Embedded Software in Real-Time Signal Processing Systems: Application and Architecture Trends

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Introduction

- Today's embedded systems (telecommunications, multimedia, and consumer electronics) require extremely short product design markets.
- Current solutions range from general purpose processor cores to application-specific instruction set processor cores (ASIP).

Introduction …continued

- Three important factors considering the future role of embedded processors in these applications (where will the embedded systems fit?):
  - Low cost, short time to market.
  - Stabilization of PC market.
  - Increase growth of wireless and multimedia applications.

Introduction ...end

- Based on observed trends, we will examine requirements of embedded software development tools.
- Focus mainly on retargetable compilation.

Overall Semiconductor Market Trends

- 1980's and early 1990's, general purpose processors, and memories contributed to evolution of VLSI technology and design methods.
- As of 1997, wireless communications, multimedia, and video games are driving VLSI technology instead.
- Wireless communication and DSP market is expected to keep growing as PC market stabilizes.

Embedded Processor Trends

- What processors are classified as embedded systems?
  - Microcontrollers (MCUs), digital signal processors (DSP), and microprocessor units (MPU, CISC and RISC).
  - ASIP is more specialized and fine tuned for applications.

Embedded Processor Trends …continued

- Overall processor market is dominated by 4-bit and 8-bit MCUs (40% of revenue).
- But MPU (8, 16, 32 bit) account for 60% of total processor sales revenue.

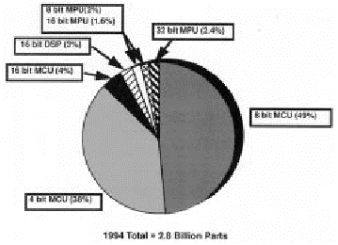


Fig. 1. Relative volumes of embedded processors in 1994.

Embedded Processor Trends …continued

- Transition from 8-bit MCU to 16 and 32-bit is slow.
- 32-bit processors sold are used for embedded systems applications (57%) than computing applications (43%).

Embedded Processors in Multimedia.

- Multimedia applications of embedded processors include set-top boxes, HDTV, digital video broadcast, videophones, 3-D video, and videogames.

Multimedia Processors

Table 1 Multimedia Processors (Set-top Boxes, Digital TV, MPEG, Videophone, Dolby)

Company	Processor	Application(s)
Philips	TriMedia™ VLIW ASIP [15]	MPEG1 encode/decode + MPEG2 decode + H.261 videophone
TCEC	68 bit VLIW DSP ASIP [16], 64 bit VLIW DSP ASIP MCU ASIP, Hard-wired ASIC	MPEG1 audio decoder, MPEG2/Dolby-AC3 audio decoder MPEG2 video encoutter control, MPEG2 video decoder
Chromatic	Mpact™ media ASIP [17]	MPEG1 and 2 video decoder + H.261 videophone
NTT	Two in-house RISC [18] + hard-wired logic	MPEG2 video encoder
Texas Instruments	MCU/DSP ASIP [19]	MPEG2 video decoder
Zoran [20]	20 bit DSP ASIP ZR38500	Dolby six channel AC-3
	20 bit DSP ASIP ZR38521	Two Channel AC-3 + MPEG1 audio
	20 bit DSP ASIP ZR38501	Two Channel AC-3 only
SGS-Thomson	8 bit MCU ASIP [21], [22]	Videophone: master control
	8 bit MCU ASIP	Videophone: bit stream processing
	VLIW DSP ASIP	Videophone: motion vector predictor

- This table shows that almost all of MPEG2 decoders are custom hard-wired logic ASIPs.
- 32 bit general processors were not used as they were not as efficient in computing functions such as inverse discrete cosine transform.

3-D Video Acceleration

Table 2 3-D Accelerator Processors

Company	Processor	Architecture Style
Philips	Trimedia™ TM-1	ASIP VLIW
Chromatic	Mpact™ media processor	ASIP (2000 MOPS)
IBM	Mfast™	Array of 20 VLIW ASIP's
Rendition	Verite™	ASIP: RISC-style processor + pixel H/W engine
3Dfx	Voodoo™	Hard-wired graphics engine
3Dlabs	Permedia™	Hard-wired graphics engine
Nvidia/SGS-Thomson	NV1 (STG2000), NV3	Hard-wired graphics engine

- ASIPs is also the popular choice in 3-D video acceleration.

Video Games

Table 3 Game-Oriented Processors

Company	Product Model	Architecture Style
Nintendo	Ultra64™ ("Magic Carpet" spec.)	MIPS R4300 RISC + Media Signal Proc. ASIP + Media Display Proc. ASIP
Sega	Saturn™	SH7604 RISC (2x)
Sony	Playstation™	Custom R3000 + hard-wired audio/graphics logic
Atari	Jaguar™	64 bit ASIP
3DO	MultiPlayer™ (M2)	PowerPC 602 processor + ARM60 processor + hard-wired graphics logic

- Most designers choose to implement a standard or customize RISC processor with one ore more dedicated ASIP(s).

Embedded Processors in Wireless Communications.

- Wireless communication as in digital cellular phone standards used in Europe (GSM, DECT), and North America.

Wireless Communications.

Table 4 Processors for GSM (Europe)

Company	Processor	Application(s)
France Telecom (CNET)	LIW DSP ASIP [28]	Hands-free ISDN terminal
	LIW (55 bit) DSP ASIP	GSM terminal
	LIW (44 bit) DSP ASIP	G.721 codec (DECT, CT2)
Alcatel	16 bit DSP ASIP [29]	GSM handset
Intitel	IEQU DSP ASIP [30]	GSM base station: equalization
	IEDM DSP ASIP	GSM base station: demodulation
Philips	"KISS" 16 bit DSP [31]	GSM handset
	Epica configurable DSP [32], [33]	DECT handset
SGS-Thomson	16 bit D950 DSP [34], [35] + user-defined co-processor	GSM, cellular, modem
Siemens	Pine™ DSP core (under license)	GSM handset

Table 5 Processors for GSM (North America and Asia–Pacific)

Company	Processor	Application(s)
AT&T	DSP16 ASIP family [36]	GSM, Modem Cellular handset Cellular base station
Northern Telecom	8 bit MCU ASIP + Motorola 56K	Cellular base station
TI	16 bit DSP C540 ASIP [37]	GSM handset
Toshiba	16 bit DSP ASIP (TC-40005)	GSM
NEC	16 bit DSP ASIP (nPD7701X)	IS-54 cellular phone
Fujitsu	Hard-wired ASIC	GSM

- ASIP dominates here too, as they conserve more power than general DSP units.

Telecommunications Applications.

- Automatic call distribution.
- Cordless Phones.
- Line interfaces for large telephone switches.
- Synchronous optical networks interface units.
- Integrated sound and data network (ISDN) phone terminals.
- Message deliver devices.
- Cryptography for secure date communications.
- Video codecs.

Telecommunications Applications …continued.

- Two thirds of design teams use commercial DSP/MCU chips.
- Two thirds of the chip volume is for in-house ASIPs.
- General purpose processors are used when time-to-market is short.
- ASIPs used in large volume, low cost applications.

Embedded Processor Trends Conclusions.

- Diversity of processor architectures are driven by low-cost consumer-oriented markets.
- Many products use different combinations of RISC, ASIP, and hardwired co-processors.
- ASIP dominates the high-volume, low cost segments of the market.

Application Trends: Complexity Growth

- Complexity for requirements are increasing.
  - New cell phones support multiple standards, GSM, CDUMA, DECT.
  - JPEG to MPEG1 to MPEG2 to MPEG4.
  - Stereo to Dolby AC3. Support for surround sound.
- Starting to support standards (DirectX), there fore less architecture freedom.

Development tools for Embedded Systems.

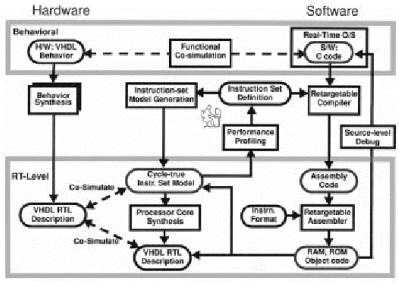
- Development tools are increasing in complexity.
- C compiler needs to optimize for code size for MCU applications.
- In DSP application, execution speed optimization is necessary.
- As of 1997, DSP optimized compiler code is still a lot slower than hand optimized code.

- Over 75% of assembly code is used in MCU applications for efficiency.
- Over 95% for DSP applications.
- Some assembly code compilers generate wrong code.
- Future requirements: improved compiler technology for embedded systems. (High level, source-level debugger.)

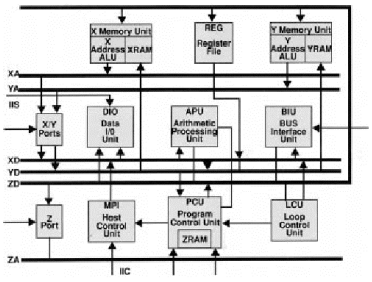
Embedded Software System Needs

- High performance compilers for low-cost, irregular architectures.
- Compilers associated with retargetable tools like profilers, source-level debuggers, incircuit emulators.
- For ASIP, ability to quickly provide feedback on instruction set selection decisions.
- Fast and accurate instruction set simulators.
- Synthesis of lightweight real-time OS.

Ideal HW/SW co-design environment.



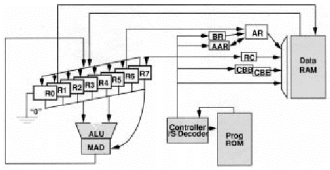
Phillips EPICS reconfigurable DSP architecture.



Phillips EPICS reconfigurable DSP architecture …continued

- Ability to quickly generate applications-specific DSP cores.

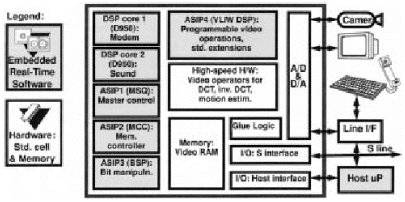
Northern Telecom DSP ASIP.



•Stripped out general connections which were not required.

•Requires optimized C-compiler due to irregular architecture.

Integrated video telephone H.263 standard.



Integrated video telephone H.263 standard.

- Transition from hard-wired implementations to mixed ASIPs and standard DSPs.
- Need for programmability due to standard.
- Need for high performance co-simulation too since significant part of chip functionality is in software.

Conclusion.

- Existing MCU and DSP processors will continue to account for majority of designs starts.
- However, ASIP provides design flexibility, reusability, and variable complexity.
- High performance C compilers are needed still.
- Multilevel simulation to easy co-design. (C-VHDL).
- Source level debugging tools are required.