Increased Cache Capacity

- Typically two or three levels of cache between processor and main memory
- Chip density increased
  - More cache memory on chip
  - Faster cache access
- Pentium chip devoted about 10% of chip area to cache
- Pentium 4 devotes about 50%

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More Complex Execution Logic

- Enable parallel execution of instructions
- Pipeline works like assembly line
  - Different stages of execution of different instructions at same time along pipeline
- Superscalar allows multiple pipelines within single processor
  - Instructions that do not depend on one another can be executed in parallel

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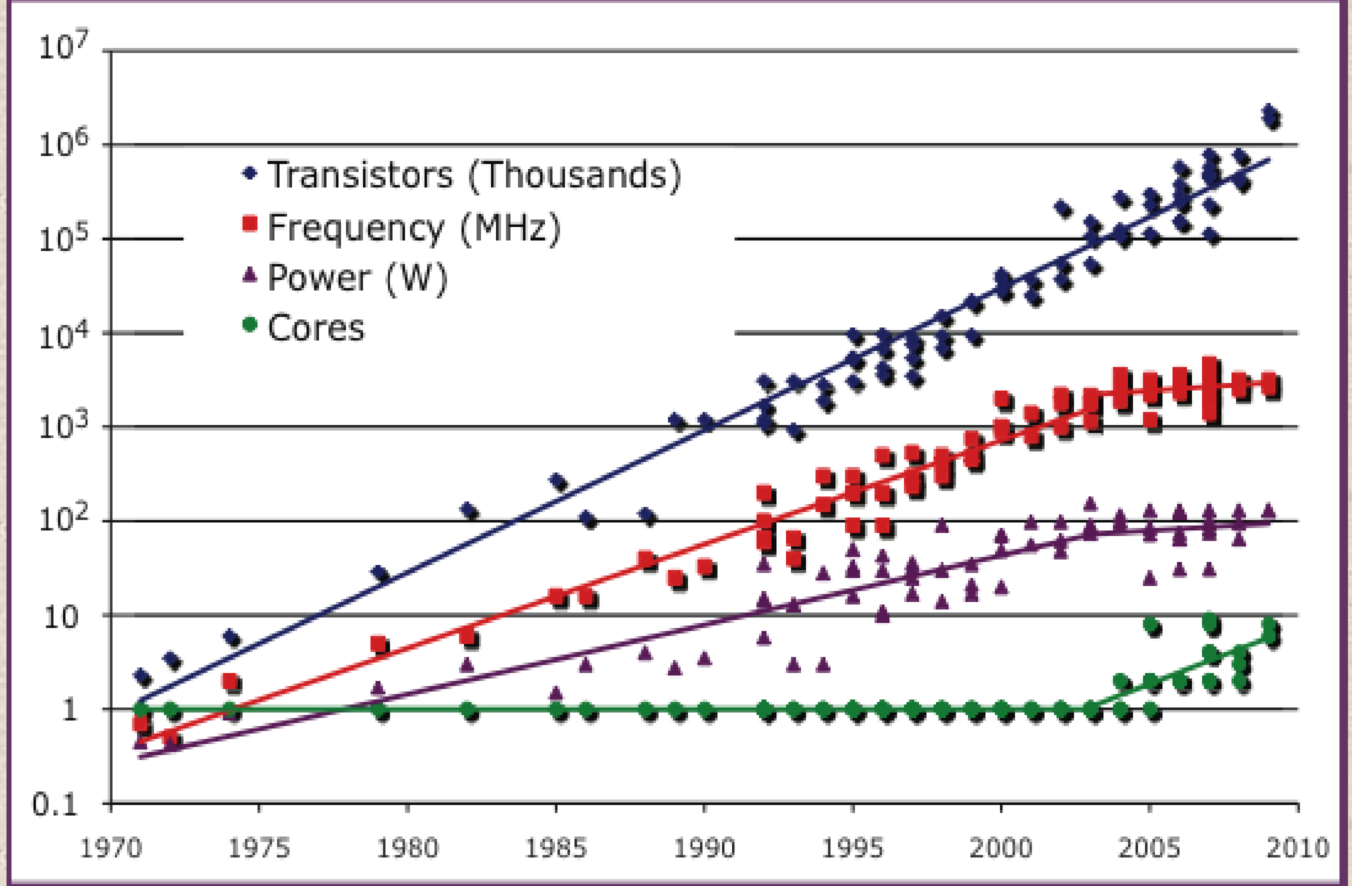
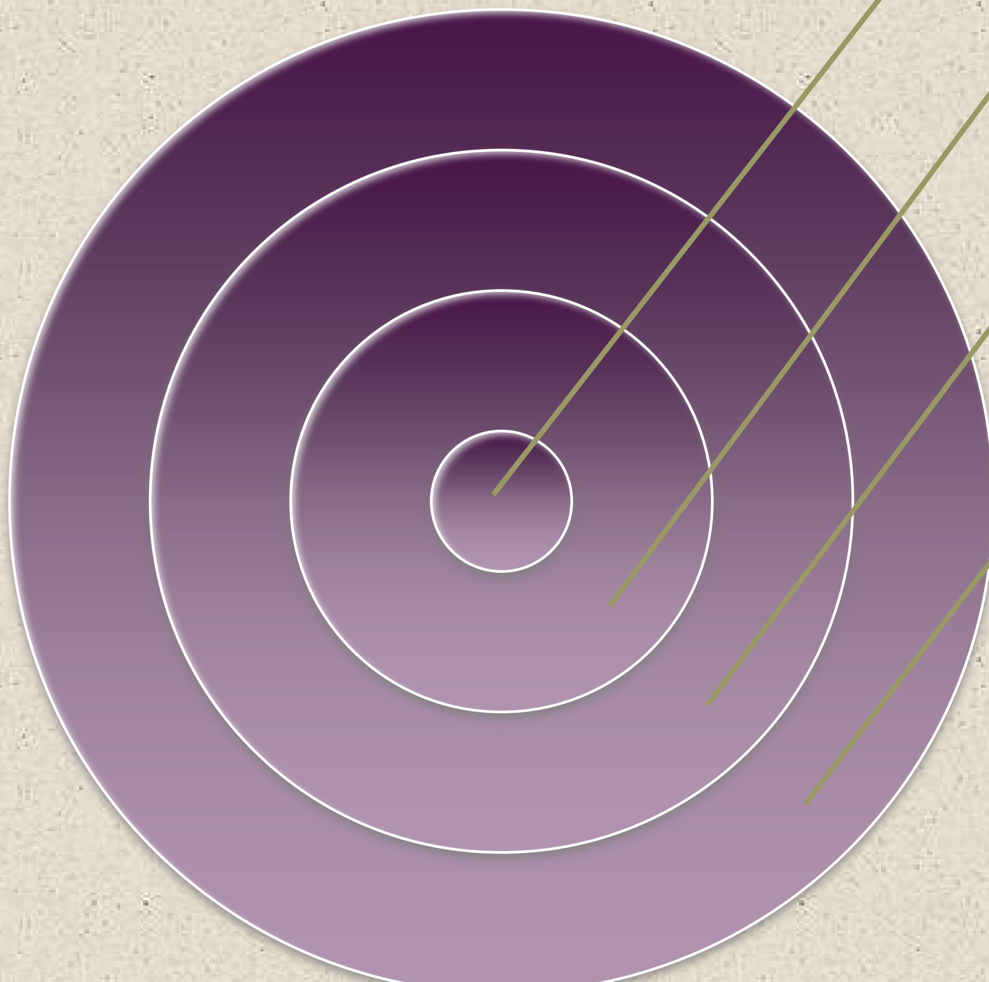
Diminishing Returns

- Internal organization of processors complex
  - Can get a great deal of parallelism
  - Further significant increases likely to be relatively modest
- Benefits from cache are reaching limit
- Increasing clock rate runs into power dissipation problem
  - Some fundamental physical limits are being reached

Processor Trends



Multicore



- The use of multiple processors on the same chip provides the potential to increase performance without increasing the clock rate
- Strategy is to use two simpler processors on the chip rather than one more complex processor
- With two processors larger caches are justified
- As caches became larger it made performance sense to create two and then three levels of cache on a chip

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Many Integrated Core (MIC) Graphics Processing Unit (GPU)

MIC	GPU
▪ Leap in performance as well as the challenges in developing software to exploit such a large number of cores ▪ The multicore and MIC strategy involves a homogeneous collection of general purpose processors on a single chip	▪ Core designed to perform parallel operations on graphics data ▪ Traditionally found on a plug-in graphics card, it is used to encode and render 2D and 3D graphics as well as process video ▪ Used as vector processors for a variety of applications that require repetitive computations

Overview

- Results of decades of design effort on complex instruction set computers (CISCs)
- Excellent example of CISC design
- Incorporates the sophisticated design principles once found only on mainframes and supercomputers
- An alternative approach to processor design is the reduced instruction set computer (RISC)
- The ARM architecture is used in a wide variety of embedded systems and is one of the most powerful and best designed RISC based systems on the market
- In terms of market share Intel is ranked as the number one maker of microprocessors for non-embedded systems

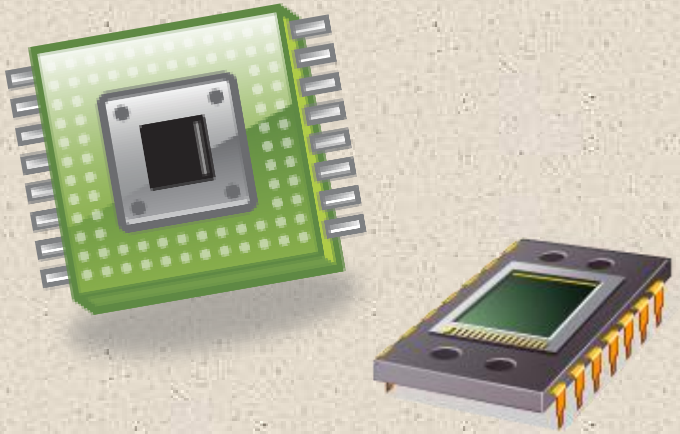
ARM

Intel

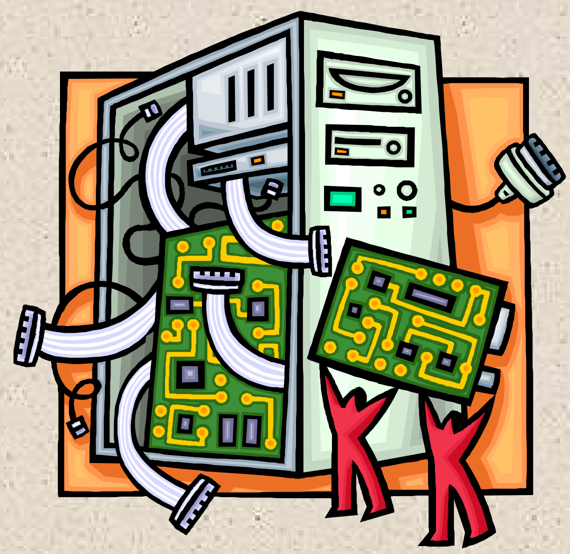
x86 Architecture

CISC

RISC



x86 Evolution



8080

- First general purpose microprocessor
- 8-bit machine with an 8-bit data path to memory
- Used in the first personal computer (Altair)

8086

- 16-bit machine
- Used an instruction cache, or queue
- First appearance of the x86 architecture

8088

- used in IBM's first personal computer

80286

- Enabled addressing a 16-MByte memory instead of just 1 MByte

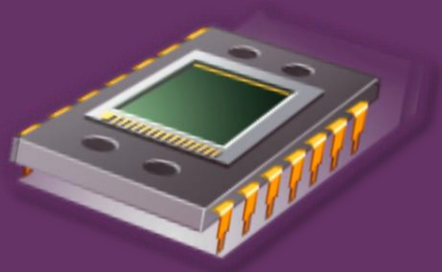
80386

- Intel's first 32-bit machine
- First Intel processor to support multitasking

80486

- More sophisticated cache technology and instruction pipelining
- Built-in math coprocessor

x86 Evolution - Pentium



Pentium

- Superscalar
- Multiple instructions executed in parallel

Pentium Pro

- Increased superscalar organization
- Aggressive register renaming
- Branch prediction
- Data flow analysis
- Speculative execution

Pentium II

- MMX technology
- Designed specifically to process video, audio, and graphics data

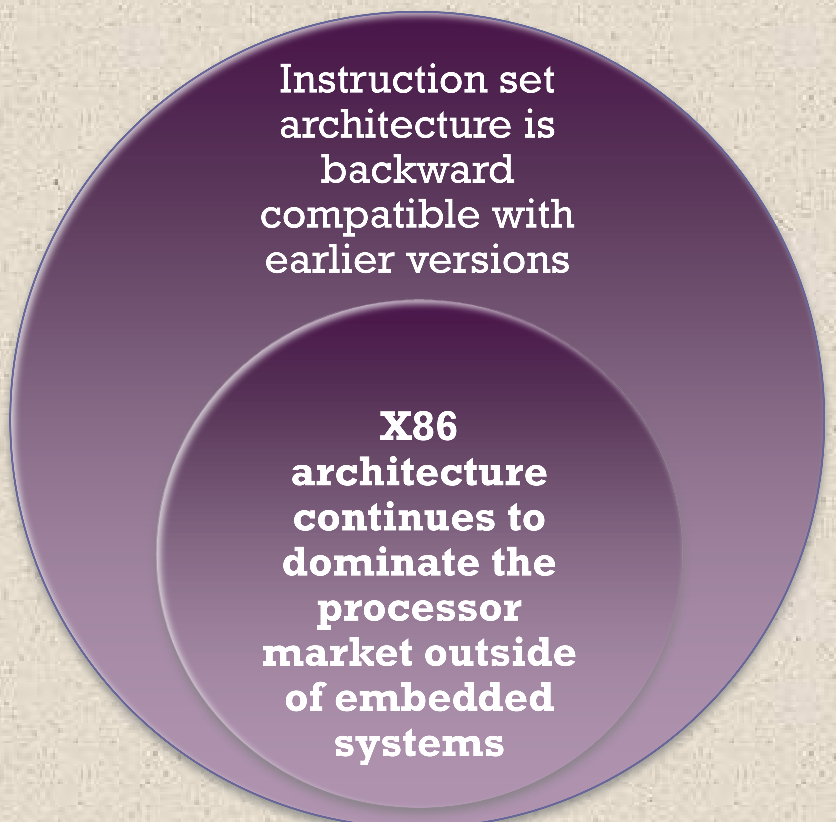
Pentium III

- Additional floating-point instructions to support 3D graphics software

Pentium 4

- Includes additional floating-point and other enhancements for multimedia

x86 Evolution (continued)



- Core
  - First Intel x86 microprocessor with a dual core, referring to the implementation of two processors on a single chip
- Core 2
  - Extends the architecture to 64 bits
  - Recent Core offerings have up to 10 processors per chip

Embedded

Systems

General definition:

"A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function. In many cases, embedded systems are part of a larger system or product, as in the case of an antilock braking system in a car."

Table 2.7
Examples of Embedded Systems and Their Markets

Market	Embedded Device
Automotive	Ignition system Engine control Brake system
Consumer electronics	Digital and analog televisions Set-top boxes (DVDs, VCRs, Cable boxes) Personal digital assistants (PDAs) Kitchen appliances (refrigerators, toasters, microwave ovens) Automobiles Toys/games Telephones/cell phones/pagers Cameras Global positioning systems
Industrial control	Robotics and controls systems for manufacturing Sensors
Medical	Infusion pumps Dialysis machines Prosthetic devices Cardiac monitors
Office automation	Fax machine Photocopier Printers Monitors Scanners

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Embedded Systems

Requirements and Constraints

Small to large systems, implying different cost constraints and different needs for optimization and reuse

Relaxed to very strict requirements and combinations of different quality requirements with respect to safety, reliability, real-time and flexibility

Short to long life times

Different environmental conditions in terms of radiation, vibrations, and humidity

Different application characteristics resulting in static versus dynamic loads, slow to fast speed, compute versus interface intensive tasks, and/or combinations thereof

Different models of computation ranging from discrete event systems to hybrid systems

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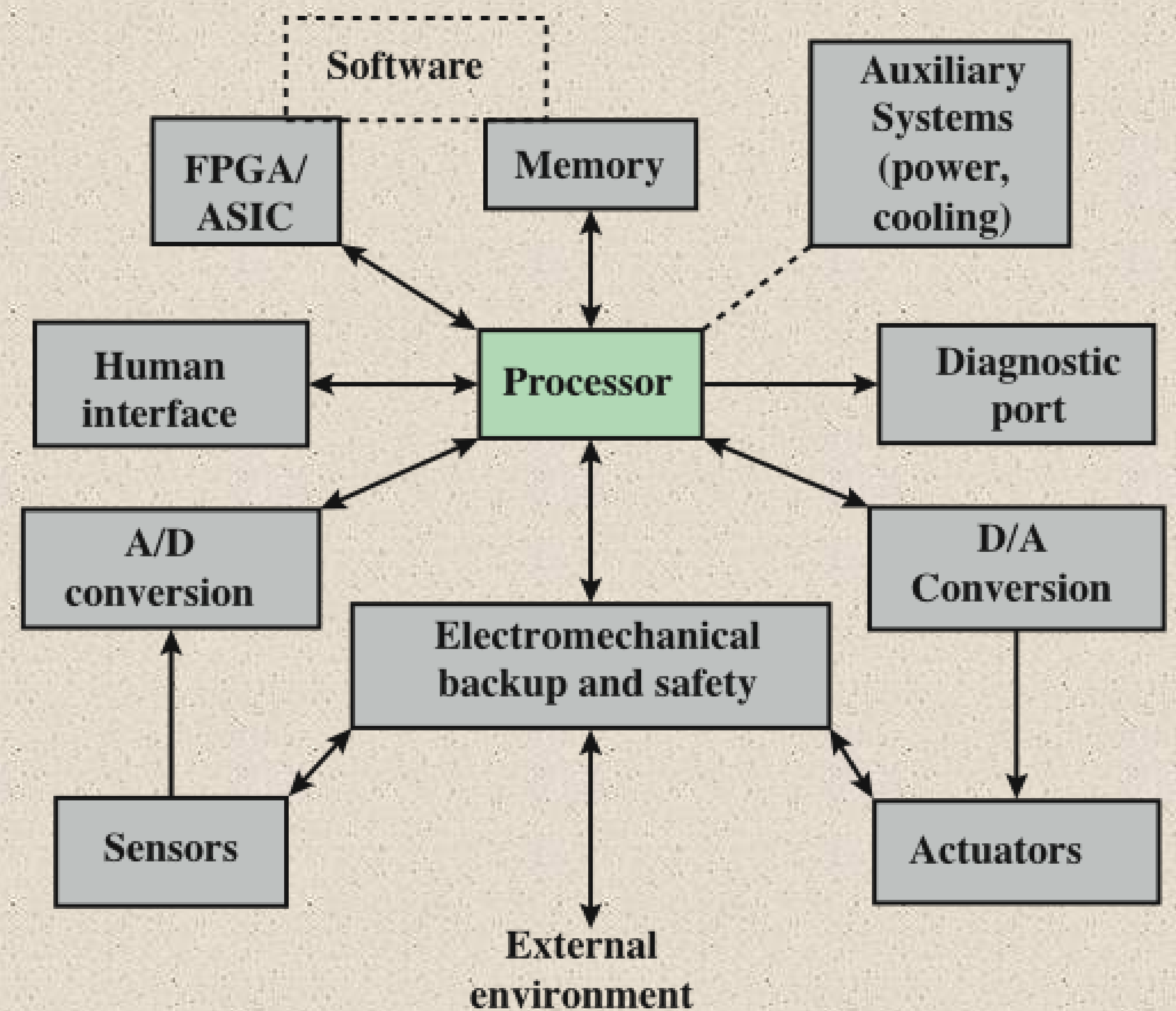
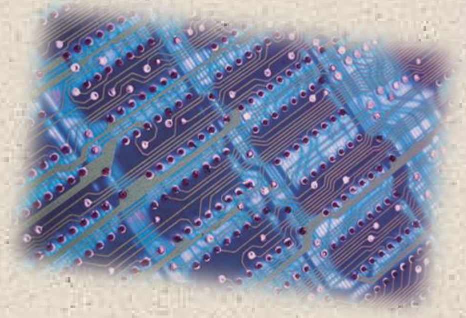
Figure 2.12
Possible Organization of an Embedded System



Acorn RISC Machine (ARM)

- Family of RISC-based microprocessors and microcontrollers
- Designs microprocessor and multicore architectures and licenses them to manufacturers
- Chips are high-speed processors that are known for their small die size and low power requirements
- Widely used in PDAs and other handheld devices
- Chips are the processors in iPod and iPhone devices
- Most widely used embedded processor architecture
- Most widely used processor architecture of any kind



ARM Evolution

Family	Notable Features	Cache	Typical MIPS @ MHz
ARM1	32-bit RISC	None	
ARM2	Multiply and swap instructions; Integrated memory management unit, graphics and I/O processor	None	7 MIPS @ 12 MHz
ARM3	First use of processor cache	4 KB unified	12 MIPS @ 25 MHz
ARM6	First to support 32-bit addresses; floating-point unit	4 KB unified	28 MIPS @ 33 MHz
ARM7	Integrated SoC	8 KB unified	60 MIPS @ 60 MHz
ARM8	5-stage pipeline; static branch prediction	8 KB unified	84 MIPS @ 72 MHz
ARM9		16 KB/16 KB	300 MIPS @ 300 MHz
ARM9E	Enhanced DSP instructions	16 KB/16 KB	220 MIPS @ 200 MHz
ARM10E	6-stage pipeline	32 KB/32 KB	
ARM11	9-stage pipeline	Variable	740 MIPS @ 665 MHz
Cortex	13-stage superscalar pipeline	Variable	2000 MIPS @ 1 GHz
XScale	Applications processor; 7-stage pipeline	32 KB/32 KB L1 512 KB L2	1000 MIPS @ 1.25 GHz

DSP = digital signal processor

SoC = system on a chip

ARM Design Categories

- ARM processors are designed to meet the needs of three system categories:

- Secure applications
  - Smart cards, SIM cards, and payment terminals

- Embedded real-time systems
  - Systems for storage, automotive body and power-train, industrial, and networking applications

- Application platforms
  - Devices running open operating systems including Linux, Palm OS, Symbian OS, and Windows CE in wireless, consumer entertainment and digital imaging applications