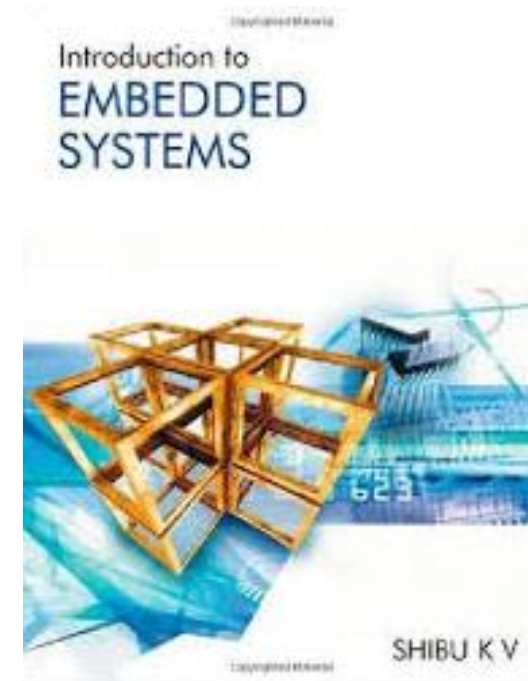


**IT-51061**

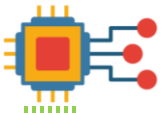
Introduction to  
**EMBEDDED SYSTEMS**  
(2<sup>nd</sup> Edition)

**SHIBU K V**



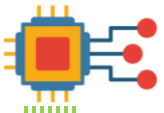
**Chapter 3**

**CHARACTERISTICS AND QUALITY ATTRIBUTES OF EMBEDDED SYSTEMS**



# Outlines

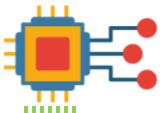
- Characteristics of Embedded Systems
- Quality Attributes of Embedded Systems



# Characteristics of Embedded Systems

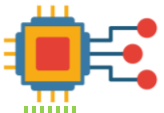
Each Embedded System possess a set of characteristics which are unique to it. Some important characteristics of embedded systems are:

1. Application & Domain Specific
2. Reactive & Real Time
3. Operates in 'harsh' environment
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.

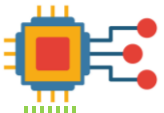


## 2. Reactive and Real Time

- ✓ 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.

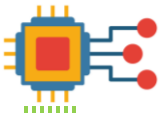
## 3. Operation in Harsh Environment

- ✓ 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.



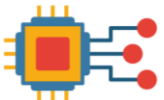
## 4. Distributed

- ✓ 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

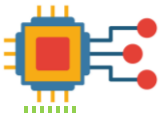
- ✓ An embedded system that is compact in size and has light weight will be desirable or more popular than one that is bulky and heavy.
- ✓ Ex. Currently available cell phones. The cell phones that have the maximum features are popular but also their size and weight is an important characteristic.



## 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

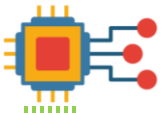
Represent the non-functional requirements that needs to be addressed in the design of an embedded system. The various quality attributes that needs to be addressed in any embedded system development are broadly classified into:

## Operational Quality Attributes

- ✓ Refers to the relevant quality attributes related to tan embedded system when it is in the operational mode or ‘online’ mode.

## Non-Operational Quality Attributes

- ✓ The Quality attributes that needs to be addressed for the product ‘not’ on the basis of operational aspects are grouped under this category.



# 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:

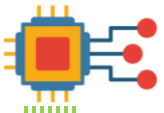
- i. Response
- ii. Throughput
- iii. Reliability
- iv. Maintainability
- v. Security
- vi. Safety

Note:

MTBF = Mean Time Between Failures

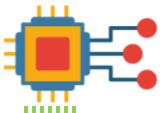
MTTR = Mean Time To Repair

Availability =  $MTBF / (MTBF + MTTR)$



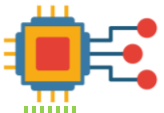
## i. Response

- ✓ Response 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.
- ✓ Ex. An embedded system deployed in flight control application should respond in a Real Time manner.
- ✓ Any response delay in the system will create potential damages to the safety of the flight as well as the passengers.
- ✓ It is not necessary that all embedded systems should be Real Time in response.
- ✓ For example, the response time requirement for an electronic toy is not at all time-critical.



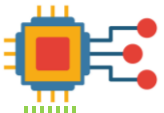
## ii. Throughput

- ✓ Throughput deals with the efficiency of system.
- ✓ It can be defined as rate of production or process of a defined process over a stated period of time.
- ✓ The rates can be expressed in terms of units of products, batches produced, or any other meaningful measurements.
- ✓ In case of card reader like the ones used in buses, throughput means how much transactions the Reader can perform in a minute or hour or day.
- ✓ Throughput is generally measured in terms of 'Benchmark'. A 'Benchmark' is a reference point by which something can be measured.
- ✓ Benchmark can be a set of performance criteria that a product is expected to meet or a standard product that can be used for comparing other products of the same product line.



### iii. Reliability

- ✓ Reliability is a measure of how much percentage you rely upon the proper functioning of the system or what is the % susceptibility of the system to failure.
- ✓ Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) are the terms used in defining system reliability.
- ✓ MTBF gives the frequency of failures in hours/weeks/months.
- ✓ MTTR specifies how long the system is allowed to be out of order following a failure.
- ✓ For an embedded system with critical application need, it should be of the order of minutes.

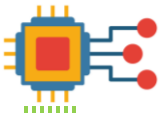


## iv. Maintainability

- ✓ Maintainability can be classified into two types:
  1. Scheduled or Periodic Maintenance (Preventive Maintenance)
    - ✓ An inkjet printer uses ink cartridges, which are consumable components and as per the printer manufacturer the end use should replace the cartridge after each 'n' number of printouts to get quality prints.
  2. Maintenance to Unexpected Failures (Corrective Maintenance)
    - ✓ If the paper feeding part of the printer fails the printer fails to print and it requires immediate repairs to rectify this problem.
    - ✓ Hence it is obvious that maintainability is simply an indication of the availability of the product for use. In any embedded system design, the ideal value for availability is expressed as

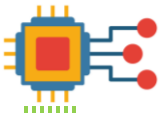
$$A_i = MTBF / (MTBF + MTTR)$$

Where  $A_i$ =Availability in the ideal condition, MTBF=Mean Time Between Failures, and MTTR=Mean Time To Repair



## v. Security

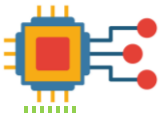
- ✓ ‘Confidentially’, ‘Integrity’, and ‘Availability’ are three major measures of information security.
- ✓ ‘Confidentially’ deals with the protection of data and application from unauthorized disclosure.
- ✓ ‘Integrity’ deals with the protection of data and application from unauthorized modification.
- ✓ ‘Availability’ deals with protection of data and application from unauthorized users.
- ✓ Certain embedded systems have to make sure they conform to the security measures.
- ✓ Ex. An electronic safety Deposit Locker can be used only with a pin number like a password.



## vi. Safety

- ✓ Safety deals with the possible damages that can happen to the operators, public and the environment due to the breakdown of an embedded system or due to the emission of radioactive or hazardous materials from the embedded products.
- ✓ The breakdown of an embedded system may occur due to a hardware failure or a firmware failure.
- ✓ Safety analysis is a must in product engineering to evaluate the anticipated damages and determine the best course of action to bring down the consequences of the damages to an acceptable level.

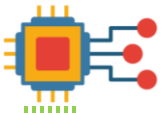




# Non-Operational Quality Attributes

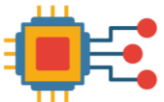
The quality attributes that needs to be addressed for the product ‘not’ on the basic of operational aspects are grouped under this category. The important quality attributes coming under this category are listed below:

- i. Testability & Debug-ability
- ii. Evolvability
- iii. Portability
- iv. Time to Prototype and Market
- v. Per Unit and Total Cost



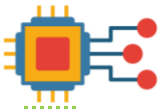
## i. Testability & Debug-ability

- ✓ Testability deals with how easily one can test his/her design, application and by which means he/she can test it.
- ✓ For an embedded product, testability is applicable to both the embedded hardware and firmware.
- ✓ Debug-ability is a means of debugging the product as such for figuring out the probable sources that create unexpected behavior in the total system.
- ✓ Debug-ability has two aspects in the embedded system development context, namely, hardware level debugging and firmware level debugging.
- ✓ Hardware debugging is used for figuring out the issues created by hardware problems whereas firmware debugging is employed to figure out the probable errors that appear as a result of flaws in the firmware.



## ii. Evolvability

- ✓ Evolvability is a term which is closely related to Biology.
- ✓ Evolvability is referred as the non-heritable variation.
- ✓ For an embedded system, the quality attribute ‘Evolvability’ refers to the ease with which the embedded product (including firmware and hardware) can be modified to take advantage of new firmware or hardware technologies.

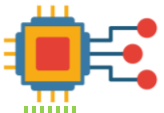


### **iii. Portability**

- ✓ Portability is a measure of ‘system independence’.
- ✓ An embedded product can be called portable if it is capable of functioning in various environments, target processors/controllers and embedded operating systems.
- ✓ A standard embedded product should always be flexible and portable.

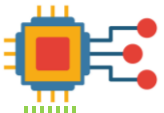
### **iv. Time-to-Prototype and Market**

- ✓ Time-to-market is the time elapsed between the conceptualization of a product and the time at which the product is ready for selling (for commercial product) or use (for non-commercial products).
- ✓ The commercial embedded product market is highly competitive and time to market the product is a critical factor in the success of a commercial embedded product.
- ✓ Product prototyping helps a lot in reducing time-to-market.



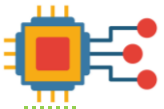
## v. Per Unit Cost and Revenue

- ✓ Cost is a factor which is closely monitored by both end user (those who buy the product) and product manufacturer (those who build the product).
- ✓ Cost is a highly sensitive factor for commercial products.
- ✓ Proper market study and cost benefit analysis should be carried out before taking decision on the per unit cost of the embedded product.
- ✓ When the product is introduced in the market, for the initial period the sales and revenue will be low.
- ✓ There won't be much competition when the product sales and revenue increase.
- ✓ During the maturing phase, the growth will be steady and revenue reaches highest point and at retirement time there will be a drop in sales volume.



## vi. Safety

- ✓ Safety deals with the possible damages that can happen to the operators, public and the environment due to the breakdown of an embedded system or due to the emission of radioactive or hazardous materials from the embedded products.
- ✓ The breakdown of an embedded system may occur due to a hardware failure or a firmware failure.
- ✓ Safety analysis is a must in product engineering to evaluate the anticipated damages and determine the best course of action to bring down the consequences of the damages to an acceptable level.



# The Product Life Cycle (PLC) Curve

