Embedded System Design & its applications in various fields

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Abstract: ***E***mbedded system is a system that has embedded software in computer hardware dedicated for an application. Embedded system is electronic systems that contain microprocessor or microcontroller, but we do not think of them as computers. We all are surrounded by an embedded system from everywhere. Embedded system finds applications in each and every field. An embedded system has three main components. First one is its hardware which includes embedded processor, peripheral, input output devices. Embedded hardware is the heart of embedded system. Second part is the software that is ROM, flash memory or media card. This is the brain of an embedded system. Third part is a Real Time Operating Systems (RTOS).The RTOS supervises the application software and control the access to system resources. This Technology based on the advancement made in development of IC fabrication process. It smartly integrates electronics, electrical & Mechanical components on a single silicon wafer similar to integrated circuit technology. Basically Embedded system believes in Good things comes in small packet. To satisfy today's market demand miniaturization is the only solution. The miniaturized devices are particularly suited for biomedical & aerospace application because of their minute size & weight. Embedded systems are characterized by special feature. An embedded system has to work against some deadlines and is constrained for power. These systems need to be highly reliable. Some embedded system has to operate in extreme environmental conditions such as very high temperatures and humidity.

Index Terms **- Embedded system, microprocessor, real time operating system**

I. INTRODUCTION

Embedded system are domain and application specific consist of hardware built around a central processing unit .This hardware also contains memory chips known as 'firmware'. Fig 1 shows the layered architecture of embedded system. The operating system runs above the hardware, and the application software runs above the operating system.The hardware of an embedded system consist of central processing unit, memory, input device, output device, communication interface, applicatio specific circuitry.

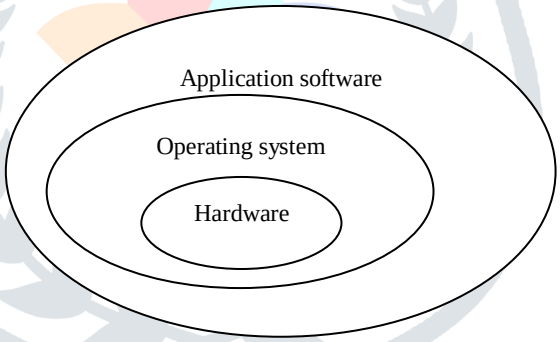

Fig.1.Architecture of an Embedded System

a) Hardware Architecture: Fig.2 shows the simplified hardware architecture of an embedded system. It consists of central processing unit, memory, input output devices, communication interfaces, and Application-specific circuitry

i) Central Processing Unit (CPU): The CPU used in an embedded system can be either General purpose processor (GPP) or Digital signal processor (DSP). GPP can be any microprocessor or microcontroller or Digital Signal Processor. For small applications a micro controller is the best one as the number of external components required will be very less. DSP is used mainly for applications in which signal processing is involved such as audio and video processing. The main function of processor is to manipulate data as per the instruction. To do this processor has to first read data and instructions from memory, read and write data to memory, write data to output devices, and read data from input devices. To do these function's processor required three types of buses that are Address bus, data bus and control bus. Fig 3 shows the interaction between CPU and memory using three buses

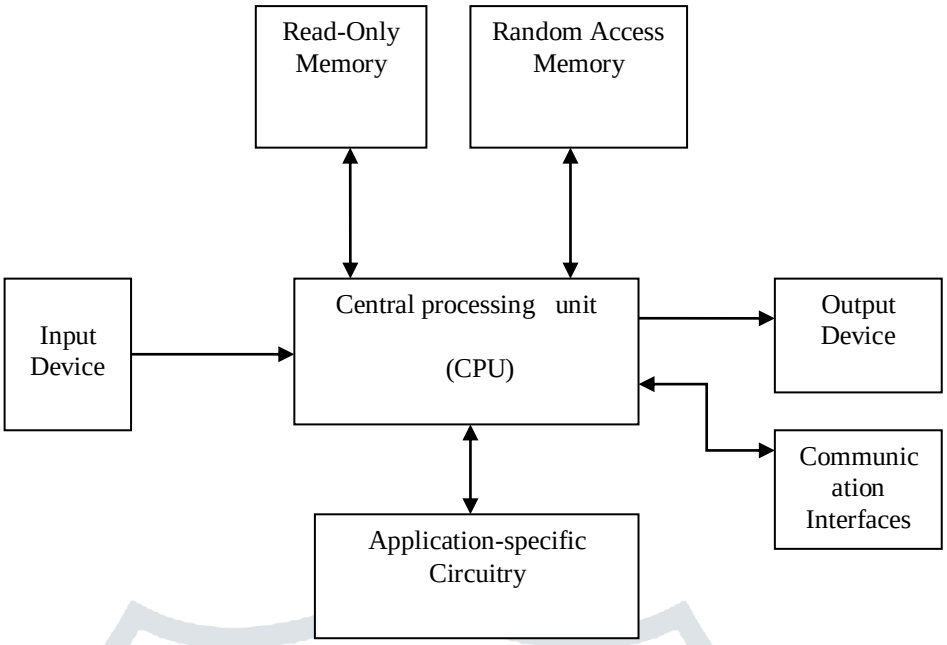

Fig.2.Hardware Architecture of an Embedded System [2]

Based on the number of memory and data buses used .there are two types of processor architecture:

i) Von Neumann Architecture
ii) Harvard Architecture

i)Von Neumann Architecture: It is the most widely used architecture which has one memory chip used to store both instruction and data

ii)Harvard Architecture: In this architecture there are two separate memory, one for program and other for instruction. Program memory stores only instructions and data memory stores only data. This architecture is much more efficient because accessing the instructions and data will be very fast.

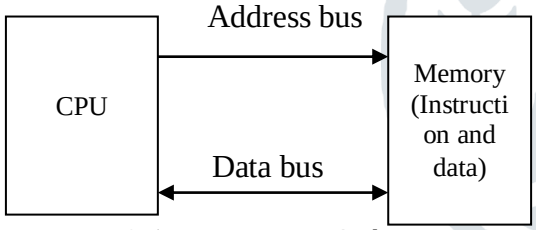

Fig.3.a) Von Neumann Architecture

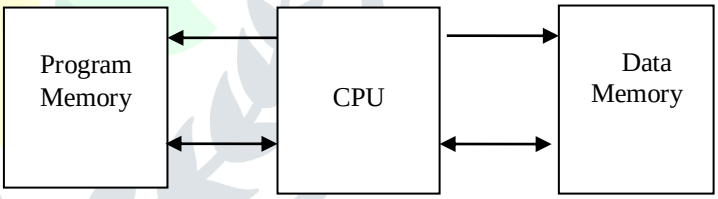

Fig.3.b) Harvard Architecture

Based on the instruction set architecture of a processor, it can be either RISC (Reduced instruction set computer) or CISC (Complex instruction set computer).The comparison table in between RISC and CISC as mention below

RISC	CISC
It has lesser number of instruction	It has greater number of instruction
There is instruction pipelining which increased execution speed	There is generally no instruction pipelining
The operations are performed on registers only, the only memory operations are load and store	The operations are performed on registers or memory depending on the instruction
A large number of registers are available	Limited number of general purpose register
Single, fixed length instruction	Variable length instruction
RISC is Harvard Architecture	CISC is Von-Neumann Architecture

ii) Communication Interfaces: It is essential for communicating with various subsystems of the embedded system and with the external world. Embedded system provided with one or few communication interfaces such as RS232, RS422, RS485, Universal serial bus, wireless interface based on IEEE 802.11,ethernet etc.

iii) Application specific circuitry: Sensors, transducers, special processing and control circuitry may be required for an embedded system, depending on its application. This circuitry interacts with processor to perform functioning.

b) Software Architecture: Embedded system software consists of an operating system and the application software. The service provided by the operating system is accessed through the Application Programming Interface (API). The operating system acts as a bridge between the user applications and the underlying system resources through a set of system functionalities and services. The work to be done by operating system is divided into number of task. Each task is implemented as an infinite loop.
The operating system has to do the following functions:
i) Process/Task management
ii) Memory management
iii) Input/output management including managing the file system
iv) Providing services to the application
v) Providing user interface
The following fig shows the software architecture of an embedded system

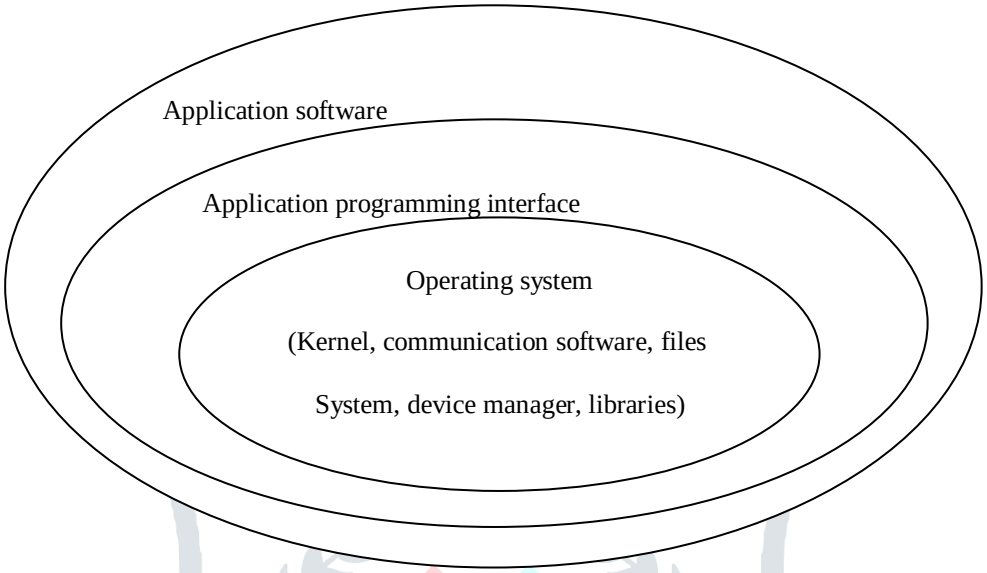

Fig.4.Software architecture of an embedded system

To perform the above mention task the operating system consist of kernel, communication software, file system, device manager, libraries.The Kernel is the heart of an operating system. Its main function is to manage the task. The task scheduling algorithm decides which task has to run next. The various kernel objects are Tasks, Tasks Scheduler, Interrupt Service Routine, Semaphore, Mutexes, Mailbox, Message Queues, Pipes, Event registrs, Signals and Timers. The Application programming interface is a set of function calls using which one can access the various kernel objects and the services provided by the kernel. Device drivers provide the necessary interface between the application and the hardware Depending on the type of kernel, operating system are classified as
i) General purpose operating system:-The kernel of such operating system is more generalized and it contains all kinds of services required for executing generic applications. The general purpose operating systems are non-deterministic in behavior, for example Windows Xp, Ms-DOS, LINUX
ii) Real Time Operating system (RTOS):-The kernel of real time operating system is referred as real, which make it suitable for building real time computing application. The real time operating systems are deterministic in behavior.RTOS implement policies and rules where no deadline is allowed. The RTOS decides which applications should run in which order and how much time needs to be allocated for each application. Windows CE, QNX, VxWorks MicroC/OS-II, etc.are the example of Real time operating system.

II CLASSIFICATION OF EMBEDDED SYSTEM

Based on the complexity and system performance the embedded systems are classified into following group:
i) Small –Scale Embedded Systems: Embedded system which are simple in application and where the performance requirements are not time critical comes under this category. It is designed with 8 or 16-bit microcontroller or DSP.A small scale embedded system may or may not contain an operating system for its functioning. For programming purpose it uses ‘C’ or MATLAB.Some of the example of small scale embedded systems are multitasking toys, stepper embedded system are Automatic chocolate vending motor controllers for robotic system, washing machine, cooking machine,fax,printer, scanner, remote for TV .etc
ii) Medium-Scale Embedded system: Embedded system which are slightly complex in hardware and software requirements fall under this category. These systems are designed with a single or few 16 or 32-bit microcontroller or digital signal processor. It uses RTOS for multitasking. Some of the examples of medium scale embedded systems are Computer networking system, banking system, ATM & credit card, video game, music system, etc
iii) Sophisticated Embedded System: Embedded system which involves highly complex hardware and software requirement fall under this category. These systems are built around high performance 32 or 64-bit RISC Processor. They may contain multiple processors or controllers and usually contain high performance real time operating system for task scheduling, prioritization and management. For example smart phone, Tablet, security products and high speed network security, multimedia processing system, etc

III a) DESIGN PROCESS IN EMBEDDED SYSTEM

Embedded system design process consists of the following steps.

i) Abstraction: While designing embedded system each problem component is first abstracted. It includes system requirements and specification

ii) Hardware and software architecture: Architecture should be well understood before a design. As per the application of the system designer must able to choose the appropriate microprocessor, microcontroller or digital signal processor. A processor is selected from consideration of instruction set, maximum bits in an operand (8, 16 or32) in a single arithmetic or logical operation, Clock frequency in MHz or GHz, Processor ability to solve the complex algorithm used in meeting the deadlines for their processing. Hardware consist of a co-processor,accelerator,controller,special function processor or single purpose processor made using an ASIC.The software architecture consist of Boot-up, initialization and RTOS software. Also it includes software for the communication with host machine.

iii) Extra functional properties: Extra functionality required in the system being developed should be well understood from the design.It would help to put the modified version of the product for user.

iv) System related family of designs: Families of related systems developed earlier are taken into consideration during designing.

v) Modular Design: System designing is decomposition of hardware and software modules. Modules should be clearly understood and should maintain continuity. A module is not permitted to change or modify functionality o another module. Effective modular design should ensure effective functional independence, cohesion and coupling

vi) Mapping: Mapping into various representations is done using the requirements of software. Transform and transaction mapping design processes are used in the designing

vii) User Interface Design: This is an important part of the design. User interface are designed as per user required system function and the analysis of environment

viii) Refinement: Each component and module needs to be refined iteratively until it becomes most appropriate for implementation.

Following fig.5 shows the embedded software development process flow

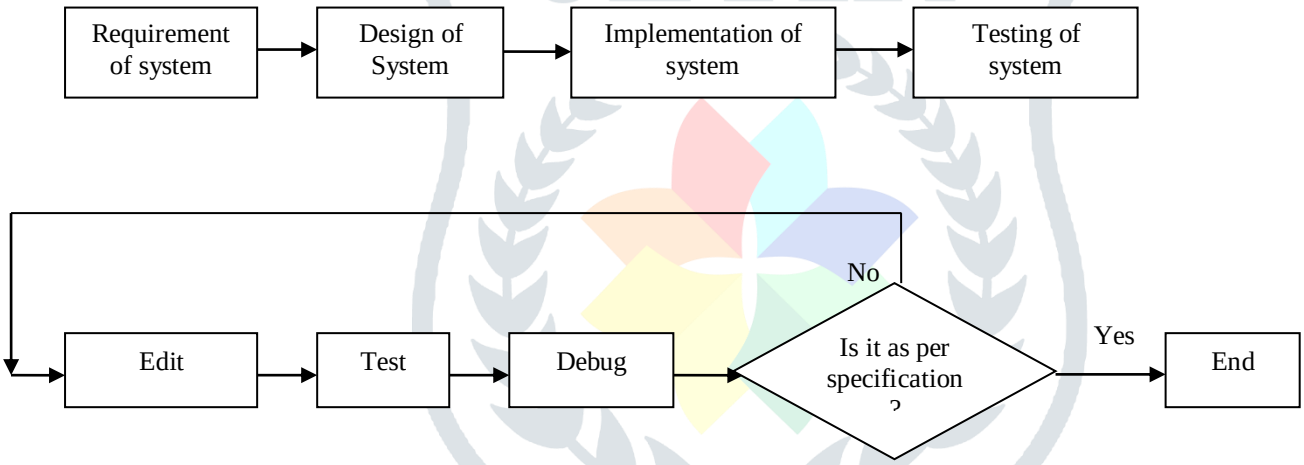

Fig.5. Embedded software development process flow

b) DESIGN METRICS OF AN EMBEDDED SYSTEM

While designing embedded system some design metrics has to be taken into consideration to meet the necessary requirement

i) Power Dissipation: Power consumed by the system is important parameter in many systems. To satisfy today's market demand power dissipation of system must be small.

ii) Performance: It is measured by time required for executing the instruction by the processor. For better performance embedded system, the execution time for instruction must be small.

iii) Process deadlines: Each process in a system has a deadline within which each of them may be required to complete the computations and give the result.

iv) User Interface: Depending on the application of system either Graphics user interface or Voice user interface.

v) Size: It is decided by physical space required and memory required for running software.

vi) Engineering cost: It is one time cost required for developing, debugging and testing hardware and software. Hence it is also called as non-recurring engineering (NRE) cost.

vii) Manufacturing cost: It is the cost of manufacturing each unit

viii) Flexibility: It is necessary to put the different version of product in the market without increase in engineering cost.

ix) Prototype development time: It is the time required for developing the prototype and testing of system functionalities

x) Time to market: It is the time required to put a product for users and consumers.

xi) System and user safety: It must be provided in every embedded system.

xii) Maintenance: It means changeability and additions in the system.

While designing an embedded system, the designer has to faced the following challenges

i) Type and amount of hardware needed

ii) Optimizing the power dissipation and energy consumption

iii) Process Deadlines

iv) Flexibility and ability to upgrade

v) Reliability

IV APPLICATION OF EMBEDDED SYSTEM

An Embedded system finds application in each and every field which includes consumer electronics, office automation, industrial automation, biomedical engineering, wireless communication, data communication, telecommunications, transportation, military etc.

i) Consumer appliances : It includes digital camera, digital diary, DVD Players, microwave oven, remote control for TV, VCD Players, smart wrist watches,palmtop,video recorders, air-conditioner etc.

ii) Office automation: The office automation product using embedded systems are copying machine, fax machine, printer, scanner, modem etc.

iii) Industrial automation: Now a day's lot of industries uses embedded system for process control. These are pharmaceutical, cement, sugar, oil exploration, nuclear energy, electricity generation and transmission. In hazardous industrial environment, where human presence has to be avoided, robots are used. The robots are now becoming very powerful and carry out many interesting and complicated tasks.

iv) Medical electronics: Embedded system plays very important role in the growth of medical electronics. It includes diagnostic devices such as ECG, EEG, blood pressure measuring device,x-ray scanners, automatic patient monitoring system, endoscopy, colonoscopy etc.

v) Computer networking and Telecommunications: Computer networking products such as bridges, routers, integrated service digital networks (ISDN), frame relay switches uses embedded system

vi) Security and Instrumentation: Advance testing and measuring equipment uses in laboratories are embedded system.It includes oscilloscope, spectrum analyzer, radio communication test set etc.These all devices are portable and easy to use.Securitry devices at homes,offices,airports for authentication and verification are embedded systems.

vii) Finance: In today's era financial transaction is done using smart cards and ATM machines.

V CONCLUSION

Since from last few decades we have seen rapid growth in microelectronics industry which makes miniaturization possible, which leads to development in embedded system design. An embedded system consists of three element hardware, operating system and application software. As far as hardware is concern, the processor is the heart of embedded system. Depending on the type of embedded system that is small scale, medium scale and sophisticated embedded system, the designer has to choose appropriate general purpose microprocessor or microcontroller or application specific instruction-set processor like DSP processor. The processor may be either of 8 bit, 16 bit, 32 bit or 64 bit as per the need of application for which the system is designed. The important considerations for designing an embedded system are reliability, performance, low power consumption, low cost, small size, limited user interface and capability to upgrade software in the field. As per the earlier discussion, while designing an embedded system designer has to keep in mind some design metrics like power dissipstion,performance,process deadlines, size, engineering cost, manufacturing cost, flexibility,prototupe development time, system and user safety etc.Now a day's embedded system find application in every industrial segment, consumer electronics,transportation,biomedical engineering ,manufacturing, process control and industrial automation, data communication,telecommunication,defence,security,computer networking etc.

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