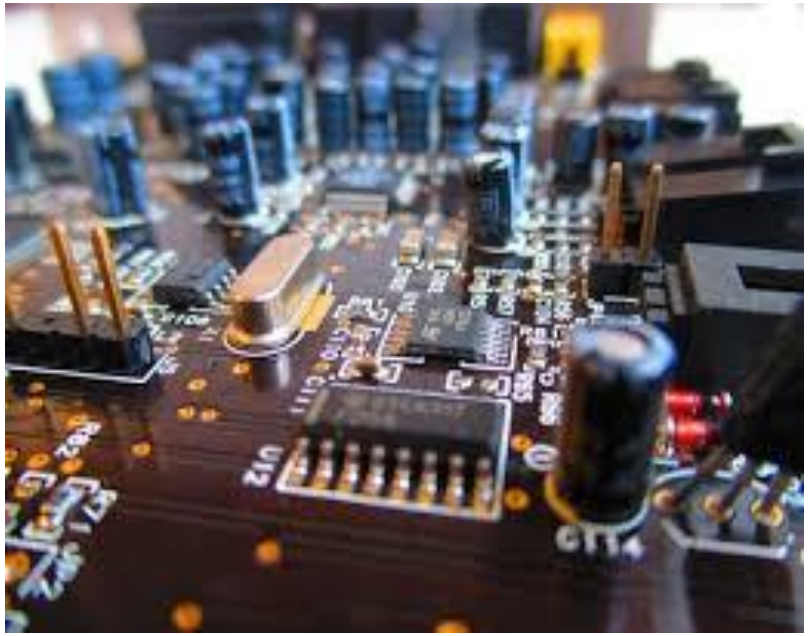
ECE 131 (Basic Electronics and Electrical Engineering)

Unit 6

Fundamentals of embedded system and its application in industrial processes



Lecture No.: L1-L2

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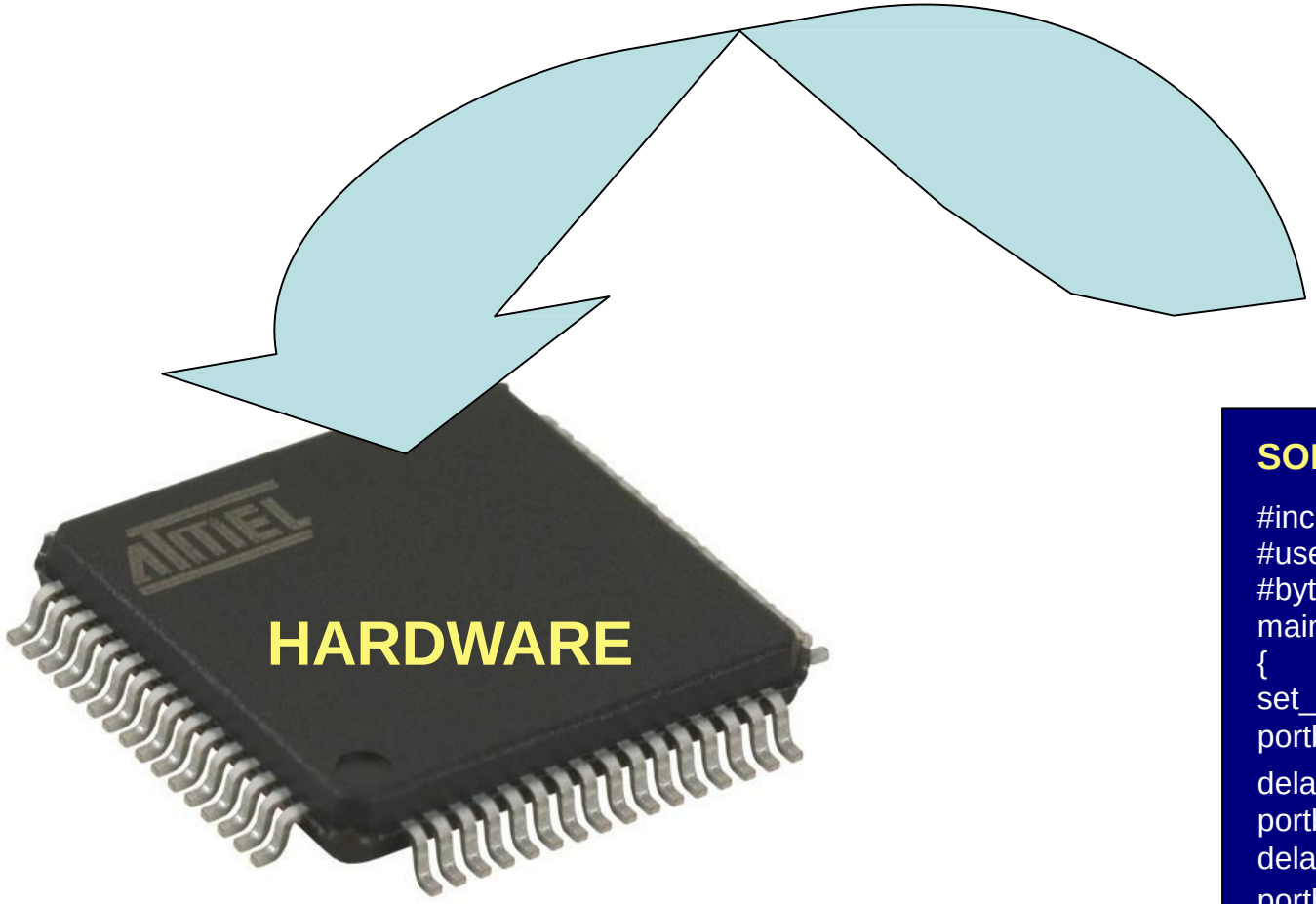
What is an Embedded System?

- An embedded system is one that has computer hardware with software embedded in it as one of its components.

Or

- We can say that it is “A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function.

What is an Embedded System?



SOFTWARE PROGRAM

```
#include <16f876a.h>
#use delay (clock=20000000)
#byte PORTB=6
main()
{
set_tris_b(0);
portb=255;        //decimal
delay_ms(1000);
portb=0x55;
delay_ms(1000);
portb=0b10101010; //binary
delay_ms(500);
}
```

Examples


SONY


SAMSUNG
12:03
12:03
Wed, 29 Aug


Cover Flow
Loose
Nelly Furtado
MENU


1200

- An embedded system is a combination of 3 things:
  a. Hardware
  b. Software
  c. Mechanical Components. And it is supposed to do one specific task only.

- **Example 1: Washing Machine**

  A washing machine from an embedded systems point of view has:

  a. Hardware: Buttons, Display & buzzer, electronic circuitry.
  b. Software: It has a chip on the circuit that holds the software which drives controls & monitors the various operations possible.
  c. Mechanical Components: the internals of a washing machine which actually wash the clothes control the input and output of water, the chassis itself.

- **Example 2: Air Conditioner**

  An Air Conditioner from an embedded systems point of view has:

  a. Hardware: Remote, Display & buzzer, Infrared Sensors, electronic circuitry.
  b. Software: It has a chip on the circuit that holds the software which drives controls & monitors the various operations possible. The software monitors the external temperature through the sensors and then releases the coolant or suppresses it.
  c. Mechanical Components: the internals of an air conditioner the motor, the chassis, the outlet, etc

- An embedded system is designed to do a specific job only. Example: a washing machine can only wash clothes, an air conditioner can control the temperature in the room in which it is placed.

- The hardware & mechanical components will consist all the physically visible things that are used for input, output, etc.

- An embedded system will always have a chip (either microprocessor or microcontroller) that has the code or software which drives the system.

COMPUTER HARDWARE

A Microprocessor

A Large Memory
(Primary and Secondary)
(RAM, ROM and caches)

Input Units
(Keyboard, Mouse, Scanner, etc.)

Output Units
(Monitor, printer, etc.)

Networking Units
(Ethernet Card, Drivers, etc.)

I/O Units
(Modem, Fax cum Modem, etc.)

General Purpose v/s Embedded Systems

File processing, playing games , browsing

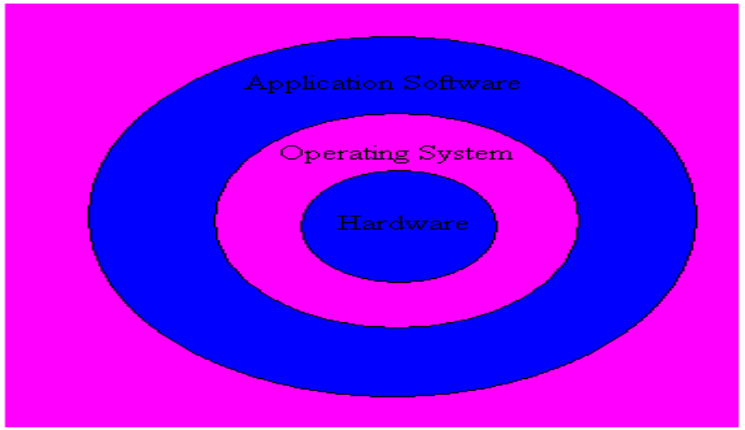
FPGA

GENERAL	EMBEDDED
Combination of generic hardware and generic operating system	Specific hardware with embedded OS
Variety of applications	Specific set of applications
Programmable.	Non- programmable (with exceptions)
Speed is priority (eg Multitasking)	Power requirements, memory, usage etc. are deciding factors (eg tracking)
Not tailored for reduced power requirements	Highly powered for power requirements
Non critical	Certain categories are highly critical
Examples: Intel, Dual Core, Core 2 Duo, AMD, etc.	DVD player, printer, washing machine, etc.

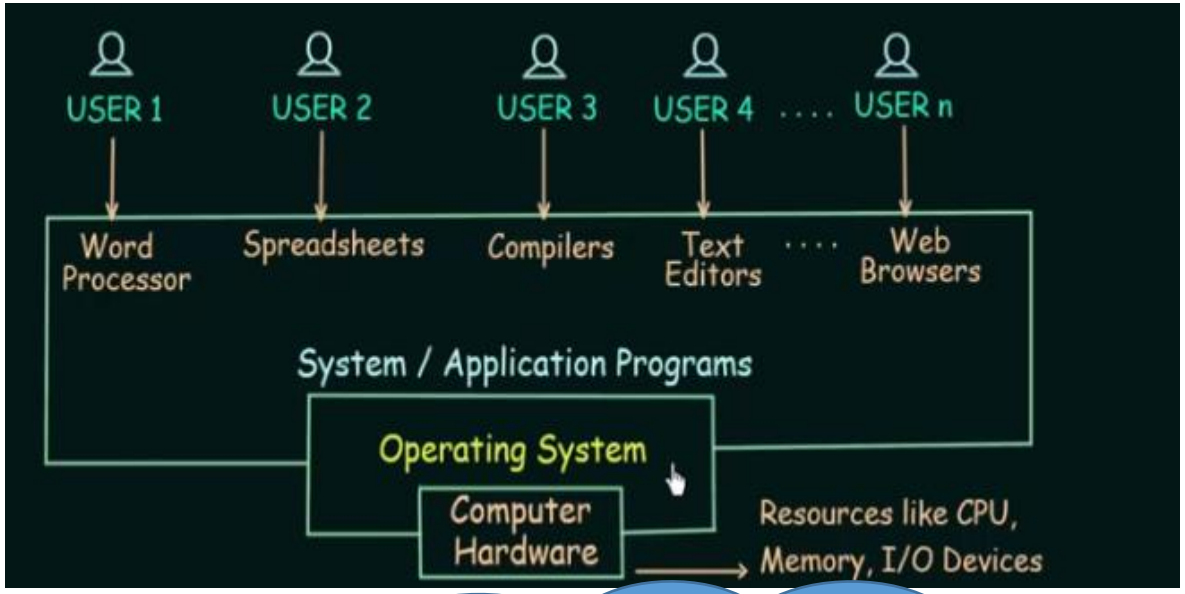
Space mission, Ic for TV , washing machine

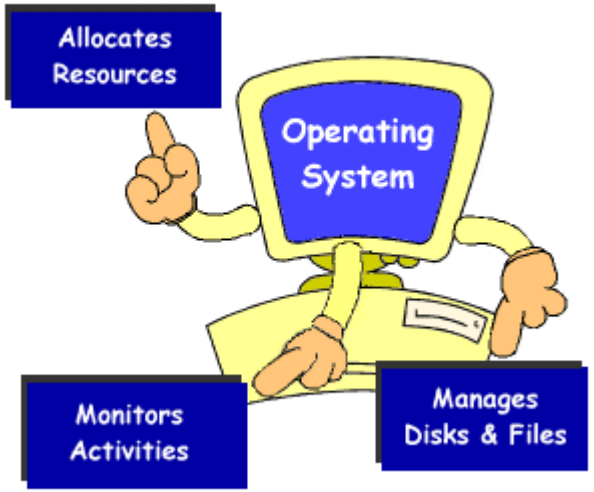
PLD's

Components of Embedded System



Layered architecture of an Embedded System





https://www.youtube.com/watch?v=vBURTt97EkA

OS does :1 Manage the hardware 2:Also provide the basis of the application Programs and act as intermediary between the computer user and hardware

Form of source code

Various OS are: Windows, Linux, Unix, ubuntu , Mac OS X , Android

QUICK QUIZ (POLL)

Which component is NOT belong to embedded system

A) Hardware

B) Word File

C) Window

D) Tracking

Embedded System: Operating system Types

- **Application Specific.**
- Includes: ASIC, PLD with I/O facilitating sensors and actuators.
- System can be: **Hard Real Time (critical)or a Soft Real Time**

➢Flight Control system, Airbag Deployment system: Hard Real Time

- Automatic Teller Machine, Media Playback system: Soft Real Time

GPOS v/s RTOS

GPOS	RTOS
General Purpose Operating System	Real Time Operating System
Non critical	Critical
It is larger in size (personal computer, a work station, a server system etc)	RTOS is small in size (eg ATM , vending Machine)
GPOS kernel is not preemptible (mostly) i.e, **based on High throughput**	The kernel of an RTOS is preemptible
Not time bound	Time bound
Synchronization is a problem with GPOS	**No issue of** Synchronization
Latency is a problem with GPOS	No latency issue
Example:- Windows, Linux, Unix etc.	Example:- VxWorks, uCos etc.

Scheduling on Priority basis with time bound

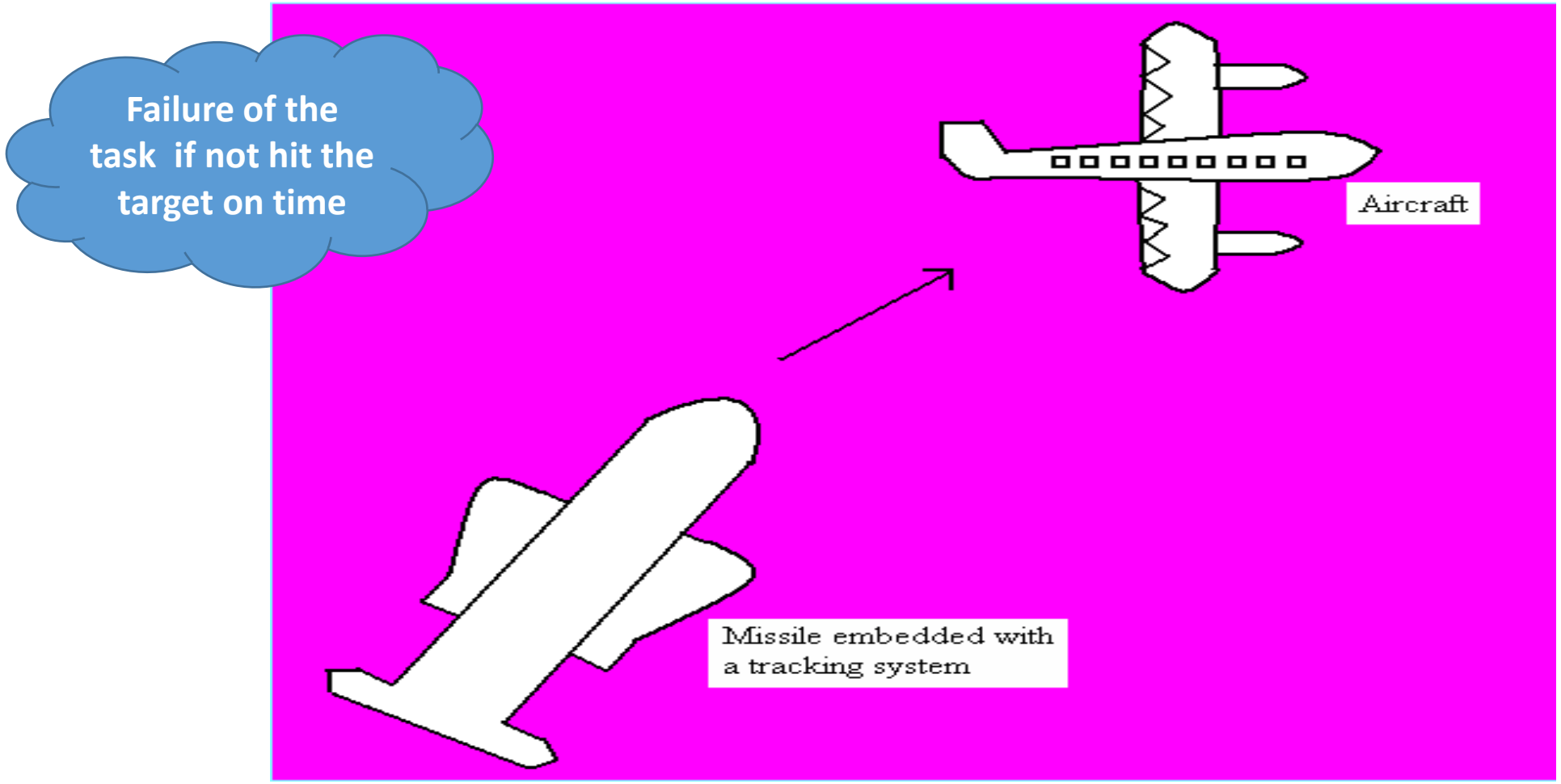
the total number of processes that complete their execution per unit time. In such a case, some times execution of a high priority process will get delayed inorder to serve 5 or 6 low

Real Time Embedded System

- Embedded systems in which some specific work has to be done in a specific time period are called real-time systems.
- It is of 2 types:
    1. Hard Real-Time
    2. Soft Real- Time

- For example, consider a system that has to open a valve within 30 milliseconds when the humidity crosses a particular threshold. If the valve is not opened within 30 microseconds, a catastrophe may occur.
- Such systems with strict deadlines are called ***hard real-time*** systems.
- The preemption period Hard Real-Time is less than few microseconds.

Hard Real-Time Embedded System



Soft Real Time Embedded System

- In some embedded systems, deadlines are imposed, but not adhering to them once in a while may not lead to a catastrophe.
- For example, consider a DVD player. Suppose, you give a command to the DVD player from a remote control, and there is a delay of a few milliseconds in executing that command. But, this delay won't lead to a serious implication.
- Such systems are called ***soft real time*** systems .
- The preemption period for a soft real time task is about few milliseconds

QUICK QUIZ (POLL)

PLD stands for:

(a) Programming Layout Device

(b) Programmable Layout Device

(c) Programmable Logic Device

(d) Programming Logic Device

QUICK QUIZ (POLL)

Which out of among have short memory

A) GPOS

B) RTOS

Purpose of Embedded Systems

- According to application, they serve following purpose:

1) Data Collection/Storage/Representation
2) Data Communication
3) Signal Processing
4) Monitoring
5) Control
6) Application specific user interface

Data Collection/Storage/Representation

- Data collection done for storage, analysis, manipulation and transmission.
- Data refers to: text, voice, image, video, electrical signals or any other measurable quantity.
- Data can be: analog or digital.
- For digital data collection, A/D converters are used.
- Data collected may or may not be stored.
- Meaningful representation of collected data by visual or audible means. (OPTIONAL)
- Example: Digital camera.

Data Communication

- Transmission achieved either by a wire line or wire less medium.
- Wireless is *de-facto* now a days.
- Example: Satellite communication system, Home networking system.
- Data Communication units:
  - ➢Wireless modules (Bluetooth, Zigbee, Wi-fi, EDGE, GPRS, etc)
  - ➢Wire-line modules (RS-232C, USB, TCP/IP, PS2, etc).
  - ➢Data Transmission Embedded systems (Network hubs, routers, switches, etc)

General Packet Radio Service (GPRS) is a packet oriented mobile data service

IEEE 802.15.4
Physical range is 10 to 20 meters

Hub connected all users and without intelligence broadcast data to all users
Switches broadcast data to required device/user based on recorded MAC addre
Router :Routes data to the networks based on IP address (either own or others)

EDGE delivers higher bit-rates per radio channel, resulting in a threefold increase in capacity and performance compared with an ordinary GSM/GPRS connection.

Parameter	Bluetooth® Low Energy (BLE)	Wi-Fi®	Zigbee®
Data Rate	1 – 3 Mbps	300 Mbps	20kb/s, 40 kb/s, 250kb/s
Frequency Band	2.4 GHz	2.4 GHz and 5 GHz	868/915 MHz, 2.4 GHz
Range	10m	190 m	100m
Security	E0 Stream cipher	WEP, WPA authentication, 128-bit Advanced Encryption Standard (AES), VPN, Firewall	128-bit AES
Risk of Data Collision	High		Medium
Maximum Number of Nodes	8	2,007	>65,000
Power Efficiency	Acceptable to Good	Varies	Excellent
Of Note	Once paired, connecting is automatic.	Connecting is automatic once it is set up.	Mesh capability creates greater signal reliability
Applications	To replace wiring in handheld devices.	The main connectivity resource for home, work, retail, and more.	Power-sipping applications; remote sensor and wireless controls
Benefits	Convenience, Cost, connect to Android, Blackberry, iOS, Tizen, and Windows.	Most widely used wireless connectivity solution. Connect to iOS and Android.	Reliable, Low Power, Cost effective, "Assemble and Forget"
Draw-backs:	Short range	Not always reliable. Higher power consumption	Not mainstream for connection to smartphones, etc.
IEEE	IEEE 802.15.1	IEEE 802.11n	IEEE 802.15.4
Markets	Mainly for portables. Widely adopted in consumer markets, retail	Ubiquitous; Widely adopted in nearly every market. Replaces cables in work areas or homes.	Better known in Industrial markets, smart homes, smart lighting.

Difference between Bluetooth/Wifi/Zigbee

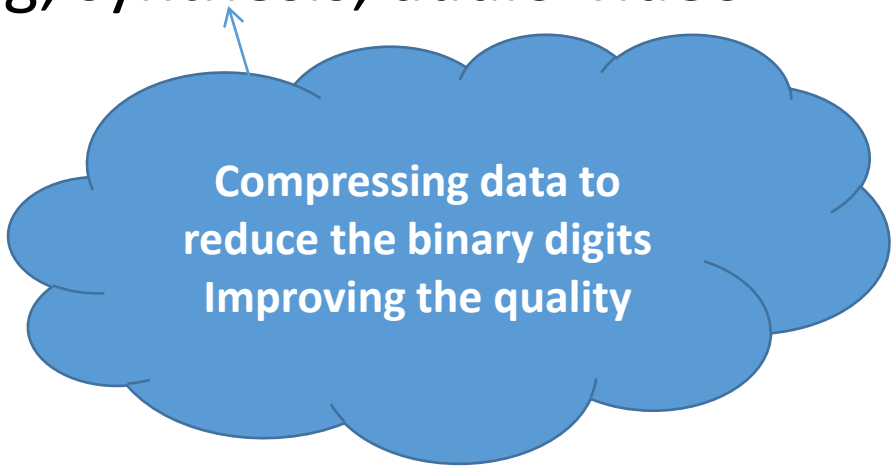
in the industrial, scientific and medical (ISM) radio bands

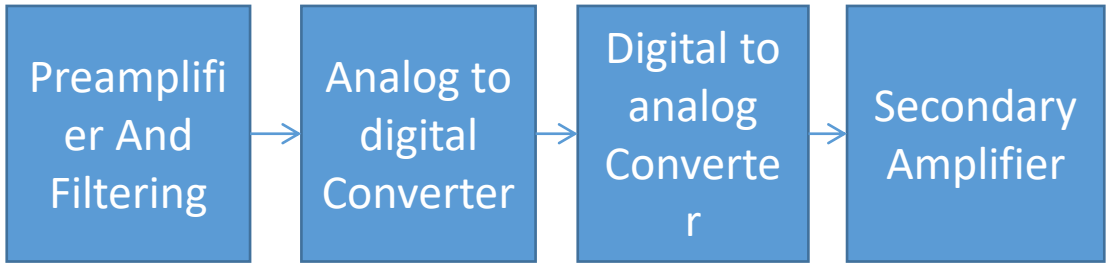
https://www.youtube.com/watch?v=1z0ULvg_pW8

Hub, Switch and Routers

Signal Processing

- Data (Data refers to: text, voice, image, video, electrical signals or any other measurable quantity.)collected by embedded systems may be used for various kinds of data processing.
- Signal Processing includes: Speech Coding, synthesis, audio-video codec, etc.
- Example: Digital hearing aids.



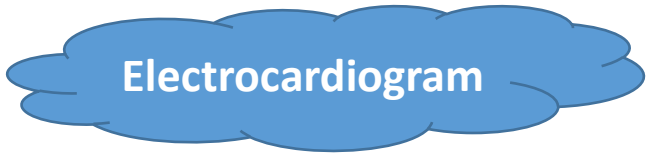


Audio out

Audio in

Monitoring

- Almost all embedded systems used in medical domain are used for monitoring purposes.
- Used to determine the state of some variables using input sensors.
- It cannot impose control over the variables.
- Example: ECG machine for monitoring the heart beat of a patient.
- Other Examples: Digital CRO, Digital Multimeter.



Control

- Embedded systems with control functionalities impose control over some variables according to the changes in input variables.
- A system with control contains both sensors and actuators.
- Sensors are connected to input for tracking changes in the environment variable. While as the actuators connected to the output are controlled as per the changes in input variable.
- Example: *Air conditioning at home.*

A sensor converts a physical event into an electrical signal, whereas an actuator converts electrical signal into a physical event.

For sensing temperature, the sensors are thermistor, thermocouple, resistance temperature detectors and thermostat. The actuators are heaters.

Application Specific User Interface

- Example: Switch, Keypad, Bells, Display Units, Mobile Phone, LCD, etc.

How user can interact or control the variables

Remotes

QUICK QUIZ (POLL)

RS-232 is an example of ?

A. A network router
B. Wire-line module
C. Wireless module
D. None of these

QUICK QUIZ (POLL)

A transducer that converts signals to a physical action is called as:

(a) Sensor

(b) Mechanical switch

(c) Actuator

(d) Buzzer

QUICK QUIZ (POLL)

Which of the following is an application of Embedded Systems?

A. Digital Signal Processing
B. Data Communication
C. Data Collection
D. All of these

Classification

- Based on:

1. Generation.
2. Complexity and Performance
3. Deterministic Behavior
4. Triggering

Based on Generation

1st Generation: 4-bit and 8-bit processors. e.g, 8085.

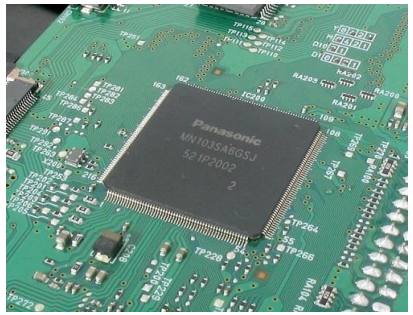
- ❑Digital telephone keyboard, Stepper motor control

2nd Generation: 8 and 16 bit processors

- ❑Much more complex Instruction set.
- ❑e.g, Data Acquisition Systems

3rd Generation: 32 bit processors

- ❑DSP and ASICs came into picture
- ❑More complex instruction set
- ❑More powerful
- ❑Examples: Motorola 68K, Pentium,



4th Generation: SoC. and Mobile Devices (Embedded).

- Example: Smart Phones and Mobile Internet Devices.

Based on Complexity and Performance

- Small Scale:

❑Power requirements are not time critical.

❑Low performance low cost 4 bit or 8 bit controllers are used.

❑May or may not contain OS.

❑Exmaple: Toys

Based on Complexity and Performance

- Medium Scale:

❑Slightly complex in hardware and software.

❑Low cost 16/32 bit controllers are used.

❑Generally contain an embedded OS for functionality

Based on Complexity and Performance

- Large Scale:

❑Highly complex in hardware and software.

❑Generally employed for critical and demanding high preferences.

❑High cost 32/64 bit controllers are used.

❑May contain multiple processors/controllers.

❑Contain high performance Real Time Operating System (RTOS) for scheduling, prioritization and management.

Based on Deterministic Behavior

- It is applicable for Real Time systems.
- Task execution behavior for an embedded system can be either deterministic or non-deterministic.
- Based on execution behavior, Real time embedded systems are classified into *Hard* and *Soft*.

Based on Triggering

- Embedded systems that are reactive in nature (like process control systems in industrial control applications) can be classified on the basis of trigger.
- Reactive systems can be either *event triggered* or *time triggered.*

QUICK QUIZ (POLL)

Which of the following is NOT an embedded system

(a) Arduino Board

(b) Raspberry pi Board

(c) Intel i3 processor

(d) Automatic Teller Machine

Application Areas of Embedded Systems

- Embedded Systems in Automobiles and in telecommunications

❑Motor and cruise control system

❑Body or Engine safety

❑Entertainment and multimedia in car

❑E-Com and Mobile access

❑Robotics in assembly line

❑Wireless communication

❑Mobile computing and networking

Application Areas of Embedded Systems

- Embedded Systems in Smart Cards, Missiles and Satellites

❑Security systems

❑Telephone and banking

❑Defense and aerospace

❑Communication

Application Areas of Embedded Systems

- Embedded Systems in Peripherals & Computer Networking

❑Displays and Monitors

❑Networking Systems

❑Image Processing

❑Network cards and printers

Application Areas of Embedded Systems

- Embedded Systems in Consumer Electronics

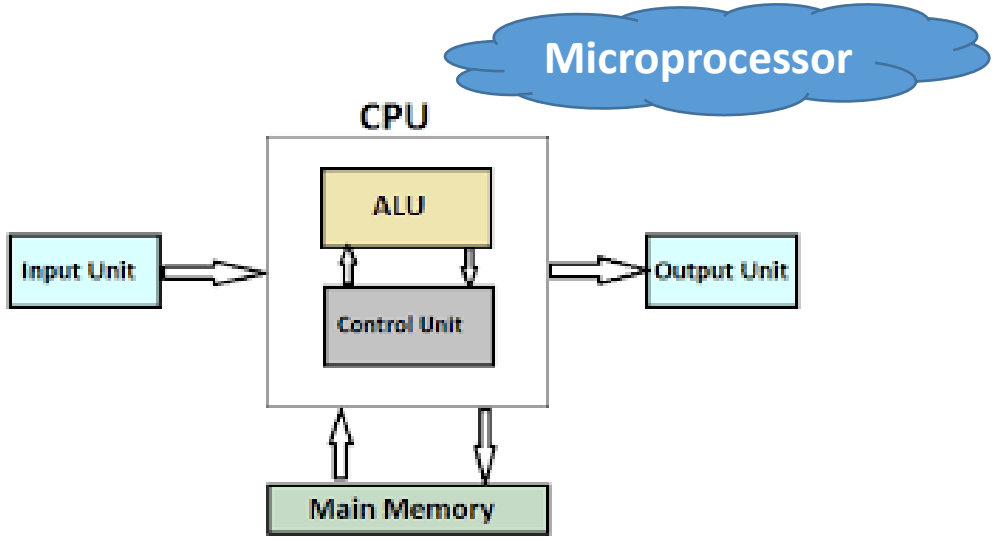
❑Digital Cameras

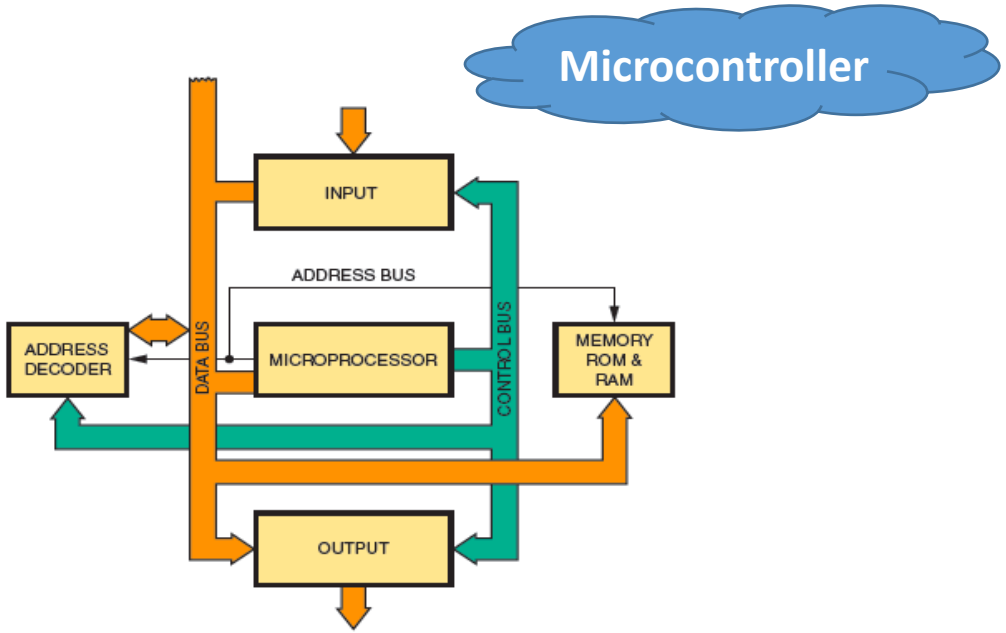
❑Set top Boxes

❑High Definition TVs

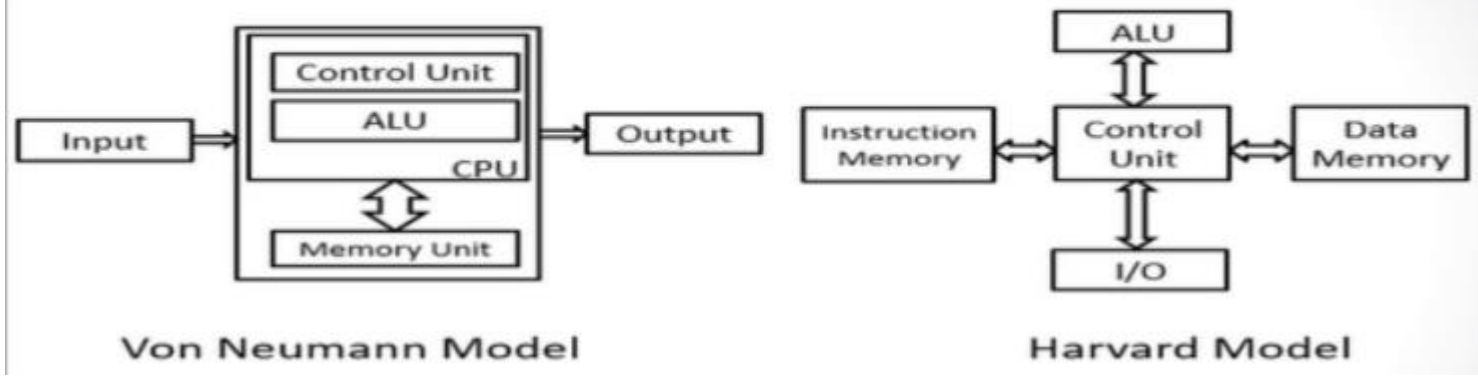
❑DVDs

Microprocessor is heart of Computer system.	Micro Controller is a heart of embedded system.
It is just a processor. Memory and I/O components have to be connected externally	Micro controller has external processor along with internal memory and i/O components
Since memory and I/O has to be connected externally, the circuit becomes large.	Since memory and I/O are present internally, the circuit is small.
Cannot be used in compact systems and hence inefficient	Can be used in compact systems and hence it is an efficient technique
Cost of the entire system increases	Cost of the entire system is low
Due to external components, the entire power consumption is high. Hence it is not suitable to used with devices running on stored power like batteries.	Since external components are low, total power consumption is less and can be used with devices running on stored power like batteries.
Most of the microprocessors do not have power saving features.	Most of the micro controllers have power saving modes like idle mode and power saving mode. This helps to reduce power consumption even further.
Since memory and I/O components are all external, each instruction will need external operation, hence it is relatively slower.	Since components are internal, most of the operations are internal instruction, hence speed is fast.
Microprocessor have less number of registers, hence more operations are memory based.	Micro controller have more number of registers, hence the programs are easier to write.
Microprocessors are based on von Neumann model/architecture where program and data are stored in same memory module	Micro controllers are based on Harvard architecture where program memory and Data memory are separate
Mainly used in personal computers	Used mainly in washing machine, MP3 players



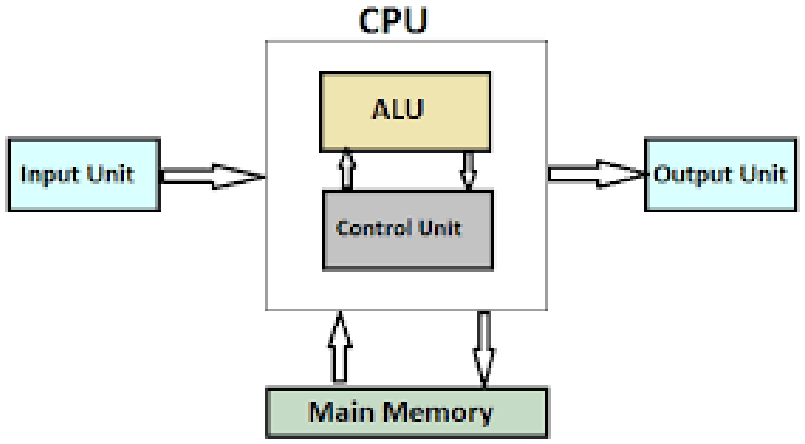


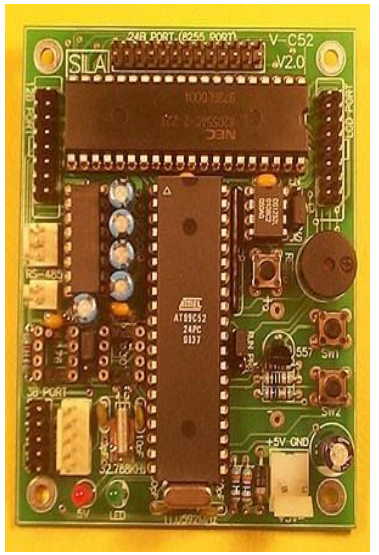
Von Neumann vs. Harvard architectures



Processor

- A processor (CPU) is the logic circuitry that responds to and processes the basic instructions that drive a computer.
- The CPU is seen as the main and most crucial integrated circuitry (IC) chip in a computer, as it is responsible for interpreting most of computers commands.
- CPUs will perform most basic arithmetic, logic and I/O operations, as well as allocate commands for other chips and components running in a computer.





Computer Basics:

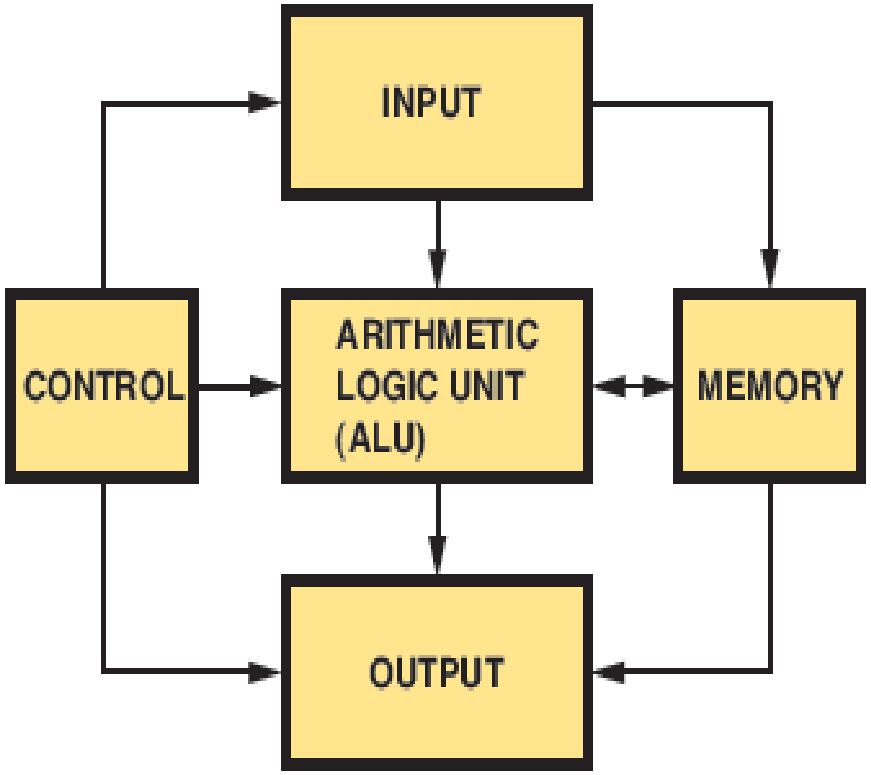
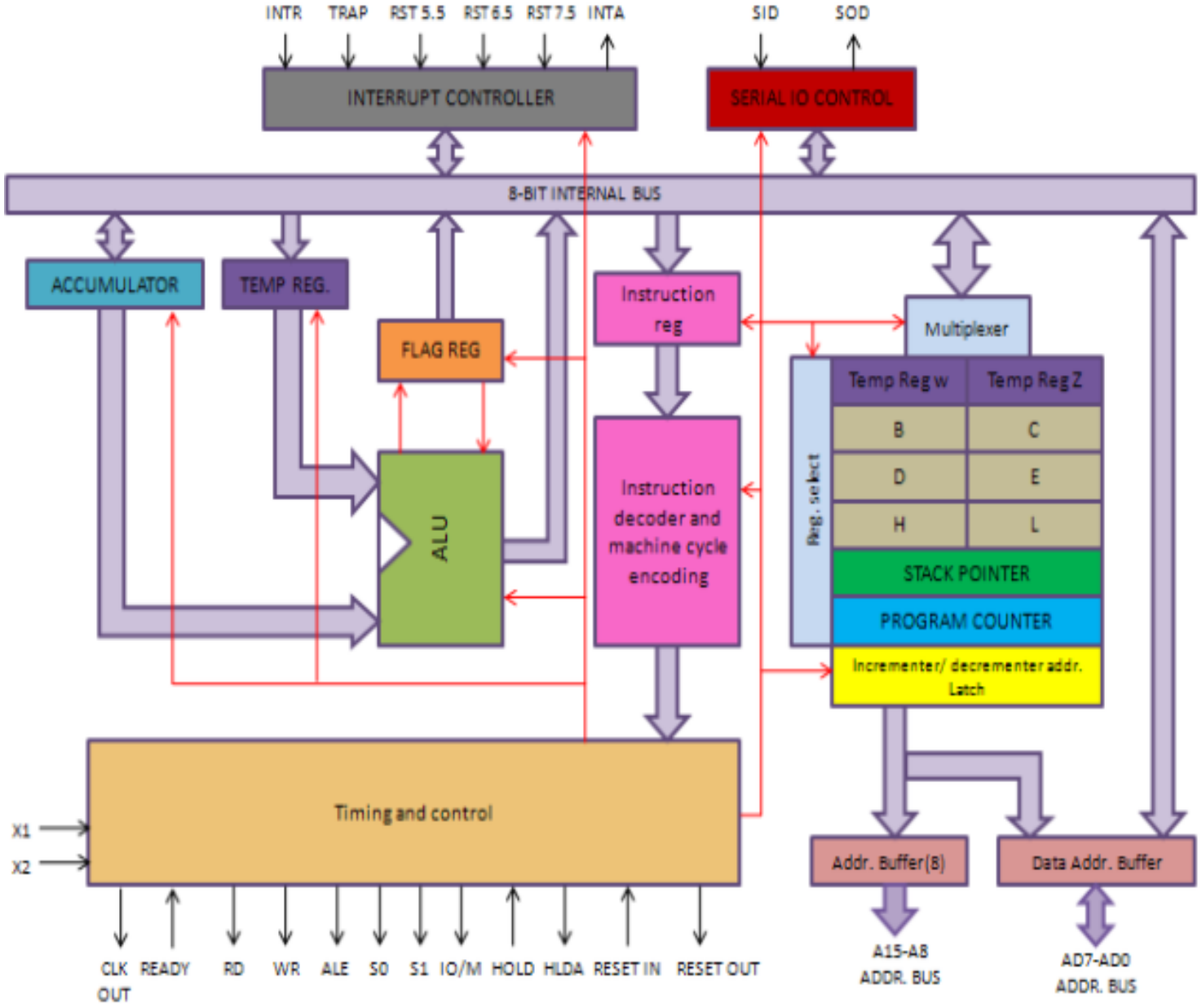
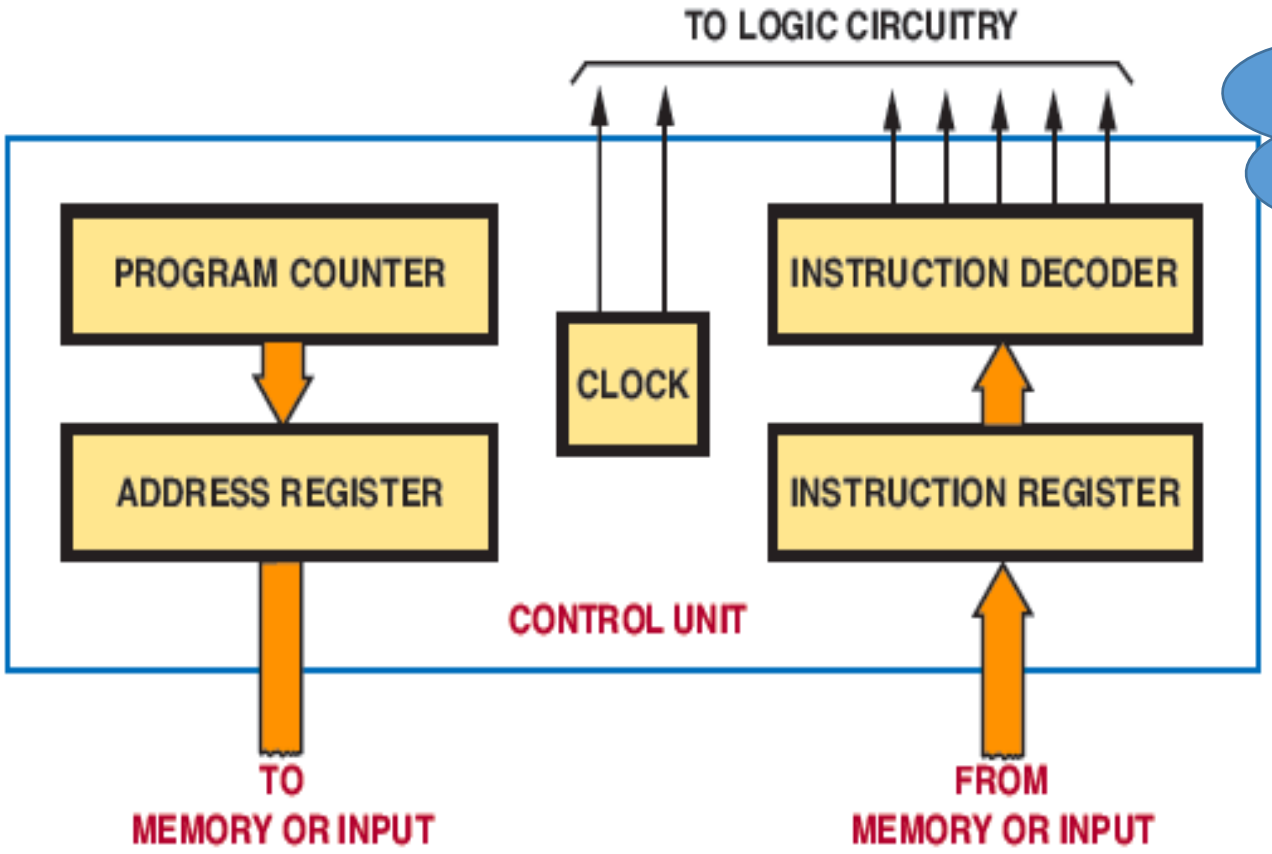


Figure: Basic blocks of a digital computer.



Explanation Slide

Computer Basics: Control Unit



program counter is a register that stores the address of the next instruction to be executed from the memory

In the technical aspect is, a stack is a LIFO data structure which is employed in the RAM area where one can store temporary data and addresses when the microprocessor jumps to a subroutine from its current task. Then the retrieved address would be used by the processor to jump back to the previous routine/job/task. A stack is also called a recursive data structure where pushing and popping happens continously.

Figure: Control unit of a computer.

Computer Basics: ALU

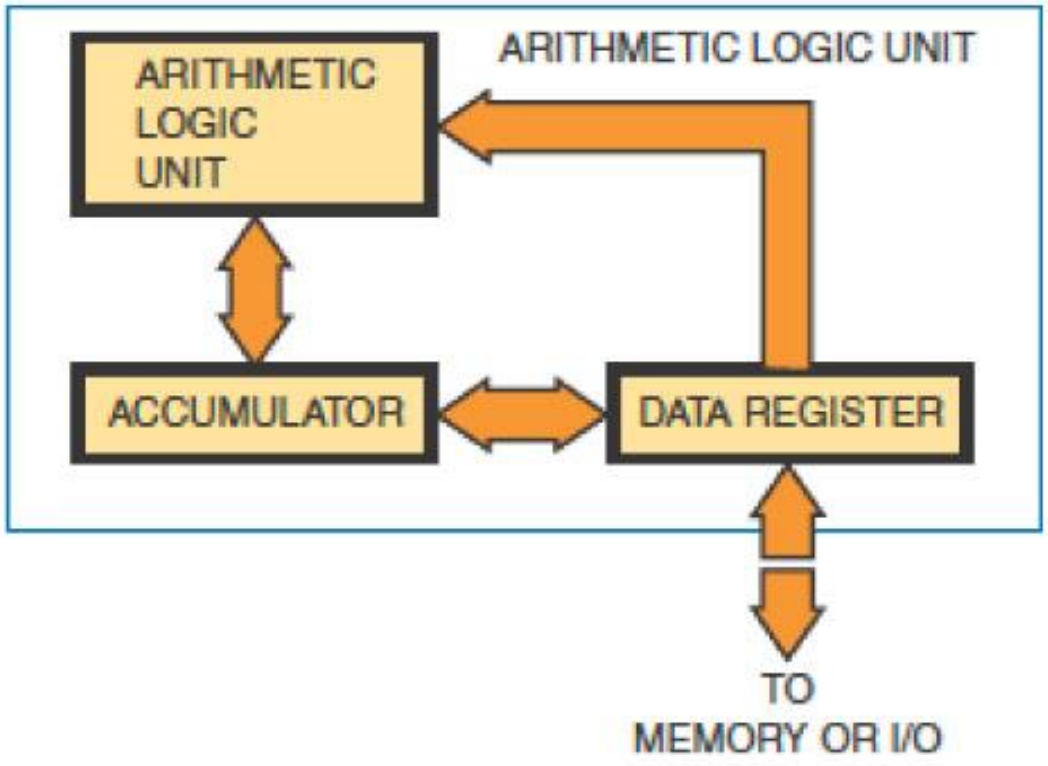


Figure 3. Arithmetic logic unit (ALU).

Computer Basics: Memory

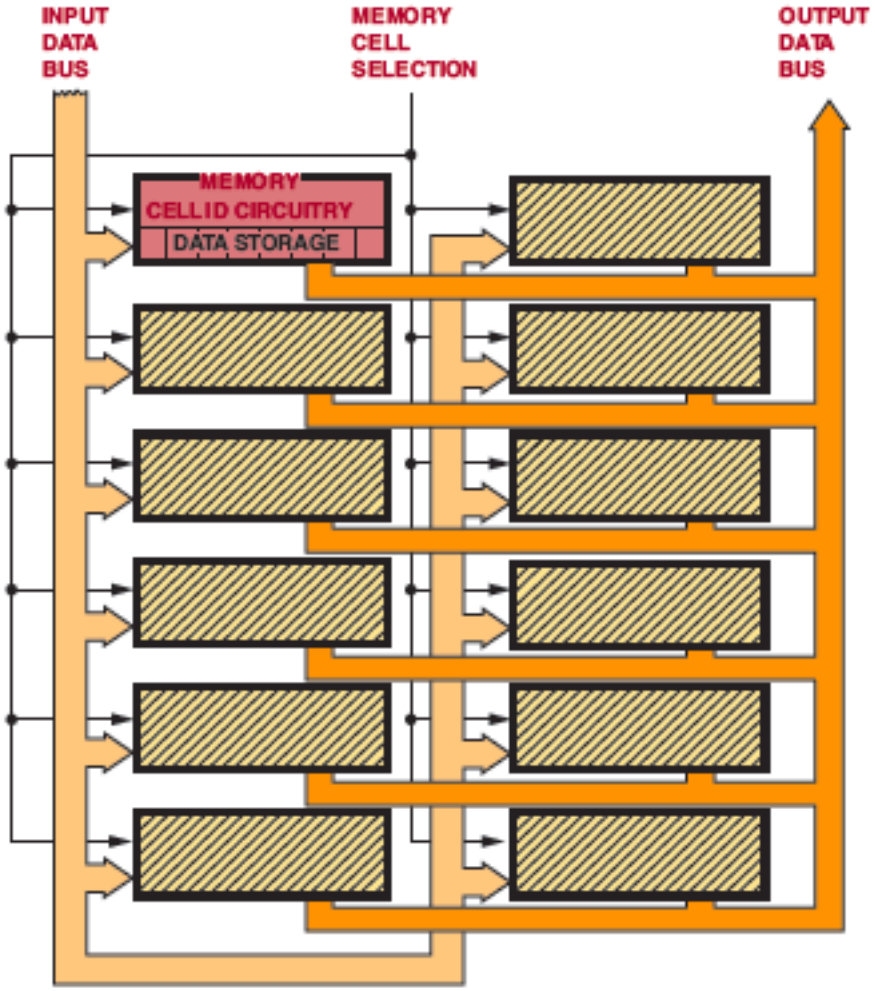


Figure 4. Memory layout for a computer.

Microcontroller: Block Diagram

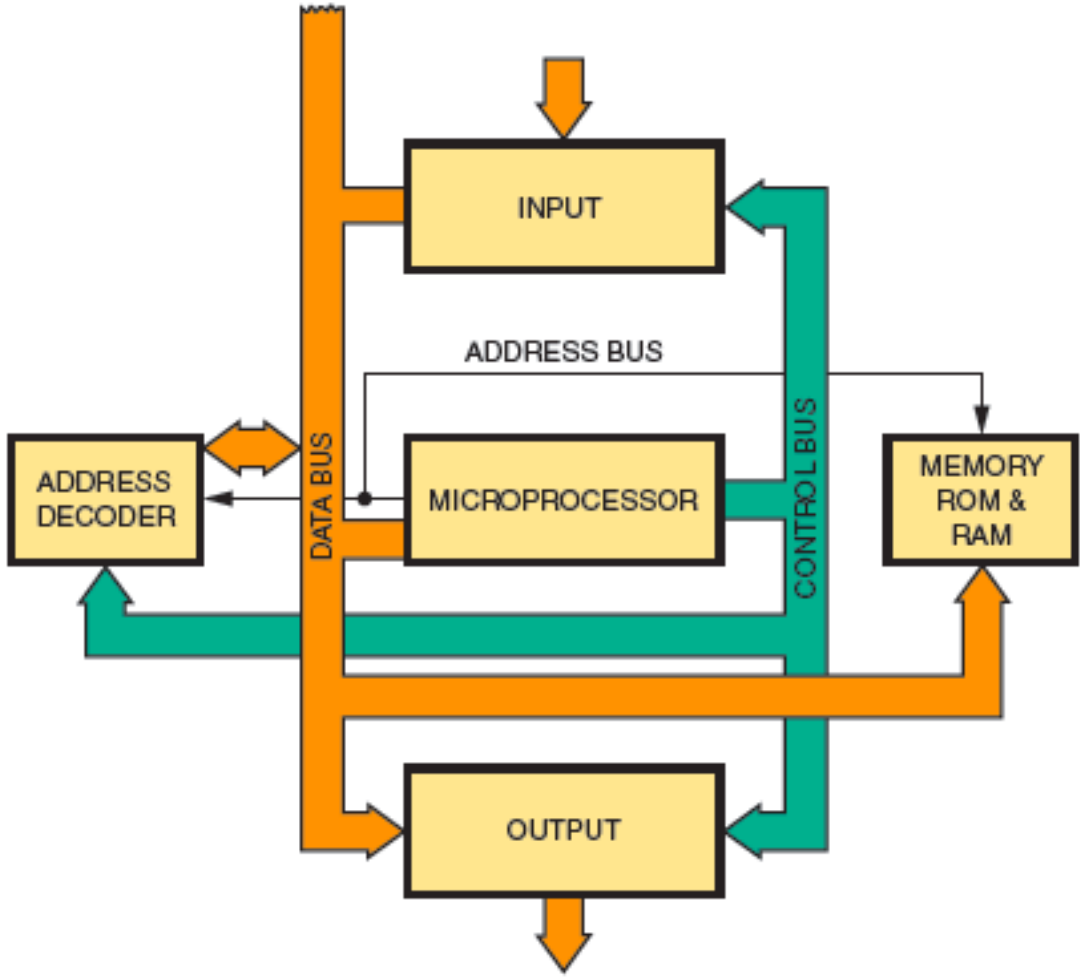


Figure: Block diagram of a microcontroller.

Digital Signal Processor

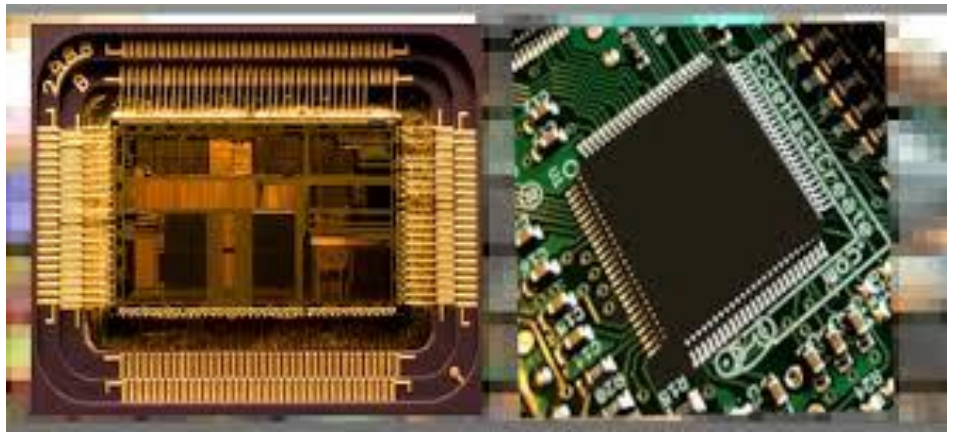
- **DSP (Digital Signal Processor) -** A DSP is a more specialized processor that is designed for optimal execution of digital signal processing algorithms which are more mathematical (eg various transformation and quantization algorithms,).
- These are different from General purpose microprocessors as these are implemented in a SIMD style (Single instruction Multiple Data) to enable executing instructions on multiple data samples to make these algorithms run faster.

Digital Signal Processor

- DSP is like… mathematics on chip.
- DSP usually run applications with hard real time constraints.
- DSPs usually process infinite continuous amount of data.
- DSPs are specially designed for efficient mathematical manipulation of digital signals.

ASIC and SoC

- **ASIC (Application Specific Integrated Circuit)** is a chip that is custom designed for a specific application. It is normally designed by a company for a specific use or for a specific customer alone. It is customized for an application and hence can be designed to meet the power and performance of that specific application.
- **SOC - (System on Chip**)- is an integrated chip that can have several system level components integrated along with a microprocessor all on a single chip.



ASIC

- An application-specific integrated circuit is an integrated circuit (IC) chip customized for a particular use, rather than intended for general-purpose use.
- For example, a chip designed to run in a digital voice recorder or a high-efficiency bitcoin miner is an ASIC.
- ASIC chips are typically fabricated using metal-oxide-semiconductor (MOS) technology, as MOS integrated circuit chips.

ASIC

- As feature sizes have shrunk and design tools improved over the years, the maximum complexity (and hence functionality) possible in an ASIC has grown from 5,000 logic gates to over 100 million.
- Modern ASICs often include entire microprocessors, memory blocks including ROM, RAM, EEPROM, flash memory and other large building blocks. Such an ASIC is often termed a SoC (system-on-chip).
- Designers of digital ASICs often use a hardware description language (HDL), such as Verilog or VHDL, to describe the functionality of ASICs

SoC (System on Chip)

- A system on chip is an integrated circuit (also known as a "chip") that integrates all components of a computer or other electronic system.
- These components typically (but not always) include a central processing unit (CPU), memory, input/output ports and secondary storage – all on a single substrate or microchip, the size of a coin.
- It may contain digital, analog, mixed-signal, and often radio frequency signal processing functions, depending on the application.

SoC (System on Chip)

- As they are integrated on a single substrate, SoCs consume much less power and take up much less area than multi-chip designs with equivalent functionality.
- Because of this, SoCs are very common in the mobile computing (such as in Smartphones) and edge computing markets.
- Systems-on-chip are typically fabricated using metal–oxide–semiconductor (MOS) technology, and are commonly used in embedded systems and the Internet of Things.

QUICK QUIZ (POLL)

Which of the following is best suited for mathematical operations?

A. General Purpose Processor
B. ASIC
C. System on chip
D. Digital Signal Processor

QUICK QUIZ (POLL)

Raspberry Pi Board falls under which category?

A. General Purpose Processor
B. ASIC
C. System on chip
D. Digital Signal Processor

QUICK QUIZ (POLL)

HDL stands for?

A. Hard Description Language
B. Hardware Design Language
C. High Description Language
D. Hardware Description Language

Computers & Accessories › Components › Motherboards › Digilent Basys3 Xilinx Artix-7 FPGA Board

Digilent Basys3 Xilinx Artix-7 FPGA Board

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FPGA

- **FPGA** ….. Field Programmable Gate Array
- **FPGA** is an array of Programmable blocks with a programmable interconnect which can be used to create programmable hardware designs.
- Designs are typically captured in an HDL and can be synthesized for the FPGA technology and **downloaded into an FPGA** and then used along with other devices in a system.
- Reconfiguration is possible by changing the design and downloading to same FPGA which makes this very useful for prototyping as well as making changes *unlike an ASIC.*

Advantages of FPGA

- The great advantage of the FPGA is that the chip is completely programmable and can be re-programmed.
- In this way it becomes a large logic circuit that can be configured according to a design, but if changes are required it can be re-programmed with an update. Thus it is programmable in the field, and in fact this gives rise to its name.
- Parallel Data Processing
- Faster time to market

Disadvantages of FPGA

- They are slower than equivalent ASICs (Application Specific Integrated Circuit) or other equivalent IC.
- They are more expensive.
- More Power consumption.
- Programming is complex.

Applications of FPGA

- ❑Aerospace and Defense
- ❑Emulation and Prototyping
- ❑Automotive
- ❑Broadcast
- ❑Consumer Electronics
- ❑Data center
- ❑High Performance Computing
- ❑Industrial
- ❑Medical
- ❑Test and Measurement
- ❑Wired and Wireless communication

https://www.xilinx.com/applications.html

FPGA vs ASIC compared

FPGA	ASIC/ASSP - SOC/non-SOC
Faster Time to Market - No layout, masks and manufacturing steps needed	Need longer design times to take care of all manufacturing steps
Field reprogrammability - Design changes can be absorbed even in field and FPGA reprogrammed	Once manufactured, need to spin again a new chip in case of bugs
More power consumption and may not be high performance because of programmable design and low clock speeds	Custom design for an application helps in designing for power/performance efficiencies
Good for prototyping and low volume designs as cost would be less	For larger volume of production, cost per unit will be much less for an ASIC
Generally not possible to have analog/mixed signal designs and limited to what vendor supports	Can support analog and mixed signal designs