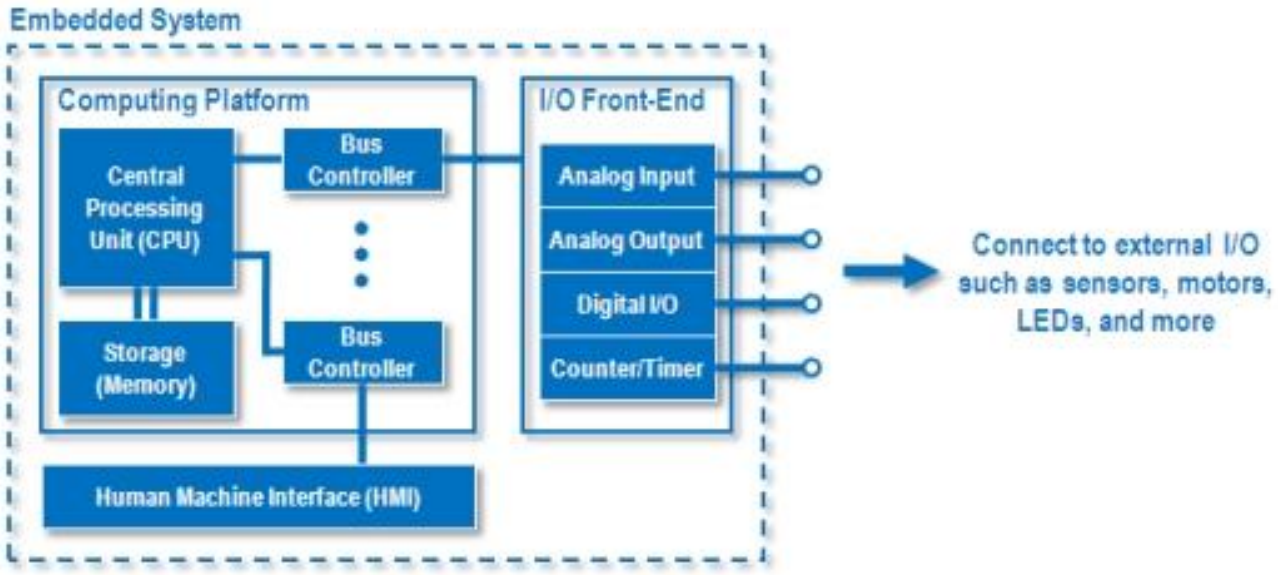
CO3053 – Embedded Systems

1. What is Embedded System?



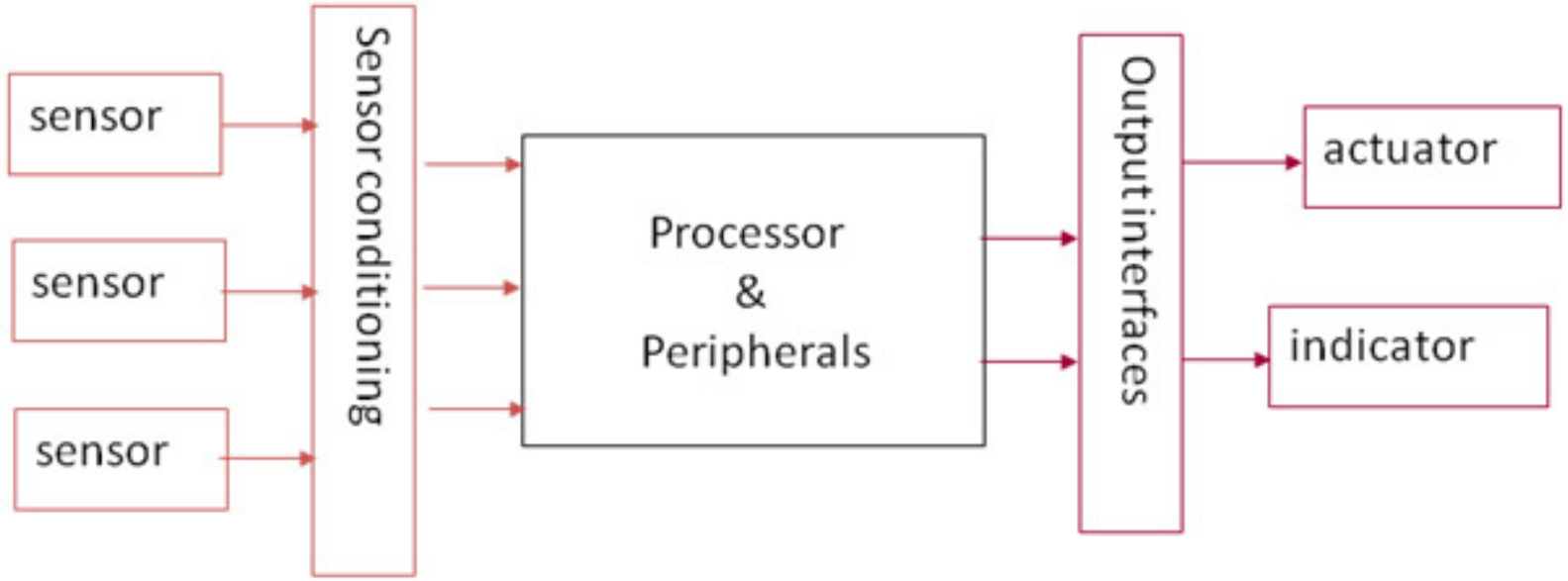
Contents

- Definition and Concept
- Characteristic
- Design Challenge
- Design Metric

What is Embedded System ?

- An embedded system is
  - **A computer system** that is **embedded** into **another larger system**.
  - Example: Cars, airplane, weapon, …

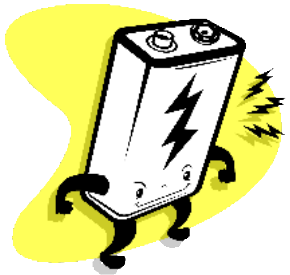
- An embedded system is designed to perform a/some **dedicated task(s)**
  - Lighting control
  - Camera control



Embedded System Applications

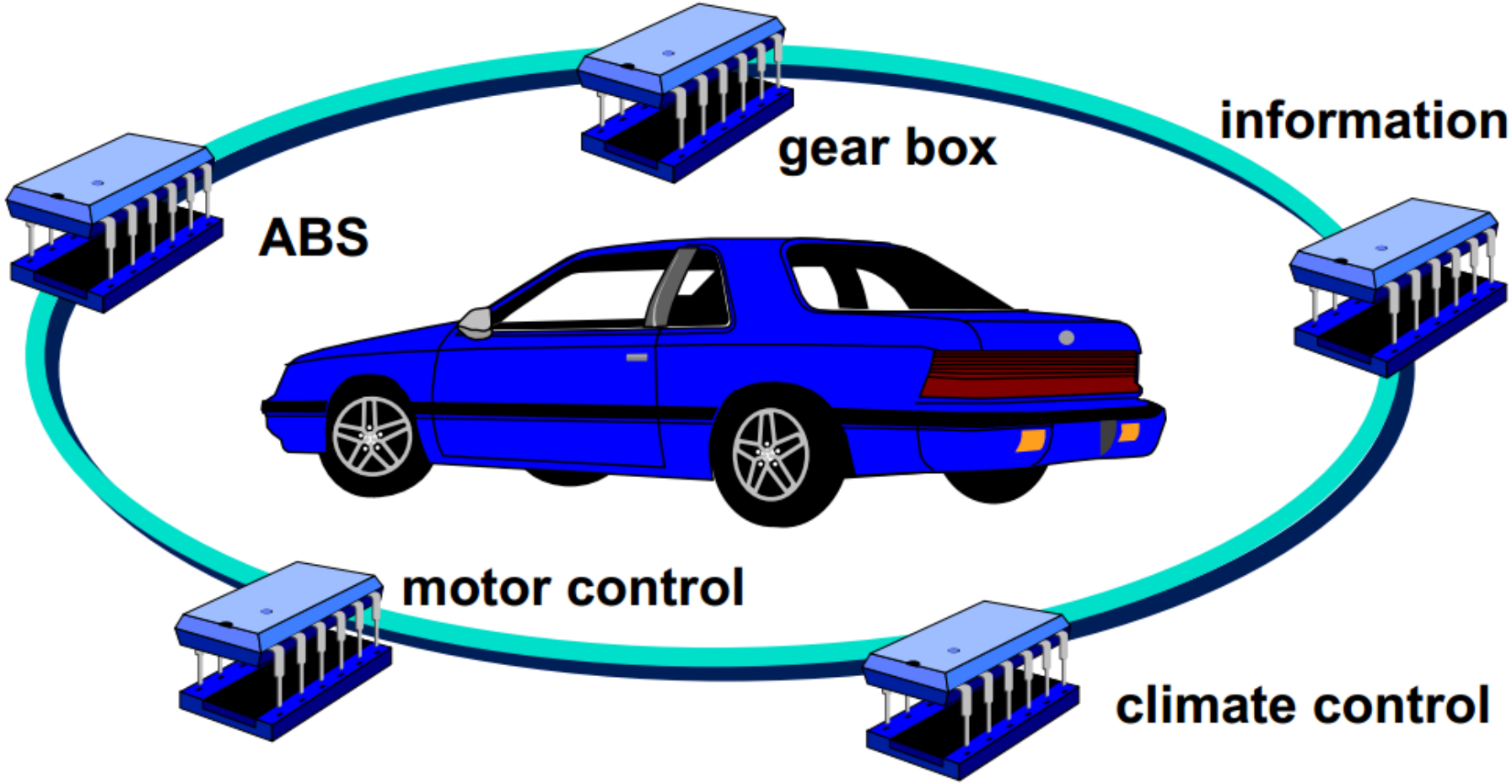
- Require very high performance
  - Communications
  - Multimedia
  - Graphics

- Must also meet strict design goals
  - Real-time performance
  - Power/energy consumption
  - Cost



Example – Automotive

- Car as an integrated control, communication and information system.



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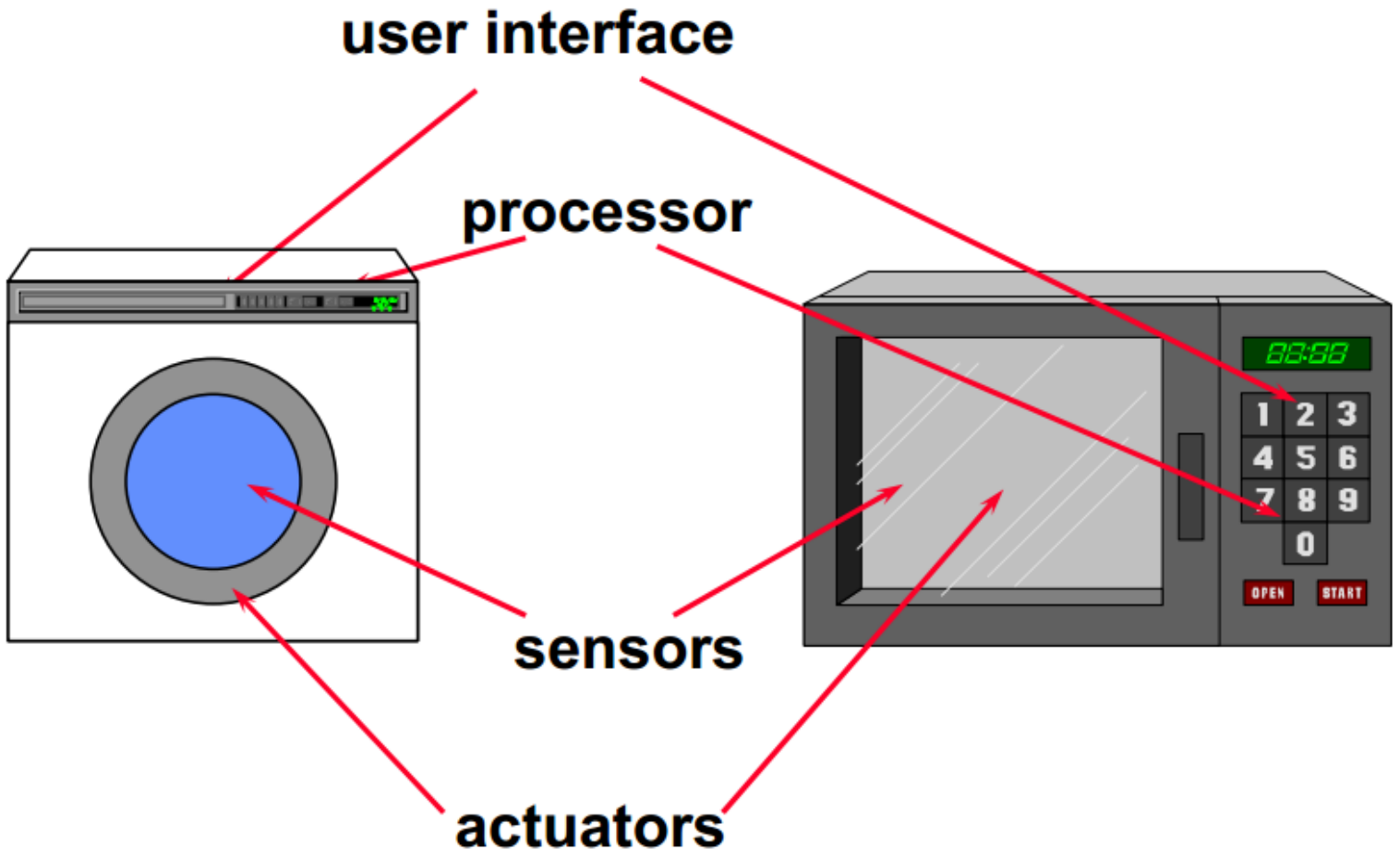
Example – Consumer Electronics

- MP3 audio, digital camera, **home electronics**



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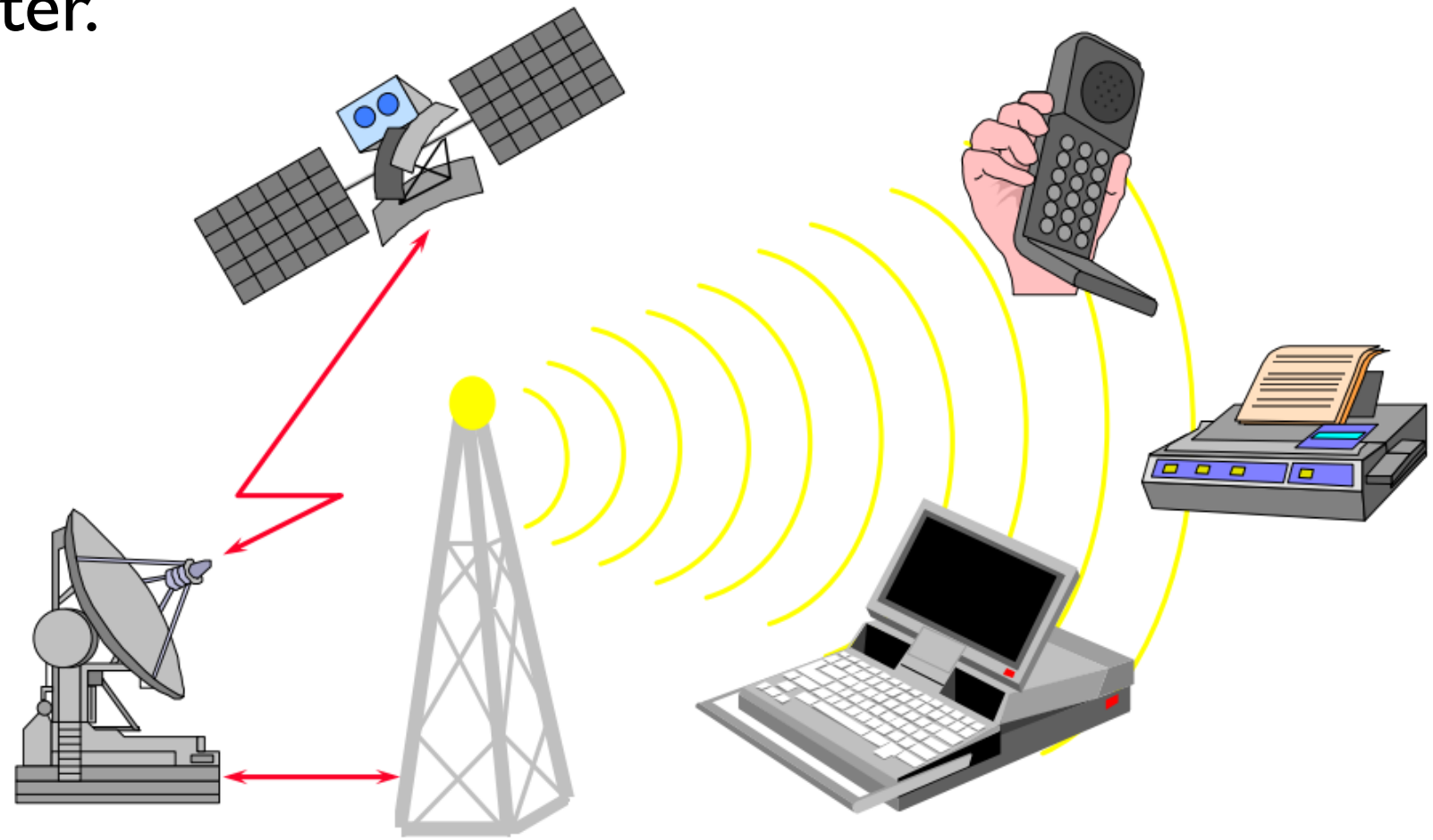
Example – Information Systems

- Wireless communication (mobile phone, wireless LAN, etc), end-user equipment, router.



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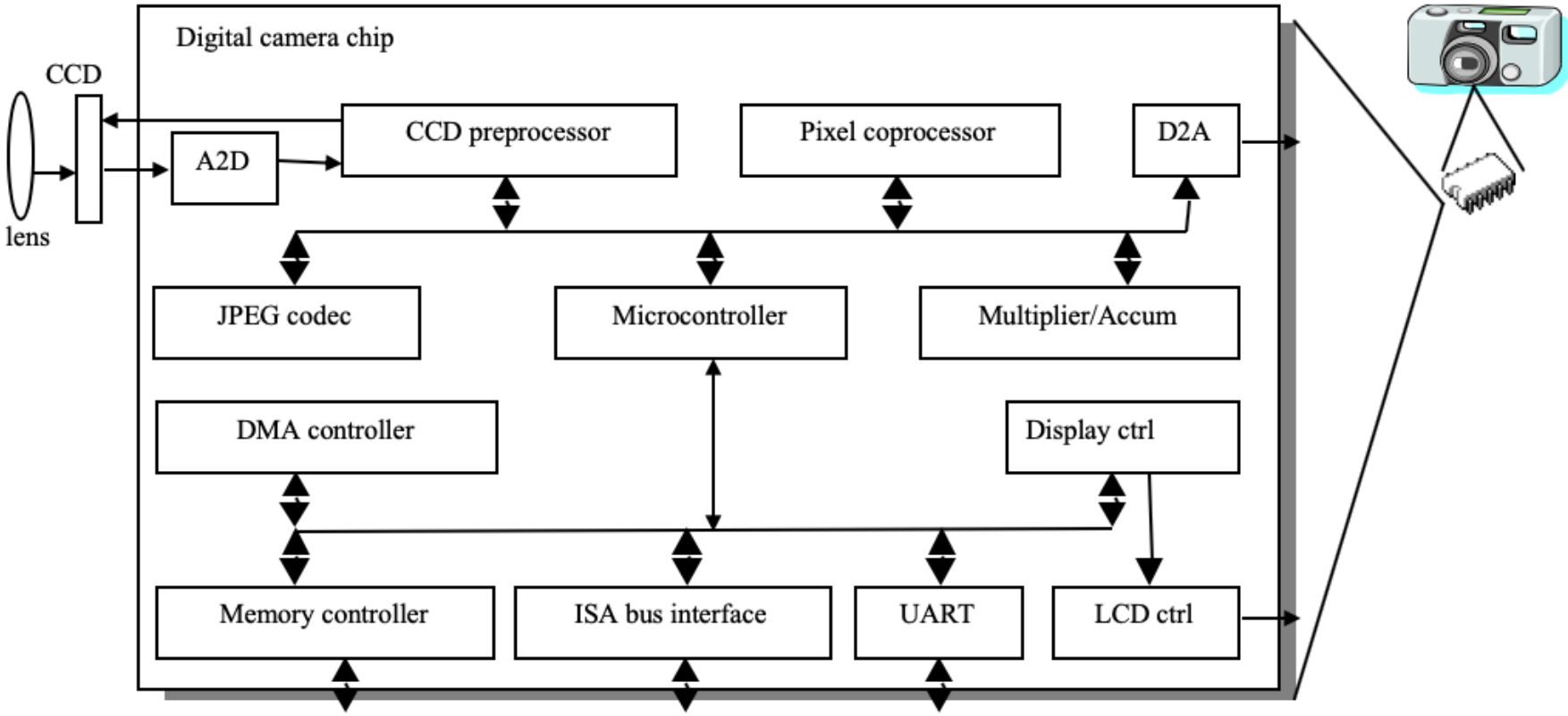
Common Characteristics of Embedded Systems

- 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



- Single-functioned -- always a digital camera
- Tightly-constrained -- low cost, low power, small, fast
- Reactive and real-time -- only to a small extent

Embedded Systems – Design Challenge

- Obvious design goal
  - Construct an implementation with desired functionality
- Key design challenge:
  - Simultaneously optimize numerous design metrics
- Design metric
  - A measurable feature of a system's implementation
  - Optimizing design metrics is a key challenge

Embedded Systems – Common Design 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 monetary 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

Embedded Systems – Common Design Metrics

- 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, CPU Technologies, Integration Level, Form Factor, Application Specific Hardware, User Interface, Connectivity, Security

Embedded Systems – Other Design Metrics

- CPU Technologies
- Integration Level
- Form Factor
- Application Specific Hardware
- User Interface
- Connectivity
- Security

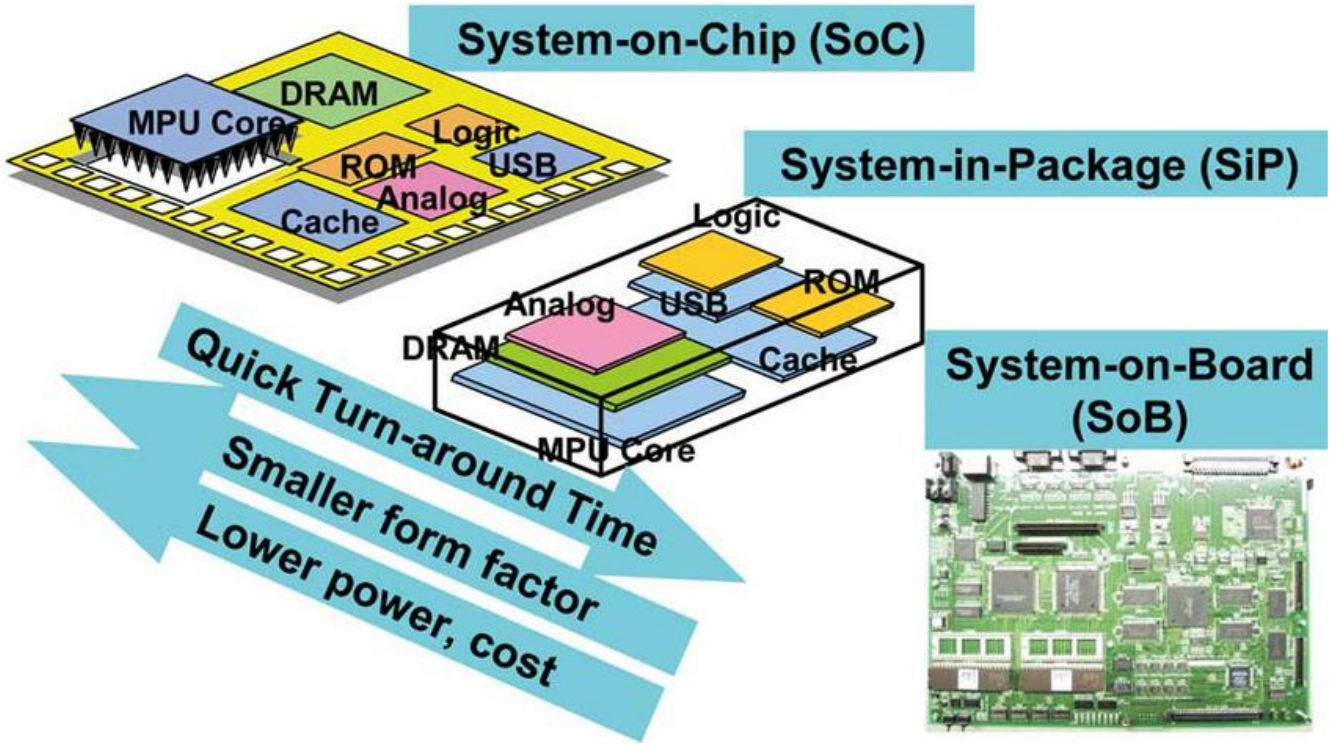
The CPU

- **General purpose**
  - 32-bit, 64-bit long time ago.
  - Clock-rate reach several GHz.
  - Included Floating Point Unit (FPU) and/or Graphic Processing Unit (GPU) with parallel processing capability.

- **Embedded System**
  - Large range of compute capability.
  - Still many 8-bit and 16-bit in small ES (PIC, AVR,…).
  - Now, many systems requires 32-bit, 64-bit CPU (ARM, ATOM,…)

Integration Level

- Early Embedded Systems
  - Separate CPU + Peripherals + …
  - Cost highly

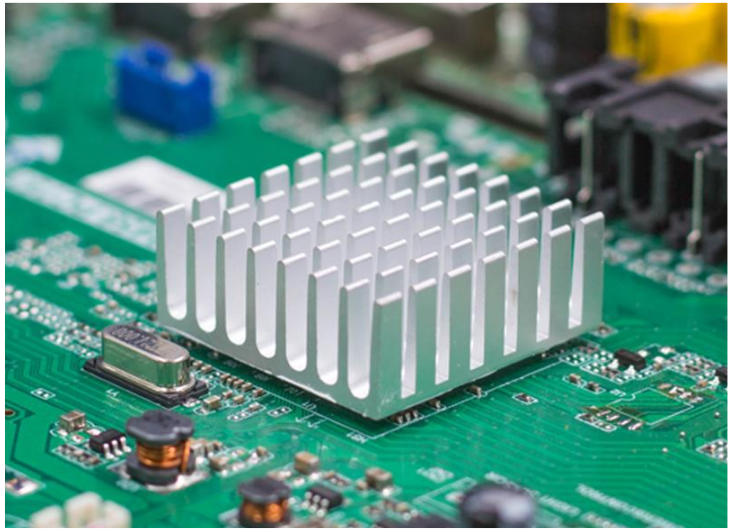


- SoC (System on a Chip)
  - Many ICs are integrated into a single Chip
  - High-density ⇢ Low-cost
  - CPU + Memory + IO or CPU + Memory + ADC
  - Many levels of integration

Image Source: Internet

Power Consumption

- Many ES rely on battery
  - Power consumption is very important
- Apply power optimization technique
  - Sleep mode
- Heat is also very important
  - Heat sink must be efficient
  - E.g. Cell phone



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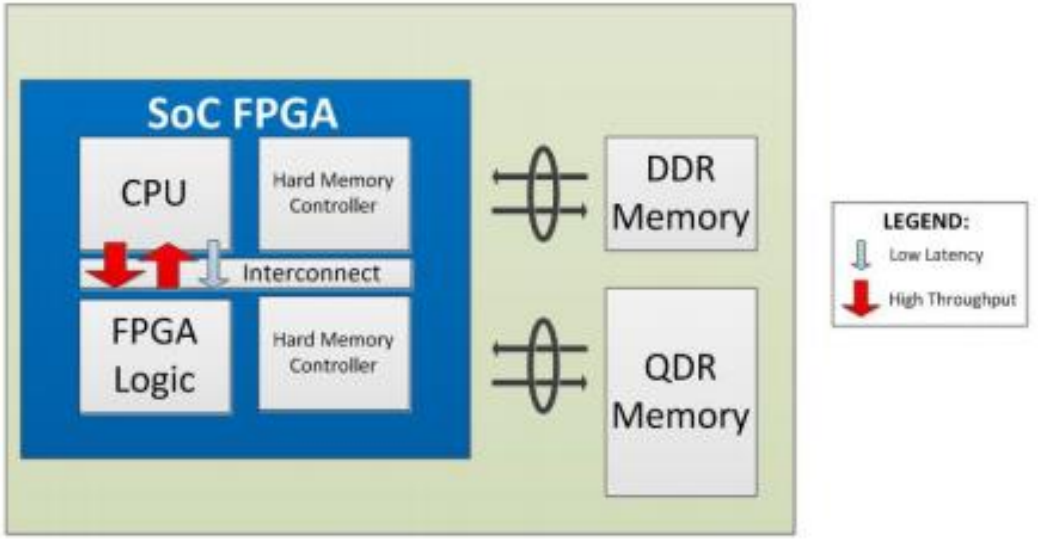
Form Factor & Expansion

- Size, pin-out, connector.
- Define some standard (Ex COM) help software development, hardware expansion
- Sometime for expansion, resources are reserved (DRAM, Flash). But these have trade-off and need to be consider carefully.

Image Source: Internet

Application Specific Hardware

- Can any SoC suit the user requirements?
- Adding other ASIC or FPGA: trade-off
  - ASIC can show better performance
  - But FPGA can show the flexibility
- Future ES: **SoC + FPGA**



- Many parts of ES need **certification**
  - E.g. **radio frequency** need to be licensed (US, Japan,…)
- Consider to use pre-certified module

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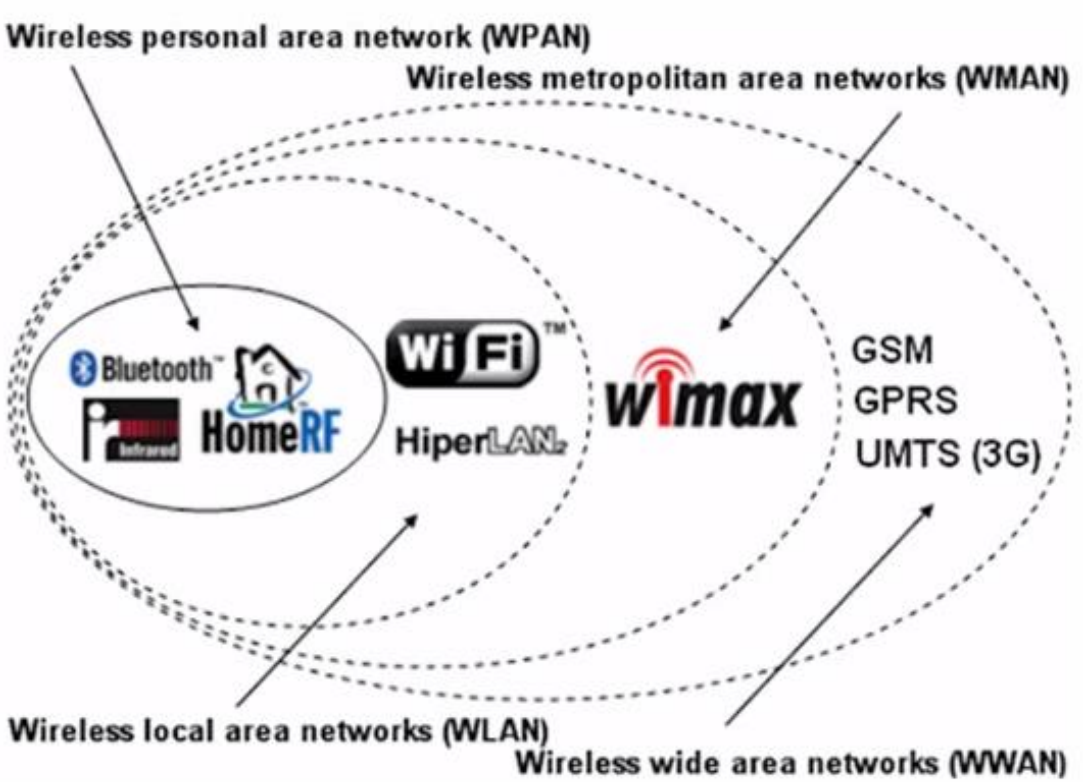
User Interface

- Many ES is interactive
  - Headed provide the display
    - E.g. touch screen. The appearance of application
  - Headless: no display.
    - Use console, key/button, or via web page

Image Source: Internet

Connectivity and Security

- For current and future ES, connectivity is very important
  - Wifi, Xbee, Bluetooth, LoRa
  - 3G/4G/5G
  - …
- **Ubiquitous**: every device can connect each other
- When the **connectivity is easy**, the **security become critical**



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Further Reading

- Audio Lecture
  - https://lectures.tik.ee.ethz.ch/es/recordings/ES_1/ES_1.html