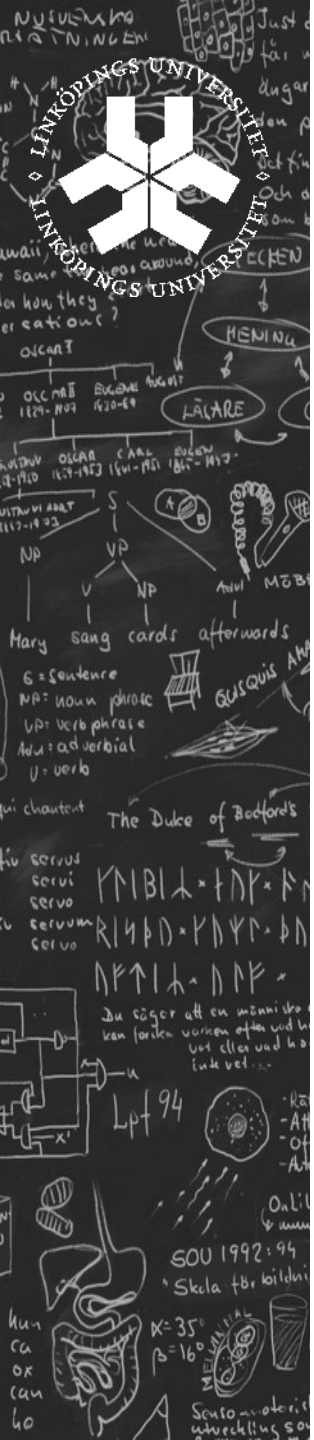


TDDI11

Embedded Software

Programmering av inbyggda system

Mikael Asplund
Department of Computer and Information Science (IDA)
Linköpings universitet
Sweden

LiU expanding reality

Course information

Course information

- Course leader: Mikael Asplund, mikael.asplund@liu.se
- Lab assistant: Ahmed Rezine, ahmed.rezine@liu.se
- Lab assistant: Nima Aghaee, nima.aghaee@liu.se
- Course adm: Madeleine Häger Dahlqvist
- Director of studies: Ahmed Rezine
- 8 Lectures
- Computer labs (13 scheduled occasions)

- 6 ECTS credits
  - Written examination: 2 ECTS
  - Labs: 4 ECTS

Labs

- Two groups: A and B
  - Identical schedule: everyone attends every lab
  - One group is assigned to one Lab assistant
- Work in pairs
- Each pair solve the labs together

- Completed lab is demonstrated to assistant
  - During scheduled lab session only
  - Both students in the pair are present
  - Both students can answer question about the solution

Material

- Course homepage: www.ida.liu.se/~TDDI11/
- **Programming Embedded systems -**
  - **An introduction to Time-Oriented Programming** by *Frank Vahid & Tony Givargis* (126 pages)
  - **With C and GNU development tools, 2nd Edition** by *Michael Barr & Anthony Massa* (301 pages)
- Articles (see web page)
- Mikrocontrollers – från assembler till RTOS
  - av Lars Bengtsson, Studentlitteratur

So what is an embedded system?

What is an embedded system?

- Definition
  - an **embedded system** special-purpose computer system, part of a larger system which it controls.
  - is computing unit that interacts with the physical environment, via inputs and outputs

Components of an embedded system

- Input (Sensors)
  - Switches and buttons
  - Light, humidity, temperature
  - Microphone, camera
- Output (Actuators)
  - LED
  - Motor controller
  - Display
  - Relay
- Microcontroller

Switch

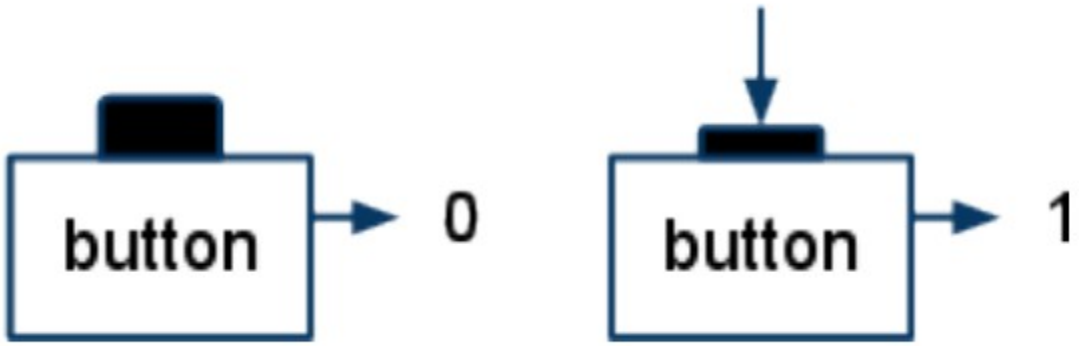
A switch is an electromechanical component with a pair of electrical contacts. The contacts are in one of two mechanically controlled states: closed or open.
When closed, the contacts are electrically connected.
When open, the contacts are electrically disconnected.

Abstraction: A component that outputs 0 or 1 when off or on

Push button

Unlike a simple switch, the push button enters its closed state when it is being *pressed. The moment the pressing force is removed, the push button* reverts to and remains in its open state.

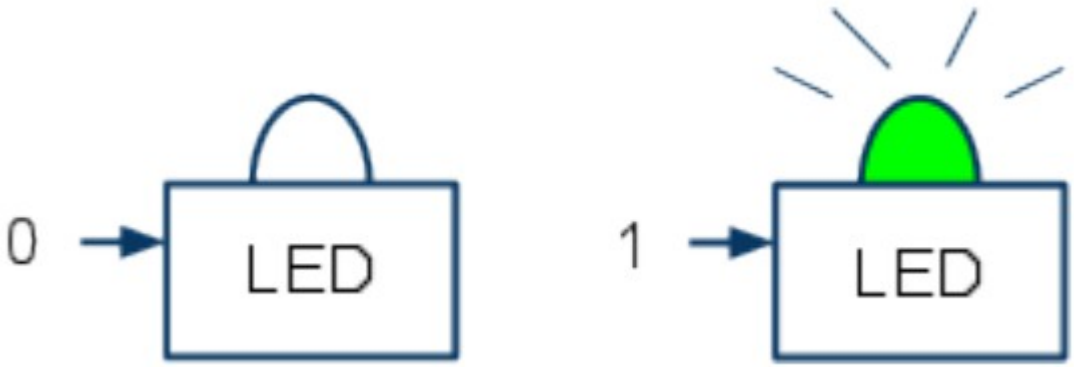
An abstraction: A switch with a button that outputs 1 when pressed and 0 otherwise



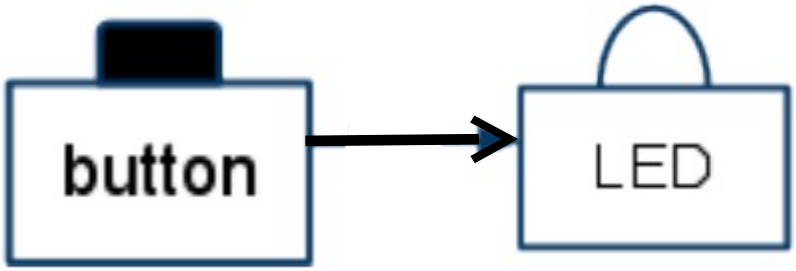
LED (Light Emitting Diode)

A light emitting diode (LED) is a semiconductor with a pair of contacts. When a small electrical current is applied to the LED contacts, the LED illuminates.

An abstraction: A component that illuminates when input is 1



Here is a system. LED illuminates if the button is pressed
Is it an embedded system?



Microcontroller

- A programmable component that reads digital inputs and writes digital outputs according to some internally-stored program

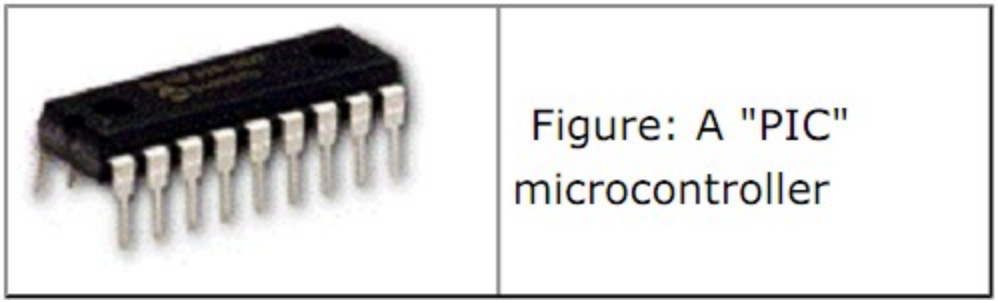
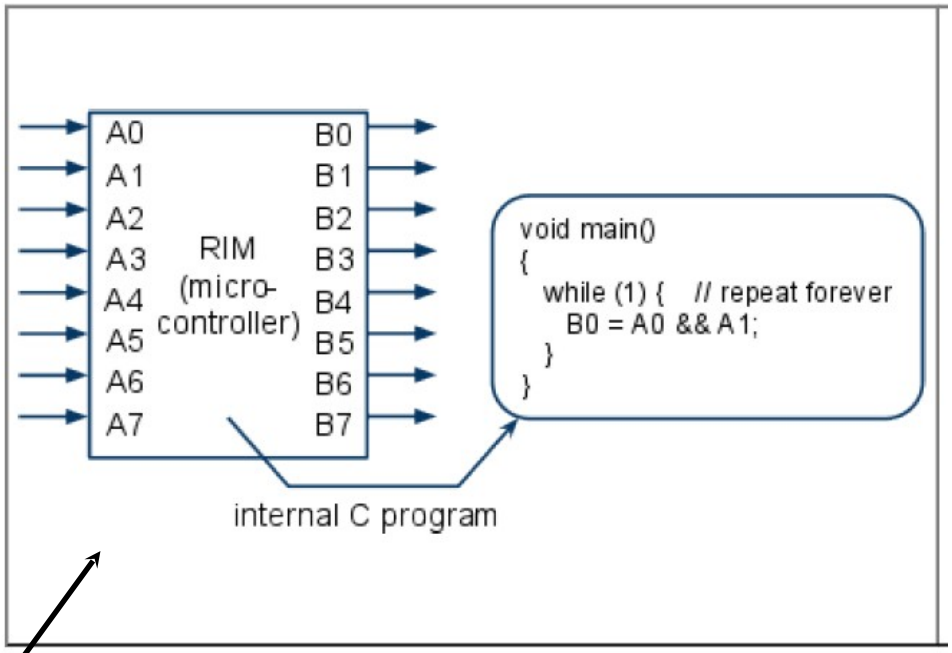


Figure: A "PIC" microcontroller

- PIC = Peripheral Interface Controller = Programmable Intelligent Computer
- Example: ATtiny2313/V

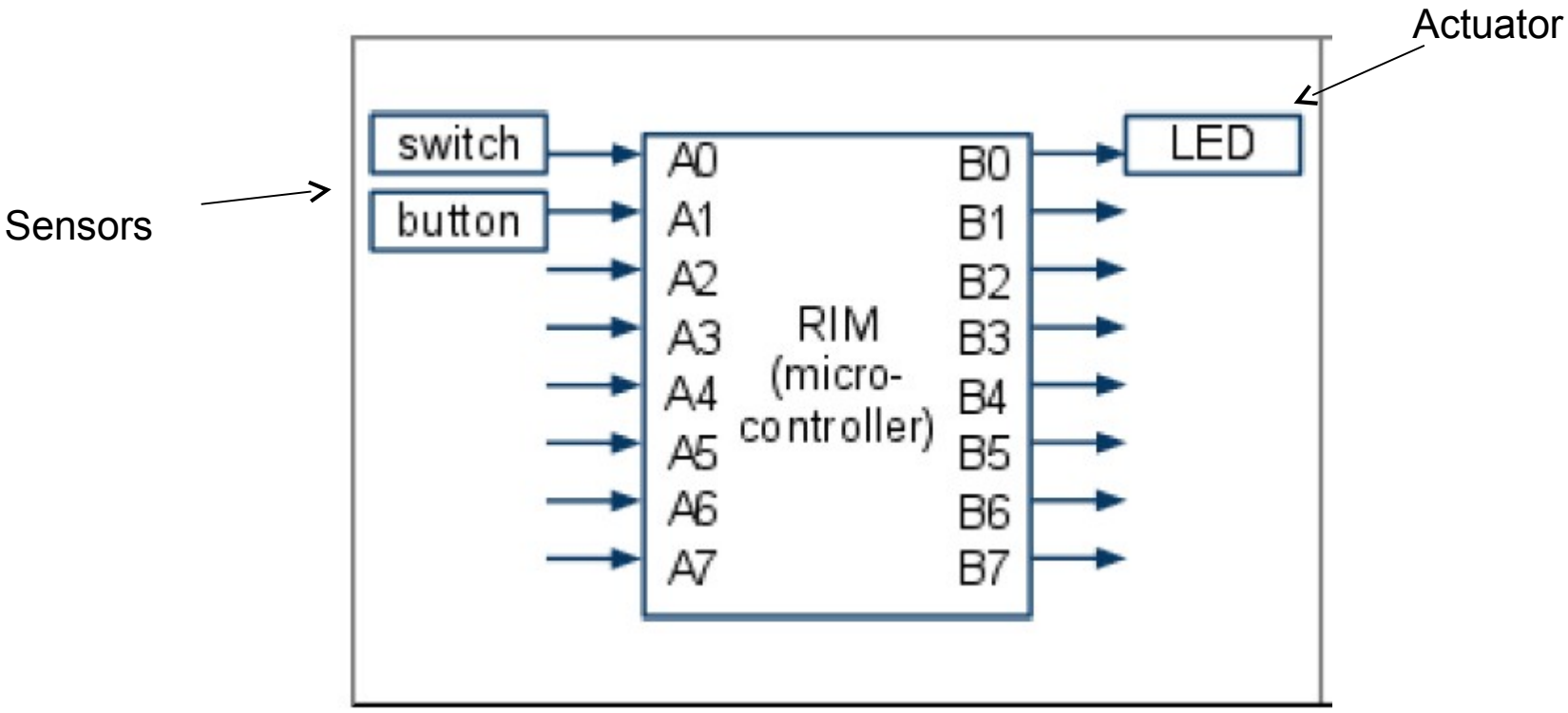
Microcontroller



Abstraction of a microcontroller

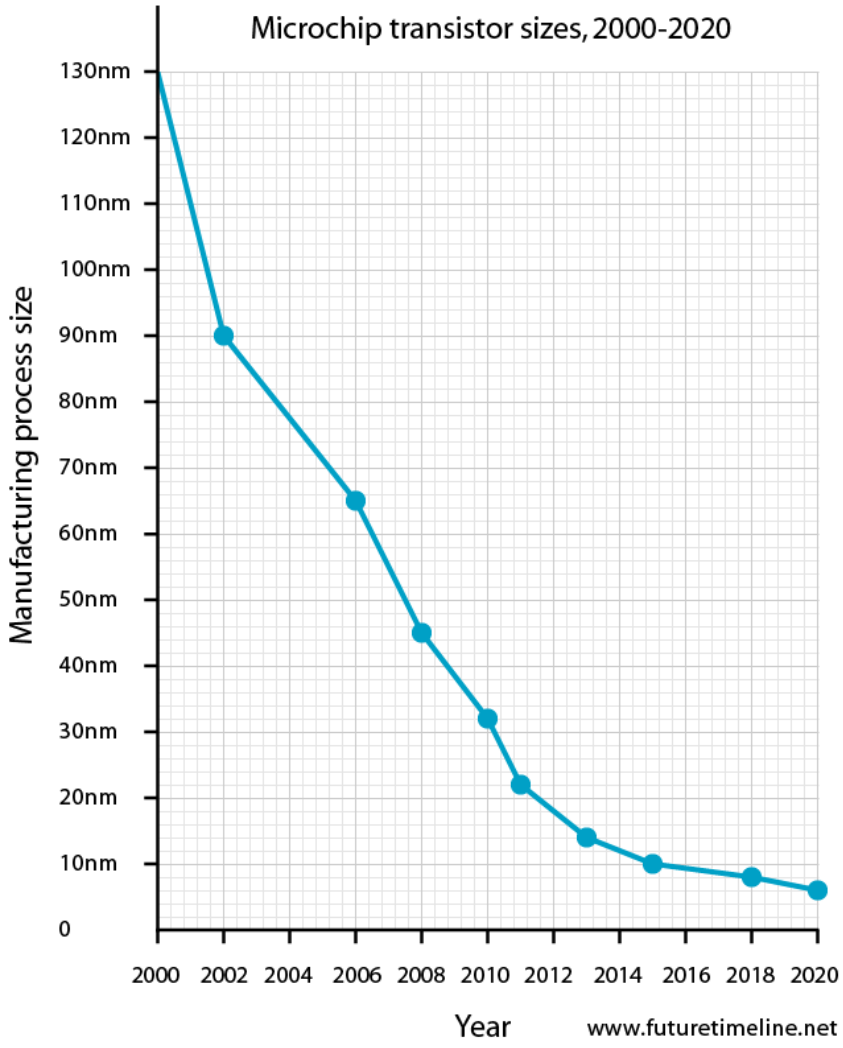
1. Capable of running software (e.g., C program)
2. 8 inputs and outputs – used by C program as implicit global variables
3. This examples shows an infinite while loop (repeat statements infinitely)

This is an embedded system

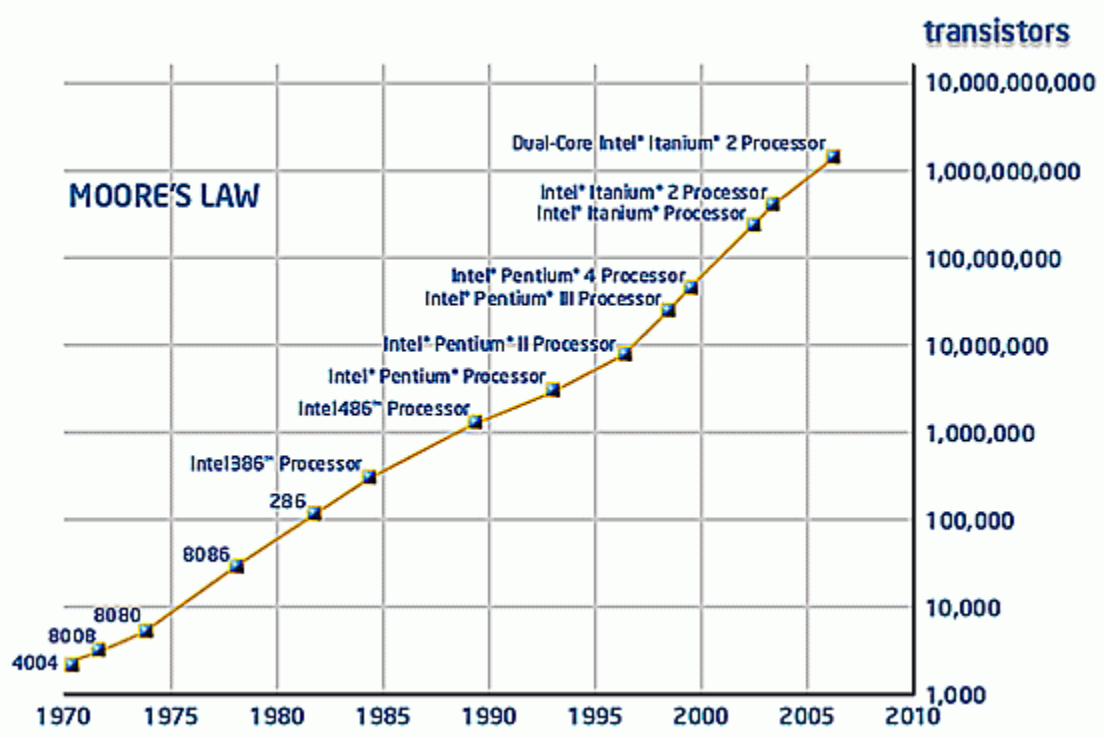


Sensors convert physical phenomena into digital input.
Actuators convert outputs to physical phenomena.

What has enabled growth of embedded systems ?

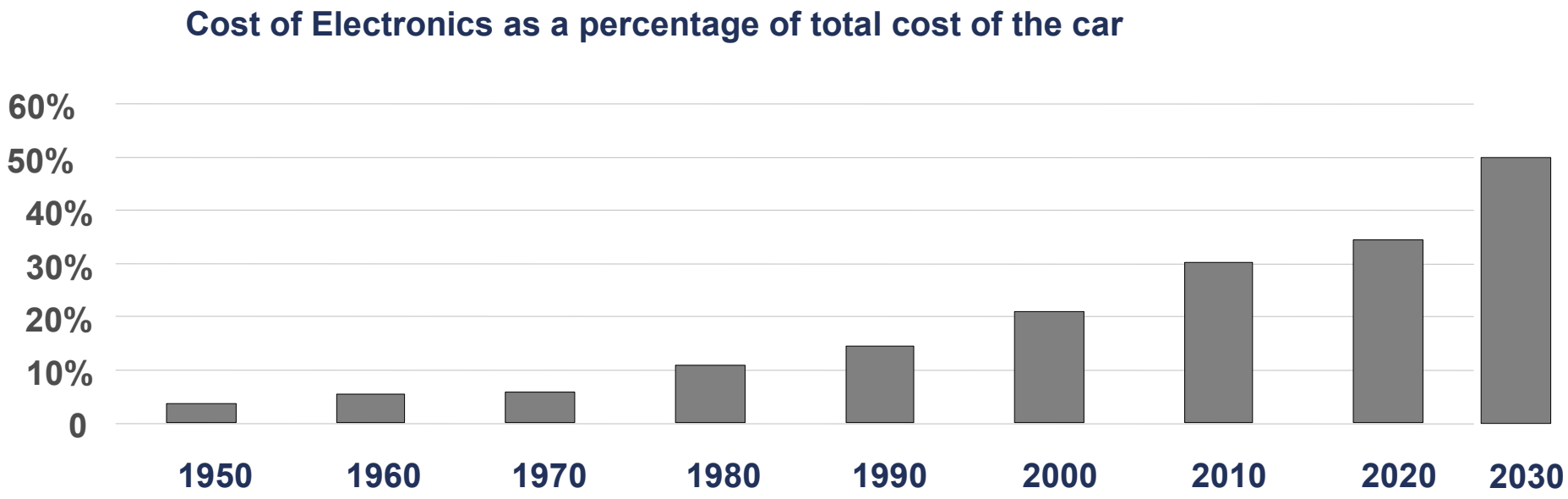


Growth in CPU Transistor Count



Why is there a course on embedded software?

Significance



2030: 50% of the total cost of a car will be electronics

Complexity

- Physical reality is unpredictable
- Multiple functionalities often result in concurrency
- Current trend:
  - Connecting devices together (Internet of Things)
  - Adaptive, autonomous and learning systems

Criticality

- Many of the application areas are safety-critical
  - Automotive
  - Avionics
  - Medicine
- Interaction with physical reality means
  - Reactivity (fast response time)
  - Real-time (guaranteed response time)
- Reliability
  - We expect devices to ”just work”
  - Cannot fix software after shipping

Resource constraints

- Let's do an exercise!

Functional vs. non-functional requirements

- Functional requirements:
  - output as a function of input.

- Non-functional requirements:
  - time required to compute output;
  - size, weight, etc.;
  - power consumption;
  - reliability;
  - etc.

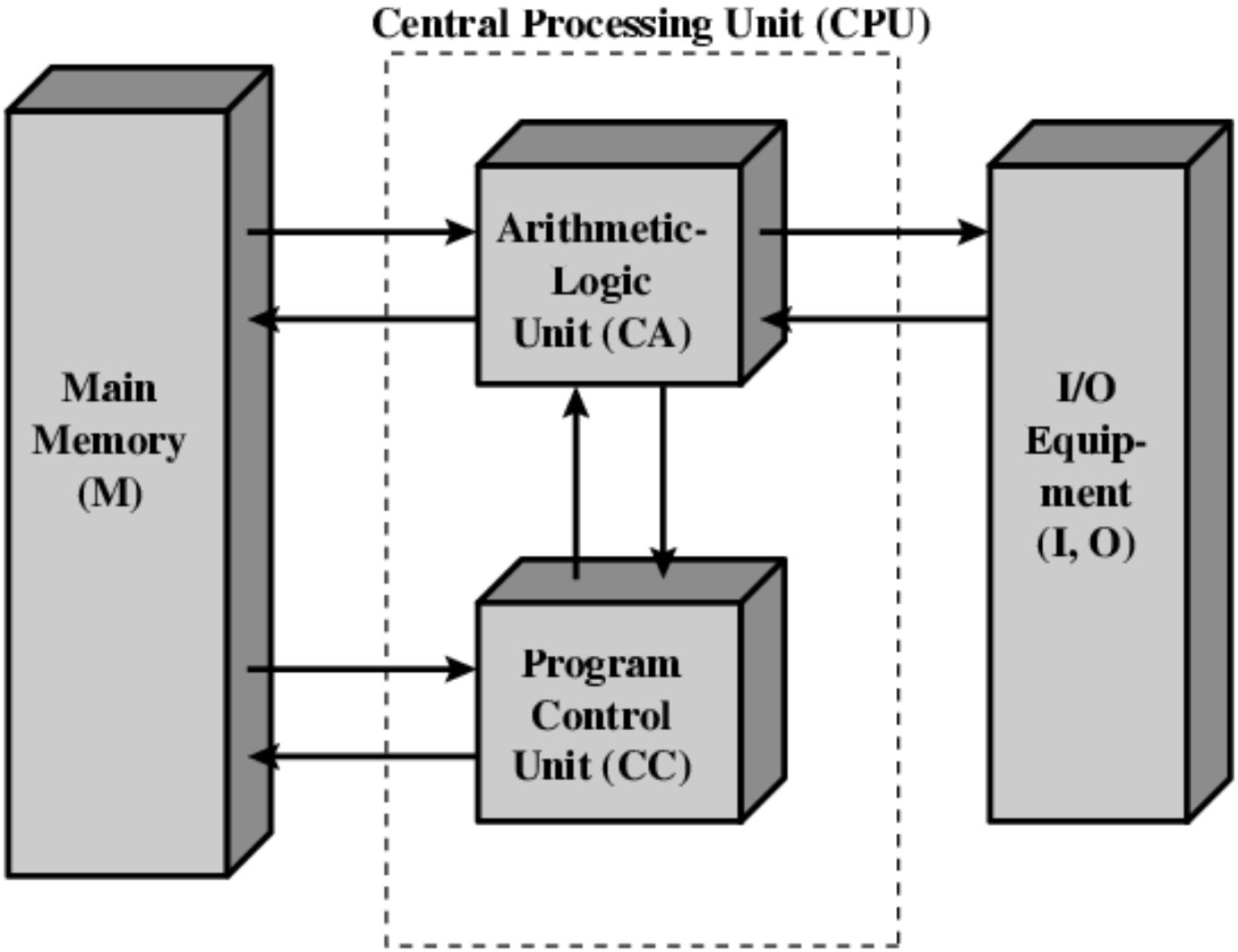
Embedded vs. real-time systems

- **Real-time system:**
  the correctness of the system behavior depends not only on the logical results of the computations, but also on the physical instant at which these results are produced
  - **Hard real-time**: missing deadline causes failure
  - **Soft real-time**: missing deadline results in degraded performance
- A real-time system is not necessarily embedded
- An embedded system is not necessarily real-time

Yet, the fundamental component remains the same!

- Essentially, an embedded computing system also have the same architecture as any other computer system

General Purpose: von Neumann



von Neumann

- Stored Program concept
- Main memory storing programs and data
- ALU operating on binary data
- Control unit interpreting instructions from memory and executing
- Input and output equipment operated by control unit

Summary

- Embedded system definition
  - special-purpose
  - interacts with physical environment through inputs and outputs
- Examples
  - All around us: transportation, medical equipment, home appliances, ...
- Challenges
  - Complexity: multiple algorithms, concurrency
  - Scarcity of resources: cost, power, size, weight,...
  - Criticality: safety-critical, real-time, reliable

Don't forget to signup for webreg, Friday the latest!

Extra material for self-study (not used in lectures)

Computing systems

- Computing systems are everywhere
- Most of us think of “desktop” computers
  - PC’s
  - Laptops
  - Servers



- But there’s another type of computing system
  - Far more common...

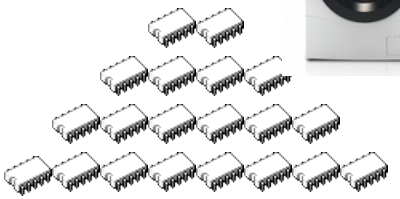
Embedded systems

- Embedded computing systems
  - Computing systems embedded within electronic devices
  - Billions of units produced yearly, versus millions of desktop units
  - Perhaps 50 per modern automobile with upto 100 million lines of software code
  - Hard to define. Nearly any computing system other than a desktop computer
- What about mobiles and tablets?

Computers are in here...

and here...

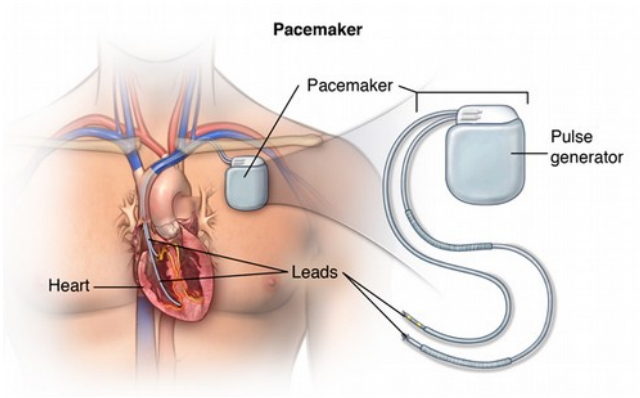
and even here...



Lots more of these, though they cost a lot less each.

Some examples from past and present

Embedded systems example



1802 COSMAC Microprocessor in early Boston Scientific pacemakers

Trivia

- “Surgeons at the Karolinska Institute in Sweden were the first to place a *fully implantable device* into a patient in 1958. Rune Elmqvist and surgeon Ake Senning invented this pacemaker, which was implanted in the chest of Arne Larsson. The first device failed after three hours, the second after two days. Larsson would have 26 different pacemakers implanted in him. He died at the age of 86 in 2001, outliving both Elmqvist and Senning.”

Embedded systems example, cont.

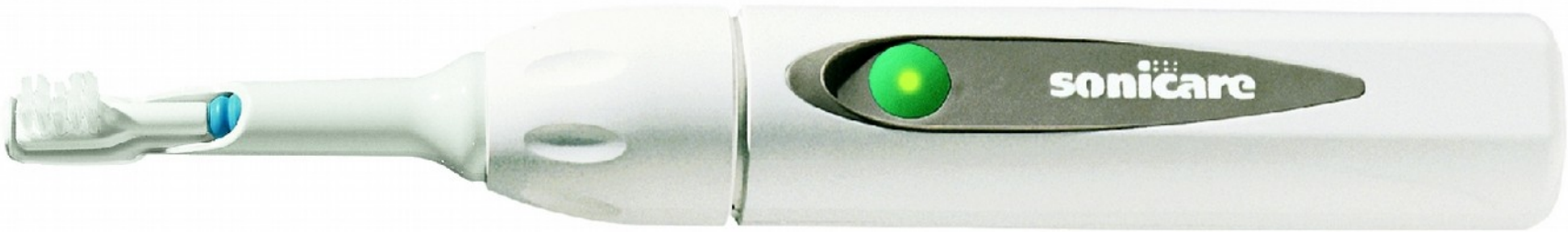
Product:Vendo V-MAX 720 vending machine.

Microprocessor: 8-bit Motorola 68HC11.

Embedded systems example, cont.

Product: Sonicare Plus toothbrush.

Microprocessor: 8-bit Zilog Z8.

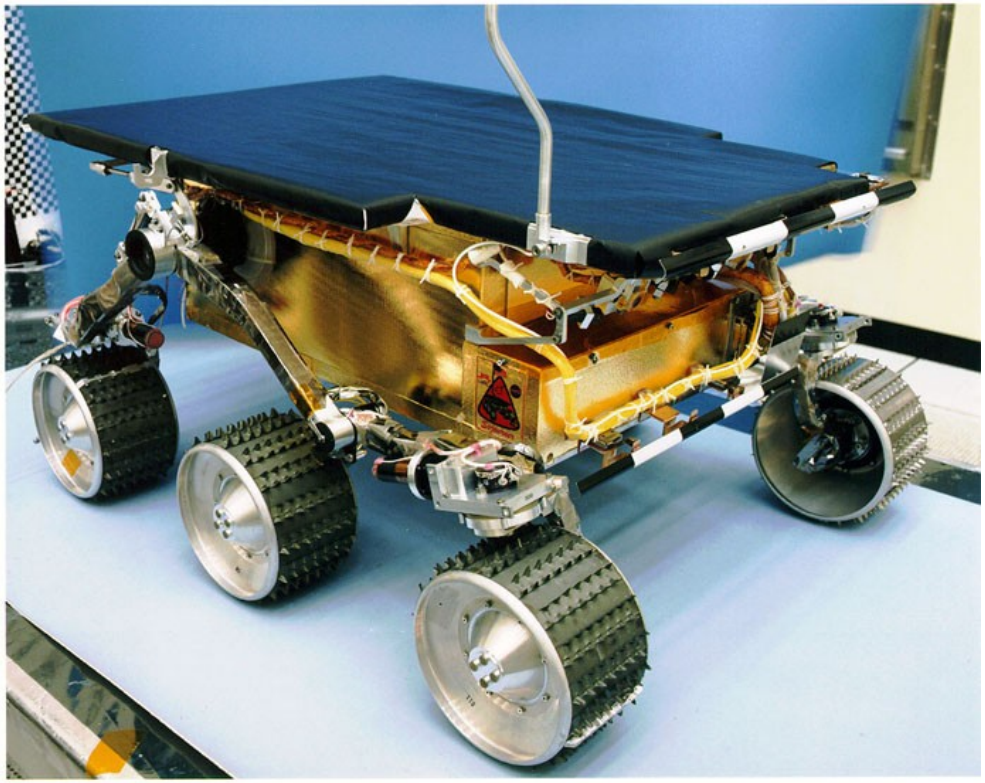


Embedded systems example, cont.

Product: Miele dishwashers.

Microprocessor: 8-bit Motorola 68HC05.

Embedded systems example, cont.



Product: NASA's Mars Sojourner Rover.

Microprocessor:
8-bit Intel 80C85.

Embedded systems example, cont.

Product: Garmin
StreetPilot GPS Receiver.

Microprocessor: 16-bit.

Embedded systems example, cont.

Product: Sony Aibo ERS-110 Robotic Dog.

Microprocessor:
64-bit MIPS RISC.

Trivia

- AIBO robots were phased out in 2006
- In 2006, AIBO was added into Carnegie Mellon University's "Robot Hall of Fame" with the description "the Sony AIBO represents the most sophisticated product ever offered in the consumer robot marketplace."

Examples can be clustered into application areas

Application areas, cont.

Computer Peripherals	Printers, scanners, keyboards, displays, modems, hard disk drives, CD-ROM drives.
Home	Dishwashers, microwave ovens, VCRs, televisions, stereos, fire/security alarm systems, lawn sprinkler controls, thermostats, cameras, clock radios, answering machines.
Industrial	Elevator controls, surveillance systems, robots.
Instrumen-tation	Data collection, oscilloscopes, signal generators, signal analyzers, power supplies.

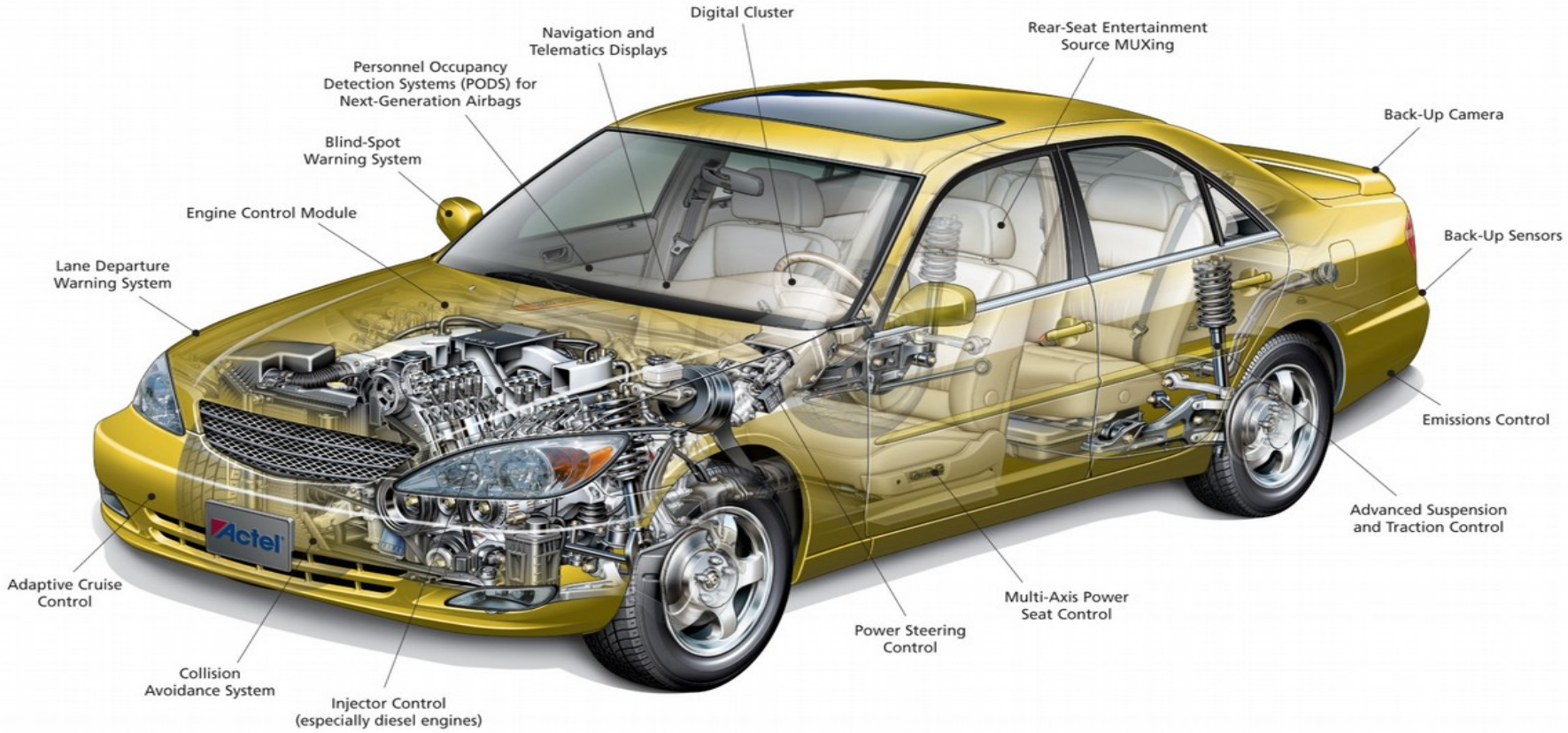
Application areas, cont.

Medical	Imaging systems (e.g., XRAY, MRI, and ultrasound), patient monitors, heart pacers.
Office Automation	FAX machines, copiers, telephones, cash registers.
Personal	Personal Digital Assistants (PDAs), pagers, cell phones, wrist watches, video games, portable MP3 players, GPS.

Application areas

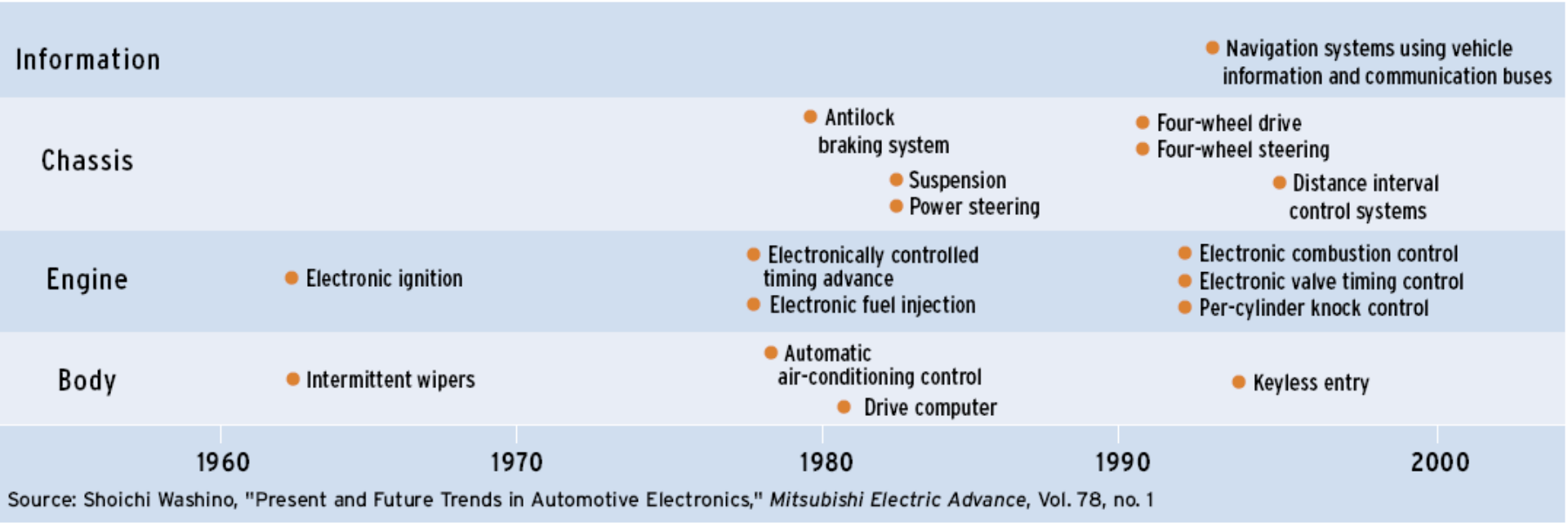
Aerospace	Navigation systems, automatic landing systems, flight attitude controls, engine controls, space exploration (e.g., the Mars Pathfinder).
Automotive	Fuel injection control, passenger environmental controls, anti-lock braking systems, air bag controls, GPS mapping.
Toys	Nintendo's "Game Boy", Mattel's "My Interactive Pooh", Tiger Electronic's "Furby".
Communi-cations	Satellites; network routers, switches, hubs.

Example application area



Example application area: automotive electronics

- What is “automotive electronics”?
  - Vehicle functions implemented with electronics
    - Body electronics
    - System electronics (chassis, engine)
    - Information/entertainment



Embedded systems evolution

- Past
  - First microprocessor: Intel 4004, 1971
- Present
  - 79% of all the processors are used in embedded systems
  - high-end cars contain more than 100 processors
- Future: Post-PC era
  - Cyber-physical systems
  - Internet of things

Embedded system : Importance

- Wide in scope – numerous application area
- Depth in scope – important within each application area

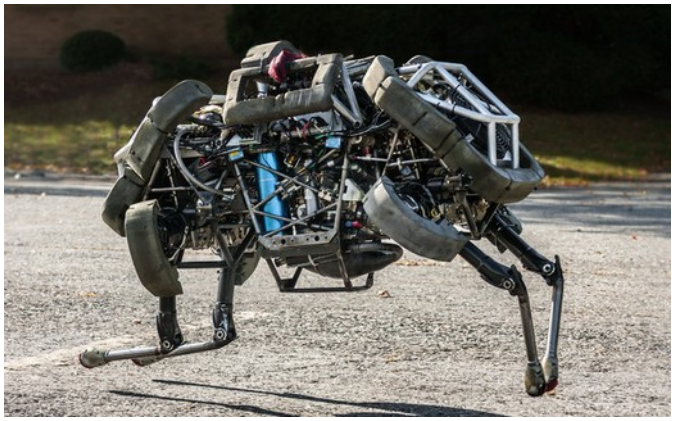
Toward future…

’Roadtesting Google’s new driverless car’ Telegraph, 2015

'Self-Driving Tesla Cars Will Be in the U.S. by summer of 2015'

- ***19 March, 2015, Nytimes***
- a software update — not a repair performed by a mechanic — would giveTesla's Model S sedans the ability to start driving themselves

"Google Adds to Its Menagerie of Robots" – NYTimes, 2013



”Amazon testing drones for delivery” – BBC, 2013

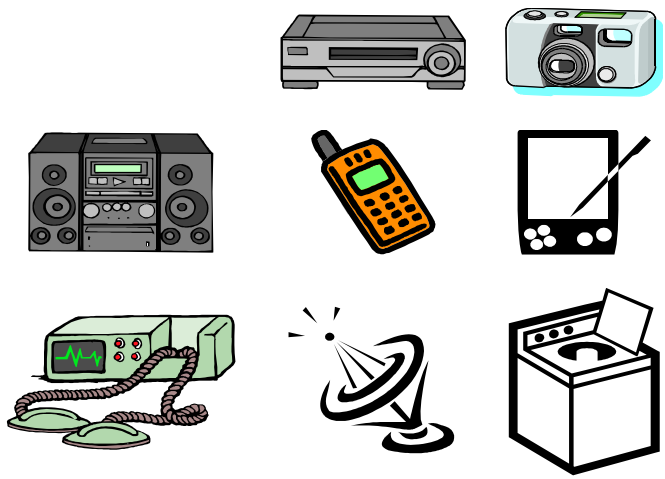
Mobiles and desktops may disappear!

- Wearables and implants to talk to ”cloud”
- Brain machine interfaces and body area networks

A “short list” of embedded systems

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

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 systems
Televisions
Temperature controllers
Theft tracking systems



And the list goes on and on