EMBEDDED SYSTEM DESIGN CONCEPTS

Characteristics & Quality Attributes Of Embedded Systems

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

CHARACTERISTICS OF EMBEDDED SYSTEM

Following are some of the characteristics of an embedded system that make it different from a general purpose computer:

1. Application and Domain specific

- An embedded system is designed for a specific purpose only. It will not do any other task.
- Ex. A washing machine can only wash, it cannot cook
- Certain embedded systems are specific to a domain: ex. A hearing aid is an application that belongs to the domain of signal processing.

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. 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 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 systems

- 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.
- Ex. A car has many embedded systems controlled to its dash board. Each one is an independent embedded system yet the entire car can be said to function properly only if all the systems work together.

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.

If more power is required then a battery of higher power or more batteries need to be accommodated in the embedded system

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QUALITY ATTRIBUTES OF EMBEDDED SYSTEM

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

There are two types of quality attributes are:-

1. Operational Quality Attributes.

- These are attributes related to operation or functioning of an embedded system. The way an embedded system operates affects its overall quality.

2. Non-Operational Quality Attributes.

- These are attributes **not** related to operation or functioning of an embedded system. The way an embedded system operates affects its overall quality.
- These are the attributes that are associated with the embedded system before it can be put in operation.

Operational Attributes

a) 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.

b) 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.

- In case of card reader like the ones used in buses, throughput means how much transaction the reader can perform in a minute or hour or day.

c) Reliability

- Reliability is a measure of how much percentage you rely upon the proper functioning of the system .
- Mean Time between failures and Mean Time To Repair are terms used in defining system reliability.
- Mean Time between failures can be defined as the average time the system is functioning before a failure occurs.
- Mean time to repair can be defined as the average time the system has spent in repairs.

d) Maintainability

- Maintainability deals with support and maintenance to the end user or a client in case of technical issues and product failures or on the basis of a routine system checkup
- It can be classified into two types :-

1. Scheduled or Periodic Maintenance

- This is the maintenance that is required regularly after a periodic time interval.
- Example : Periodic Cleaning of Air Conditioners Refilling of printer cartridges.

2. Maintenance to unexpected failure

- This involves the maintenance due to a sudden breakdown in the functioning of the system.
- Example:

1. Air conditioner not powering on
2. Printer not taking paper in spite of a full paper stack

e) Security

- Confidentiality, Integrity and Availability are three corner stones of information security.
- Confidentiality deals with protection data from unauthorized disclosure.
- Integrity gives protection from unauthorized modification.
- Availability gives protection from unauthorized user
- 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.

f) Safety

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

- A safety analysis is a must in product engineering to evaluate the anticipated damage and determine the best course of action to bring down the consequence of damages to an acceptable level.

Non Operational Attributes

a) Testability and Debug-ability

- It deals with how easily one can test his/her design, application and by which mean he/she can test it.
- In hardware testing the peripherals and total hardware function in designed manner
- Firmware testing is functioning in expected way
- Debug-ability is means of debugging the product as such for figuring out the probable sources that create unexpected behavior in the total system

b) Evolvability

- For embedded system, the qualitative attribute "Evolvability" refer to ease with which the embedded product can be modified to take advantage of new firmware or hardware technology.

c) Portability

- Portability is measured of "system Independence".
- An embedded product can be called portable if it is capable of performing its operation as it is intended to do in various environments irrespective of different processor and or controller and embedded operating systems.

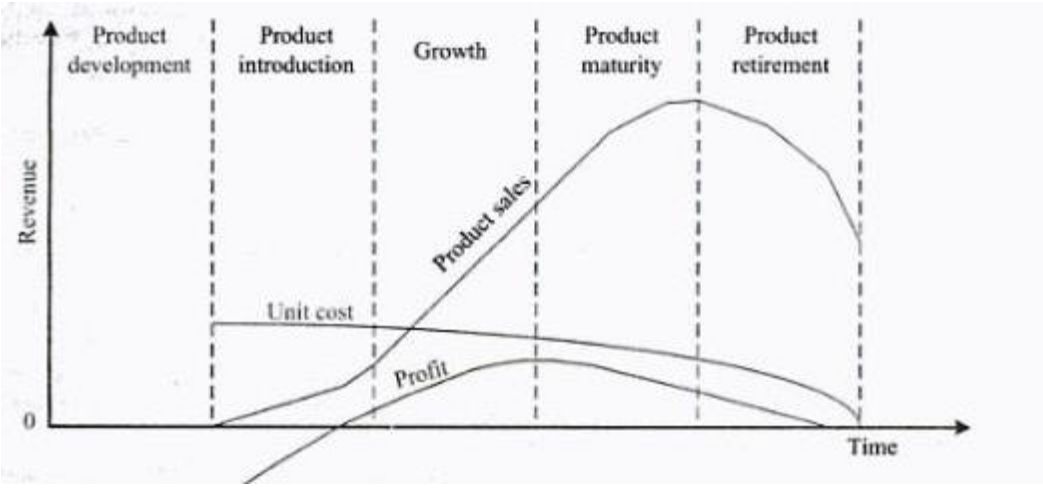
d) Time to prototype and market

- Time to Market is the time elapsed between the conceptualization of a product and time at which the product is ready for selling or use
- Product prototyping help in reducing time to market.
- Prototyping is an informal kind of rapid product development in which important feature of the under consider are develop.

- In order to shorten the time to prototype, make use of all possible option like use of reuse, off the self component etc**.**

e) Per unit and total cost

- Cost is an important factor which needs to be carefully monitored. 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.



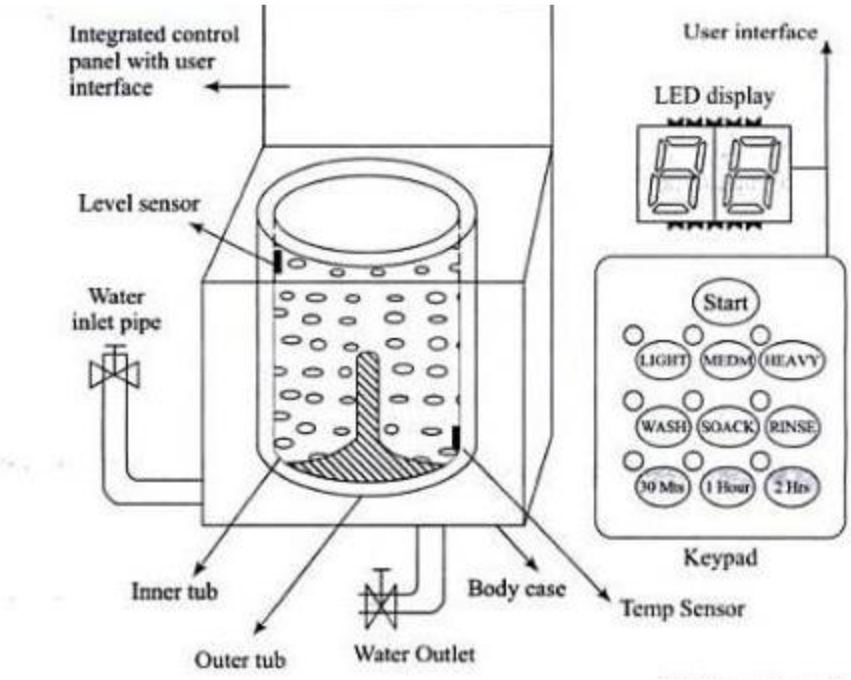
Embedded Systems-Application and Domain specific

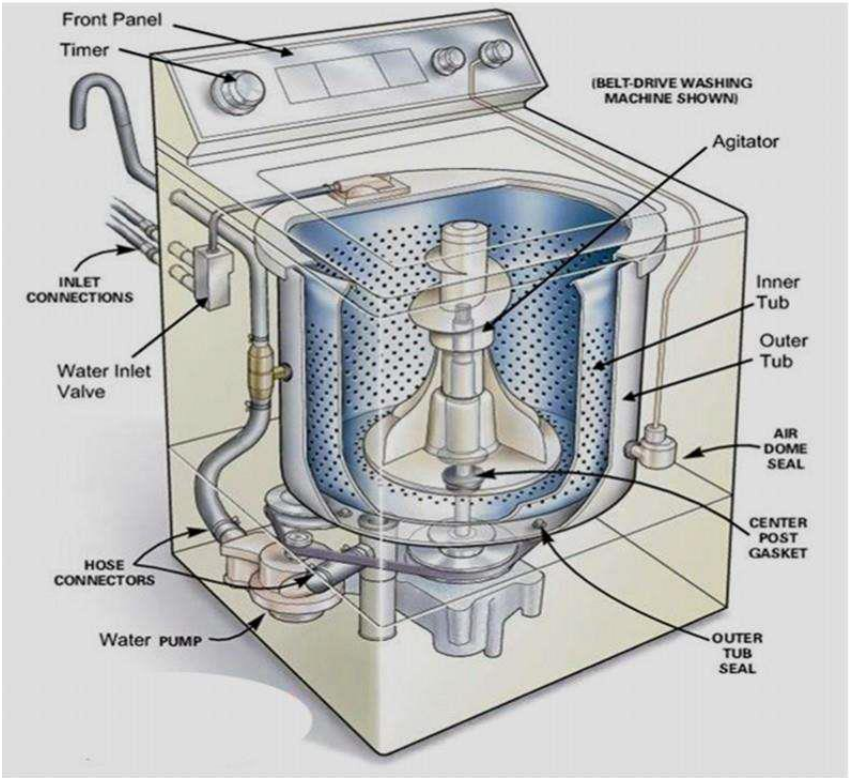
Application specific systems : Washing Machine

Let us see the important parts of the washing machine; this will also help us understand the working of the washing machine:

1) Water inlet control valve: Near the water inlet point of the washing there is water inlet control valve. When you load the clothes in washing machine, this valve gets opened automatically and it closes automatically depending on the total quantity of the water required. The water control valve is actually the solenoid valve.

2) Water pump: The water pump circulates water through the washing machine. It works in two directions, re-circulating the water during wash cycle and draining the water during the spin cycle.





3) Tub: There are two types of tubs in the washing washing machine: inner and outer. The clothes are loaded in the inner tub, where the clothes are washed, rinsed and dried. The inner tub has small holes for draining the water. The external tub covers theinner tub and supports it during various cycles of clothes washing.

4) Agitator or rotating disc: The agitator is located inside the tub of the washing machine. It is the important part of the washing machine that actually performs the cleaning operation of the clothes. During the wash cycle the agitator rotates continuously and produces strong rotating currents within the water due to which the clothes also rotate inside the tub. The rotation of the clothes within water containing the detergent enables the removal of the dirt particles from the fabric of the clothes. Thus the agitator produces most important function of rubbing the clothes with each other as well as with water.

In some washing machines, instead of the long agitator, there is a disc that contains blades on its upper side. The rotation of the disc and the blades produce strong currents within the water and the rubbing of clothes that helps in removing the dirt from clothes.

5) Motor of the washing machine: The motor is coupled to the agitator or the disc and produces it rotator motion. These are multispeed motors, whose speed can be changed as per the requirement. In the fully automatic washing machine the speed of the motor i.e. the agitator changes automatically as per the load on the washing machine.

6) Timer: The timer helps setting the wash time for the clothes manually. In the automatic mode the time is set automatically depending upon the number of clothes inside the washing machine.

7) Printed circuit board (PCB): The PCB comprises of the various electronic components and circuits, which are programmed to perform in unique ways depending on the load conditions (the condition and the amount of clothes loaded in the washing machine). They are sort of artificial intelligence devices that sense the various external conditions and take the decisions accordingly. These are also called as fuzzy logic systems. Thus the PCB will calculate the total weight of the clothes, and find out the quantity of water and detergent required, and the total time required for washing the clothes. Then they will decide the time required for washing and rinsing. The entire processing is done on a kind of processor which may be a microprocessor or microcontroller.

8) Drain pipe: The drain pipe enables removing the dirty water from the washing that has been used for the washing purpose.

Automotive Embedded System (AES)

- The Automotive industry is one of the major application domains of embedded systems.
- Automotive embedded systems are the one where electronics take control over the mechanical system. Ex. Simple viper control.
- The number of embedded controllers in a normal vehicle varies somewhere between 20 to 40 and can easily be between 75 to 100 for more sophisticated vehicles.
- One of the first and very popular use of embedded system in automotive industry was microprocessor based fuel injection.

Some of the other uses of embedded controllers in a vehicle are listed below:

a. Air Conditioner

b. Engine Control

c. Fan Control

d. Headlamp Control

e. Automatic break system control

f. Wiper control

g. Air bag control

h. Power Windows

AES are normally built around microcontrollers or DSPs or a hybrid of the two and are generally known as Electronic Control Units (ECUs).

Types Of Electronic Control Units(ECU)

1. High-speed Electronic Control Units (HECUs):

a. HECUs are deployed in critical control units requiring fast response.

b. They Include fuel injection systems, antilock brake systems, engine control, electronic throttle, steering controls, transmission control and central control units.

2. Low Speed Electronic Control Units (LECUs):-

a. They are deployed in applications where response time is not so critical.

b. They are built around low cost microprocessors and microcontrollers and digital signal processors.

c. Audio controller, passenger and driver door locks, door glass control etc.

- **Automotive Communication Buses**

Embedded system used inside an automobile communicate with each other using serial buses. This reduces the wiring required.

Following are the different types of serial Interfaces used in automotive embedded applications:

a. Controller Area Network (CAN):-

- CAN bus was originally proposed by Robert Bosch.
- It supports medium speed and high speed data transfer
- CAN is an event driven protocol interface with support for error handling in data transmission.

b. Local Interconnect Network (LIN):-

- LIN bus is single master multiple slave communication interface with support for data rates up to 20 Kbps and is used for sensor/actuator interfacing

- LIN bus follows the master communication triggering to eliminate the bus arbitration problem

- LIN bus applications are mirror controls , fan controls , seat positioning controls

c. Media-Oriented System Transport(MOST):-

- MOST is targeted for automotive audio/video equipment interfacing
- A MOST bus is a multimedia fiber optics point–to- point network implemented in a star , ring or daisy chained topology over optical fiber cables.
- MOST bus specifications define the physical as well as application layer , network layer and media access control.