Revolutions towards Embedded Systems

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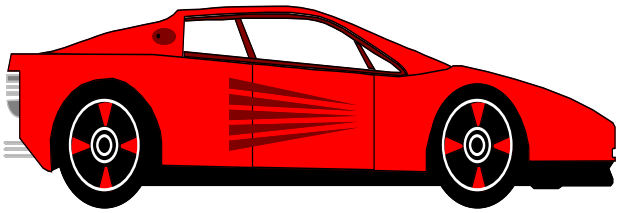
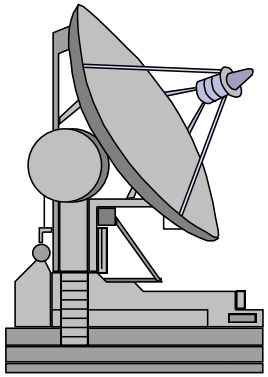
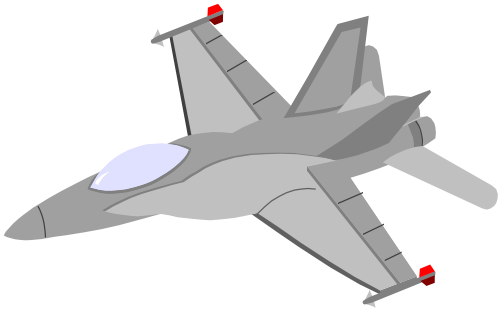
Lecture References:

- Book:
  - *Embedded System Design*, **Author:** P. Marwedel
  - *Embedded System Design: An Introduction to Processes, Tools and Techniques*, **Author:** Arnold Berger, Arnold S. Berger
- Lecture Materials:
  - http://webct.edtec.unsw.edu.au/
  - *Saeid Nooshabadi*, Microprocessor and Interfacing

What is an Embedded System ??







Examples of Embedded Systems

Office systems and mobile equipment	Building systems	Manufacturing and Process Control
Answering machines	Air conditioning	Automated factories
Copiers	Backup lighting and generators	Bottling plants
Faxes	Building management systems	Energy control systems
Laptops and notebooks	CCTV systems	Manufacturing plants
Mobile Telephones	Fire Control systems	Nuclear power stations
PDAs, Personal organisers	Heating and ventilating systems	Oil refineries and related storage facilities
Still and video cameras	Lifts, elevators, escalators	Power grid systems
Telephone systems	Lighting systems	Power stations
Time recording systems	Security systems	Robots
Printer	Security cameras	Switching systems
Microwave	Sprinkler systems	Water and sewage systems

Example of Embedded Systems

Transport	Communications	Other equipment
Aeroplanes Trains Buses Marine craft Jetties Automobiles Air Traffic Control Signalling Systems Radar Systems Traffic Lights Ticketing machines Speed cameras, Radar speed detectors	Telephone systems Cable systems Telephone switches Satellites Global Positioning System	Automated teller systems Credit card systems Medical Imaging equipment Domestic Central Heating control VCRs

Automotive Embedded Systems

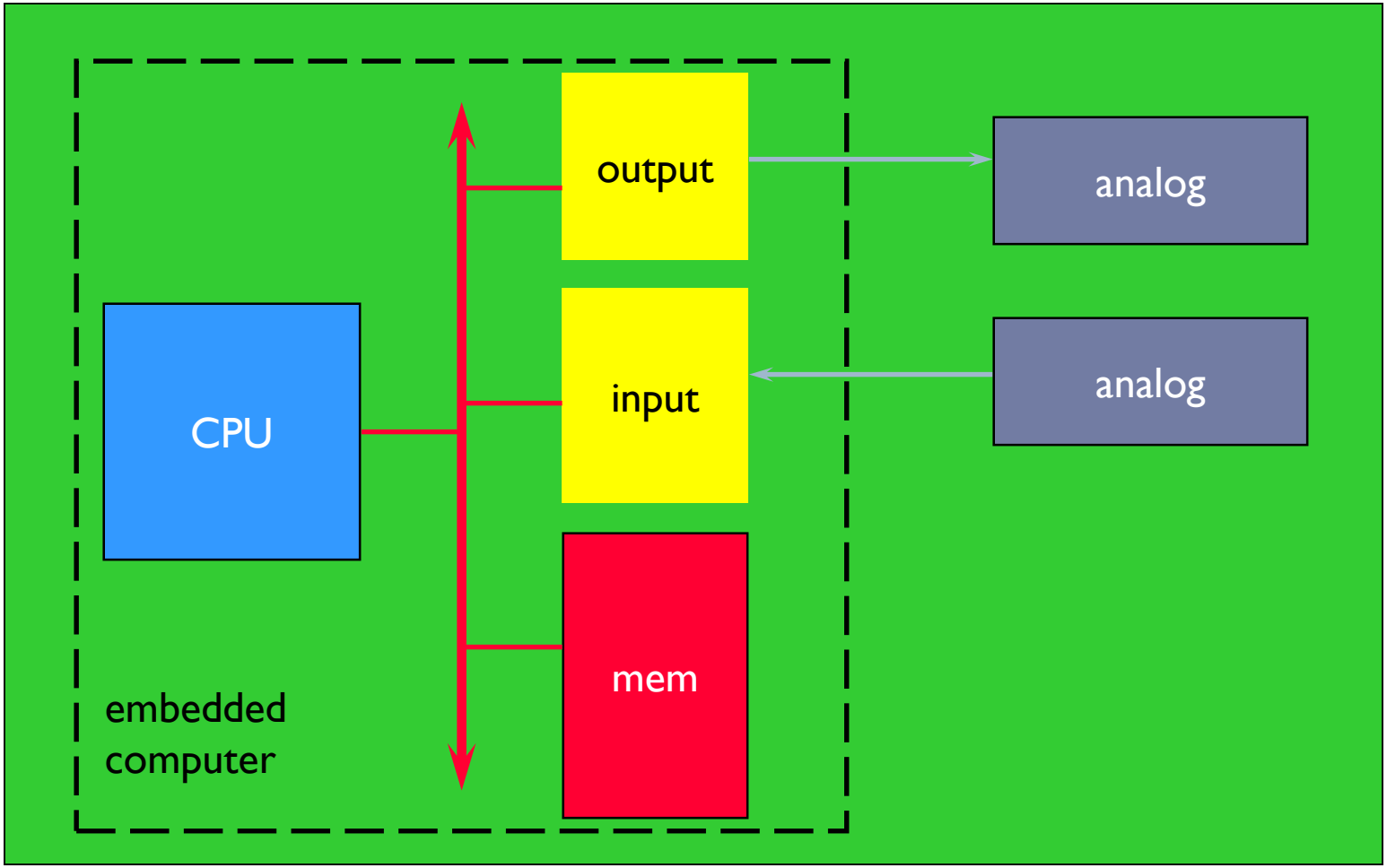
- Today's high-end automobile may have 100 microprocessors:
  - 4-bit microcontroller checks seat belt;
  - Microcontrollers run dashboard devices;
  - 16/32-bit microprocessor controls engine.

- **Example:**
- BMW 850i brake and stability control system
  - **Anti-lock brake system (ABS):** pumps brakes to reduce skidding.
  - **Automatic stability control (ASC+T):** controls engine to improve stability.
  - ABS and ASC+T communicate.
    - ABS was introduced first---needed to interface to existing ABS module.

Embedded Systems Rule the Market

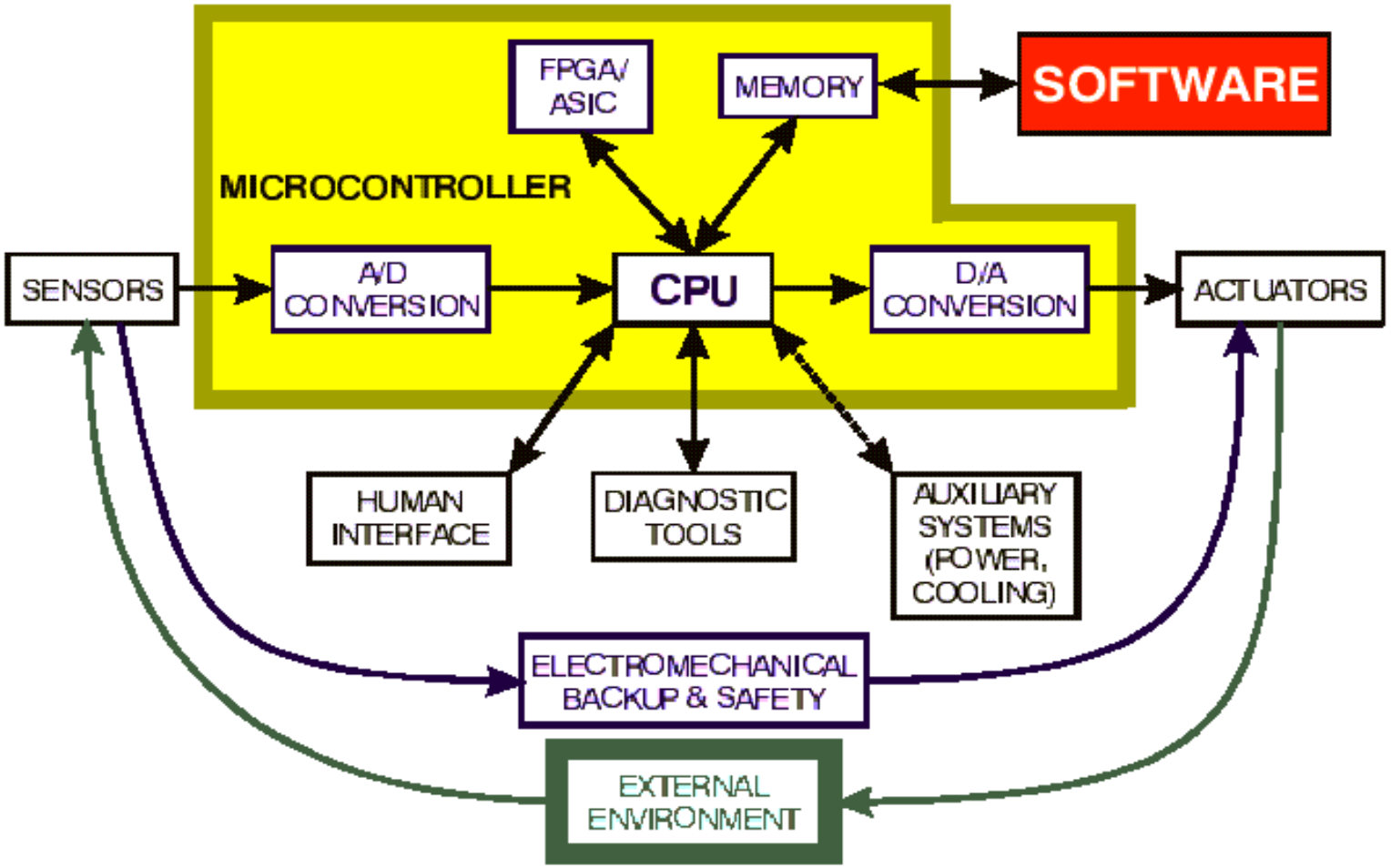
- **80 Million PCs vs. 3 Billion Embedded CPUs Annually**
- Embedded market is growing; whereas PC market is mostly saturated

Embedding a Computer



An Embedded Control System Designer's View

- **Measured by: Cost, Time-to-market, Cost, Functionality, Cost & Cost.**



A Customer View

- **Reduced Cost**
- **Increased Functionality**
- **Improved Performance**
- **Increased Overall Dependability**
  - (Debatable, but can be true)

At the high end of the scale

Processor: Intel Pentium 4
Frequency: 3.2GHz
Power consumption: 103 W
*Intel document no. 300561-002

At the low end of the scale

Processor can consume no more than 250-300mW

Embedded Devices

Computer Technology → Dramatic Change

- Processor
  - 2X in speed every 1.5 years;
    100X performance in last decade
- Memory
  - DRAM capacity: 2X / 2 years; **64X size in last decade**
  - Cost per bit: improves about 25% per year
- Disk
  - capacity: > 2X in size every 1.0 years
  - Cost per bit: improves about 100% per year
  - **250X size in last decade**

Computer Technology → Dramatic Change!

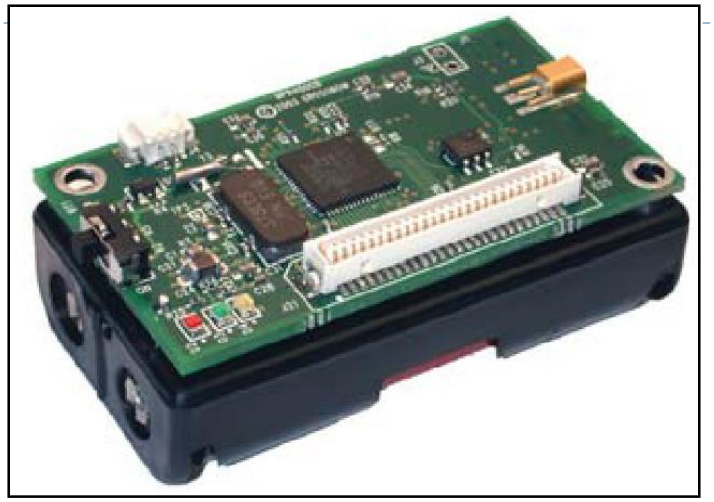
- State-of-the-art PC when you graduate:
  (at least…)
  - Processor clock speed: 5000 MegaHertz (5.0 GigaHertz)
  - Memory capacity: 4000 MegaBytes (8.0 GigaBytes)
  - Disk capacity: 2000 GigaBytes (2.0 TeraBytes)
  - New units! Mega => Giga, Giga => Tera

(Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta = 10^{24})

Now a days, Kilo, Mega, etc. are incorrect Terminologies!

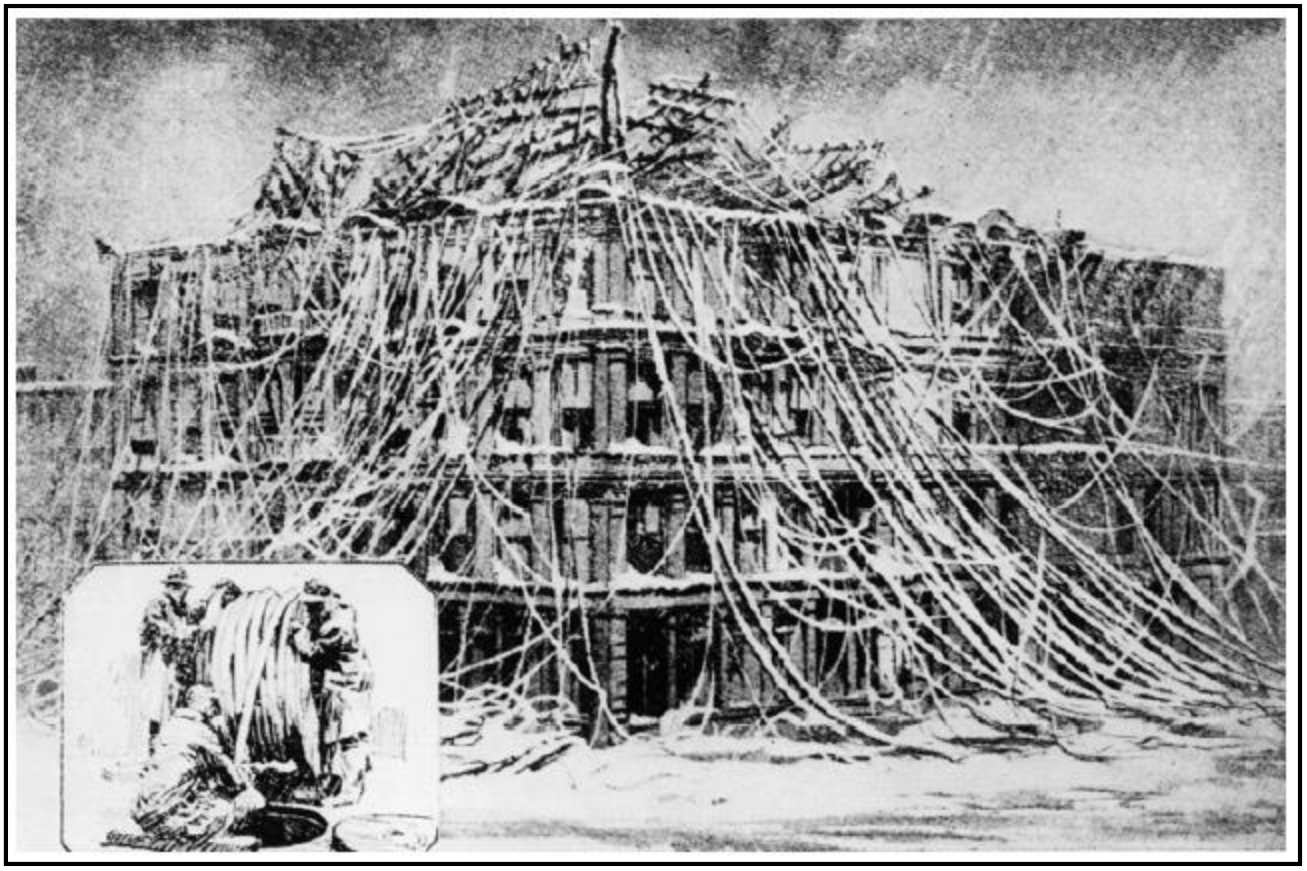
Computer Technology → Dramatic Change!

Another Example of Computer Revolution



Original IBM PC (1981)	*MICAZ Mote (2005)*
4.77 MHz	4 MHz
16-256 KB RAM	128 KB RAM
160 KB Floppies	512 KB Flash
~ $6K (today)	~ $35
~ 64 W	~14 mW
25 lb, 19.5 x 5.5 x 16 inch	0.5 oz, 2.25 x 1.25 x 0.25 inch

Another Revolution to Reach Here: **Wireless Revolution**



Boston central telephone station at 40 Pearl Street after the blizzard of 1881

Technology Projection Challenge for Energy: Communication/Computation

	1999 (Bluetooth Technology)	2004
Communication	(150nJ/bit)	(5nJ/bit)
	1.5mW*	50uW
Computation		~ 190 MOPS
		(5pJ/OP)

Assume: 10kbit/sec. Radio, 10 m range.

Large cost of communications relative to computation continues

Bottom Line …

- By ***Computer Systems*** we often mean
  - General-purpose, digital computers that interact with humans and possibly with each other.

- Change in Trend using ***Embedded Systems***
  - More special purpose-computers
  - More scenarios without humans in the loop
  - More environments where computing is not the explicit / main goal.

Bottom Line …

- **Computer Systems**
  - Interactive (HCI)
  - Discrete Time not counted
  - Stand-alone / Networked
  - Isolated Environment
- **Embedded Systems**
  - Reactive (Event-driven)
  - **Timeliness** is important to critical
  - Computing Component may be controlled by ***external system***
  - ***Alien Environment*** (may affect function)

Implications (*of being embedded*)

- **Low cost hardware**
  - Software Development cost (one-time) vs. Per-shipped-item cost (recurring)
- **Very Limited Storage Space**
  - Convoluted Algorithms and Aggressive Optimization
  - Space complexity !!
- **Development Environment is different from execution environment**
  - Can't do all time test-bed implementation, rather depending on simulation
  - Constrained process; innovative techniques?

Implications (***of being embedded***)

- **Long and un-interrupted running times**
  - Always running system !!
  - Can't reset flight control system or cardiac pacemaker at operation
- **Alien (Uncontrolled) Environments**
  - Harsh and human un-attendant scenario
  - Increase reliability constraints
- **Timeliness expectations**
  - Time complexity !!
  - Specific approaches for design, development and testing

Thank You !!