Embedded System Concepts :-

1) Introduction :- Design of any system is not difficult if we know the fundamentals similiarly E.S also.

→ Like any other General Computing systems, Embedded System also Posses a set of characteristics which are unique to E.S under Consideration.

→ The General Computing System & Embedded Systems are highly domain and application specific in nature.

i.e they are specifically designed for certain set of application in Consumer Electronics; telecom; automotive industry control, measurment system etc;

* → An Embedded system is an electrical / electro mechanical system which specifically designed for an application Catering to specific domain.

→ An E.S Contains processing unit (or) System on chip (SOC) (or) Application specific Integrated circuit (ASIC) | Application specific Standard Product (ASSP) (or) Programmable logic Device (PLD) like FPGA (or) CPLD on. I/O subsystem which facilitates interaction of sensors & actuators which acts like messengers from and to Real world

→ Depending on the response requirements and type of applications for which E.S is designed, an Embedded System can be a Real-time (or) a Non-Real time System.

→ the response for real time is flight Control system, Airbag Development System ; Automotive etc;)

→ Non-Real time :- Automatic Teller machines (ATM), media Playback system ; etc-)

Learning objectives :-

1. What an Embedded System
2. diff b/w E.S & General Computing Systems
3. History of E.S
4. Classifications of E.S based on Performance, Complexity & Area in which Evolved
5. Domain & Area applications of E.S.
6. Different Purpose of E.S
7. Real life bounding of Embedded technology.

Embedded Systems:-

(1) System:- is a way of working (or) organizing (or) doing one (or) many task according to a fixed plan, Program (or) set of rules.

→ A System is also an arrangement in which all the units assemble and work together according to plan (or) Program.

(2) Embedded System:-

Def:-1:- It is a System that has Embedded Software & Computer hardware, which makes it a System dedicated for an application (or) specific Part of an application (or) Product (or) an Part of larger System.

Def:-2 Any devices that included a Programmable Computer that not itself intended to be general Purpose Computer and a fax machine (or) a clock built from a MP is an Embedded Computing System.

Def:-3 E.S are electronic System that contain a M.P (or) M.C but we do not link them as Computers. the Computer is hidden (or) Embedded in the System.

2) A Computer is system that has many (4) Components

(1) micro Processor
(2) (Semiconductors, (hard disk, diskettes, Cartridges, magnetic memory) CD-Roms, memory Sticks)
(3) i/p unit such as touch screen, video monitor fax, ...
(4) i/p units such as keyboards, Scanner
(5) o/p " " LCD Screen, video monitor
(6) n/w units → Ethernet, Serials
(7) An OS → g.P.S

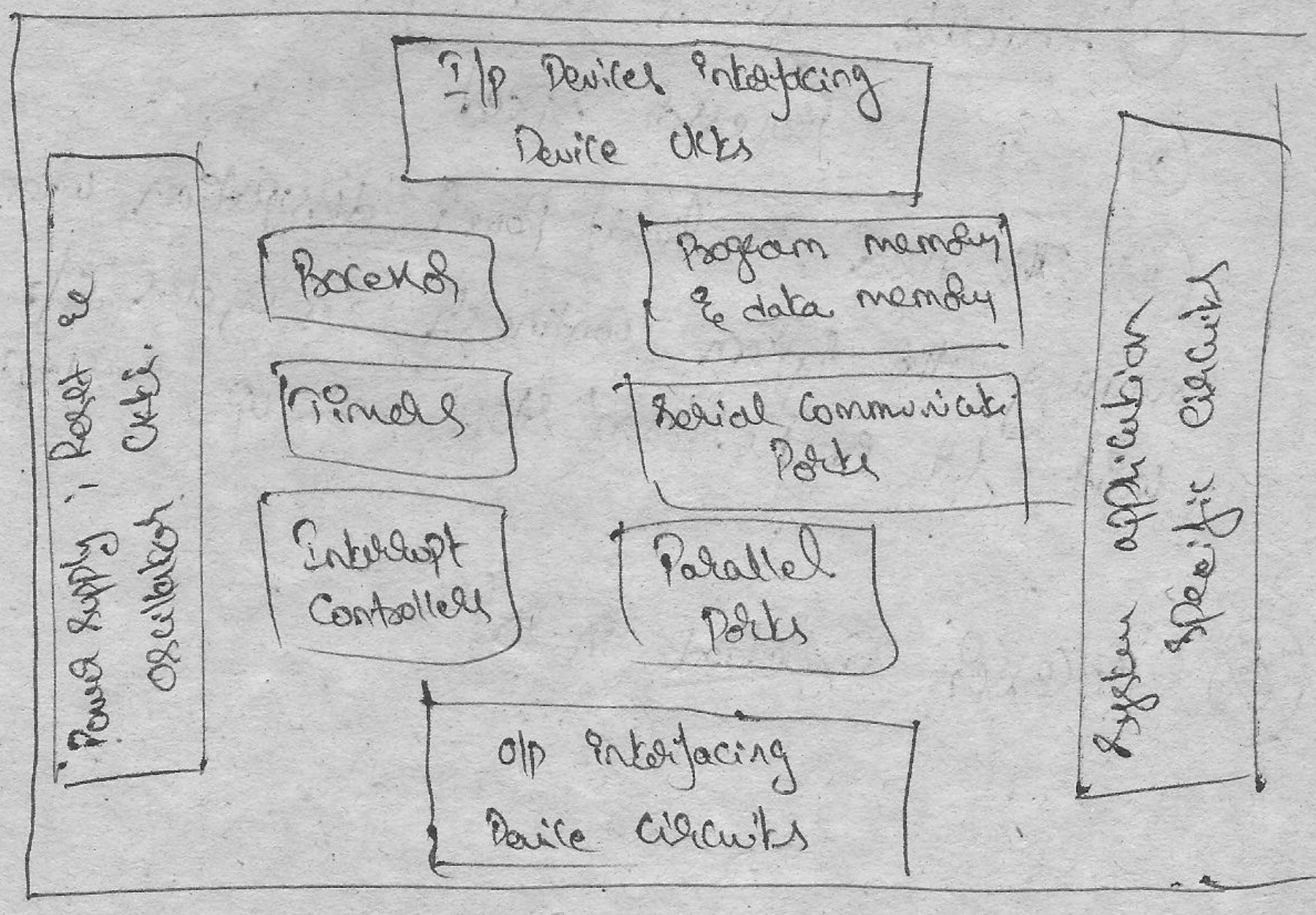
(3) An Embedded System has 3- Components

(1) hardware similar to Computer; as Software usually embeds in the Rom (or) Flash memory; or usually donot need a secondary harddisk & CD memory.

(2) Embeds main application Software. The application Software may Concurrently perform a series of tasks (or) Process (or) threads

(3) Embeds Real time Operating Syst. (RTOS) that supervises the application Software running on hardware, And organize access to a resource o/c to ~~Principle~~ priorities of task in Systems, it Provide mechanism to let the Process run a Process as scheduled and Context

H/w radical Bocesds.



(4) Characteristics:-

(1) Real time - & multicircle operation define the ways in which System works, react to events, interrupts, & schedules the System functioning on real time.

(2) Latency :- refers to the waiting period b/o running the codes of task (os) interrupt service routine.

(3) Complex algorithms

(4) " graphic users interface (GUI's)

(5) dedicated functions.

(5) Constraints :- designed based on 3-types

(1) Available system memory

(2) " Processor speed

(3) The need to limit Power dissipation when running the system Continously on Cycles of wait for Events. 'run' stop', wake up, & sleep.

(4) Processor Embedded in to.

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a) Difference b/w General Computing & Embedded Systems :-

General Purpose System	Embedded System :-
(i) A System which is a combination of a generic hardware and a General Purpose O.S for executing a variety of applications	(i) It is combination of special purpose hardware and Embedded OS for executing a specific set for application
(ii) Contains General Purpose O.S	(ii) May (or) may not contain O.S
(iii) Applications are alterable (programmable) by the user	(iii) the firmware of E.S is Re-programmed and it is non-alterable by enduser.
(iv) Performance is key deciding factor in selection of system (faster / Better)	(iv) Applications are specific Requirements (Performance ; Power requirements ; memory usage).
(v) Less/not at all tailored towards reduced Operating Power requirements options for different levels of Power management	(v) Highly tailored to take advantages of power saving modes supported by hardware and O.S.
(vi) Response requirement not critical time	(vi) For certain category of E.S like mission critical system, the response time requirement is highly critical
(vii) Need not be deterministic in execution behavior	(vii) Execution behavior is deterministic for certain type of E.S like Hard Real time systems.
Eg:- Desktop System	Eg:- Smart Phones.

(*) If we have PC, Laptop, etc., it used for multipurpose for performing no of applications like printing (Photos (or) Documents) & able to work with Microsoft office for document work. → G.C.S

(*) Now let us Consider a DVD Player used for playing movies etc., If it is Possible for you to change O.S of your DVD? If it is Possible to add a Printer application and also develop O.S for it? → Embedded System.

7) History of Embedded Systems:-

→ E.S existed before IT revolution.

→ E.S (olden days) were built around the old vaccum tubes & transistors technologies and Embedded algorithm was developed in low level languages

→ Advance in semiconductor & nanotechnology & IT revolution gave way to development of miniature E.S.

→ 1st recognised modern E.S is Apollo Guidance Computer (AGC) developed by "MIT instrumentation Lab" for lunar expedition.

→ Lunar Expedition → ran the inertial guidance systems of both the "Command module (CM)" & "Lunar Excursion Module" (LEM)

designed to encircle the moon

designed to go down to moon surface and land there safely.

→ featured in total 18-Engines

16-reaction control thrusters

descent Engine & Ascent Engine

→ "descent Engine" → designed to Provide thrust to LM out of lunar orbit and land it safely on the moon.

→ MIT's original design was based on 4K words of fixed memory (Read only memory) and 256 words of erasable memory (Random Access memory).

→ By June 1963 it reached to 10k (10,000) of fixed and 1k (1000) of erasable memory.

→ The clock freq of first microchip Proto model used in AGC was 1.024 MHz & it was derived from 2.048 MHz Crystal clock.

→ the computing unit for AGC consisted approximately 11 instructions and 16-bit word logic.

Around 5000 IC's (3 i/p NOR gates, RTL logic) supplied by Fairchild Semiconductor used in design.

→ the used interface unit of AGC is known as DSKY (Display/keyboard) which looked like Calculator type keypad. with array of numerals. used for ~~computing~~ inputting commands to module numerically.

→ The first mass produced E.S was the guidance Computer for minuteman-1 missile in 1961.

It was the Autonetic D-17 guidance Computer built using discrete transistors logic and a hard-disk for main memory

The first IC was produced in 1958-september but Computers using them didn't began until 1963.

→ Some early uses were in E.S notably used by NASA for Apollo Guidance computer (AGC) and by US-military in minuteman-2 inter continental ballistic missile.

8) Classification * of * Embedded * systems :-

Considerations based on.

(i) Based on generation.

(ii) Complexity and Performance requirements.

(iii) Based on deterministic behavior → Applicable for Real time systems.
↳ A/c to application/task defines deterministic/non-deterministic

(iv) Based on triggering.
↳ Process Control system in industrial Control applications classified based on trigger.
↳ Reactive system can be either Event triggered/time triggered.

(i) Classification Based on Generation :-

(a) First Generation :- Early E.S were built around 8-bit MP's. like (8085 & Z80) and 4-bit MC (micro controllers). Simple in hardware developed circuits with firmware in Assembly code.

Eg:- Digital Keypads of telephones ; Stepper motors control units.

(b) Second generation :- this E.S built around 16-bit MP & 8/16-bit MC following 1st generation E.S.

The instruction set of the IInd generation were much more Powerful & Complex than 1st generation.

Some of IInd generation E.S contains operating systems for their operation. Data Acquisition systems, SCADA systems, etc.;

(c) Third generation :- With advances in microprocessor technology, developers started making use of Powerful Embedded systems 32-bit Processors & 16-bit MC for design.

A new concept of application & domain specific Processors/ Controllers like Digital Signal Processing (DSP) and Application specific I.C (ASIC's) came in to Picture.

The instruction set of became more Powerful & Complex and Concept of Pipeling also introduced.

The different Processor like Intel Pentium, Motorola 68K, etc., gained attention in high Performance.

E.S spread area towards robotics, media, industrial Process Control, n/w Store,

(d) fourth generation :- The advent of System on chip (SoC), reconfigurable Processors & multiprocessor are bringing high Performance, tight integration and miniaturization into Embedded device market.

The SoC techniques implement to System on chip by integrating different functionalities with a Processor Core

on an IC.

the 4th-generation E.S making use of high performance real time Embedded operating systems for their functioning.

Eg:- Smart phone devices, mobile internet devices (MID's)...

(ii) classification Based on Complexity & Performance :-

(i) Small Scale E.S :- which are simple in application needs and where the performance requirements are not time Critical fall under this category.

Eg:- Electronic toy.

Small scale E.S are usually built around low performance and low cost 8 (or) 16-bit microprocessors / microcontrollers.

A. small scale E.S may/not may contain O.S. for functionating.

(ii) Medium Scale Embedded systems :- E.S which are slightly complex in hardware & software requirements fall under this category. which these are built for medium performance, low cost 16 (or) 32-bit µP/µC (or) DSP processors. These may usually contain E.O.S (either general purpose (or) Real time O.S) for functionating.

(iii) Large Scale E.S / Complex systems :- E.S which are involved highly complex hardware (or) software requirements fall under category. which are used for highe performance. Such system commonly built around high performance 32 (or) 64-bit RISC Processors / Controllers (or) System on chip (RSoC) (or) multicore Processor And Reconfigurable system (or) Programmable logic devices.

They may contain multiple µP/µC and hardware Co-units accelerators for affording the processing requirements for main Proces. of system.

* Eg:- Decoding / Encoding of media, Cryptographic function implementation are Examples.

Complex systems usually contain (RTOS) for task scheduling.

9) Major * Applications * Areas of E.S :-

E.S technology has acquired a new dimension from its first generation model, Apollo guidance Computer to the latest Radio navigation system Combined with - car entertainment technology and MP based smart running shoes launched by Adidas on April 2005.

Ex:- List :-

1) Consumer electronics :- CamCorders, Camdas etc.,
2) Household appliances :- TV, DVD's players, washing machine, fridge, microwave oven,
3) Home automation & security system :- Air conditioners, sprinklers, intruder detection alarms, closed circuit tv. Camdas, fire alarms etc.,
4) Automotive industry :- Anti lock Breaking system (ABS), Engine Control, ignition system, Automatic navigation system etc.,
5) Telecom :- Cellular phones, telephone switches, handset multimedia. applications etc.,
6) Computer Peripherals :- Printers, Scanners, fax machines, etc.,
7) Computer n/w systems :- n/w routers, switches, hubs, firewalls, etc
8) Health Care :- Different kinds of scanners, EEG, ECG machines.
9) Measurement & Instrumentation :- Digital multimeters, digital CRO's. logic analyzers PLC systems. etc.,
10) Banking & Retail :- Automatic teller machines (ATM's) & Currency counters, Point of sales (POS)
11) Card Readers :- Bar Codes, Smart Card readers, hand held devices etc.,

10) Purpose of Embedded Systems :-

1) Data Collection | Storage | Representation
2) Data Communication
3) Data Signal Processing
4) monitoring
5) Control
6) Application Specific User interface.

1) Data Collection / Storage / Representation :- E.S designed for data collection from external world. Data Collection is usually done for storage purpose, analysis, manipulation and transmission. where Data refers (text, voice, image, video, electrical signal, measurable quantities). Data can be either analog (or) digital.

E.S with analog data Capturing will be in analog signal but data Capturing of digital Collection mechanism converts to analog signals to corresponding digital signals. (A/D Converters)

The Collected data may be stored directly in the system (or) it may be processed may be transmitted to some other systems (or) by system (or) it may be deleted instantly after giving meaningful info.

Eg:- Digital Camera.

2) Data Communication :-

The data Collecting Embedded terminals itself can incorporate data Communication units like wireless modules (Bluetooth, ZigBee, WiFi, EDGE, GPRS etc.,) (or) wireline modules (RS 232-C, USB, TCP/IP, P2P, etc.,)

3) Data Signal Processing :-

data is (voice, video, image, electrical signal, etc.,) collected in E.S may be used for various kinds of data processing. E.S with signal processing functionalities are employed in application demanding signal processing like Speech processing, Synthesis, Audio Video Codec, transmission application.. etc;

Eg:- A digital hearing aid.

4) Monitoring:-

→ E.S specially designed for monitoring Purpose.

→ E.S coming under medical domain are monitoring functions only which are used for determining the state of some variables using i/p sensors.

Eg:- Electro Cardiogram (ECG) machine for monitoring heart beat. The sensors used in ECG are the different electrodes connected to the patients body.

5) Control:-

Eg:- Air Conditioners for controlling room temp.

6) Application Specific user interface:-

like buttons, switches, keypads, lights, bells, displays (mike, etc.)

Eg:- mobile phone., vibration alert. //.

10) Characteristics & Quality Attributes of E.S:-

(i) Characteristics of E.S:-

(a) Application & domain specific
(b) Reactive & Real Time
(c) operates in harsh environments
(d) Distributed
(e) Small size & weight
(f) Power Concerns.

(a) Application & Domain Specific :-

E.S is having certain functions to perform and they are developed in such a manner to do intended functions only. which cannot be used for any other purpose.

Eg:- An AC be able to replace an Embedded Control unit of microwave oven and air Conditional Control unit. because which are specified design units.

(b) Reactive & Real time :-

E.S are in constant interaction with Real world through sensors & user-defined i/p devices which are connected to i/p port of system. Any changes happening in Real world (is called Event) are captured by the sensors (or) i/p devices in Real-time & the Control algorithm running inside the unit reacts in designed manner to bring Controlled o/p variable to desired level.

→ The Event may be Periodic (or) unPredicted one.

→ If the Event is an unPredicted one then such system should be designed in such a way that it should be scheduled to capture the Events without missing them. E.S produce changes in o/p in response to changes in the i/p. So they are generally referred as Reactive systems.

→ Real time system operations means timing behaviors of system. should be deterministic.

ie the System should respond to request (or) tasks in known amount of time.

Eg:- Flight Control ; Antilock Brake System (ABS).

(c) operated in Harsh Environment :-

→ no required E.S should be deployed in Environments (like dusty/temp)

→ ie designer should take care of operating systems condition of area where it is implemented.

(d) Distributed :-

→ The term distributed means that E.S may be a Part of larger System.

→ Many no:- of distributed syst/m form a single large Embedded control unit.

Eg:- Automatic vending machine
(Contains vending machine Card reader, a vending unit, etc:)
(or)
(Automatic Teller machine (ATM's) Contain Card reader; transaction unit; Currency Counter; dispatching/vending Currency; Printer unit; ... Etc:)

(e) Small size and weight :-

In E.S Compactness is significant depending factor.

(f) Power Concerns :-

E.S should be designed in such a way as to minimise the heat dissipation by the system.

The Production of high amount of heat demands Cooling requirement like Cooling fans which occupies additional space and make system bulky.

The more the Power Consumption less the battery life.

11) Quality Attributes of Embedded Systems :-

" " are the non-functional requirements that need to be documented Properly in any system design.

If Quality attributes are more Concrete and measurable it will give a positive impact on the system development Process and End Product.

(1) Operational Quality Attributes.
(2) Non-operational " .

① Operational Quality Attributes :-

represents it when operational mode (or) Online mode..

(a) Response
(b) Throughput
(c) Reliability
(d) Maintainbility
(e) Security
(f) Safety.

(a) Response :- measures performance of system.

(b) Throughput :- deals with efficiency of system. defined as the rate of production (or) operation of 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."

→ the throughput is generally measured in terms of Benchmark.

A benchmark is reference point by which something can be measured.

(c) Reliability :- is a measure of how much % you can rely upon the proper functioning of the system (or) what is the % susceptibility of the system to failures.

→ Mean Time Between Failures (MTBF) & Mean Time To Repair (MTTR) are terms define Reliability.

→ MTBF gives freq of failures in hours/weeks/months.

→ MTTR gives specifies how long the system is allowed to be out of order following failure.

(d) Maintainability :- deals with support & maintenance to end user (or) client in case of technical issues. and product failures.

→ Reliability & maintainability are two complementary disciplines.

→ A more reliable system means a system with less Corrective maintainability requirments.

→ As reliability increases the chance of failure and non-functioning also reduces, there by need for maintainability is also reduced.

→ Maintainability is closely related to System availability.

" Maintainability classified "

" Scheduled " " Periodic maintenance "

→ Eg:- Printer is typically illustrating two types of maintainability.
→ Printer Cartridge that can be replaced after 'n' no of Printouts.
to get quality Prints. → Eg for 'Scheduled (or) Periodic maintence'.
→ If Paper feeding part of the Printer fails the Printer fail to Print and requires immediate repair to rectify then it is
→ Eg for Maintainance to unexpected failure

∴ The ideal value for availability *

$$A_i = \frac{MTBF}{(MTBF + MTTR)}$$

A_i → Availability in ideal Condition
MTBF → mean time B/w failures
MTTF → " " To Repair.

(e) Security:- Confidentiality ; integrity ; & Availability
→ i.e (Availability metioned in Maintainability)
→ Confidentiality deals with Protection of data and application from an authorised disclosure.
→ Integrity is deals with the Protection of data and application from an authorised modification
Eg:- PDA (Personal Digital Assistant) used in shared resource (or) individual resource like (username ; Password to access Person Profile).

(f) Safety :- Safety & Security are two Confusing terms.

→ Safety deals with the Possible damages that Can happen to the operators, Public and Environments due to break down of an E.S. (or) due to Emission of radioactive (or) hazardous materials from E.S.

→ Break down Causes due to hardware & firmware failures.

(2) Non-operational Quality Attributes :-

Not the quality attributes that need to be addressed for Product on basis of operational aspects

- ✓ (a) Testability & Debug-ability
- ✓ (b) Evolvability
- ✓ (c) Portability
- ✓ (d) Time to Prototype and market
- ✓ (e) Per unit and total Cost.

(a) Testability & Debug ability :- deals with how Easily one Can test his/her design, application and by which mean he/she test it.

Testability applicable for both hardware & firmware.

Debug ability :- is means of debugging the Product as such for figuring out Probable Sources that Create un-expected behaviours in total system.

→ Debug ability has two aspects → Context → hardware level debugging
development → firmware " "

~~→ Hardware level debugging~~

(b) Evolvability :- It is closely related to biology. Evolvability is referred as non-heritable variation.

i.e (hardware & firmware) Can be modified to take advantage of new firmware (or) hardware technologies.

(c) Portability:- measures of System independence

→ A system is said to be portable if the product is capable of functioning as such in various environments, target processors/controllers & embedded operating systems.

→ In embedded products term "Porting" represents the migration of embedded firmware written for one target processor eg(Intel x86) to different target processor (say Hitachi SH3 processor).

Eg:- like changing programming languages to processors; platforms

(d) Time to Prototype and Market:-

→ Time to market is the time elapsed b/w conceptualisation of a product and the time at which product is ready for selling (or) use.

→ The commercial embedded product market is highly competitive and time to market the product is a critical factor in the success of commercial embedded product.

* (like, mobiles, media players) ...

→ Prototyping is a normal kind of rapid product development in which the important features of product under consideration are developed.

make use of all possible options like the use of off-the-shelf components, re-usable assets etc.,

(e) Per unit cost and Revenue:-