

# Embedded Systems

## Definition of Embedded system

A unique electronic or electro-mechanical system (resided in a system) that consists of highly specialized hardware and software components in order to perform a dedicated task or operation is referred as embedded system. It consists self-contained operating system, hence, the user cannot reconfigure its OS and applications.

Embedded system contains a layered architecture of three main components which is illustrated in figure.

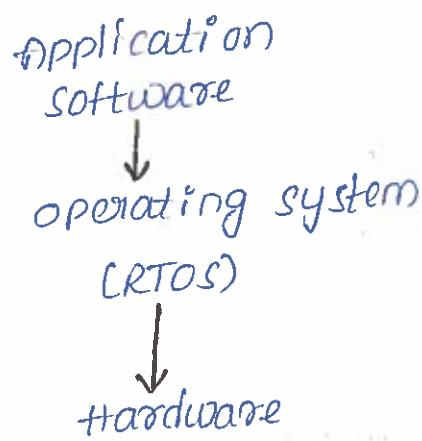


Figure : Embedded system

The application software is used to perform various tasks, threads and processes.

A real time operating system is used to monitor the application software running on hardware. It allows to perform various tasks based on the schedule and priority. The hardware of the embedded system is similar to computer.

## components of Embedded system Hardware

The components of an Embedded system hardware are,

1. power supply
2. Reset circuit
3. oscillator circuits
4. Input devices, interfacing/driver circuits
5. processor
6. Timer
7. Interrupt controller
8. program memory and data memory
9. serial communication ports
10. parallel ports
11. outputs interfacing/driver circuits
12. system application specific circuits.

### 1. power supply

Most of the embedded systems are associated with their own power supplies. The power supplied to each of the units in an Embedded system is within some defined range of voltages called operation range i.e., each unit operates in any one of the following operating ranges,

- i)  $5.0V \pm 0.25V$
- ii)  $3.3V \pm 0.3V$
- iii)  $2.0V \pm 0.2V$
- iv)  $1.5V \pm 0.2V$

2 The Embedded systems that don't have power supply of their own are connected to an external power supply or can use charge pumps to get powered up.

## 2. Reset circuit

It is an important circuit associated with an Embedded system. It is activated for a fixed period of time and then gets deactivated. When the reset circuit is activated, the control points to the default start-up address. After a few clock cycles, the reset circuit will be deactivated. This results in the activation of the processor circuit, which will start execution the program from the start-up address.

## 3. oscillator circuits

It is the basic requirement of a processor to control different clocking needs of the CPU, system timers and C.P.U machine cycles. An oscillator circuit basically controls the execution time of an instruction. It uses a crystal or a ceramic resonator or an external IC oscillator to serve the purpose of a clock circuits.

## 4. Input Devices, Interfacing/Driver circuits.

A keypad or a keyboard can be used as an input device to provide user inputs to the embedded system. An embedded system must be associated with the required interfacing, key de-bouncing circuit and software drivers to receive inputs from an input device.

## 5. processor

processor is the most essential part of an Embedded system. It comprises of two basic units, program flow control unit (CU) and execution unit (EU).

The control unit (CU) contains a fetch unit that is responsible for fetching of instructions from the memory.

The execution unit (EU) contains an Arithmetic and Logic unit (ALU) in addition to the circuits that perform data transfer and data conversion operations and that can execute instructions such as halt, interrupt or jump to perform a program control task.

## 6. Timers

Timers are used to measure elapsed time or to count some external events. A timer circuit is also called a Real-time clock (RTC). A RTC also helps in determining software controlled delays and time-outs.

## 7. Interrupt controller

An Embedded system handles interrupt handling mechanism called 'interrupt controller'. When two or more devices are connected to a system, the system processor must fulfill all the requirements of these devices by running the appropriate interrupt service routines (ISRs). If at all an interrupt occurs, the interrupt controllers of the system handles it.

## 8. program memory and data memory

The Embedded system use various types of memories to store program and data. They are,

i) Read only memory (ROM) or PROM or EEPROM  
for storing application programs.

ii) Random access memory (RAM)

For storing variables and stacks during program execution.

iii) Flash, caches or EEPROM

For storing non-volatile results and copies of instructions and data.

## 9. serial communication ports

An embedded system can perform serial communication using a serial I/O port. A system can send or receive a serial stream of bits along a serial port through modem. A serial port is preferred when a long distance communication and interconnections are to be performed. The different types of serial ports available are,

i) serial UART port [UART - Universal Asynchronous Receiver and Transmitter]

ii) serial synchronous port

iii) serial interfacing port.

## 10. parallel ports

An embedded system can perform parallel communication using parallel I/O ports. A system can send or receive parallel streams of bits along a parallel port.

## 11. Outputs Interfacing / Driver Circuits

The embedded system displays the output on output devices such as Light Emitting Diode (LED), Liquid crystal display (LCD), touch screen display (TSC) panel etc, performing write operation on the output ports.

## 12. System Application Specific Circuits

The applications such as signal processing, voice processing, automatic control, instrumentation and data acquisition can be run on a system only if the system has the required application specific circuit circuits and software for both Digital-to-Analog conversion (DAC) unit and Analog-to-Digital conversion (ADC) unit.

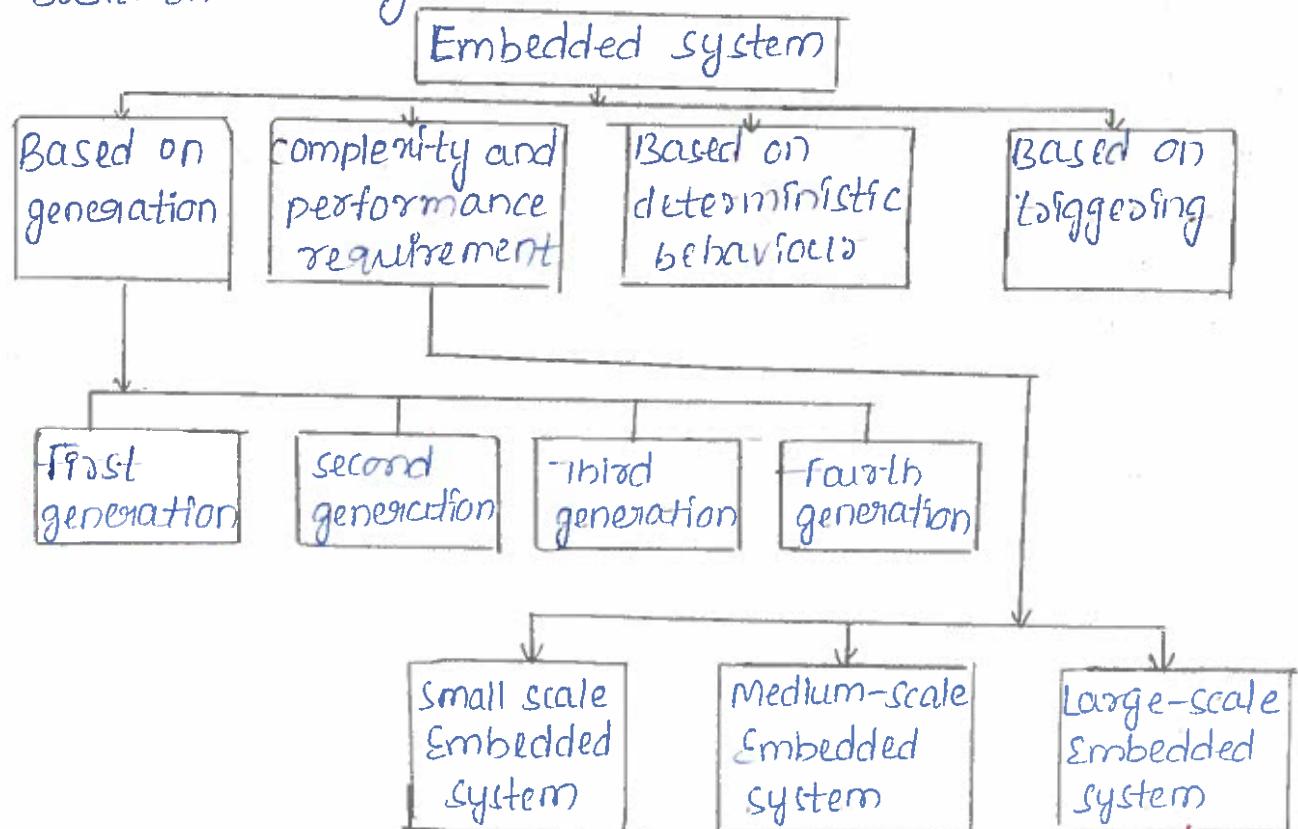
## Embedded systems vs General computing systems

Embedded system	General purpose computing system
<ul style="list-style-type: none"><li>→ A unique electronic or electro-mechanical system (designed in a system) that consists of highly specialized hardware and software components to perform a dedicated task or operation is referred as embedded system.</li></ul>	<ul style="list-style-type: none"><li>→ A system that performs various operations by using generic hardware and General purpose operating system (GPOS) is referred as a general purpose computing system.</li></ul>
<ul style="list-style-type: none"><li>→ This system may or may not employ an operating system.</li></ul>	<ul style="list-style-type: none"><li>→ This system employs General purpose operating system (GPOS).</li></ul>

## 4. Embedded system

Embedded system	General purpose computing system
→ The response time requirement is highly significant.	→ The response time requirement is insignificant.
→ Specific execution behaviour is required in hardware all the time.	→ Specific execution behaviour is not required.
→ The software programs are pre-programmed and cannot be changed by the end users.	→ Applications (software) are programmable by end users.
→ It is customized to save the power modes which are supported by hardware and operating system.	→ It is not customized to reduce the power requirements of the operating system.
→ The system selection depends on application specific requirements.	→ The system selection depends on its performance.

Classification of Embedded system:  
Based on following criteria



## 1) Based on generation:

First generation:

- Built around 8 bit microprocessor like 8085, and 4 bit microcontrollers.

→ Simple fn hardware circuit & firmware developed.

Examples: digital telephone keypads, stepper motor control

Second generation:

- Built around 16 bit microprocessors and 8 or 16 bit microcontrollers

→ They are more complex and powerful than first generation

→ in μP/MC.

→ Some of the second gen. Embedded systems contained embedded operating system for their operation.

→ Examples: data acquisition system, SCADA systems.

Third generation:

- Built around 32 bit processors and 16 bit microcontroller
- concepts like digital signal processors (DSP) and application specific integrated circuits (ASIC) evolved.

→ complex and powerful and the concept of instruction pipelining also evolved.

Examples: Robotics, Media, networking etc.

Fourth generation:

→ Built around 64-bit μP & 32-bit MC.

→ The concept of system on chips (SOC), multicore processor

→ also evolved.

→ Highly complex & very powerful.

Examples: Smart phones, mobile internet devices (MID).

## 2) Based on complexity & performance:

1) Small scale E.S:

→ Simple in application need

→ performance requirements are not time-critical.

→ small scale E.S are usually built around low performance

→ and low cost

5. → 8 or 16 bit µPLC

→ may or may not contain operating system.

Example: An electronic toy.

2) Medium scale E.S:

→ slightly complex for hardware and firmware.

→ Built around medium performance.

→ low cost

→ 16 or 32 bit µPLC

Example: Industrial machines

3) Large scale E.S / complex systems:

→ highly complex hardware and firmware.

→ Built around 32 or 64 bit RISC µPLC or PLDS or multi-core processors.

→ response is time-critical

Examples:- Decoding/Encoding of media, Mission critical applications.

3) Based on deterministic behaviour:

→ This classification is applicable for 'real-time systems'.

→ The task execution behaviour for an Embedded system must be deterministic or non-deterministic.

→ Based on execution behaviour real-time embedded system are divided into hard and soft.

4) Based on triggering:

→ Embedded systems which are "reactive" in nature can be based on triggering.

→ Reactive systems can be

\* Event triggered

\* Time triggered

## Major application areas in Embedded system:

Embedded technology has acquired a new dimension from its first generation model. The Apollo guidance computer, to the latest radio navigation system combined with in-car entertainment technology is the microprocessor based 'smart' running shoes launched by Adidas in April 2005

The application areas and the products in the Embedded domain are countless. A few of the important domains & products are listed below

1. consumers electronics: camcorders, cameras etc
2. household appliances: TVs, DVD players, washing machine, fridge, microwave oven
3. home automation and security systems: Air conditioners, sprinklers, fire alarms.
4. automotive industry: anti-lock braking systems (ABS), engine control, ignition systems.
5. Telecom : cellular telephones, telephone switches, handset multimedia application.
6. computer peripherals : printers, scanners, fax machine
7. computer networking system: network routers, switches, hubs, firewalls etc.
8. health care : Different kinds of scanners, EEG, ECG
9. measurement & instrumentation : Digital multimeters, digital CROs, logic analyzers, PLC.
10. Banking & Retail : automatic teller machines (ATM) and currency counters, point of sales (POS)
11. card readers : Different kinds of scanners, EEG, Barcode, smart card readers, hand held devices

## 6. characteristics and quality attributes of Embedded system

### characteristics of Embedded system

#### 1. Application and domain specific:

→ An embedded system is designed for a specific purpose only. It will not do any other task.

→ certain Embedded systems are specific to a domain.

#### 2. Reactive and real time

→ certain Embedded systems are designed to react to the events that occur in the nearby environment. These events also occur real-time.

→ An embedded system uses sensors to take inputs and has actuators to bring out the required functionality.

#### 3. operation in harsh environment

→ certain Embedded systems are designed to operate in harsh environments like very high temperature of the deserts or very low temperature of the mountains or extreme rains.

→ These Embedded systems have to be capable of sustaining the environmental conditions it is designed to operate in.

#### 4. Distributed

→ certain Embedded systems are part of a larger system and thus form components of a distributed system.

→ These components are independent of each other but have to work together for the larger system to function properly.

#### 5. small size and weight

→ An embedded system that is compact in size and has light weight will be desirable or more popular than one

that is bulky & heavy

→ example - currently available all phones.

The cell phones that have the maximum features are popular

- but also their size & weight is an important characteristic.

## 6. power concerns

- It is desirable that the power utilization and heat dissipation of any Embedded system is low
- If more heat is dissipated then additional units like heat sinks or cooling fans needs to be added to the circuit
- If more power is required then a battery of high power or more batteries need to be accommodated in the Embedded system.

## Quality Attributes of Embedded system

Those are the attributes that together form the deciding factor about quality of an embedded system.

These are ~~two~~ types of Quality attributes

### 1. Response

- It is a measure of quickness of the system.
- It gives you an idea about how fast your system is tracking the input variables.
- Most of the embedded system demand fast response which should be real-time

### 2. Throughput

- It deals with the efficiency of system
- It can be defined as rate of production or process of a defined process over a static period of time.

### 3. Reliability:

- It is the measure of how much percentage you rely upon the proper functioning of the system.

→ mean time b/w failures and mean time to repair are terms used in defining system reliability.

#### 4. maintainability:

→ maintainability deals with support and maintenance to the end user or a client in case of technical issues and product failures or a routine system checkup

#### 5. security

→ confidentiality, integrity and availability are three corner stones of information security

→ confidential data deals with protecting data from unauthorized disclosure.

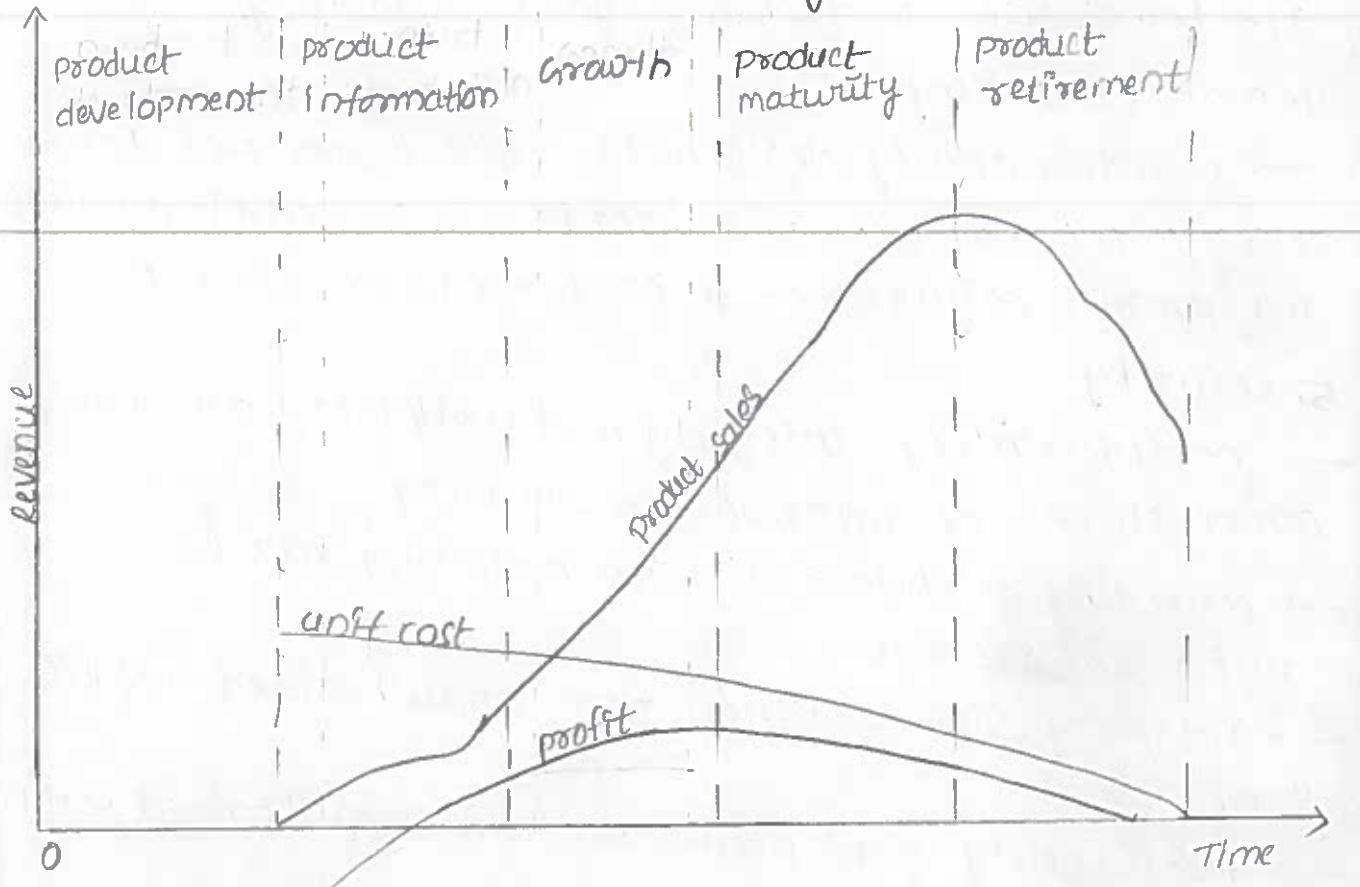
→ Integrity give protection from unauthorized modification.

→ Availability gives protection from unauthorized person.

#### 6. safety

→ safety deals with the possible damage that can happen to the operating person and environment due to the operating person and environment due to breakdown of an embedded system or due to emission of hazardous materials from the embedded products.

# Product Life cycle of Embedded system :



## 1. Designing and developing product

During this stage product is designed and developed with proper investments.

## 2. product introduction

During the stage product is introduced into the market and stage sale and revenue is less.

## 3. Growth

During this stage awareness of product increases, resulting in increased product sales and revenue.

## 4. product maturity

At this stage, growth and sales remain stable and revenue reaches its peak.

## 5. product declination

Sales get decreasing due to various reasons such as technology changes, introduction of new or similar product etc, thus it can be observed.

From the curve that the total revenue increases from product introduction and get reduce when it reaches revenue peak.