REFERENCES:-

- http://gwentechembedded.com/what-are-the-key-features-of-an-embedded-system/
- https://www.embedded-computing.com/embedded-computing-design/the-top-five-features-to-consider-when-selecting-embedded-design-software
- https://www.infopulse.com/blog/challenges-and-issues-of-embedded-software-development/
- https://www.guru99.com/embedded-systems-tutorial.html
- https://www.watelectronics.com/pic-microcontroller-architecture-and-applications/
- https://www.theengineeringprojects.com/2016/11/top-10-embedded-systems-software-development-tools.html
- https://www.elprocus.com/difference-between-avr-arm-8051-and-pic-microcontroller/

CHAPTER - 1

WHAT IS A SYSTEM?

A system is an arrangement where its entire component assembles work according to the specific defined rules. It is a method of organizing, working, or performing one or more tasks according to a fixed plan.

EMBEDDED?

The word embedded implies that it lies inside the overall system, hidden from view, forming an integral part of greater whole.

WHAT IS AN EMBEDDED SYSTEM?

a. An embedded system can be either an independent system, or it can be a part of a large system. It is mostly designed for a specific function or functions within a larger system.
b. A computer system that executes a specific set of functions as part of a larger device is known as an Embedded System.
c. It is a system whose principal function is not computational, but which is controlled by a computer embedded within it.
d. An embedded system is a dedicated computer system, designed to work for single or few specific functions often within a larger system. Embedded Systems, therefore, are
    - Built to function with little or no human intervention
    - Specially designed keeping in consideration the tasks that need completion in the most efficient way

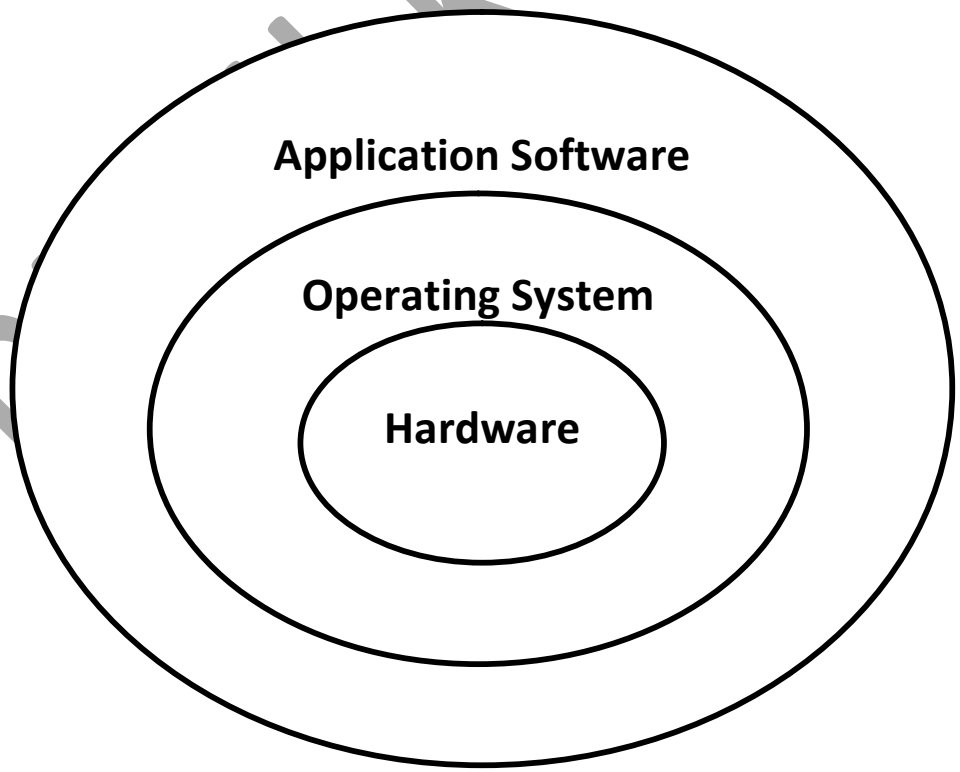
Most of our gadgets like washing machines, microwave ovens, ATMs and mobile phones have embedded-system in them.

HISTORY OF EMBEDDED SYSTEM

- First Modern Embedded System:-In 1960, embedded system was first used for developing Apollo Guidance System by Charles Stark Draper at MIT Instrumentation Laboratory.
- First Mass-Product Embedded System:- In 1961-65, Autonetics, developed the D-17B computer used for Minuteman Missile Guidance System.
- First High-Volume of Integrated Circuits:- In 1966, for the Minuteman – II, the D-17 was replaced.

- First Embedded System for Vehicle:- In 1968, first embedded system for a vehicle was released. In 1969, the Volkswagen 1600's fuel injection was controlled by a microprocessor.
- First 4-Bit Microprocessor:- In 1971, the Intel 4004 was designed by a microprocessor.
- Microsoft is Born:- In 1975, Bill Gates and Paul Alien deliver the BASIC compiler to MITS.
- First Home computer with Touch Screen Technology:- In 1983, Hewlett-Packard's HP-150 utilized a grid of Infrared beams across the front of the monitor, detecting the finger movement.
- Embedded System Go Wireless:- In 1992, there were more than 10 million mobile phones inuse.
- Windows Embedded CE 1.0:- In 1996, Microsoft entered the embedded marketplace by designing windows embedded CE 1.0.
- Android Technology Steps Forward:- In 2005, Google acquired Android Inc.
- All-In-One embedded Mobile Device:- In 2007, Apple's first iPhone was launched.
- Today &Beyond:- Over 95% of electronics chips produced are for embedded systems. Their use in everyday products is a major evolution everywhere that technology is used.

LAYOUT ARCHITECTURE OF EMBEDDED SYSTEM:-

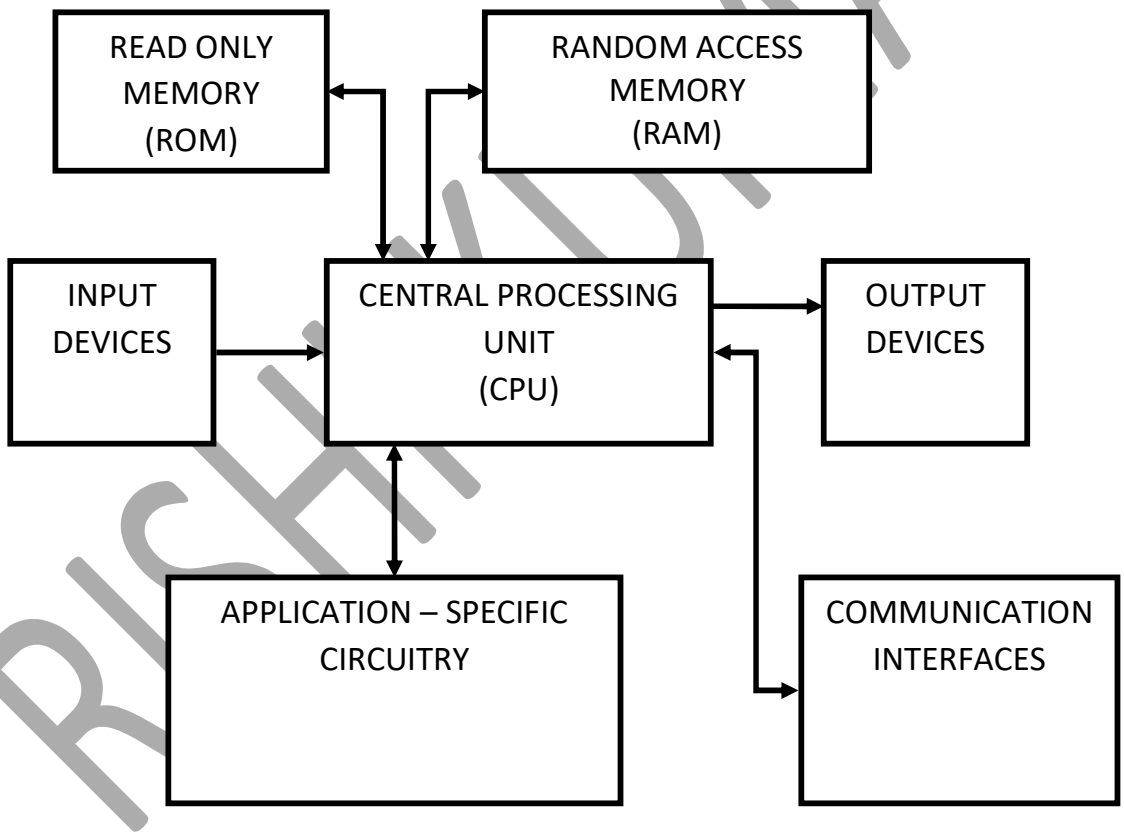


In this Architecture, three layers are there, Hardware, Operating System and Application software.

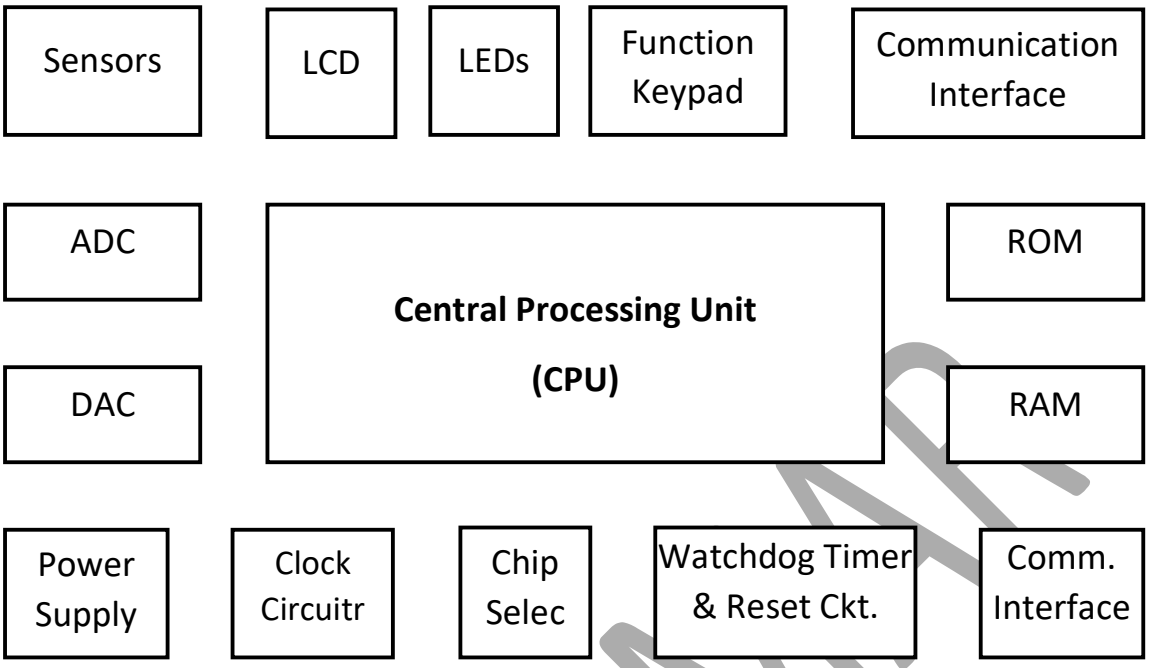
Hardware is centered layer on which operating system runs and outmost/upper layer is application software.

Unlike every computer, every embedded system may not have an operating system like small embedded system such as remote control, AC, toys etc. For application involving complex processing, operating system is required. In such systems, application software and operating system are integrated and then entire software is transferred on to the memory chip. “The software loaded on the memory chip is called as Firmware.” After loading the software on memory, software will continuously run for long time and one don’t need to reload new software.

ARCHITECTURE / FUNCTIONAL BLOCK OF EMBEDDED SYSTEM:-



Simplified HardwareArchitecture of Embedded System



Functional Block Diagram of Embedded System

Central processing unit (CPU): - CPU consists of ALU, general purpose register, stack pointer, instruction pointer, memory address register, memory data register and instruction decoder.It performs arithmetic and logic operations, manipulate data, read data and instructions from memory, read and write data to memory, write data to output device and read data from input device.It also has three types of buses data bus, address bus and control & status bus.

Memory: -Embedded system can have three type of memory chips

1. Random access memory (RAM)
2. Read-only memory (ROM)
3. Hybrid memory

These are used to store program and data permanently or temporary.

Clock Circuitry: -Crystal oscillator is connected externally to the system for generating clock input and clock circuitry is inbuilt to the processor.All the processes are related to the clock.The clock frequency gives the idea about the speed of the processor compared to another processor i.e. higher is clock frequency higher is the speed of processor.

Watchdog Timerand Reset Circuitry: -In every embedded system, processor need to be reset.In some system, reset button is given and by pressing the button processor resets but in mostly systems, no reset button is provided.In these systems, watchdog timer is used to reset the

processor automatically if it is if it does not receive signal periodically from the processor shows everything is right.

Chip Select (CS): -CS is the is a signal which identify a peripheral connected to processor to communicate.The chip select signal is available to all the peripheral connected to the bus.

Input / Output devices: -I/O devices are used to input signal / data into system or to give display output signal / data on the display devices.Input devices are sensors & transducers, ADC, function keypad etc. and output devices are LEDs, LCDs, etc.Data maybe input / output using dynamic memory access (DMA) controller.The peripheral connected to embedded system processor are provided with SPI interface for inter-integrated circuit bus (I^2C) bus.

Debug Port: -JTAG(Join Test Access Group) port is a standardized port to access the internal circuitry of the processor. JTAG port is used to debugging as well as to download the software on the embedded system.

JTAG port consists of four signals

1. Test data input (TDI)
2. TestOutput (TDO)
3. Test mode select (TMS)
4. Test clock (TCK)

Communication Interfaces: -A number of communication interface are there with embedded system to interact with external world.These are

1. Serial interface using RS232
2. Serial interface using RS422
3. Universal serial bus
4. Infrared
5. Ethernet
6. Wireless interface based on IEEE 802.11 LAN standard
7. Bluetooth radio interface

Power Supply Unit: -In embedded system, there are so many components which requires different DC voltage supply such as +12 volt, -12 volt, +5 volt etc. Theses voltage are provided from main power supply unit (PSU)

An AC adaptor converts the main supply into DC supply and this DC supply is connected in different DC voltages by DC - DC converter. DC - DC converter is of two types

a) **Linear regulation: -**In this, output voltage is fixed and less than the input voltage.It requires less components so it is less costly and of low noise. But its efficiency is less and waste more power e.g. IC LM 78xx
b) **Switching regulator: -**In this, output voltage can be step up or step down the input voltage or invert the input voltage.This type of regulator requires more components then linear regulator, so occupy more space, more costly and produces more noise, while its efficiency is more and waist less power during conversion e.g. Maxim's MAX603, 604, 1615, 724.

TYPE OF EMBEDDED SYSTEM:-

Embedded system can be classified on the basis of

1. Based On Performance And Functional Requirement:-
   a. Real Time Embedded System
   b. Standard Alone Embedded System
   c. Networked Information Appliances Embedded System
   d. Mobile Device Embedded System
2. Based On Capacity / Performance Of The Microcontroller
   a. Small Scale Embedded System
   b. Medium Scale Embedded System
   c. Sophisticated Embedded System

Real Time Embedded System:- A Real Time Embedded System provides output within a defined specific time. That is, real time embedded systems are designed and created to perform some specific work in pre-specified time. These can also be categorised as:-

i) Hard Real Time Embedded Systems
ii) Soft Real Time Embedded System

The system with strict deadline to do the specific work is called hard hard real time embedded system. For example, in missile system, which has to track and intercept an enemy aircraft. If there is a delay in tracking the aircraft and if the missile misses the deadline, the enemy aircraft may drop a bomb which cause losses of many lives.

In some embedded systems, deadlines are imposed, but not adhering to them once in a while may not lead to a catastrophe, these systems are called soft real time embedded system. For example, DVD players, if in execution of command given to DVD player from a remote, there occurs some millisecond delay, this delay would not lead to a serious implication.

Standalone Embedded System:- As the name suggest, these are those systems which works in standalone mode i.e. by themselves. They do not depend on a host system. They receives input from transducers or commands from a human being by pressing a button, process them and produces the desired output. For example, Digital Camera, Microwave Oven, DVD Player, Air-Conditioner, TV etc.

Network Information Appliances Embedded System:- These systems are dependent on connected network to perform its assigned tasks. These systems consists of components like Sensors, Controller etc. which are interconnected. Many of these systems are built on general purpose processes. For example, Weather Monitoring System

Mobile Embedded System:- These are special categories of embedded system which are smaller in size and can be used in smaller device. For example, Mobile Phone, Personal Digital, Assistant Digital Camera etc. There are some limitations with these systems which are memory constraints, small size and lack of good user interfaces.

Small Scale Embedded System:- Small Scale Embedded Systems are mostly designed and developed by using small microcontroller like 8 bit or 16 bit microcontroller. This system can be powered by a battery source.

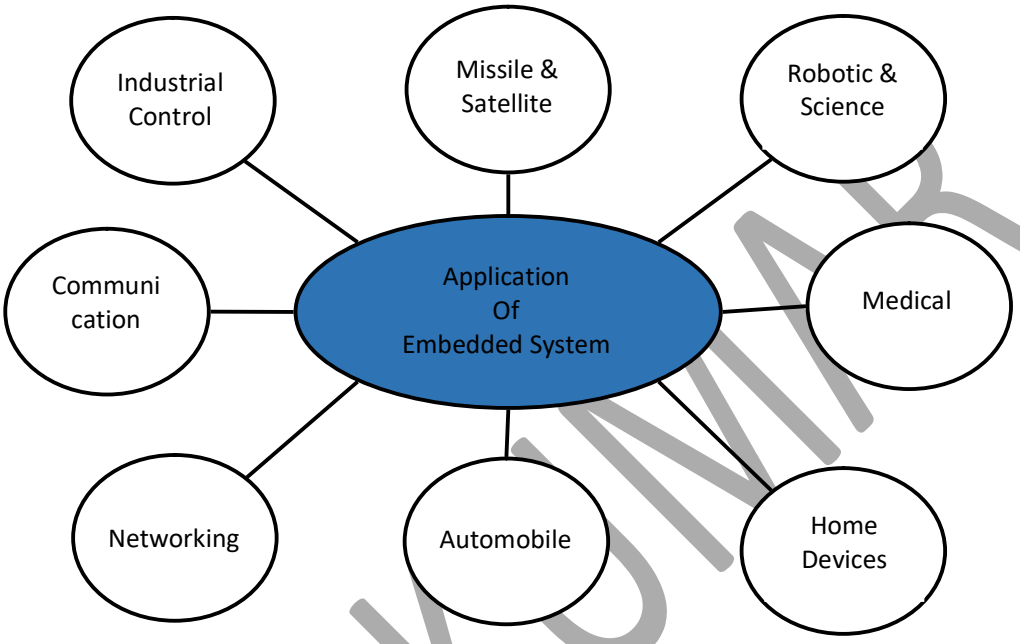
Medium Scale Embedded Systems:- These systems are designed by using 16 bit or 32 bit microcontroller. This system offer a lot of hardware complexities as well as software complexities like C, C++, Java etc., so not preferred by the most of the users.

Sophisticated Embedded Systems:- These systems have many hardware and software complexities which function on multiple algorithms. They need IPS, ASIP and PLA and a processor which combine in the final system.

CHAPTER - 2

APPLICATIONS OF EMBEDDED SYSTEM

1. Major areas of Application of embedded systems are:



Applications of embedded systems in these areas are:

Embedded System are used in Industrial Controlin:-

i) Assembly Lines
ii) System for feedback
iii) System for Data Collection
iv) Control Systems
v) Nuclear Reactors

Embedded System are used in Missile & Satellites in:-

i) Guidance Systems
ii) Navigation Systems
iii) Defense
iv) Aerospace
v) Missile
vi) Space Station

Embedded System are used in Robotic science in:-

i) Ground Vehicles
ii) Drones
iii) Industrial Robots
iv) Under Water Vehicles
v) Robotics in assembly Line

Embedded System are used in Medical in:-

i) Dialysis Machine
ii) Infusion Pumps
iii) Cardiac Monitors
iv) MRI

v) CT Scan
vi) ECG Machine
vii) Blood Pressure Monitor Device
viii)Heart Beat Monitor Device

Embedded System are used in Automobiles in:-

i) Motor Control Systems
ii) Ignition systems
iii) Engine safety
iv) Car Multimedia
v) Door Locks
vi) Air Bags
vii) Parking Assistant systems
viii)Lighting systems
ix) Anti-stealing Alarm
x) Wipers Motion

Embedded System are used in Networking in:-

i) Router
ii) Hubs
iii) Electronic Instruments
iv) Image Processing
v) Monitor
vi) Display
vii) Network Cards
viii)Printers

Embedded System are used in Home Devices in:-

i) Television
ii) Digital Cameras
iii) Computers
iv) Printers
v) Video Games
vi) Home Entertainment System (PS4)
vii) Set Top Boxes
viii)AC

2. Real Time applications of embedded systems:-

a. For detecting Rash Driving onHighways
b. For Street Light Control
c. For Traffic Signal Control Systems
d. For Vehicle Tracking
e. For Auto Intensity Control
f. For Home Automation Systems
g. For Industrial Temperature Control
h. For War Field Spying Robots

3. Applications of embedded systems on the basis of Small-Scale, Medium Scale & Sophisticated Embedded Systems:-

A. Applications on the basis of Small-Scale Embedded Systems:-

i) Washing Machine
ii) DSO
iii) Spectrum Analyser
iv) Cooking Machine
v) Multitasking Toys
vi) Fax
vii) Photocopy
viii) Printer
ix) Scanner
x) Remote for TV
xi) Industrial Moisture recorder cum controller
xii) Automatic Chocolate Vending Machines

xiii) Stepper Motor control for a Robotic system
xiv) Point-of-sale (PoS) terminals

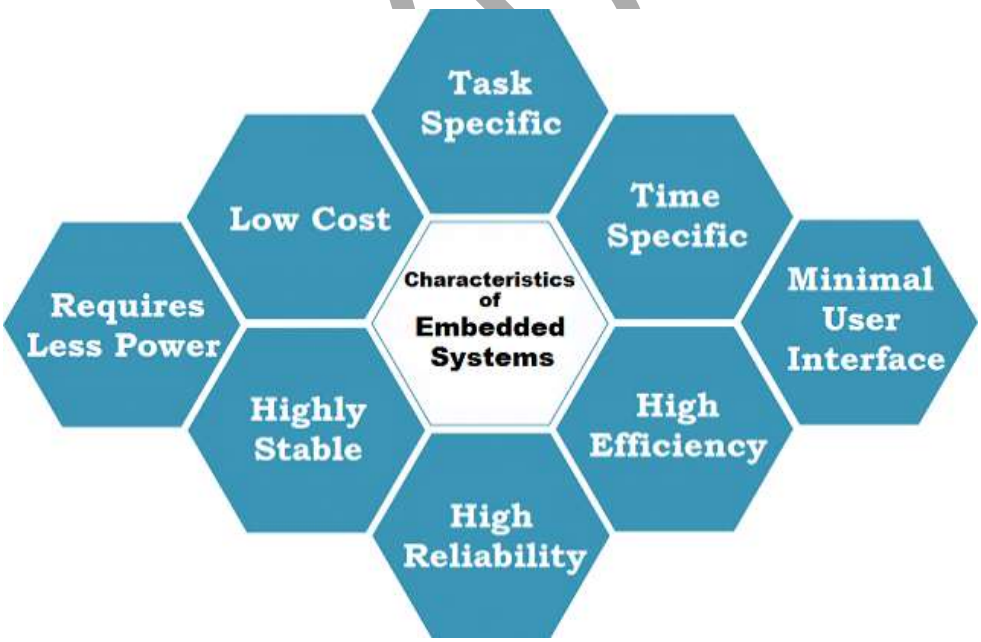
B. Applications on the basis of Medium-Scale Embedded Systems:-

i) Computer Networking System
ii) Internet Appliances
iii) Banking Systems
iv) Cable TV
v) Set-Top-Box
vi) Cellular Phone
vii) Image filtering
viii) Image Processing
ix) Speech Processing
x) Video Processing
xi) Embedded Firewell/router
xii) Entertainment Systems like video game, music systems

C. Applications on the basis of Sophisticated Embedded Systems:-

i) Mobile or Tablet
ii) Speech Processing System
iii) Interfacing System (400 MHz)
iv) Networking System (400 MHz)
v) GB rate encryption rate products
vi) Wireless LAN embeddedSystem
vii) Security Products

CHARACTERISTICS OF EMBEDDED SYSTEMS



Some of the key characteristics of Embedded Systems are as mentioned below.

- All Embedded Systems are task specific. They do the same task repeatedly /continuously over their lifetime. An mp3 player will function only as an mp3 player.
- Embedded systems are created to perform the task within a certain time frame. It must therefore perform fast enough. A car's brake system, if exceeds the time limit, may cause accidents.

- They have minimal or no user interface (UI). A fully automatic washing machine works on its own after the programme is set and stops once the task is over.
- Embedded systems cannot be changed or upgraded by the users. Hence, they must rank high on reliability and stability. They are expected to function for long durations without the user experiencing any difficulties.
- Microcontroller or microprocessors are used to design embedded systems.
- Embedded systems need connected peripherals to attach input & output devices.
- Developed around a real time operating system.
- Required limited memory.
- They are low cost system.
- They can work with less power.
- They are small sized systems.
- It does not need any specific memory as in computer.

FEATURES OF AN EMBEDDED SYSTEM

1. Embedded systems execute pre-programmed functions and they have a particular set of requirements.
2. Embedded systems perform a specific function or a set of specific functions unlike a computer, which is used to carry out a wide number of functions.
3. They are not always independent devices. Embedded systems form smaller parts of a much larger device that carries out a specific task.
4. The program scripted for an embedded system is called a firmware and is stored on a read-only or flash memory.
5. Embedded systems are application specific & single functioned, the programs are executed repeatedly.
6. Efficiency is of paramount importance for embedded systems.
7. Embedded systems are typically designed to meet real-time constraints.
8. Embedded systems often interact (sense, manipulate & communicate) with the external world through sensors and actuators and hence are typically reactive systems.
9. They generally have minimal or no user interface
10. Ease of use:Ease of use is also a very important feature. Tools that are difficult to use can be frustrating for developers and lengthen development times.
11. Device/core support:Selected embedded system software must support selected device.

12. Technical support:Finally, consider the type of technical support that a vendor is able to provide.

CHAPTER - 3

PIC Microcontroller Architecture and Applications

PIC microcontroller was developed in the year 1993 by microchip technology. The term PIC stands for Peripheral Interface Controller. It was developed for supporting PDP computers to control its peripheral devices and that's why it was named Peripheral Interface Controller. These microcontrollers are very fast and easy to execute a program compared with other microcontrollers. PIC Microcontroller architecture is based on Harvard architecture & support RISC architecture.

Microcontroller is an integrated chip which consists of CPU, RAM, ROM, timers, and counters, etc. PIC microcontroller architecture consists of RAM, ROM, CPU, timers, counters and supports the protocols such as SPI, CAN, and UART for interfacing with other peripherals.

PIC Microcontrollers from Microchip Company are divided into 4 large families:

- First family : PIC10 (10FXXX) called Low End
- Second family : PIC12 (PIC12FXXX) called Mid-Range
- Third family : PIC16 (16FXXX)
- Fourth family : PIC 17/18 (18FXXX)

PIC microcontrollers are very popular due to their ease of programming, wide availability, easy to interfacing with other peripherals, low cost, large user base and serial programming capability (reprogramming with flash memory), etc.PIC microcontrollers are extensively used for industrial purpose due to low power consumption, high performance ability and easy of availability of its supporting hardware and software tools like compilers, debuggers and simulators.

WHAT IS A PIC MICROCONTROLLER?

PIC (Programmable Interface Controllers) microcontrollers are the worlds smallest microcontrollers that can be programmed to carry out a huge range of tasks. These microcontrollers are found in many electronic devices such as phones, computer control systems, alarm systems, embedded systems, etc. Various types

of microcontrollers exist, even though the best are found in the GENIE range of programmable microcontrollers.

The main features of PIC microcontrollers are RAM, flash memory, Timers/Counters, EEPROM, I/O Ports, USART, CCP (Capture/Compare/PWM module), SSP, Comparator, ADC (analog to digital converter), PSP(parallel slave port), LCD and ICSP (in circuit serial programming) The 8-bit PIC microcontroller is classified into four types on the basis of internal architecture such as Base Line PIC, Mid Range PIC, Enhanced Mid Range PIC and PIC18

ARCHITECTURE OF PIC MICROCONTROLLER

PIC Microcontroller architecture is based on Harvard architecture and supports RISC architecture (Reduced Instruction Set Computer).

The PIC microcontroller architecture comprises of CPU, I/O ports, memory organization, A/D converter, timers/counters, interrupts, serial communication, oscillator and CCP module which are discussed in detailed below.

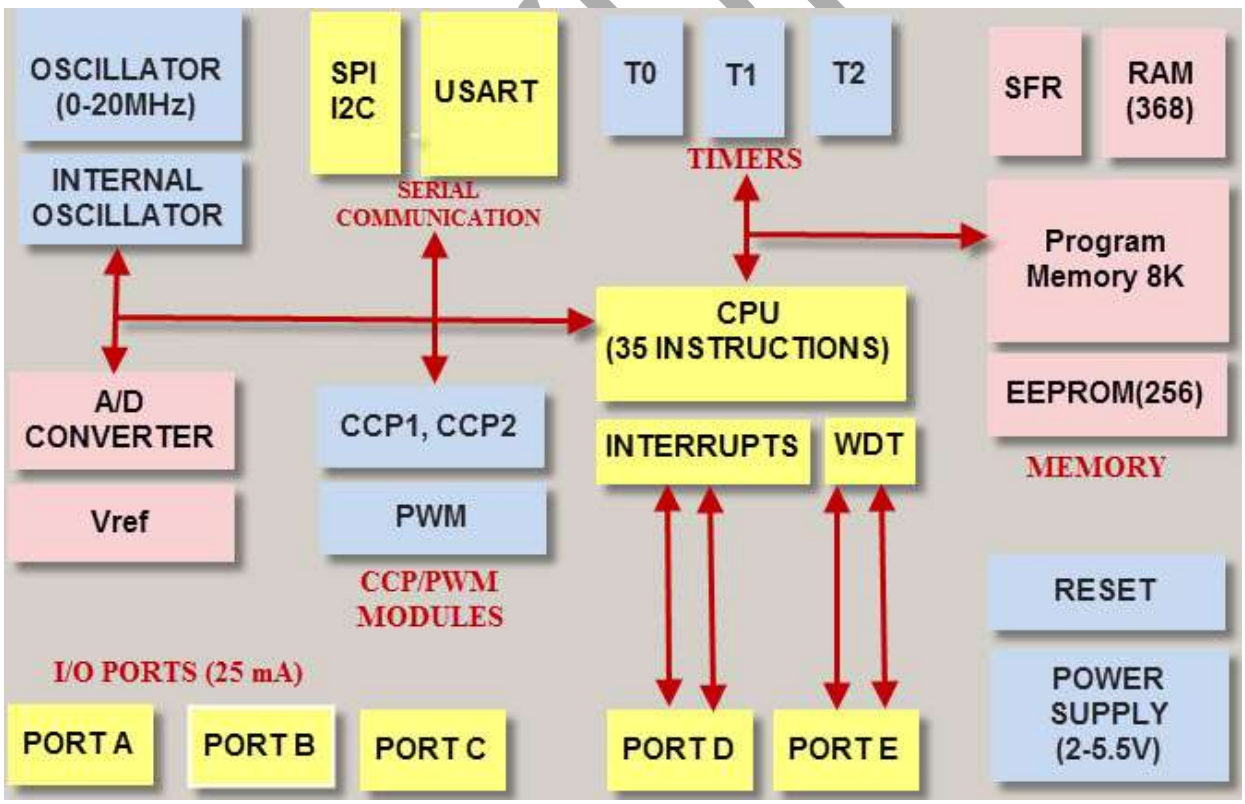
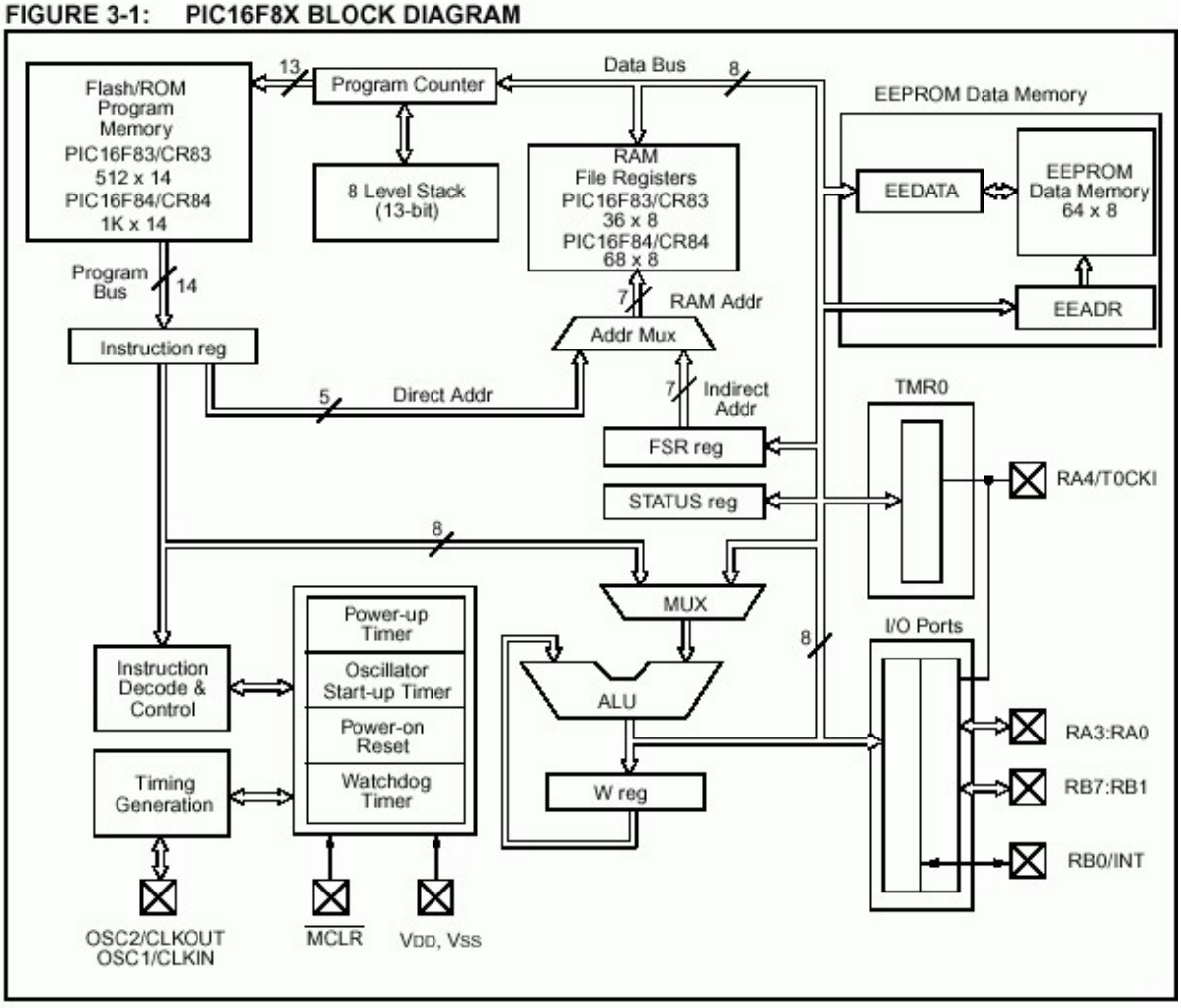


FIGURE 3-1: PIC16F8X BLOCK DIAGRAM



CPU (CENTRAL PROCESSING UNIT)

PIC microcontroller CPU consists

- Arithmetic logic unit (ALU)
- Memory unit (MU)
- Control unit (CU)
- Accumulator

Arithmetic logic unit is mainly used for arithmetic operations and to take logical decisions. Memory is used for storing the instructions after processing. To control the internal and external peripherals, control unit is used which are connected to the CPU and the accumulator is used for storing the results and further process.

MEMORY ORGANIZATION

The memory module in the PIC microcontroller architecture consists of RAM (Random Access Memory), ROM (Read Only Memory) and STACK.

1. Random Access Memory (RAM) / Data Memory:

RAM is an unstable memory which is used to store the data temporarily in its registers. The RAM memory is classified into two types: Special Function Registers (SFR) and General Purpose Registers (GPR).

a. General Purpose Registers (GPR)

These registers are used for general purpose only as the name implies. We use registers for storing the numbers. So these registers don't have any special function,- CPU can easily access the data in the registers.

b. Special Function Registers

These registers are used for special purposes only as the name SFR implies. These registers will perform according to the functions assigned to them , and they cannot be used as normal registers. STATUS register are used for showing the operation or status of the program only, not for storing data.. So, user cannot change the function of the SFR; the function is given by the manufacture at the time of manufacturing.Three important SFRs for programming are:

STATUS register: It changes the bank

PORT registers: It assigns logic values 0 or 1 to the ports

TRIS registers: It is a data direction register for input and output

2. Read Only Memory (ROM)

Read only memory is a stable memory which is used to store the data permanently. In PIC microcontroller architecture, ROM stores the instructions or program. The ROM is also called as program memory, wherein the user will write the program for microcontroller and saves it permanently, and finally the program is executed by the CPU.

a. Electrically Erasable Programmable Read Only Memory (EEPROM)

In the normal ROM, we can write the program for only once we cannot use again the microcontroller for multiple times. But, in the EEPROM, we can program the ROM multiple times.This memory is not directly mapped in the register file. It is indirectly addressed through the SFRs. There are six SFRs which are used to read and write to this memory (EECON1, EECON2, EEDATA, EEDATH, EEADR, EEADRH).

b. Flash Memory/Program Memory:

Flash memory is also programmable read only memory (PROM) in which we can read, write and erase the program thousands of times. Generally, the PIC microcontroller uses this type of ROM.PIC microcontroller can have 8K words x 14 bits of Flash program memory that can be electrically erased and reprogrammed.

3. STACK

When an interrupt occurs, first the PIC microcontroller has to execute the interrupt and then existing process address. For the same, existing process address is stored in the stack. After completing the execution of the interrupt, the microcontroller calls the process with the help of address, which is stored in the stack and get executes the process.

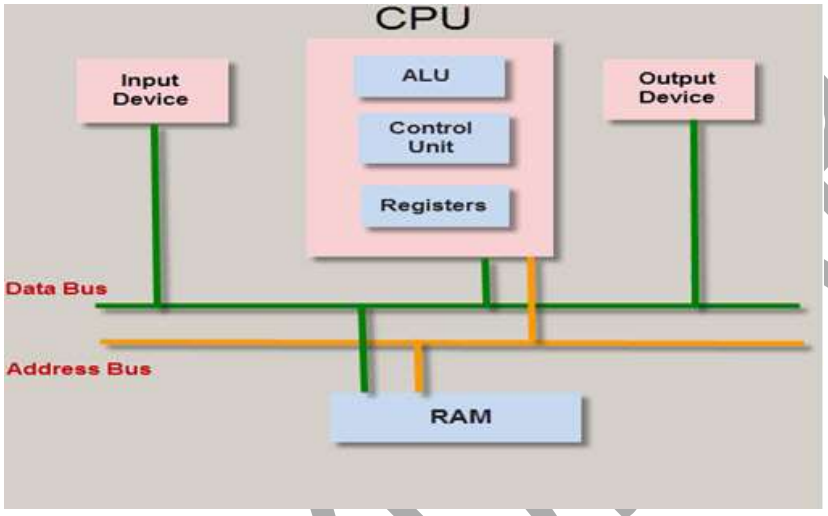
I/O PORTS

- The series of PIC16 consists of five ports such as Port A, Port B, Port C, Port D & Port E.
- Port A is an 16-bit port that can be used as input or output port based on the status of the TRISA (Tradoc Intelligence Support Activity) register.
- Port B is an 8- bit port that can be used as both input and output port.
- Port C is an 8-bit and the input of output operation is decided by the status of the TRISC register.
- Port D is an 8-bit port acts as a slave port for connection to the microprocessor BUS.
- Port E is a 3-bit port which serves the additional function of the control signals to the analog to digital converter.

BUS

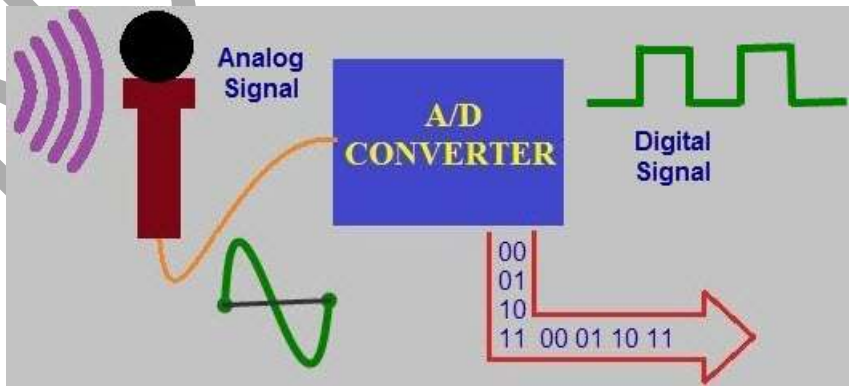
BUS is used to transfer and receive the data from one peripheral to another. It is classified into two types such as data bus and address.

1. **Data Bus:** It is used for only transfer or receive the data.
2. **Address Bus:** Address bus is used to transmit the memory address from the peripherals to the CPU. I/O pins are used to interface the external peripherals; UART and USART both are serial communication protocols which are used for interfacing serial devices like GSM, GPS, Bluetooth, IR , etc



A/D CONVERTERS

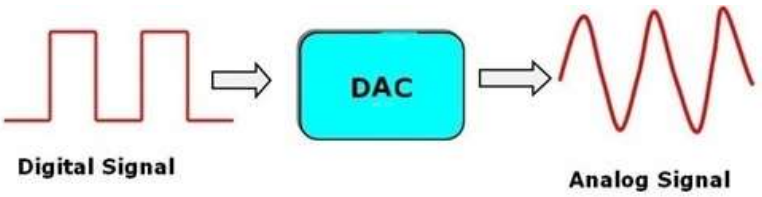
The main intention of this analog to digital converter is to convert analog voltage values to digital voltage values. A/D module of PIC microcontroller consists of 5 inputs for 28 pin devices and 8 inputs for 40 pin devices. The operation of the analog to digital converter is controlled by ADCON0 and ADCON1 special registers. The upper bits of the converter are stored in register ADRESH and lower bits of the converter are stored in register ADRESL. For this operation, it requires 5V of an analog reference voltage.



A/D CONVERTER

D/A CONVERTER:

There are no **analog outputs in PIC Microcontroller.** To get analog output we have to use external Digital-to-Analog Converter (DAC). It can convert 8 bits of digital number from the eight digital outputs of PIC microcontroller.



TIMERS/ COUNTERS

PIC microcontroller has four timer/counters wherein the one 8-bit timer and the remaining timers have the choice to select 8 or 16-bit mode. Timers are used for generating accuracy actions, for example, creating specific time delays between two operations.

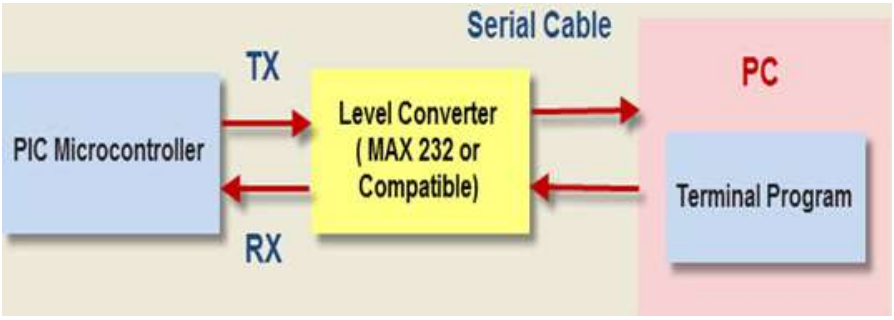
INTERRUPTS

PIC microcontroller consists of 20 internal interrupts and three external interrupt sources which are associated with different peripherals like ADC, USART, Timers, and so on.

SERIAL COMMUNICATION

Serial communication is the method of transferring data one bit at a time sequentially over a communication channel.

- **USART:** Universal synchronous and Asynchronous Receiver and Transmitter. It is used for transmitting and receiving the data bit by bit over a single wire with respect to clock pulses. The PIC microcontroller has two pins TXD and RXD. These pins are used for transmitting and receiving the data serially.
- **SPI Protocol:** Serial Peripheral Interface. This protocol is used to send data between PIC microcontroller and other peripherals such as SD cards, sensors and shift registers. PIC microcontroller support three wire SPI communications between two devices on a common clock source. The data rate of SPI protocol is more than that of the USART.
- **I2C Protocol:** Inter Integrated Circuit is used to connect low speed devices such as EEPROMS, microcontrollers, A/D converters, etc. PIC microcontroller support two wire Interface or I2C communication between two devices which can work as both Master and Slave device.



Serial Communication

OSCILLATORS

Oscillators are used for timing generation. PIC microcontroller consist of external oscillators like RC oscillators or crystal oscillators. The value of the capacitor is connected to every pin that decides the mode of the operation of the oscillator. The modes are crystal mode, high-speed mode and the low-power mode. In case of RC oscillators, the value of the resistor & capacitor determine the clock frequency and the range of clock frequency is 30KHz to 4MHz.

CCP MODULE

Capture/compare/PWM where it works in three modes such as capture mode, compare mode and PWM mode.

- **Capture Mode:** Capture mode captures the time of arrival of a signal, or in other words, when the CCP pin goes high, it captures the value of the Timer1.
- **Compare Mode:** Compare mode acts as an analog comparator. When the timer1 value reaches a certain reference value, then it generates an output.
- **PWM Mode:** PWM mode provides pulse width modulated output with a 10-bit resolution and programmable duty cycle.

ADVANTAGES OF PIC MICROCONTROLLER:

- PIC microcontrollers are consistent and faulty of PIC percentage is very less.
- The performance of the PIC microcontroller is very fast because of using RISC architecture.
- When comparing to other microcontrollers, power consumption is very less and programming is also very easy.
- Interfacing of an analog device is easy without any extra circuitry

DISADVANTAGES OF PIC MICROCONTROLLER:

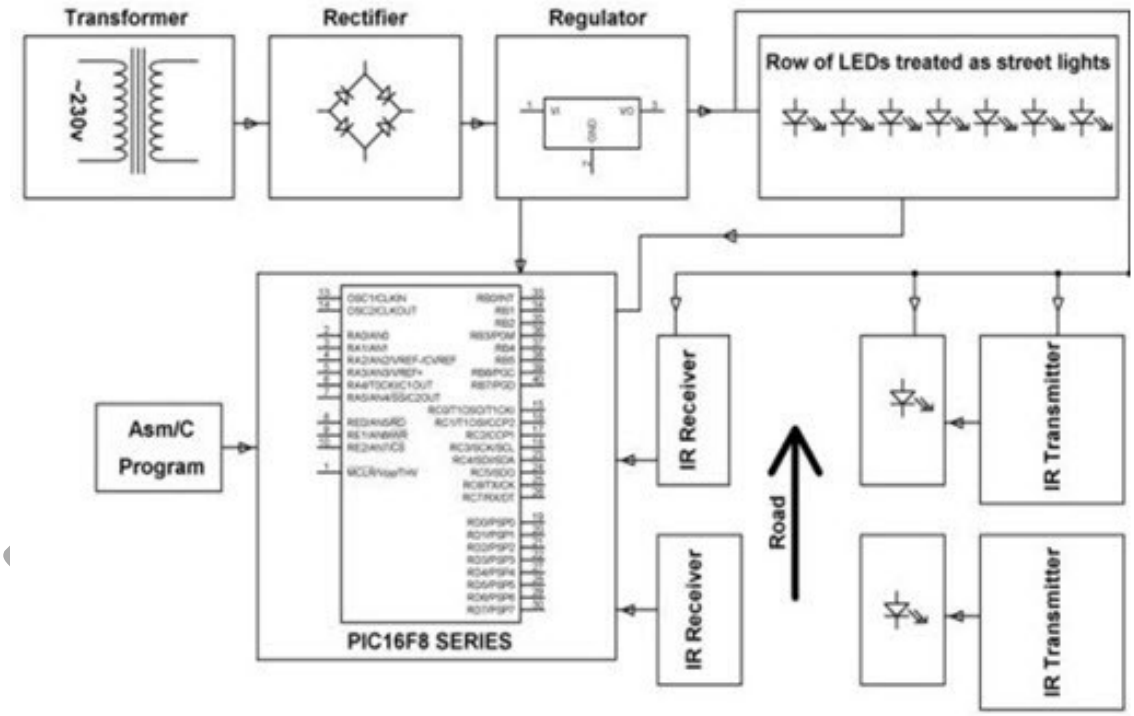
- The length of the program is high
- One single accumulator is present
- Program memory is not accessible

PIC Microcontroller Applications

The PIC microcontroller projects can be used in different applications, such as peripherals, audio accessories, video games, etc. For better understanding of this PIC microcontroller, the following project demonstrates PIC microcontroller's operations.

Street Light that Glows on Detecting Vehicle Movement:

The main intention of this project is to detect the movement of vehicles on highways to switch on a block of street lights ahead of it, and also switch off the trailing lights to conserve energy. In this project, a PIC microcontroller is done by using assembly language or embedded C.



The power supply gives the power to the total circuit by stepping down, rectifying, filtering and regulating AC mains supply. When there are no vehicles on highway, then all lights will turn OFF so that the power can be conserved. The IR sensors are placed on the road to sense the vehicle movement. When there are vehicles on highway, then the IR sensor senses the vehicle movement immediately, it sends the commands to the PIC microcontroller to switch ON/OFF the LEDs. A bunch of LEDS will be turned on when a vehicle come near to

the sensor and once the vehicle passes away from the sensor the intensity will become lower than the LEDs will turn OFF.

CHAPTER - 5

EMBEDDED SOFTWARE

Embedded Software is the software that controls an embedded system. All embedded systems need some software for their functioning. Embedded software or program is loaded in the microcontroller which then takes care of all the operations that are running. For developing this software, a number of different tools are needed which include editor, compiler, assembler and debugger. Let's have a look on them.

EMBEDDED SYSTEM SOFTWARE DEVELOPMENT TOOLS

1. Editor

- This is where you write the code for your embedded system.
- The code is written in some programming language. Most commonly used language is C or C++.
- The code written in editor is also referred to source code.

2. Compiler

- A compiler is used when you are done with the editing part and made a source code.
- The function of compiler is to convert the source code in to object code.
- Object code is understandable by computer as it in low level programming language.
- So we can say that a compiler is used to convert a high level language code in to low level programming language.

3. Assembler

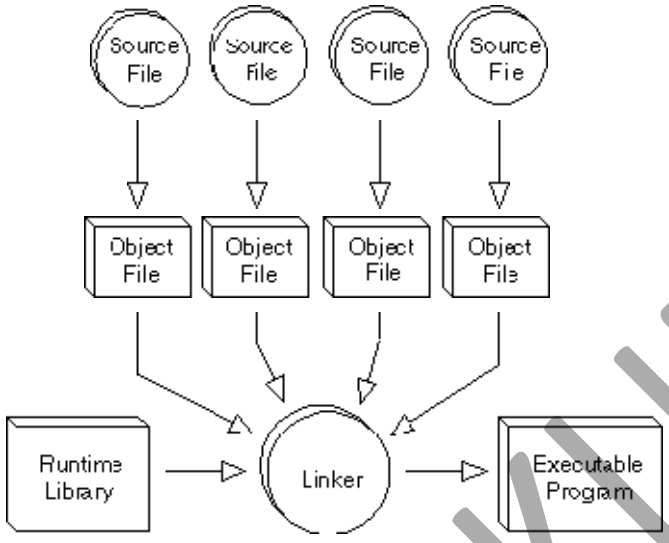
- The function of an assembler is to convert a code written in assembly language into machine language.
- All the mnemonics and data are converted in to opcodes and bits by an assembler.
- We all know that our computer understands binary and it works on 0 or 1, so it is important to convert the code into machine language.

4. Debugger

- As the name suggests, a debugger is a tool used to debug your code.
- It is important to test whether the code you have written is free from errors or not. So, a debugger is used for this testing.

- Debugger goes through the whole code and tests it for errors and bugs.
- It tests your code for different types of errors for example a run time error or a syntax error and notifies you wherever it occurs.
- The line number or location of error is shown by debugger so you can go ahead and rectify it.

5. Linker



- A linker is a computer program that combines one or more object code files and library files together in to executable program.
- It is very common practice to write larger programs in to small parts and modules to make job easy and to use libraries in your program.
- All these parts must be combined into a single file for execution, so this function requires a linker.

6. Libraries

- A library is a pre written program that is ready to use and provides specific functionality.
- For Embedded Systems Software Development Tools, libraries are very important and convenient.
- Library is a file written in C or C++ and can be used by different programs and users.
- For example, arduino microcontroller comes with a number of different libraries that you can download and use while developing your software.
- For instance, controlling LED or reading sensor like an encoder can be done with a library.

7. Simulator

- A simulator helps you to see how your code will work in real time.

- You can see how sensors are interacting, you can change the input values from sensors, and you can see how the components are working and how changing certain values can change parameters.

Integrated Development Environment (IDE) – Embedded Systems Software Development Tools

- An Integrated Development Environment is software that contains all the necessary tools required for embedded software development.
- For creating software for you embedded system, you need all of the above mentioned tools.
- So it is very helpful to have software that can provide all of the necessary tools from writing to testing of your code, in one package.
- An IDE normally consists of a code editor, compiler and a debugger.
- An IDE also provides a user interface.
- An example of IDE is Microsoft visual studio. It is used for developing computer programs and supports different programming languages.
- Other examples of IDE that are common are given below.
  - Android Studio
  - Eclipse
  - Code Blocks
  - BlueJ
  - Adobe Flash Builder etc.
- Depending on what kind of microcontroller you are using, you can choose from many different software applications. Some of these Embedded Systems Software Development Tools are discussed:-

1. MPLAB

- MPLAB is an integrated development environment from Microchip technology.
- It is a software that runs on your personal computer and is needed to create program for your PIC microcontroller.
- It helps in editing, debugging and programming of microchip microcontroller that you use in your embedded system.
- For developing embedded software for your system using MPLAB, you have to go through the following steps:

- The first step in this design process is to choose the PIC microcontroller that meets the requirements and parameters for your system.
- Know all the components of your embedded system by making a rough design.
- Next step is to write code for your embedded software. It is your choice to write code in assembly language or some high level programming language.
- Now you have to make your code ready to program your microcontroller. So using compiler / assembler convert code into machine code.
- The fifth step is to debug your code to remover errors.
- Finally, upload the code in to your microcontroller. And it is ready to be used in the embedded system.

- There are many important features of MPLAB which are really helpful in software development which are:
  - Free C compilers
  - Macros
  - Complex breakpoints
  - Third party tools
  - Change variables in watch window etc.

2. Arduino Software

- Arduino software is used if you are working with Arduino Microcontroller.
- It is also open source software just like MPLAB that runs on your personal computer.
- Arduino software helps you to create program for your microcontroller providing all the necessary embedded software tools.

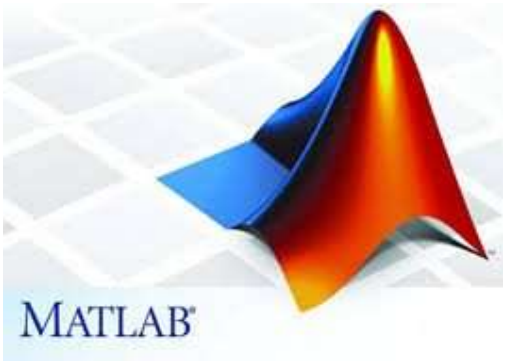
- The codes that you write on arduino software are referred to as sketches and have an extension .ino.
- IDE of arduino is very user friendly and has a lot of features that make your job easy. For example, you can open multiple files with different extensions in one window.
- With arduino you can make use of a number of different libraries for your functions and peripherals. Some of them are:
  - LiquidCrystal
  - WiFi
  - Audio
  - RTC
  - LedControl
  - Robot

- Matrix
- Capacitive Sensing

3. Keil

- Keil is an IDE for a wide range of microcontrollers including 8051, 251, ARM7, and C16x/ST10 microcontrollers.
- This software includes compiler, assembler, linker, debugger, simulator etc.
- This software is also easy to use and learn.
- The software for 8051 is used by professional embedded system developers and beginners both.

4. MATLAB



- MATLAB is one of the very important tools for software developers.
- It provides you with an environment where you can solve all of your computational problems.
- You can work with matrices, graphs, vectors, functions, arrays, plots etc. You can make algorithms. Also you can create user interfaces.
- With MATLab, you can also interface programs written in other programming languages.
- MATLlab comes with additional software, Simulink that enables you to create simulation.
- It is really a helpful tool for embedded software developers, as you can work on sensors data, plot it and see response by changing certain variables.

5. LabVIEW

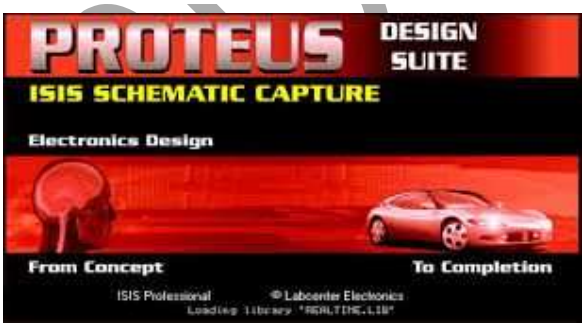
- Labview stands for Laboratory Virtual Instrument Engineering Workbench. This software is also used for viewing output.

- The main functions that can be performed using LabVIEW are data acquisition, industrial automation and instrument control.
- This software is basically for visual programming language.
- Some of the benefits of LabVIEW are:
  - Libraries
  - Interfacing to devices
  - Parallel programming
  - User community

6. PSpice

- SPICE stands for Simulation Program for Integrated Circuits Emphasis, and PSpice is its version for personal computers.
- PSpice is simulation software that is used for simulating circuits.
- It helps in analyzing electronic circuitry, verifying circuit designs and predicting their behavior.
- It has a number of libraries for digital and analog components.
- The components that are available include
  - resistors,
  - capacitors,
  - voltage and current sources,
  - Inductances etc.

7. Proteus



- Proteus is kind of simulation software where you can create circuits, make model of your embedded system including microcontroller to see how it works, measure circuit parameters, change sensor values and much more.
- It helps you to create PCB (printed circuit board) design for your embedded system.
- Microcontroller simulation is an important feature of this software where you can load a hex file to your microcontroller in the design, connect all other components to it and see how it works.

- This software runs only on Windows operating system.

8. Visual Studio

Visual Studio is also an IDE provided by Microsoft.

- It is used for developing computer programs for Microsoft Windows.
- It can support different programming languages and basically consists of a code editor and a debugger.
- With this software you can build different mobile apps, window apps, extensions, games etc. The choice of language is yours.
- Now I am moving to the next tool which is EasyEDA.

9. EasyEDA

- EasyEDA is an online tool that you can use to create schematics, PCB designs, and simulations.
- Since it is an online tool that runs on web, there is no need for you to download and install it in your personal computer. Instead you can run it directly.
- Also there is no need of updating your software or to remove bugs, as it is online tool and keeps updating itself. New features are added automatically.
- Another advantage is that it runs on all types of OS (windows, linux etc.) as EasyEDA works on your web browser.

10. Altium

- Altium which is also PCB designing software.
- PCB designing is very important part of developing an embedded system, so it is good to know all the available resources for PCB design.
- The PCB designing module of Altium has a lot of features including
  - Adding hole tolerance
  - PDF 3D export
  - Live Drill Drawing
  - Supporting Embedded Components etc.

CHAPTER - 6

Main Difference between AVR, ARM, 8051 and PIC Microcontrollers

	8051	PIC	AVR	ARM
Bus width	8-bit for standard core	8/16/32-bit	8/32-bit	32-bit mostly also available in 64-bit
Communication Protocols	UART, USART,SPI,I2C	PIC, UART, USART, LIN, CAN, Ethernet, SPI, I2S	UART, USART, SPI, I2C, (special purpose AVR support CAN, USB, Ethernet)	UART, USART, LIN, I2C, SPI, CAN, USB, Ethernet, I2S, DSP, SAI (serial audio interface), IrDA
Speed	12 Clock/instruction cycle	4 Clock/instruction cycle	1 clock/ instruction cycle	1 clock/ instruction cycle
Memory	ROM, SRAM, FLASH	SRAM, FLASH	Flash, SRAM, EEPROM	Flash, SDRAM, EEPROM
ISA	CLSC	Some feature of RISC	RISC	RISC
Memory Architecture	Von Neumann architecture	Harvard architecture	Modified	Modified Harvard architecture
Power Consumption	Average	Low	Low	Low
Families	8051 variants	PIC16,PIC17, PIC18, PIC24, PIC32	Tiny, Atmega, Xmega, special purpose AVR	ARMv4,5,6,7 and series
Community	Vast	Very Good	Very Good	Vast
Manufacturer	NXP, Atmel, Silicon Labs, Dallas, Cyprus, Infineon, etc.	Microchip Average	Atmel	Apple, Nvidia, Qualcomm, Samsung Electronics, and TI etc.

Cost (as compared to features provide)	Very Low	Average	Average	Low
Other Feature	Known for its Standard	Cheap	Cheap, effective	High speed operation Vast
Popular Microcontrollers	AT89C51, P89v51, etc.	PIC18fXX8, PIC16f88X, PIC32MXX	Atmega8, 16, 32, Arduino Community	LPC2148, ARM Cortex-M0 to ARM Cortex-M7, etc.