Introduction

What are Embedded Systems?

- An embedded system is an electronic/electro-mechanical system designed to perform a specific function and is a combination of both hardware and firmware(software).

- An embedded system is a system that has embedded software and computer-hardware which makes it a system dedicated for an application(s) or specific part of an application or product or a part of a larger system.

- Wayne Wolf defines embedded system as - " it is any device that includes a programmable computer but is not itself intended to be general purpose computer".

- An embedded system is an electronic system, which includes a single chip microcomputers (Microcontrollers) like the ARM or Cortex or Stellaris LM3S1968.

- It is configured to perform a specific dedicated application.

- An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system.

- Here the microcomputer is embedded or hidden inside the system. Every embedded microcomputer system accepts inputs, performs computations, and generates outputs and runs in real time.

Examples of embedded system:

– Smartphones
– Set-top boxes
– Televisions
– Video Games
– Refrigerators
– Cars
– Planes
– Elevators
– Remote Controls
– Alarm Systems

- **Components of a computer system:**

A computer is a system that has the following or more components:

1.A microprocessor
2.A large memory of the following two kinds:
a) Primary memory(semiconductor Ram,ROM and fast accessible cache)
b) Secondary memory(magnetic memory located in hard disks,optical memory CD-ROMs and memory sticks)
3.I/O units such as touch screen ,modem etc
4.Input units such as keyboard,mouse etc
5.Output units such as monitor,printer etc
6. Networking units such as Ethernet card, front end processor based server,bus,drivers etc.
7.An operating system that has general purpose user and application software in the secondary memory.

- **Components of an embedded system:**

An embedded system is a system that has three main components embedded in it:

1.It embeds the hardware similiar to a computer.

2.As its software usually embeds in the ROM or flash memory it usually do not need a secondary hard disk and CD memory as in a computer.

3.It embeds a real time operating system(RTOS) that supervises the application software running on hardware and organizes access to a resource according to the priorities of the task. It provides a mechanism to let the processor run a process as scheduled and context switch between the various processes.It sets the rules during the execution of the application software.

- **Differences between General Purpose and Embedded system**

General purpose Computing system	Embedded system
1. A system which is a combination of a generic hardware and a **general purpose operating system** for executing **a variety of applications.**	1. A system which is a combination of a special purpose hardware and an **embedded OS** for executing a **specific set of applications.**
2.Contains a General Purpose Operating System(GPOS).	2.May or may not contain an operating system for functioning.
3. Applications are **alterable(programmable**) by the user(It is possible for the end user to reinstall the operating system and also add or remove user applications.)	3.The **firmware of the embedded system is pre-programmed and it is non-alterable by the end-user.**(There may be exceptions for systems supporting OS kernel image flashing through special hardware settings)
4.**Performance** is the key deciding factor in the selection of the system.	4.**Application specific requirements**(like performance,power requirements,memory usage etc) are the key deciding factors).
5.**Less/not at all tailored towards reduced operating power**,options for different levels of power management.	5. Highly tailored to take advantage of the power saving modes supported by the hardware and the operating system.
6.Response requirements are **not time-critical.**	6.For certain category of embedded system like mission critical systems the response time requirements **is highly critical**.
7.Need not be **deterministic** in execution behavior.	7.Execution behavior is deterministic for certain types of embedded system like ‘Hard real time systems’.

Characteristics of Embedded System:

1.Complex Algorithms: The operations performed by the microprocessor may be very sophisticated.

2.User Interface: Microprocessors are frequently used to control complex user interfaces that may include multiple menus and many options.

3. Real time: Many embedded systems have to perform in real time-if the data is not ready by a certain deadline, the system breaks.

4.Multirate: Embedded computing systems have several real time activities going on at the same time.They may simultaneously control some operations that run at slower rates and others that run at faster rate: Ex –Multimedia operations.

5.Manufacturing cost: Manufacturing cost is determined by many factors-type of microprocessor used, the amount of memory required and the types of IO devices.

6.Power and energy: Power consumption directly affects the cost of the hardware since a larger power supply may be necessary.Energy consumption affects battery life,which is important for many applications.

Classification of Embedded Systems:

- **Based on Generation**
- **Based on Complexity & Performance Requirements**
- **Based on deterministic behavior**
- **Based on Triggering**

1. Embedded Systems - Classification based on Generation

1. First Generation: The early embedded systems built around **8-bit microprocessors** like 8085 and Z80 and **4-bit microcontrollers**

EX. stepper motor control units, Digital Telephone Keypads etc.

2. Second Generation: Embedded Systems built around **16-bit microprocessors** and **8 or 16-bit microcontrollers,** following the first generation embedded systems

EX.SCADA, Data Acquisition Systems etc.

3. Third Generation: Embedded Systems built around high performance **16/32 bit Microprocessors/controllers,** Application Specific Instruction set processors like Digital Signal Processors (**DSPs**), and **Application Specific Integrated Circuits (ASICs**).The instruction set is complex and powerful.

EX. Robotics, industrial process control, networking etc.

4. Fourth Generation: Embedded Systems built around System on Chips (SoC's), Re- configurable processors and multicore processors. It brings high performance, tight integration and miniaturization into the embedded device market

EX Smart phone devices, MIDs etc.

2. Embedded Systems - Classification based on Complexity & Performance

1. **Small Scale:** The embedded systems built around **low performance and low cost 8 or 16 bit microprocessors/ microcontrollers.** It is suitable for simple applications and where performance is not time critical. It may or may not contain OS.

2.**Medium Scale**: Embedded Systems built around **medium performance, low cost 16 or 32 bit microprocessors / microcontrollers or DSPs**. These are slightly complex in hardware and firmware. It may contain GPOS/RTOS.

3. **Large Scale/Complex:** Embedded Systems built around high performance **32 or 64 bit RISC processors/controllers, RSoC or multi-core processors and PLD.** It requires complex hardware and software. These system may contain multiple processors/controllers and co-units/hardware accelerators for offloading the processing requirements from the main processor. It contains RTOS for scheduling, prioritization and management.

3. Embedded Systems - Classification Based on deterministic behavior:

It is applicable for Real Time systems. The application/task execution behavior of an embedded system can be either deterministic or non-deterministic

These are classified into two types:

1. Soft Real time Systems: Missing a deadline may not be critical and can be tolerated to a certain degree

2. Hard Real time systems: Missing a program/task execution time deadline can have catastrophic consequences (financial, human loss of life, etc.)

4. Embedded Systems - Classification Based on Triggering:

These are classified into two types:

1. Event Triggered : Activities within the system (e.g., task run-times) are dynamic and depend upon occurrence of different events **.**

2. Time triggered: Activities within the system follow a statically computed schedule (i.e., they are allocated time slots during which they can take place) and thus by nature are predictable.

Major Application Areas of Embedded Systems:

- **Consumer Electronics:** Camcorders, Cameras etc.
- **Household Appliances:** Television, DVD players, washing machine, Fridge, Microwave Oven etc.
- **Home Automation and Security Systems:** Air conditioners, sprinklers, Intruder detection alarms, Closed Circuit Television Cameras, Fire alarms etc.
- **Automotive Industry:** Anti-lock breaking systems (ABS), Engine Control, Ignition Systems, Automatic Navigation Systems etc.
- **Telecom:** Cellular Telephones, Telephone switches, Handset Multimedia Applications etc.
- **Computer Peripherals:** Printers, Scanners, Fax machines etc.
- **Computer Networking Systems:** Network Routers, Switches, Hubs, Firewalls etc.
- **Health Care:** Different Kinds of Scanners, EEG, ECG Machines etc.
- **Measurement & Instrumentation:** Digital multi meters, Digital CROs, Logic Analyzers PLC systems etc.
- **Banking & Retail:** Automatic Teller Machines (ATM) and Currency counters, Point of Sales (POS)
- **Card Readers:** Barcode, Smart Card Readers, Hand held Devices etc.