creates new opportunities

- Broadband Internet enables video on demand
- Product convergence: cellphone+video 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, cost, and risk

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

Scope

Processor selection for consumer video products with varying features:

- Application a mix of video and audio, still image, …
  - Portable media players, cell phones, still or video cameras, set-top boxes, security, …
- Using streaming or stored content
- Battery or line powered, portable or fixed
- Cost constrained
- Input/output quality varies by application
  - E.g., lower quality video for cell phone, high quality video for set-top box

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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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

Audio and Video Codec Requirements

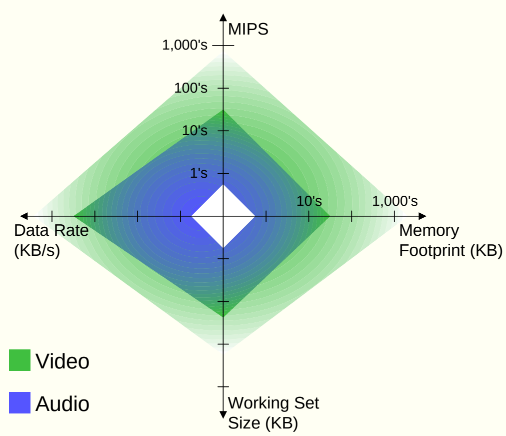
Including Post-processing

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, H.264, WMV9, DivX …
- Alpha blending, scaling
- Lower precision (≤16 bits)
- High throughput



Processor Selection Criteria

Cost

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

Packaging options
- Sizes
- Temperature ranges
- Ease of manufacture

I/O Requirements

Processors must support multiple I/O interface types and standards
- Basic in-system serial & parallel (e.g., CCD, I²S, SPI, "host port")
- Storage ports (e.g., glueless SDRAM, ATA, flash)
- External connectivity (e.g., 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 coprocessors reduce load on core processor

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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Benchmarking Options

Applications	Portable video 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	…	

Avoiding the Extremes

MIPS (millions of instructions per second) and MFLOPS (millions of floating-point operations per second) are easy to measure…

- …but "instructions" and "operations" are poorly defined, making the results useless

DSP16410 single instruction:

```
A0=A0+P0+P1 P0=Xh*Yh P1=Xl*Yl Y=*R0++ X=*PT0++
```

TMS320DM64x single instruction:

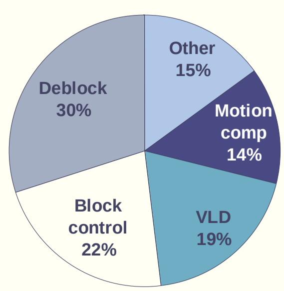
```
ADD   A0,A3,A0
```

Full-application benchmarks can have very accurate results…

- …but they are impractical to implement

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 Video Kernel Benchmarks™, BDTI DSP Kernel Benchmarks™



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

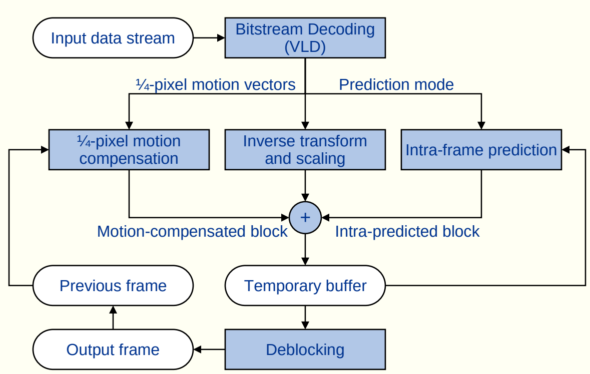
Can benchmark the entire system
- Capture effects of memory size, bandwidth, etc.
- Does not capture effects of combining multiple tasks

Example: BDTI Video Encoder and Decoder Benchmarks™

Model modern video compression standards
- Subset of functions, modes
- Motion estimation algorithm specified by BDTI

Capture 70%-90% of typical workload

Much easier to implement than a full codec



BDTI Video Decoder Benchmark™

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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)	✓	

Example Application Processor

Philips PNX4103

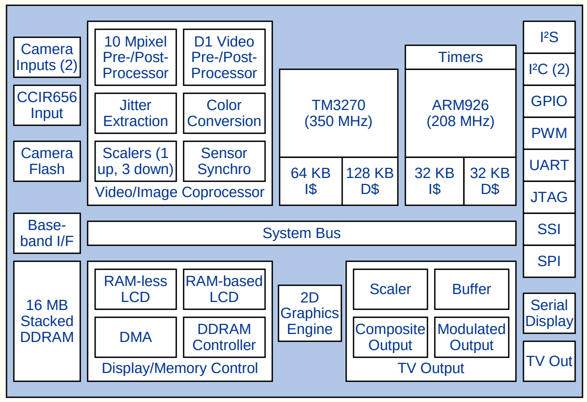
Two cores:
- 208 MHz ARM9E
- 350 MHz 5-issue VLIW TM3270 media processor

Accelerators for pre-, post-processing

BDTIsimMark2000 score: 430 (ARM only)

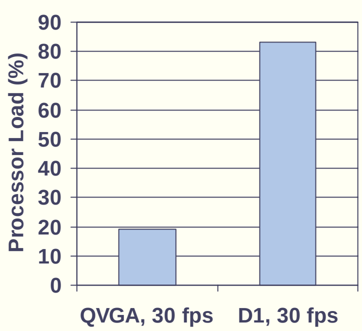
TM3270 performance:
- H.264 MP decode (D1 @ 30 fps): ~210 MHz
- MPEG-4 ASP decode (D1 @ 30 fps): ~100 MHz

Price not disclosed

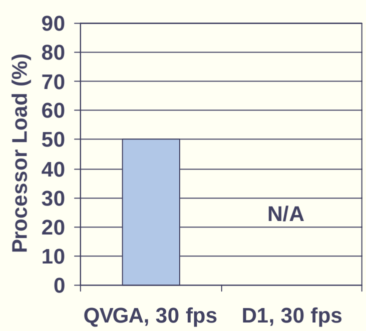


PNX4103 Benchmark Results

BDTI Video Decoder Benchmark™



BDTI Video Encoder Benchmark™



Benchmarks run on the TM3270, a 350 MHz, 5-issue VLIW core.
No external memory was required for this benchmark.
Results measured via simulator.

Example Application Processor

Freescale i.MX21

Based on a 266 MHz ARM9E

Accelerators for MPEG-4 and H.263 encode and decode, video pre-/post-processing

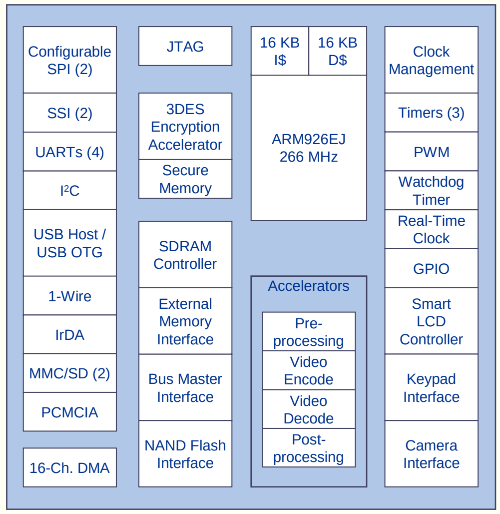
Strong emphasis on energy-saving design

- Accelerators
- Active well biasing

BDTIsimMark2000 score: 550

MPEG-4 decode (CIF @ 30 fps): ~5 MHz

Price $17, qty 10k



Application Processors

Strengths and Weaknesses

- ➡ Adequate performance for portable video
  - ⬇ Typically less powerful than other types of processors
- ⬆ Emphasis on energy efficiency
- ➡ Programming model may be simple or complex
- ⬆ 32-bit GPP core is a good target for non-media tasks
  - ⬆ E.g., TCP/IP network stacks
- ➡ Good tools, but generally weak on support for video application development
- ⬆ Very good third-party OS, software component support
- ⬆ Compatibility good for ARM core
  - ⬇ But generally use proprietary video processing hardware
- ⬆ High integration

Example Media Processor

Texas Instruments TMS320DM6446

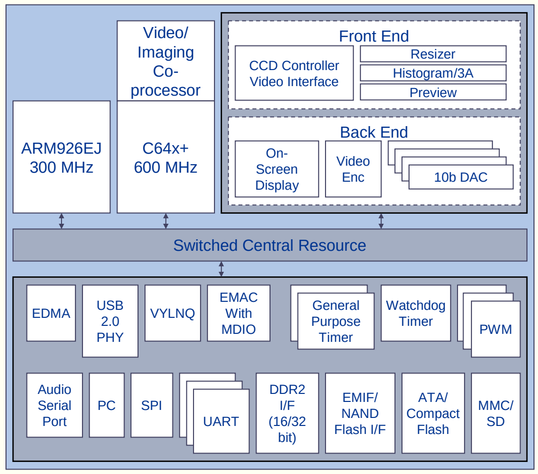
Two cores:
- 300 MHz ARM9E
- 600 MHz 8-issue VLIW DSP core

Accelerators for video encoding

BDTImark2000™ score: 6590 ('C64x+ only)

Maximum performance:
- H.264 MP encode and decode D1: @ 30 fps
- MPEG-4 SP encode and decode: 720p @ 30 fps

Price $35, qty 10k



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Media Processors

Strengths and Weaknesses

- ⬆ Higher performance than most DSPs, GPPs
  - ⬆ High performance peripherals, coprocessors
- ⬇ Very complex programming models
- ⬆ Better support for video processing in development tools, infrastructure, compared to GPPs
  - ⬇ 3rd party SW support weaker than other processor types
  - ⬆ Vendor-provided SW support can be strong
- ⬇ Application performance compiler-dependent
  - ⬇ Compilers can be poor quality
- ➡ Maturing technology—but roadmaps unclear
- ⬆ Development cost, risk, lower than ASIC, FPGA

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Example FPGA

Altera Stratix II EP2S15

Includes specialized fixed-function blocks:

- Multipliers
- PLLs
- Memory blocks
- High-speed I/O

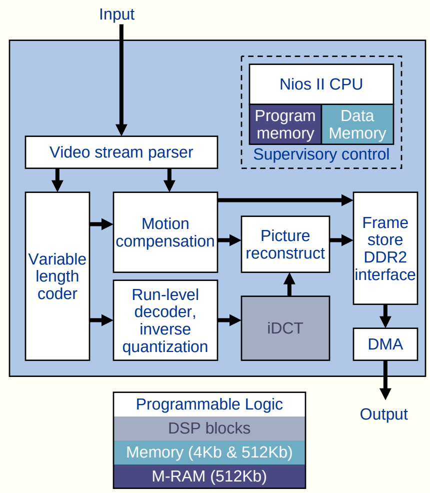
Supports Nios II RISC "soft core"

Real-time MPEG-2 decode (1080p @ 30 fps): 133 MHz

- Requires ~65% of device

Price $28, qty 10k

- Pin-compatible HardCopy II structured ASIC starts at $15, qty 100k



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FPGAs

Strengths and Weaknesses

- ⬆ Massive performance gains over instruction set processors on some video tasks
  - ⬆ Huge throughput, cost/performance advantages over DSPs, 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 applications not proven

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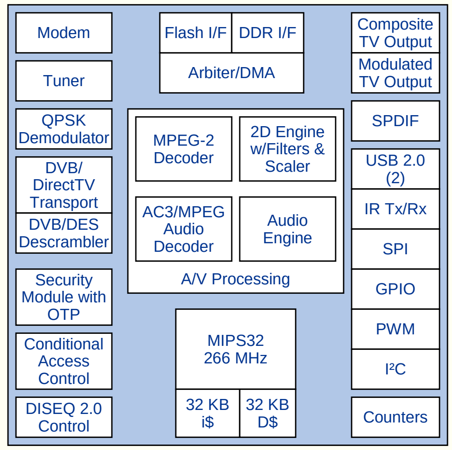
Example ASSP
Broadcom BCM7312

- Targets set-top boxes for digital satellite TV
- Fixed-function hardware:
  - MPEG-2 video decode (D1 @ 30 fps)
  - Audio decoding
  - 2D graphics
- Includes 266 MHz MIPS32 core
- Application-specific integration
  - RF tuner and demodulator
  - Satellite descramblers
  - Access control hardware
- Price not provided



ASSPs
Strengths and Weaknesses

- ⬆ Often very well matched to the application
  - ⬆ SoCs with extensive integration
  - ⬆ Typically paired with extensive application-specific software
  - ⬆ 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

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Trends

Growing markets attract new competitors
- Not all processors are well suited for video

Technology, competition push performance up; price and power consumption down
- Enabling new products, new functionality

Algorithms becoming more demanding

Applications becoming more complex

Processors becoming more complex
- Many heterogeneous multiprocessors
- Integration increasing

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

Conclusions

Choosing the best processor is hard
- 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

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