CPE 746 Embedded Real-Time Systems-Fall06

Introduction to Types of RTSs

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Embedded Systems

- An embedded system is a special-purpose system in which the computer is completely encapsulated by the device it controls.
- Unlike a general-purpose computer, such as a personal computer, an embedded system performs pre-defined tasks, usually with very specific requirements.
- Since the system is dedicated to a specific task, design engineers can optimize it, reducing the size and cost of the product.
- Embedded systems are often mass-produced, so the cost savings may be multiplied by millions of items.

Main Components

- It is divided into 4 segments namely: embedded processors, embedded software, embedded boards and embedded memory.

  - Embedded processors is divided into microcontroller (MCU), microprocessor (MPU), and digital signal processor (DSP) segments.

  - Embedded Memory includes various types of random access memory (RAM) and programmable read-only memory (PROM) memory, as well as flash memory.

  - Software for embedded applications which includes real-time operating systems (RTOS) and portable operating systems

Embedded operating system

- An embedded operating system is an operating system dedicated for embedded computer system.
- These operating systems are designed to be very compact and efficient. with many functionalities that non-embedded computer operating systems provide. and which may not be used by the specialized applications they run.
- They are frequently also Real time operating system
- Examples Embedded Linux , QNX , Windows CE ,Windows XP Embedded

Real-time operating system (RTOS)

- Is a class of operating system intended for Real-time applications.
- RTOS will typically use specialized scheduling algorithms in order to provide the real-time developer with the tools necessary to produce deterministic behavior in the final system.
- Tow type of RTOS

  - An event-driven operating system.

  - A time-sharing design switches tasks on a clock interrupt .

Real Time Constraints

- Many Embedded Systems must meet real-time constraints
  - A real-time system must react to stimuli from the controlled object (or the operator) within the time interval dictated by the environment.
  - For real-time systems, right answers arriving too late are wrong.

- Frequently connected to physical environment through sensors and actuators.

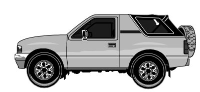
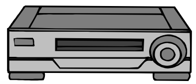
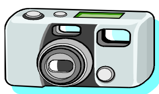
- Event-driven (RTOS) mapped between the percepts (sensors) and the proportional acts.

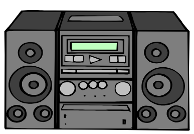
Embedded Systems Market

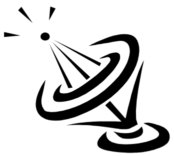
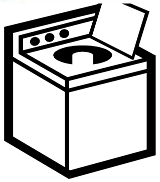
- Anti-lock brakes
- Auto-focus cameras
- Automatic teller machines
- Automatic toll systems
- Automatic transmission
- Avionic systems
- Battery chargers
- Camcorders
- Cell phones
- Cell-phone base stations
- Cordless phones
- Cruise control
- Curbside check-in systems
- Digital cameras
- Disk drives
- Electronic card readers
- Electronic instruments
- Electronic toys/games
- Factory control
- Fax machines
- Fingerprint identifiers
- Home security systems
- Life-support systems
- Medical testing systems
- Modems
- MPEG decoders
- Network cards
- Network switches/routers
- On-board navigation
- Pagers
- Photocopiers
- Point-of-sale systems
- Portable video games
- Printers
- Satellite phones
- Scanners
- Smart ovens/dishwashers
- Speech recognizers
- Stereo systems
- Teleconferencing system
- Televisions
- Temperature controllers
- Theft tracking systems
- TV set-top boxes
- VCR's, DVD players
- Video game consoles
- Video phones
- Washers and dryers







Embedded systems from real life (Cars)

- Multiple processors
  - Up to 100 Networked together
- Multiple networks
  - Body, engine, telemetric, media, safety

- Large diversity in processor types:
  - 8-bit – door locks, lights, etc.
  - 16-bit – most functions
  - 32-bit – engine control, airbags

- Functions by embedded processing:
  - ABS: Anti-lock braking systems
  - ESP: Electronic stability control
  - Airbags
  - Efficient automatic gearboxes
  - Theft prevention with smart keys
  - Blind-angle alert systems
  - ... etc ...

The future is embedded, Embedded is the future!

- Growing economical importance of embedded systems: Worldwide
  - mobile phone sales surpassed 156.4 mln units in Q2 2004,

    a 35% increase from Q2 2003
  - The worldwide portable flash player market exploded in 2003 and is expected to grow from 12.5 mln units in 2003 to over 50 mln units in 2008.
  - The number of broadband lines worldwide increased by almost 55% to over 123 mln in the 12 months to the end of June 2004.
  - Today's DVR (digital video recorders) users - 5% of households - will grow to 41% within five years.
  - 79% of all high-end processors are used in embedded systems.
  - Cars market , peripheral computer devices ……………

What's the market for Embedded Systems?

- The world market for embedded systems development is around $250 billion and is expected to grow at 26%
- Cisco, Wind River Systems, Sun Microsystems, Integrated Systems, Microware Systems, and QNX Software Systems are among the prominent developers of embedded systems.
- According to a study, Future of Embedded Systems Technologies, the market for embedded systems is expected to grow at an average annual growth rate of 16% over the period.

What's the future of embedded systems in the world (in India as an example)?

•At present India exports embedded systems worth to the tune of $+10 billion and this could grow to $50 billion within two to three years.

•Embedded system requires considerable domain knowledge, say in automotive, telecom or medical for which the system has to be designed.

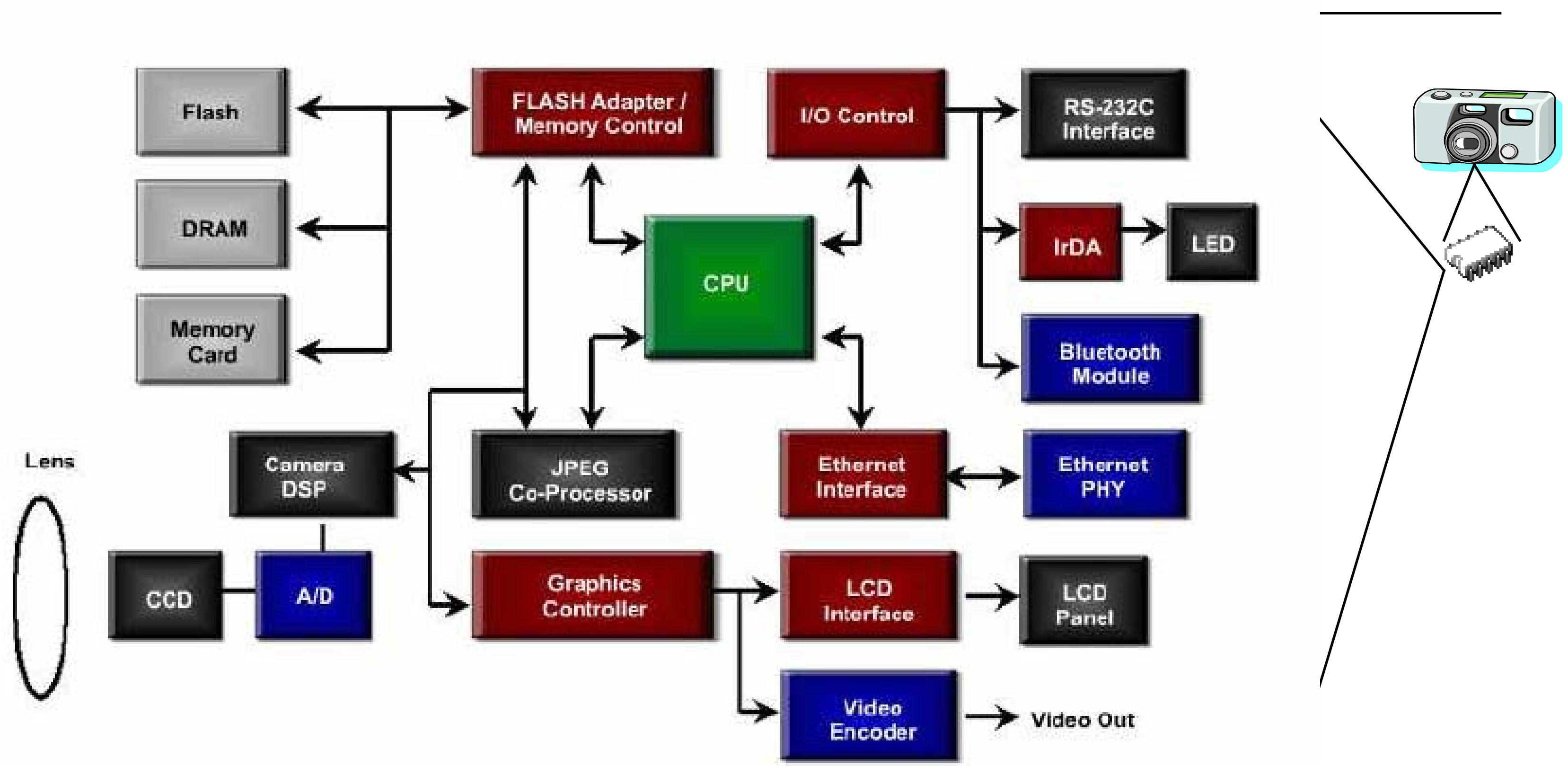
• 15% of HCL staff is working on embedded systems. It contributes more than 30% of HCL Technologies revenues.

•Wipro has around 4,000 people in embedded systems. If the telecom services are included then the number goes up to 9,000.

Common Characteristics of Embedded Systems

- Single-functioned
  - Executes a single program, repeatedly
- Tightly-constrained
  - Low cost, low power, small, fast, etc.
- Reactive and real-time
  - Continually reacts to changes in the system's environment
  - Must compute certain results in real-time without delay

An embedded system example -- a digital camera



- Single-functioned -- always a digital camera
- Tightly-constrained -- Low cost, low power, small, fast
- Reactive and real-time.

Optimizing Design Metrics

- Common metrics
  - **Unit cost**: the monetary cost of manufacturing each copy of the system, excluding NRE cost
  - **NRE** cost (Non- Recurring Engineering cost): The one-time cost of designing the system
  - **Size**: the physical space required by the system
  - **Performance**: the execution time or throughput of the system
  - **Power**: the amount of power consumed by the system
  - **Flexibility**: the ability to change the functionality of the system without incurring heavy NRE cost
  - **Time-to-prototype**: the time needed to build a working version of the system
  - **Time-to-market**: the time required to develop a system to the point that it can be released and sold to customers
  - **Maintainability**: the ability to modify the system after its initial release
  - **Correctness**, **safety**, **many more**

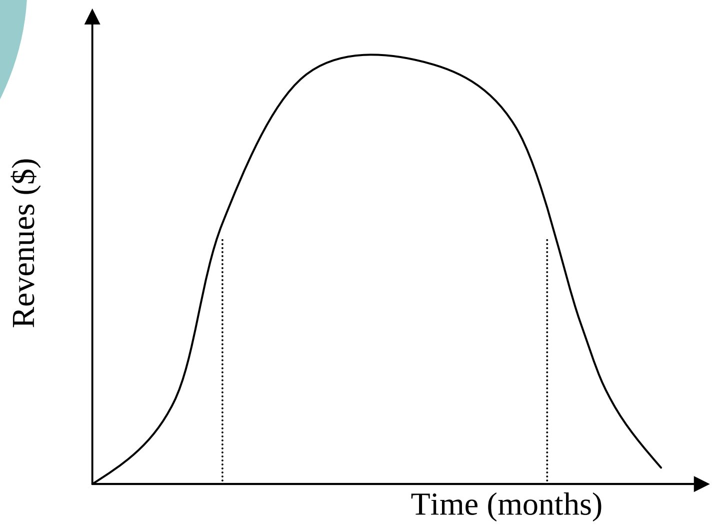
NRE and unit cost metrics

- Costs:
  - Unit cost: the monetary cost of manufacturing each copy of the system, excluding NRE cost
  - NRE cost (Non-Recurring Engineering cost): The one-time monetary cost of designing the system
  - *total cost = NRE cost + unit cost * # of units*
  - *per-product cost = total cost / # of units*

    cost = (NRE cost / # of units) + unit cost

  - Example
    - NRE=$2000, unit=$100
    - For 10 units
      - total cost = $2000 + 10*$100 = $3000
      - per-product cost = $2000/10 + $100 = $300

Time-to-market: a demanding design metric



- Time required to develop a product to the point it can be sold to customers
- Market window
  - Period during which the product would have highest sales
- Average time-to-market constraint is about 8 months
- Delays can be costly

The performance design metric

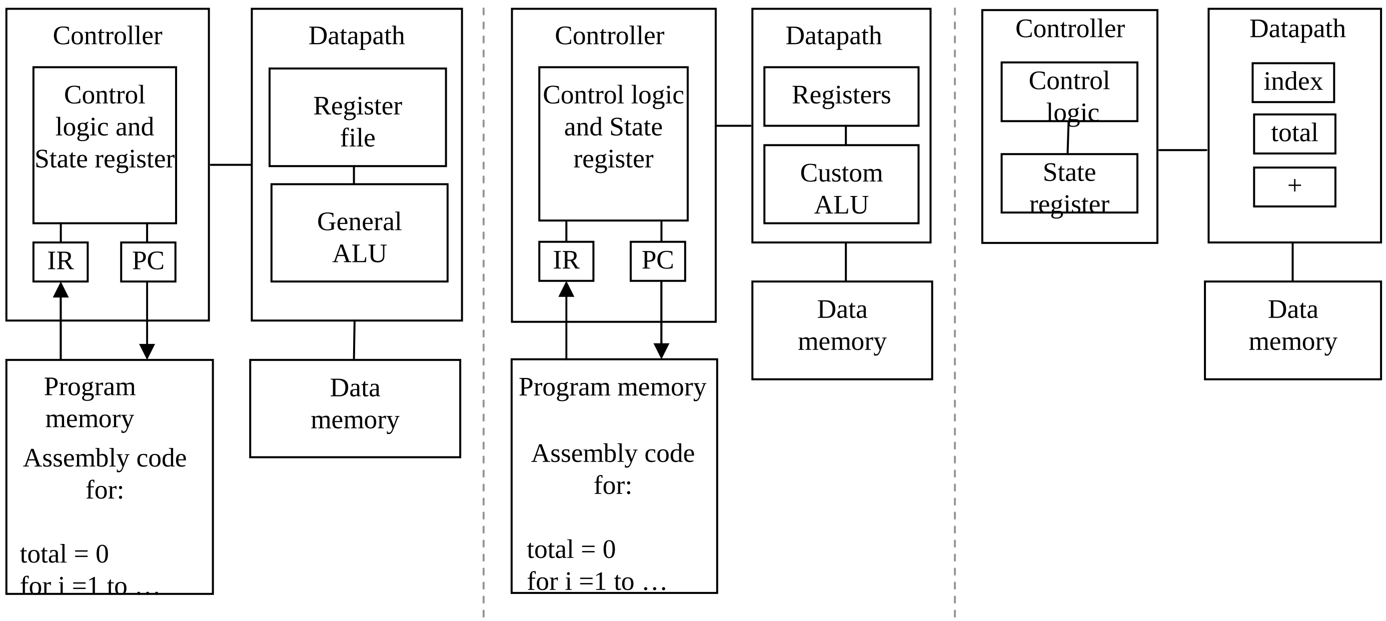
- Widely-used measure of system
  - Clock frequency, instructions per second – not good measures
  - Digital camera example – a user cares about how fast it processes images, not clock speed or instructions per second
- Latency (response time)
  - Time between task start and end
  - e.g., Camera A process images in 0.25 seconds
- Throughput
  - Tasks per second, e.g. Camera A processes 4 images per second
  - Throughput can be more than latency seems to imply due to concurrency, e.g. Camera B may process 8 images per second (by capturing a new image while previous image is being stored).

Embedded system technologies

- Technology
  - A manner of accomplishing a task, especially using technical processes, methods, or knowledge
- Three key technologies for embedded systems
  - Processor technology
  - IC technology
  - Design technology

Processor technology

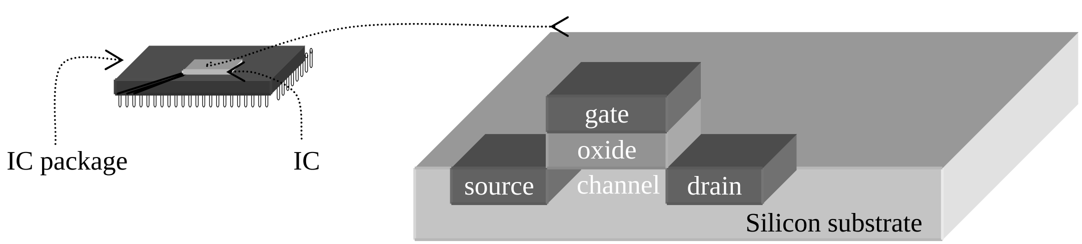
- The architecture of the computation engine used to implement a system's desired functionality
- Processor does not have to be programmable
  - "Processor" *not* equal to general-purpose processor



General-purpose ("software") **Application-specific** **Single-purpose** ("hardware")

IC technology

- The manner in which a digital (gate-level) implementation is mapped onto an IC
  - IC: Integrated circuit, or “chip”
  - IC technologies differ in their customization to a design
  - IC’s consist of numerous layers (perhaps 10 or more)
    - IC technologies differ with respect to who builds each layer and when

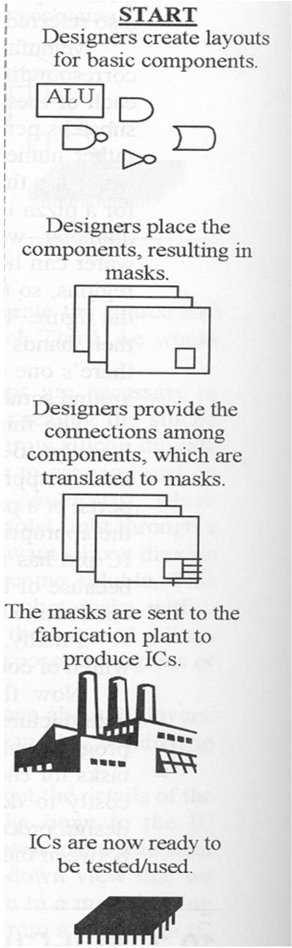


IC technology

- Three types of IC technologies
  - Full-custom (VLSI)
  - Semi-custom (ASIC)
  - PLD (Programmable Logic Device) (FPGA)

Full Custom

- Very Large Scale Integration (VLSI)
  - All layers are optimized.
- Placement
  - Place and orient transistors.
- Routing
  - Connect transistors
- Benefits
  - Excellent performance, small size, low power
- Drawbacks
  - High cost long, time-to-market



Semi-custom (ASIC)

- Lower layers are fully or partially built
  - Designers are left with routing of wires and maybe placing some blocks
- Benefits
  - Good performance, good size, less NRE cost than a full-custom implementation (perhaps $10k to $100k)
- Drawbacks
  - Still require weeks to months to develop

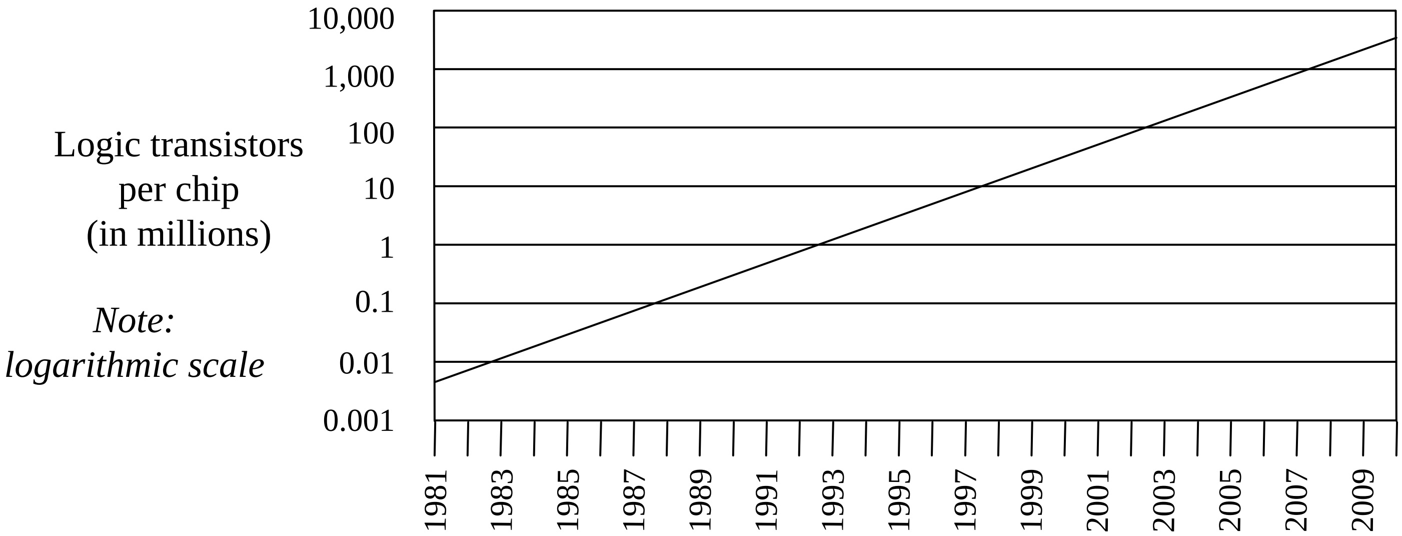
PLD (Programmable Logic Device)

- (FPGA) Field Programmable Gate Array
- All layers already exist
  - Designers can purchase an IC
  - Connections on the IC are either created or destroyed to implement desired functionality.
  - Field-Programmable Gate Array (FPGA) very popular
- Benefits
  - Low NRE costs, almost instant IC availability.
  - Great time to market
- Drawbacks
  - Bigger, expensive (perhaps $30 per unit), power hungry, slower

Moore's law

- The most important trend in embedded systems
  - Predicted in 1965 by Intel co-founder Gordon Moore

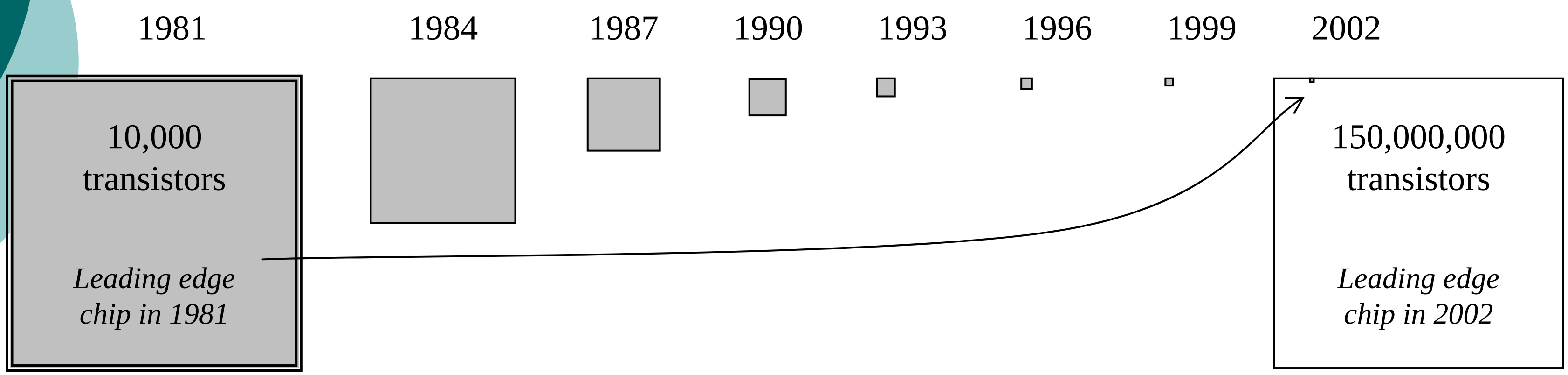
IC transistor capacity has doubled roughly every 18 months for the past several decades



Moore's law

- This growth rate is hard to imagine, most people underestimate
- How many ancestors do you have from 20 generations ago
  - i.e., roughly how many people alive in the 1500's did it take to make you?
  - 2^{20} = more than *1 million people*
- *(This underestimation is the key to pyramid schemes!)*

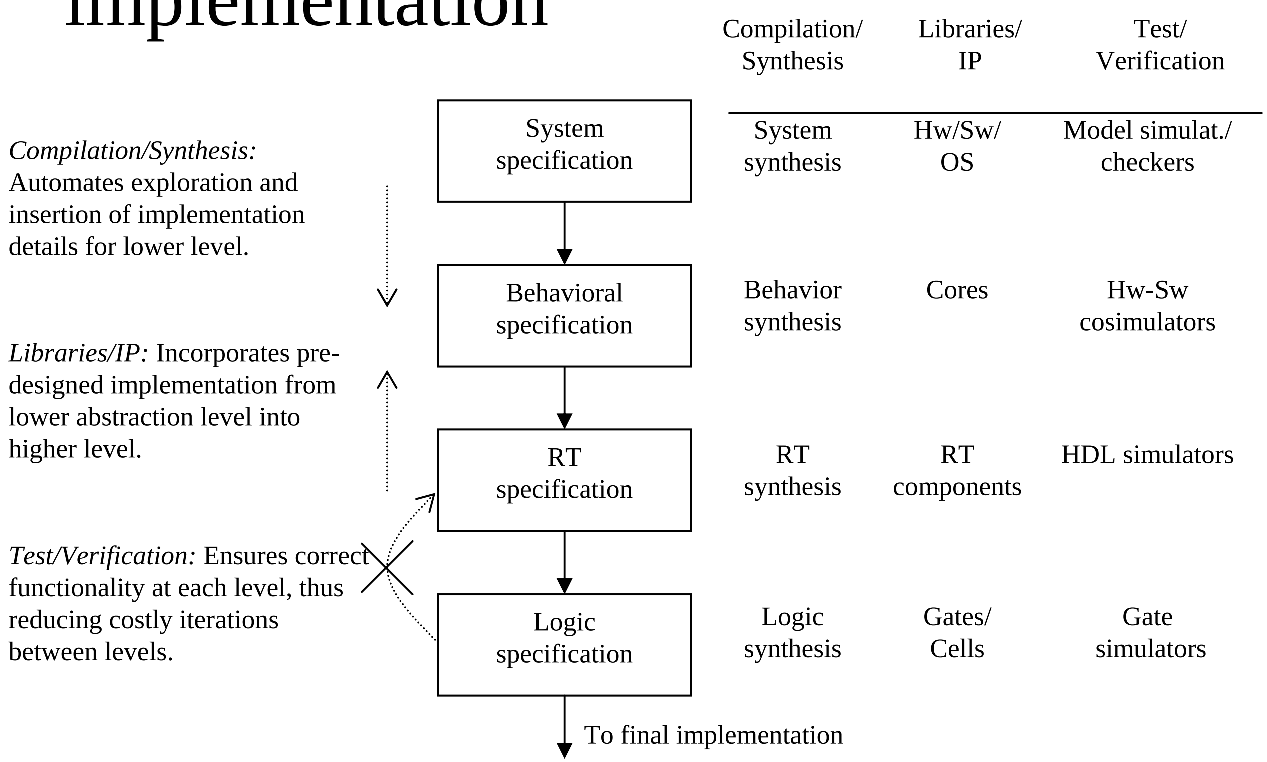
Graphical illustration of Moore's law



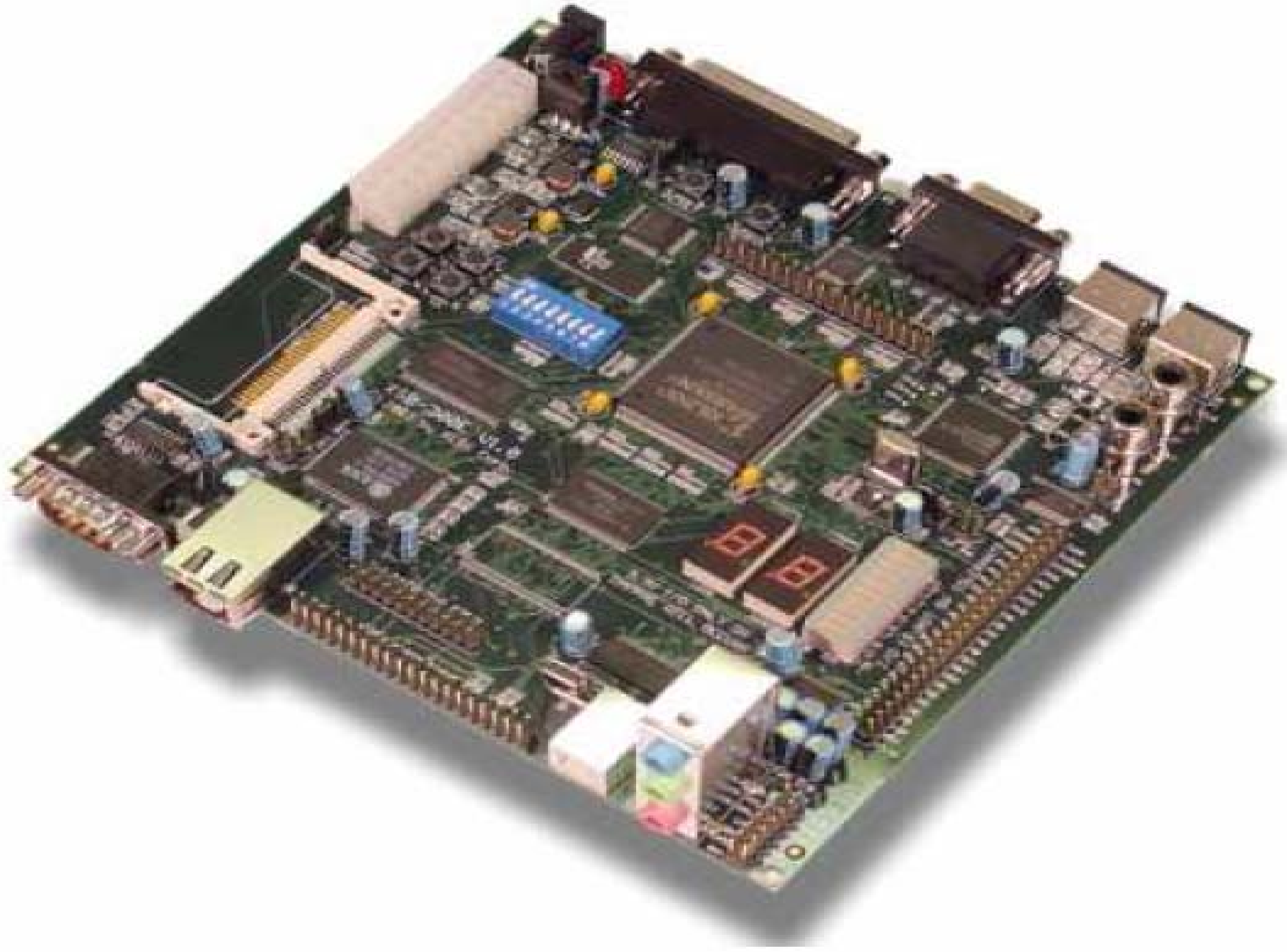
- Something that doubles frequently grows more quickly than most people realize!
  - A 2002 chip can hold about 15,000 1981 chips inside itself

Design Technology

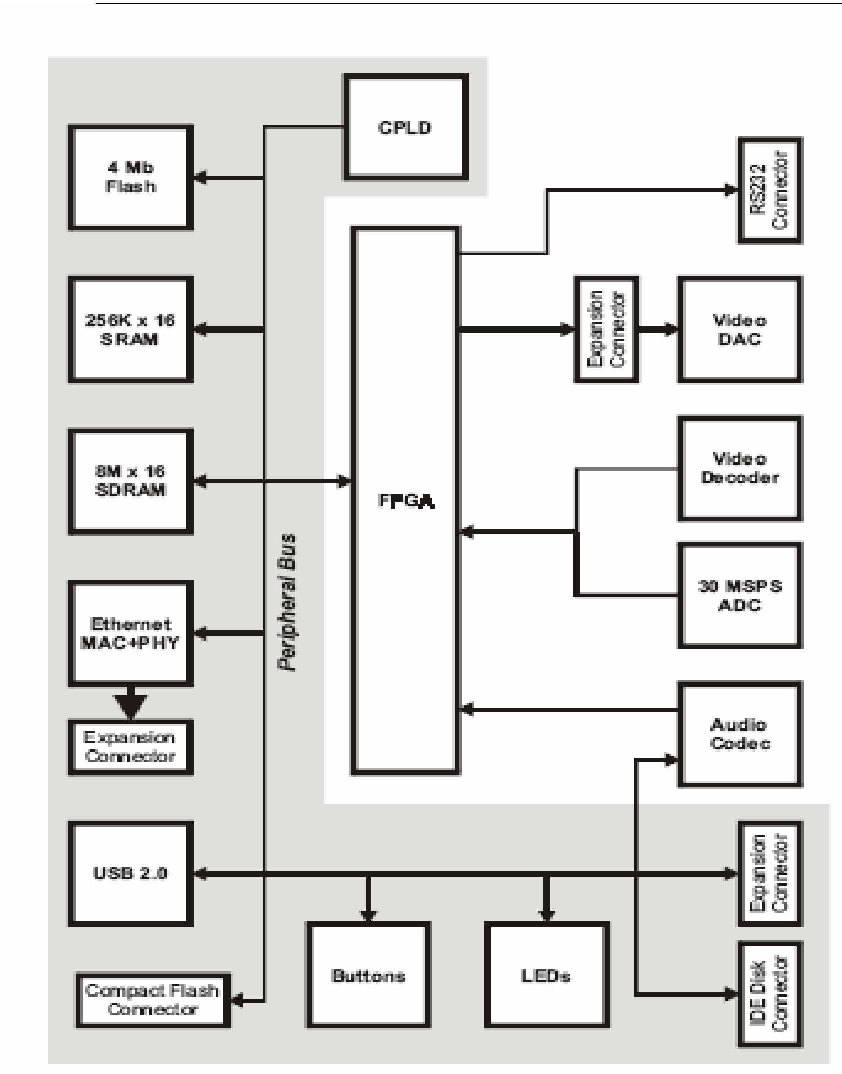
- The manner in which we convert our concept of desired system functionality into an implementation



Detailed Example



Detailed Example



XC2S300E FPGA
XC9572 CPLD
256K x 16 SRAM
8M x 16 SDRAM
512K x 8 Flash
6-channel NTSC video decoder
12-bit, 30 MSPS ADC
80 MHz, 30-bit video DAC
20-bit, 4-input, 1-output stereo codec
Microphone/line-in/line-out jacks
10/100 Ethernet MAC+PHY
USB 2.0 peripheral port
Six pushbuttons, DIP switch
Two LED digits, barograph
Three programmable oscillators
Two expansion headers w/ 75 I/O pins
Peripheral header w/ 18 I/O pins
Parallel and Serial port
Compact Flash interface
IDE hard disk interface
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Summary

- Embedded systems are everywhere
- Key challenge: optimization of design metrics
  - Design metrics compete with one another
- A unified view of hardware and software is necessary to improve productivity
- Three key technologies
  - Processor: general-purpose, application-specific, single-purpose
  - IC: Full-custom, semi-custom, PLD
  - Design: Compilation/synthesis, libraries/IP, test/verification