UNIT-1
INTRODUCTION TO EMBEDDED SYSTEMS

- Definition
- History
- Classification
- Purpose
- Embedded system Vs general purpose computing systems
- Characteristics and Quality Attributes of an embedded system.

- **SYSTEM**: It is an arrangement in which all its units are assembled and work together according to set of rules

- **EMBEDDED SYSTEM**
  - It is a combination of software and hardware
  - It is designed to perform a particular task
  - The task has to be completed in a given time

- An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints.
- Embedded systems contain processing cores that are either microcontrollers, or digital signal processors (DSP). A processor is an important unit in the embedded system hardware. It is the heart of the embedded system

- Physically, embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, and largely complex systems like hybrid vehicles, MRI, and avionics.
- Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

Embedded systems are commonly found in consumer, cooking, industrial, automotive, medical, commercial and military applications.

- Telecommunications systems employ numerous embedded systems from telephone switches for the network to mobile phones at the end-user.
- Computer networking uses dedicated routers and network bridges to route data. Consumer include personal digital assistants (PDAs), mp3 players, mobile phones, videogame consoles, digital cameras, DVD players, GPS receivers, and printers.
- Many household appliances, such as microwave ovens, washing machines and dishwashers, include embedded systems to provide flexibility, efficiency and features.

History

- In 1960, embedded system was first used for developing Apollo Guidance System by Charles Stark Draper at MIT.
- In 1965, Autonetics, developed the D-17B, the computer used in the Minuteman missile guidance system.
- In 1968, the first embedded system for a vehicle was released.
- Texas Instruments developed the first microcontroller in 1971.
- In 1987, the first embedded OS, VxWorks, was released by Wind River.
- Microsoft's Windows embedded CE in 1996.
- By the late 1990s, the first embedded Linux system appeared.
- The embedded market reach $140 billion in 2013.
- Analysts are projecting an Embedded market larger than $40 billion by 2030.

classification

- Based on generation
- Based on complexity and performance
- Based on determistic behaviour
- Based on trigerring

Based on generation

- First generation embedded systems(1G)
- Second generation embedded systems (2G)
- Third generation embedded systems (3G)
- Fourth generation embedded systems (4G)

First generation Embedded systems(1G)

- Built around 8 bit microprocessor& micro controller
- Simple in hardware circuit & firmware developed.
- Examples: Digital telephone keypads

second generation Embedded systems (2G):

- Built around 16 bit micro processors & 16 bit micro controllers
- They are more complex and powerful than 1Gmicro processor and micro controller
- Example: SCADA systems

Third generation Embedded systems (3G):

- Built around 32 bit micro processors & 16 bit micro controllers
- Concepts like DSPs and ASICs are evolved.
- Examples: Robotics, Media etc.,

Fourth generationEmbedded systems:

- Built around 16 bit micro processors & 16 bit micro controllers
- Concepts like SoC, multicore processors are evolved
- Highly complex & very powerful
- Examples: Smart phones.

Based on complexity and performance

- Small scale embedded systems
- Medium scale embedded systems
- Large scale embedded systems

Small scale embedded systems:

- Simple in application need.
- Performance not time-critical.
- Built around low performance and low cost 8 or 16 bit up/uc.
- Example: Electronic toy.

Medium-Scale embedded systems:

- Slightly complex in hardware and firmware requirement
- Built around medium performance and low cost 16 or 32 bit up/uc
- Usually contain operating system
- Examples: Industrial machines

Large-Scale embedded systems :

- Highly complex hardware and firmware
- Built around 32 or 64 bit RISC up/uc or PLDs or Multicore processors
- Examples: Mission critical applications

Based on deterministic behaviour

- This classification is applicable for “Real Time” systems.
- The task execution behaviour for an embedded systems may be deterministic or non-deterministic
- Based on execution behaviour real time embedded systems are divided into hard and soft

Based on triggering

- Embedded systems which are “reactive” in nature can be based on triggering
- Triggering systems can be:

✔ Event triggered

✔ Time triggered

PURPOSE OF AN EMBEDDED SYSTEM

1. Data Collection/Storage/Representation
2. Data communication
3. Data signal processing
4. Monitoring
5. Control
6. Application specific user interface

Data Collection/Storage/Representation

- Data collection is usually done for storage, analysis, manipulation and transmission
- Data can be analog or digital
- Embedded systems with analog data capturing techniques collect data directly in the form of analog signal.
- If the data is digital it can be directly captured by digital embedded system.
- A digital camera is a typical example of an embedded System with data collection/storage/representation of data

Data communication:

- Embedded data communication systems are deployed in applications from complex satellite communication to simple home networking systems.
- Data can either be transmitted by analog means or by digital means.
- Network hubs, routers, switches are examples of dedicated data transmission embedded systems

Data signal processing:

- Embedded systems with signal processing functionalities are employed in applications demanding signal processing like speech coding, audio video codec, transmission applications etc.
- A digital hearing aid is a typical example of an embedded system employing data processing.
- Digital hearing aid improves the hearing capacity of hearing impaired person.

Monitoring:

- All embedded products coming under the medical domain are with monitoring functions.
- Electro cardiogram machine is intended to do the monitoring of the heartbeat of a patient but it cannot impose control over the heartbeat.
- Other examples with monitoring function are digital CRO, digital multimeters, and logic analyzers.

Control:

- A system with control functionality contains both sensors and actuators.
- Sensors are connected to the input port for capturing the changes in environmental variable and the actuators connected to the output port are controlled according to the changes in the input variable.
- Air conditioner system used to control the room temperature to a specified limit is a typical example for CONTROL purpose.

Application specific user interface

- Buttons, switches, keypad, lights, bells, display units etc are application specific user interfaces.
- Mobile phone is an example of application specific user interface.
- In mobile phone the user interface is provided through the keypad, system speaker, vibration alert etc.

Embedded system Vs general purpose computing systems

- The Embedded System and the General purpose computer are at two extremes. The embedded system is designed to perform a specific task.
- whereas as per definition the general purpose computer is meant for general use. It can be used for playing games, watching movies, creating software, work on documents or spreadsheets etc.

Criteria	General Purpose Computer	Embedded system
Contents	It is combination of generic hardware and a general purpose OS for executing a variety of applications.	It is combination of special purpose hardware and embedded OS for executing specific set of applications
Operating System	It contains general purpose operating system	It may or may not contain operating system.
Alterations	Applications are alterable by the user.	Applications are non-alterable by the user.
Key factor	Performance" is key factor.	Application specific requirements are key factors.
Power Consumption	More	Less
Response Time	Not Critical	Critical for some applications

Characteristics of an embedded system

- The characteristics of embedded system are different from those of a general purpose computer and so are its Quality metrics.
- This gives a brief introduction on the characteristics of an embedded system and the attributes that are associated with its quality

- Unlike general purpose computing systems, embedded systems possess certain specific characteristics and these characteristics are unique to each embedded system.

- Some of the important characteristics of an embedded system are:

1. Application and domain specific
2. Reactive and Real Time
3. Operates in harsh environments
4. Distributed
5. Small size and weight
6. Power concerns

1. Application and Domain Specific

- An embedded system is designed for a specific purpose only.
- It will not do any other task.
- Ex. Air conditioner's embedded control unit, it cannot replace microwave oven
- Ex. A washing machine can only wash, it cannot cook..
- Because the embedded control units of microwave oven and air conditioner are specifically designed to perform certain specific tasks.
- Certain embedded systems are specific to a domain: ex. A hearing aid is an application that belongs to the domain of signal processing and telecom with another control unit designed to serve another domain like consumer electronics.

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.
- Ex. Flight control systems, Antilock Brake Systems (ABS), etc. are examples of Real Time systems
- Ex. An air conditioner adjusts its mechanical parts as soon as it gets a signal from its sensors to increase or decrease the temperature when the user operates it using a remote control.
- 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 a dusty one or a high temperature zone or an area subject to vibrations and shock or 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

- The term distributed means that embedded systems may be a part of a larger system.
- These components are independent of each other but have to work together for the larger system to function properly.
- Ex. An automatic vending machine is a typical example for this. The vending machine contains a card reader (for pre-paid vending systems), a vending unit, etc. Each of them are independent embedded units but they work together to perform the overall vending function.

- Ex. Automatic Teller Machine (ATM) contains a card reader embedded unit, responsible for reading and validating the user's ATM card, transaction unit for performing transactions, a currency counter for dispatching/vending currency to the authorized person and a printer unit for printing the transaction details.
- This can visualize these as independent embedded systems. But they work together to achieve a common goal.

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 and heavy.
- Ex. Currently available cell phones. The cell phones that have the maximum features are popular but also their size and weight is an important characteristic.

6. Power Concerns

- It is desirable that the power utilization and heat dissipation of any embedded system be low.
- If more heat is dissipated then additional units like heat sinks or cooling fans need to be added to the circuit.
- Ex. The production of high amount of heat demands cooling requirements like cooling fans which in turn occupies additional space and make the system bulky. Nowadays ultra low power components are available in the market.
- Select the design according to the low power components like low dropout regulators, and controllers/processors with power saving modes.
- Also power management is a critical constraint in battery operated application.
- The more the power consumption the less is the battery life.

Quality Attributes of Embedded Systems

- Quality attributes are the non-functional requirements that need to be documented properly in any system design.
- If the quality attributes are more concrete and measurable, it will give a positive impact on the system development process and the end product.
- The various quality attributes that needs to be addressed in any embedded system development are broadly classified into two, namely

i. Operational Quality Attributes

ii. Non-Operational Quality Attributes

Operational Quality Attributes

- The operational quality attributes represent the relevant quality attributes related to the embedded system when it is in **the operational mode or 'online' mode. The important quality attributes coming under this category are listed below:**

I. Response
II. Throughput
III. Reliability
IV. Maintainability
V. Security
VI. Safety

2. Non Operational Attributes

- The quality attributes that needs to be addressed for the product **'not' on the basic of operational aspects are grouped under this category. The important** quality attributes coming under this category are listed below:

i. Testability & Debug-ability

ii. Evolvability

iii. Portability

iv. Time to prototype and market

v. Per unit and total cost