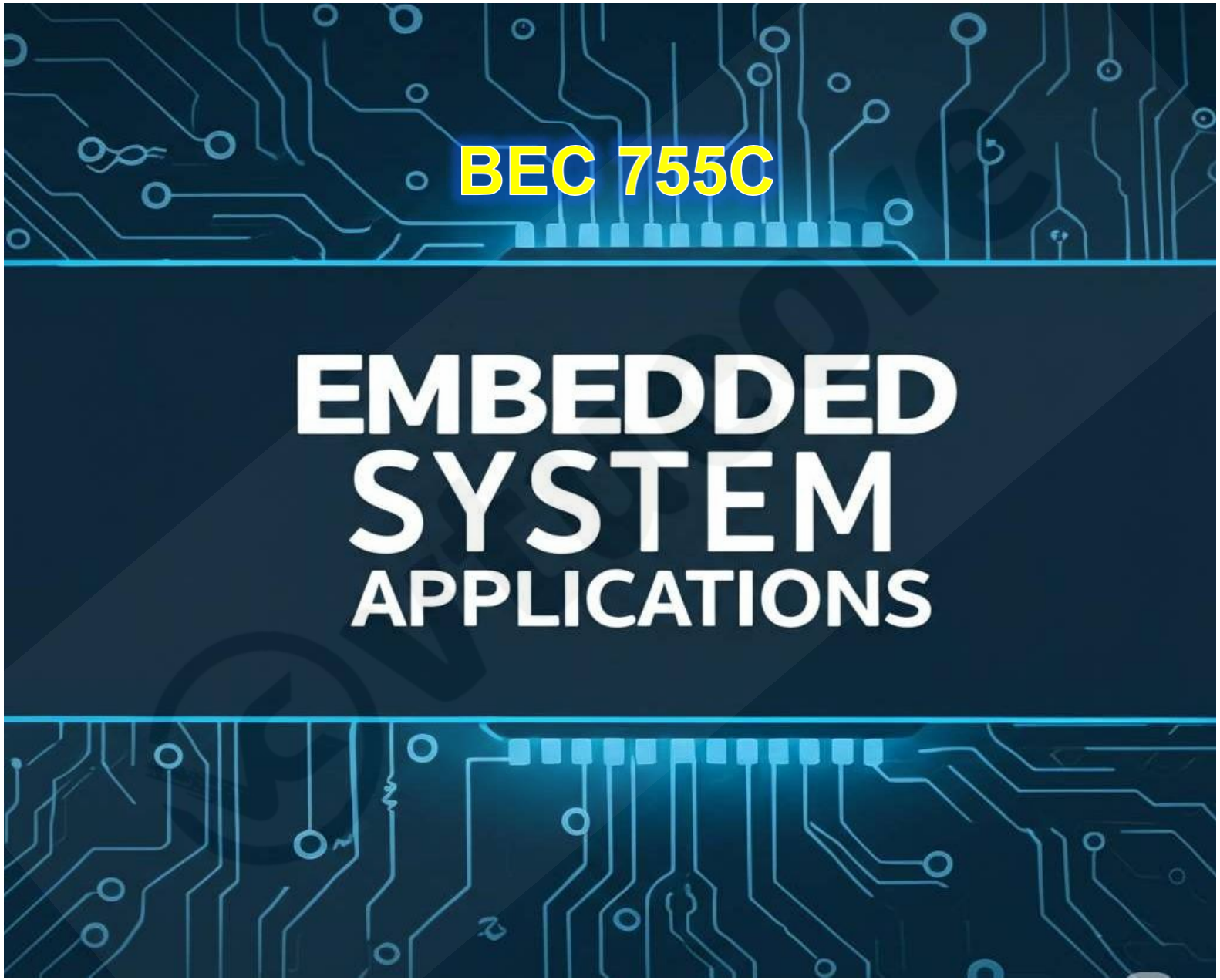

BEC 755C
EMBEDDED
SYSTEM
APPLICATIONS

MODULE - 1

Introduction to Embedded Systems

- Application domain of embedded systems
- desirable features and general characteristics of embedded systems
- model of an embedded system
- microprocessor Vs Microcontroller
- example of a simple embedded system
- figure of merit for an embedded system,
- classification of MCUs: 4/8/16/32 bits
- history of embedded systems, current trends.
- (Text: 1.1 to 1.9)

MODULE - 1

Introduction to Embedded Systems

Definition of the term 'embedded systems'

The application domain of embedded systems

The model of an embedded system

The difference between an MCU and an MPU

The working of a simple embedded system

The figures of merit for an embedded system

Classification of MCUs on the basis of data bus widths

The history and current trends of the embedded systems industry

Introduction to Embedded Systems

- It is an electronic system designed to perform one or a limited set of functions, using hardware and software.

- PC can be excluded as it is a general-purpose system.

Introduction to Embedded Systems

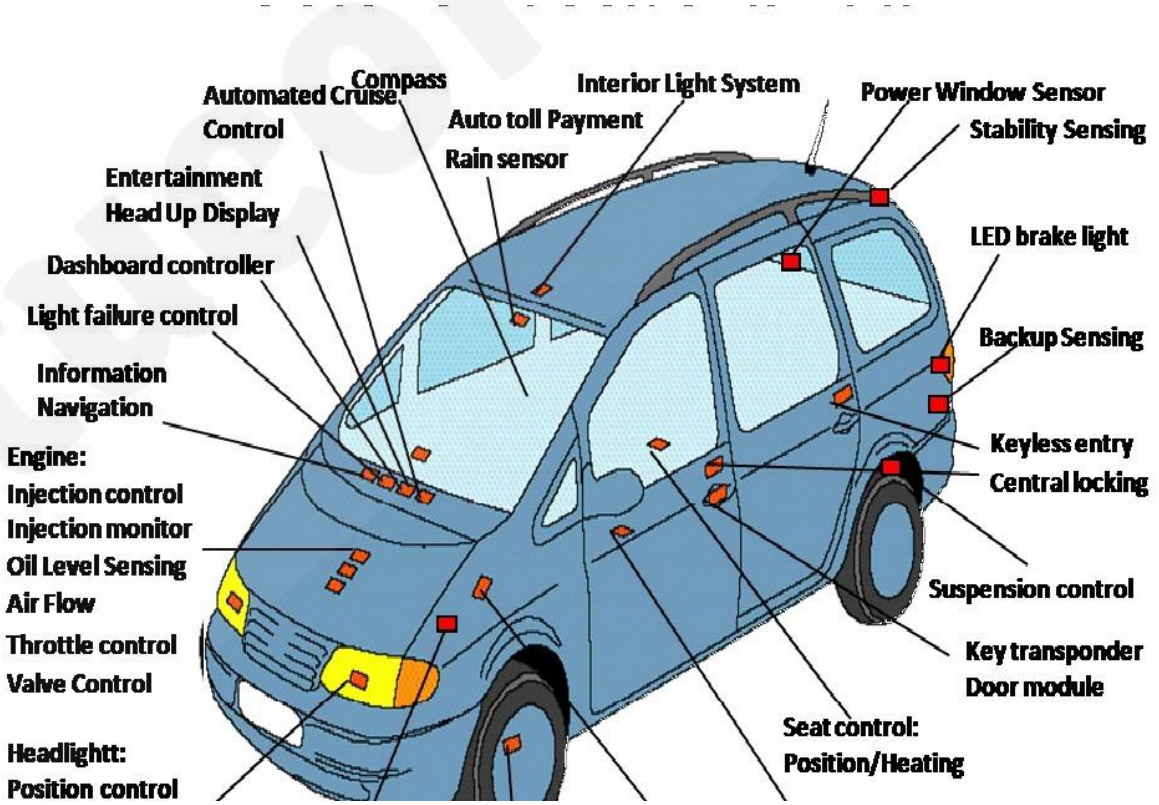
- It's a **"special purpose"** computing unit.

(It has both hardware and software)

- The software is "burned" into the Read-Only Memory (ROM) and is referred to as "firmware". (software associated with specific function)

Introduction to Embedded Systems

- **Example:** In a car, numerous Electronic Control Units (ECUs) are present.
- Each of them has a processor which controls one or other parts of car engine, brakes, lights and doors. These are all systems embedded into the vehicle and **adds intelligence to the operation of the vehicle**.

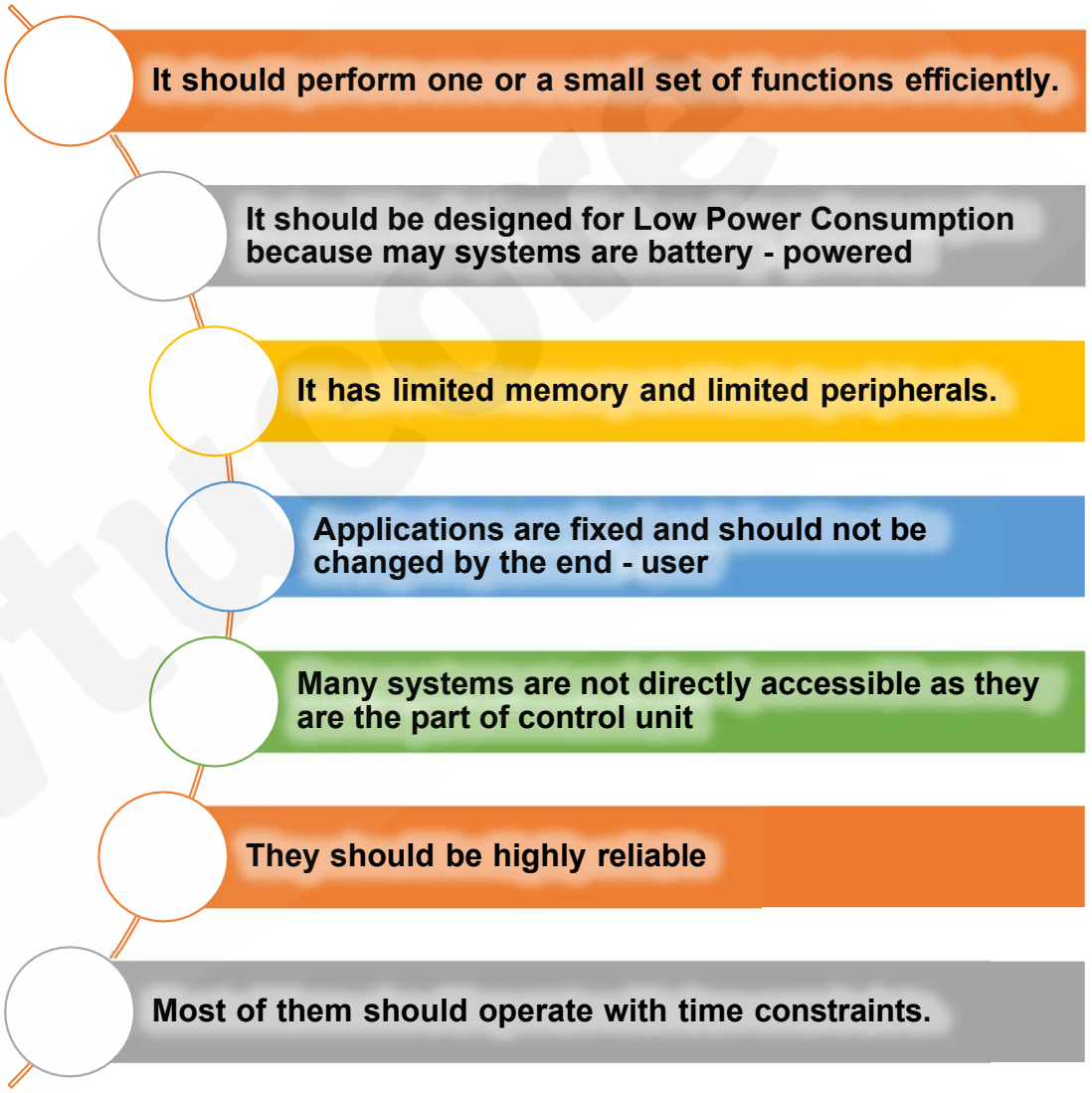


Application Domain of Embedded Systems

Embedded systems are found in nearly every aspect of modern life:

- **Consumer Electronics:** Cameras, TVs, microwave ovens
- **Household Appliances:** Air conditioners, security systems
- **Automobile Controls:** Anti-lock braking systems (ABS), engine control
- **Handheld Devices:** Mobile phones, MP3 players
- **Medical Equipment:** Scanners, ECG and EEG units
- **Computer Peripherals:** Printers, scanners, webcams
- **Networking:** Routers, switches
- **And many more:** Factories, aviation, military, robotics, and even toys.

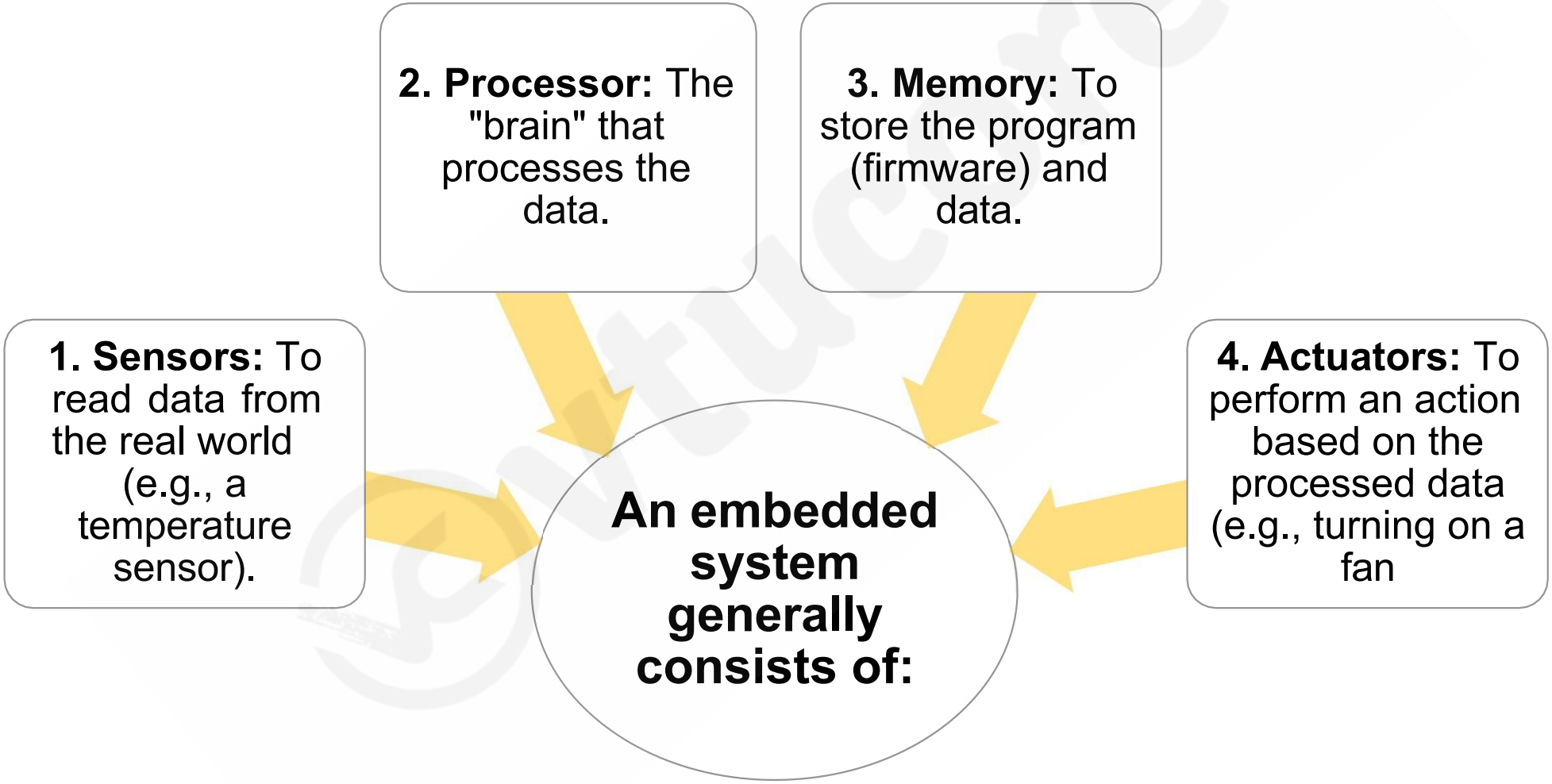
Desirable features and general characteristics of Embedded Systems



Why PC is not considered as an embedded system?

- **PCs are designed for a wide variety of tasks** (word processing, computation, communication, scanning, printing etc).
- **Memory is available in the form of RAM, ROM,**
- **General Purpose:** New applications can be installed by the user at any time.
- **Power is not the main constraint:** While desirable, low-power design is not the primary guiding principle as it is in many embedded devices.

A simple model of an embedded system



General model of an embedded system

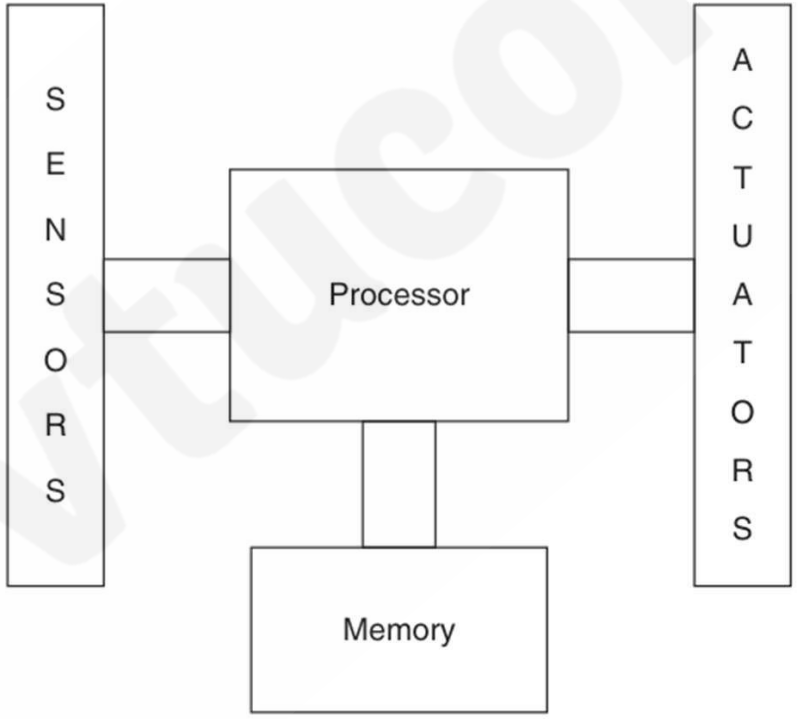


Figure 1.2 | General model of an embedded system

Microprocessor (MPU)

- **Microprocessor Unit (MPU)**
- The central processing core (e.g., Intel Pentium).
- High computational power.
- Requires external chips for memory, I/O ports (serial and parallel) and timers.
- Used in general-purpose systems like PCs where computational power is the main focus.

Microprocessor (MPU)

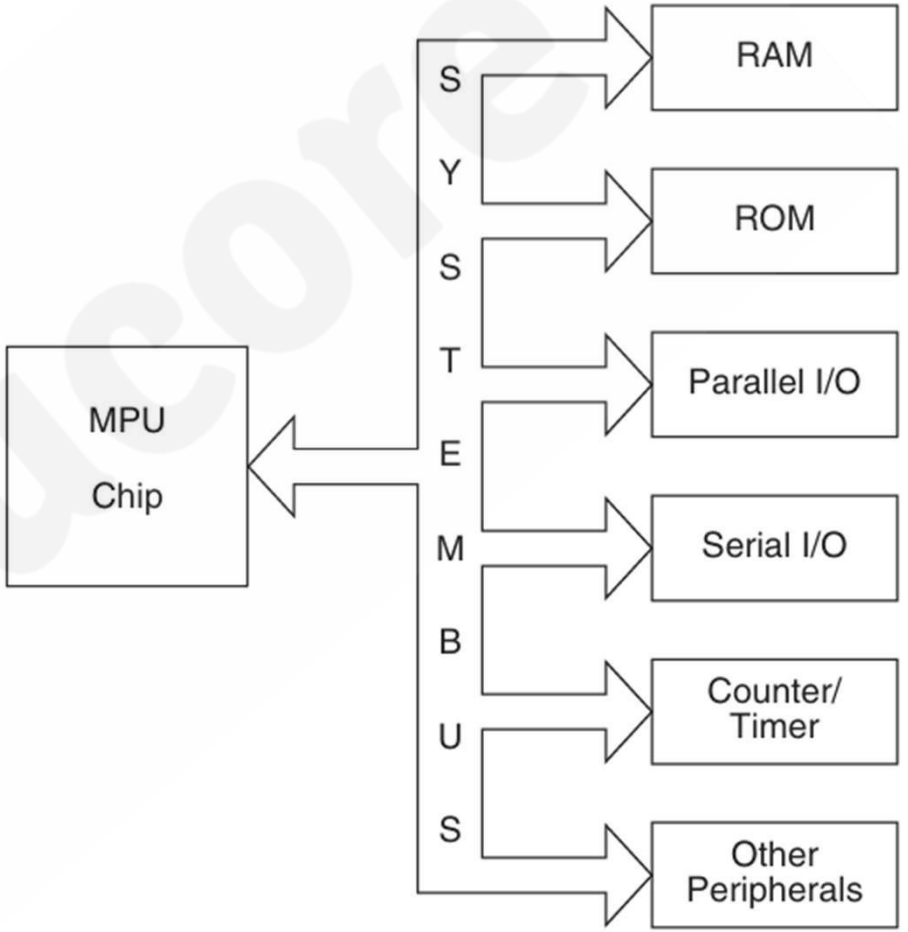


Figure 1.3 | An MPU with peripherals and memory external to the chip

Microcontroller (MCU)

- **Microcontroller Unit (MCU)**
- A "computer on a chip."
- Includes a processor core, memory (RAM, ROM), and peripherals (timers, I/O ports serial and parallel) on a single chip.
- Self-contained and designed for interfacing and control.
- The heart of most embedded systems.

Microcontroller (MCU)

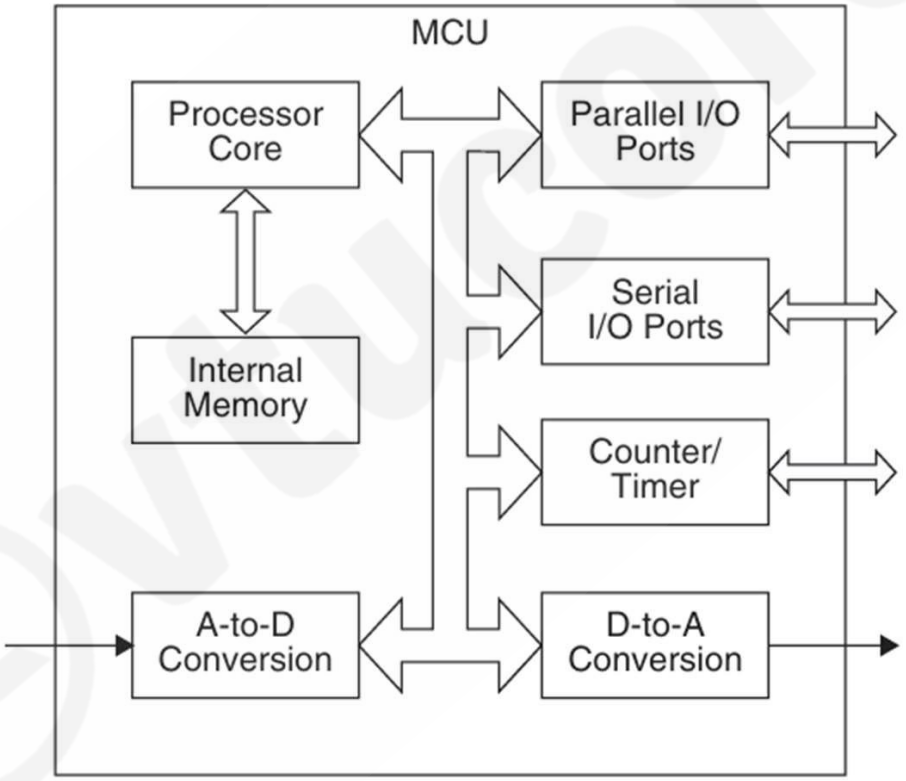


Figure 1.4 | An MCU with peripherals and memory inside the chip

Example of a Simple Embedded System: Temperature Monitor

- **Input:** A temperature sensor.
- **Processing:**
  - An Analog-to-Digital Converter (ADC) inside the MCU converts the sensor's analog signal to a digital value.
  - The MCU compares this value to a pre-set reference temperature.
  - The program runs in a continuous "superloop".
- **Output (Actuation):**
  - Displays the current temperature.
  - Activates an alarm if the temperature is too high.
  - Starts a cooling fan motor.

Example of a Simple Embedded System: Temperature Monitor

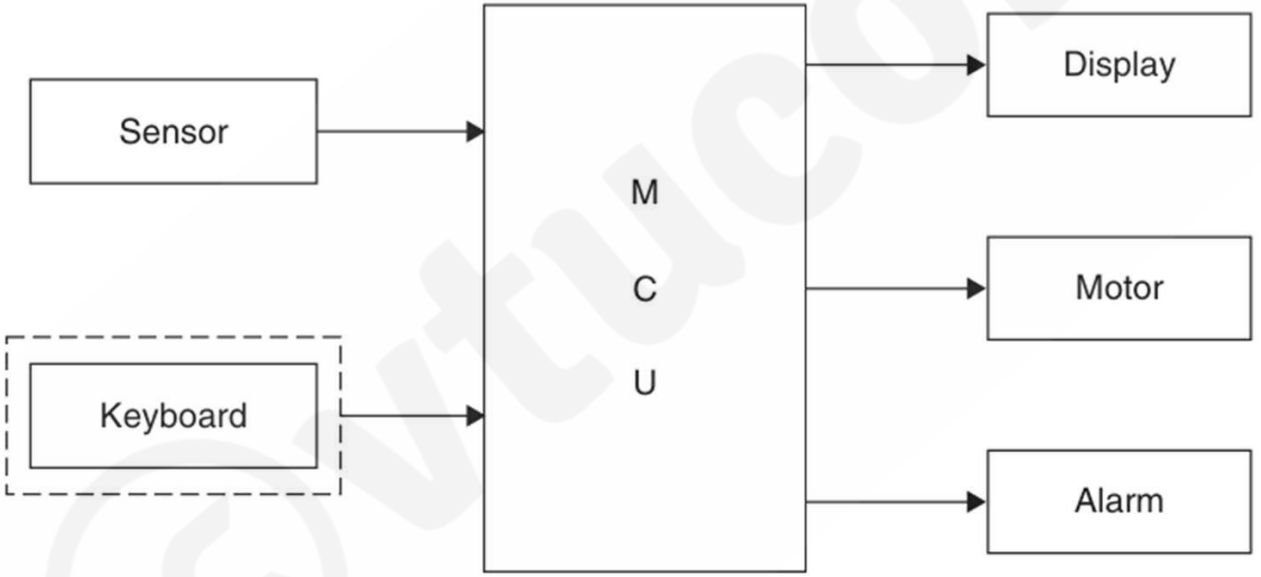


Figure 1.6 | A simple temperature monitor

Figures of Merit for an Embedded System

- Key design objectives for embedded systems:
- **Low-Power Dissipation:**
  - ❖ Most devices are battery powered and hene required have low power dissipation
  - ❖ Required to reduce excessive heating.
- **Small Physical Size:**
  - ❖ Many embedded devices are hand-held devices or has to be fnt into small space.
  - ❖ Hence PCB should be small with very less extra chips

Figures of Merit for an Embedded System

- **Small Code Size:**
  - ❖ Firmware (System code which is tested and debugged) should be fit within the limited on-chip ROM of MCU
  - ❖ On-chip ROM is expensive
- **High Speed of Response :**
  - ❖ Fast response is required. Fast response means higher clock frequency which increases the power dissipation. Compromise has to be done
  - ❖ **Real-Time Response:** The system must respond within a required deadline to be effective

Classification of MCUs by Data Bus Width

- **4-bit MCUs:** For simple applications with minimal computation, like toys (eg: which use only switches and direct actuation)
- **8-bit MCUs:** The most widely used type for moderately complex operations (e.g., 8051, PIC families).
- **16-bit MCUs:** Offer a balance of performance and low-power consumption (e.g., TI's MSP430).
- **32-bit MCUs:** For complex applications requiring low power, high speed and computing power, like image and video processing (e.g., used in smartphones, iPod, PDA).

Classification of MCUs by Data Bus Width
ASIC

- **ASIC: Application Specific Integrated Circuit**
- It is an IC
- Hardware integration of a complex algorithm
- They are efficient and fast
- They are expensive
- Example: Video codec (coder-decoder)

Classification of MCUs by Data Bus Width FPGA

- **FPGA: Field Programmable Gate Array**
- Programmable hardware (reconfigurable even when it is a part of the circuit)
- Number of logic cells are interconnected
- Logic cells and interconnects are programmable using Hardware Description Language (HDL) and synthesis tools
- Very high device density
- Hardware design is cheap and flexible
- Less efficiency compared to ASIC
- Examples: Xilinx, Altera, Altec etc are the companies supplying FPGAs

Classification of MCUs by Data Bus Width
DSP Processors

- **DSP Processors (Digital Signal Processing)**
- Instruction set suitable for Signal Processing and complex math applications
- Suitable for floating point operations
- Suitable for processing of real time speech, image and video
- Texas Instruments, Analog Devices, Nvidia, Lucent etc. are some of the companies which produce DSP processors
- The current trend is to have a general-purpose core and a DSP core on the same chip so that the tasks can be partitioned.

A Brief History of Embedded Systems

- **1974:** Texas Instruments releases the first microcontroller, the TMS 1000. (RAM, ROM, clock circuit, along with the processor on a single chip)
- **1977:** Intel introduces the 8048, widely used in PC keyboards.
- **1980:** Intel launches the highly successful 8051 microcontroller and it was called MCS-51 architecture.
- **1982:** Intel introduces the 80186 as an "embedded processor" with integrated peripherals like timers, DMA controllers, clock generators etc.
- This was followed by other microcontrollers like PIC by Microchip and ATMega by AVR
- **Modern Era:** The growth is fueled not just by microcontrollers but also by advancements in sensors, actuators, displays and software.

Challenges in the field of Embedded Systems

- New and innovative products are coming into the market
- The 3 P’s of innovation are “Price, Performance and Power”
- Performance has to be increased by keeping the price and power low
- Low power dissipating processors, sensors, actuators etc which should give high performance
- High performance means highest computational capability and highest possible speed

Current Trends in Embedded Systems

- **Multi-core Processors:** Using multiple processor cores at lower clock speeds to increase performance without a massive increase in power consumption. Often combines a general-purpose core with a specialized one (like a DSP).
- **Embedded and Real-Time Operating Systems (RTOS):** As systems become more complex, operating systems like Linux, Android and newer version of Symbion are becoming common to manage multiple tasks.
- **Newer Areas of Deployment:** Rapid growth in entertainment, healthcare, automotive, communications, and military applications.

QUESTIONS

1. Explain what an embedded system is, with few examples.
2. How is software embedded into an ES?
3. Name four fields of applications for an embedded system.
4. List three characteristics that an embedded system should possess.
5. Can an electronic tablet be listed as an embedded system? Substantiate your answer.
6. What is the difference between an MCU and an MPU?
7. Why is power dissipation a very important factor in embedded design?
8. Why are DSP processors used in embedded design?
9. Name two new areas of deployment for embedded systems.
10. Name two commercial products based on the ARM processor.

EXERCISES

1. Draw a block diagram of an embedded system which can be used for measuring short distances.
2. Name a few embedded products in the field of bio-medical engineering.