The future of embedded systems is poised for significant growth and innovation. These are integrated into a wide range of devices and systems, from smartphones and home appliances to industrial machinery and automotive vehicles.

Several trends and developments are shaping the future of embedded systems.

① Internet of things integration
② AI and Machine learning
③ Edge computing
④ Advanced Connectivity
⑤ Security and Safety
⑥ Energy efficiency
⑦ Customization & Heterogeneity
⑧ Open Source and Collaboration
⑨ Environmental considerations
⑩ Regulatory and Ethical considerations

Definition

* A special purpose computer custom built to ser a specific purpose.

* General purpose Computers	Special purpose Computers
① They serve more than one specific purpose like Gaming, Music, movies etc.	① They are custom made to serve a particular functi Less expensive and can no do everything.
② Ex: Laptop, Desktop, Mobile, Tablet etc.	Ex: Calculator, Refrigerator, Camera etc.

* Microcontroller, Microprocessor, System on chip (S.C)s Field programmable Gate Arrays (FPGA)s will be used to build the Circuit to work specific worklet/task.

* Elements of embedded systems

Input devices
Output devices
Sensors
storage devices
Communication protocols
Power supply
User Interface
Operating System

Classification of Embedded Systems

1) Subsystems

2). Standalone systems

3). Networked systems.

Embedded subsystems,

* It is placed inside something bigger system, as a part of a larger system. These are independently useless.

* Examples : Display unit in Car
  Mouse, Keyboard in Computer
  Switching dashboard in Microwave Oven.

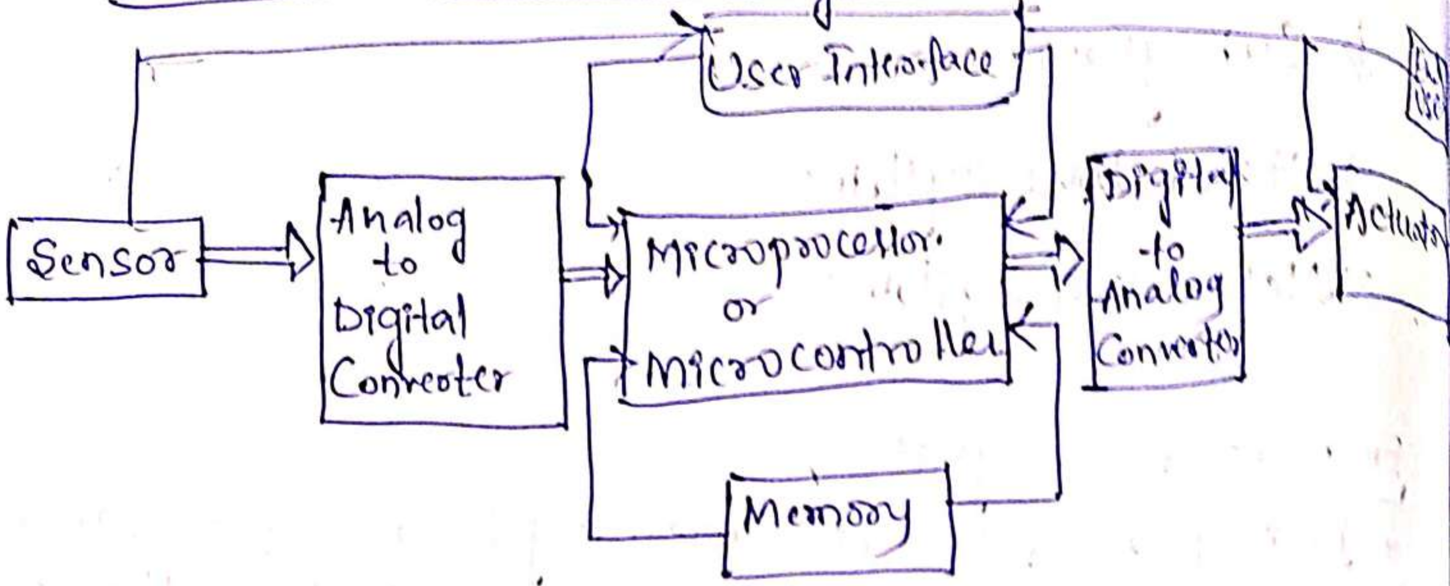
Standalone systems,

* These can perform it's functions independently.
* The components and techniques used to build these belong to the same class as the subsystems class of embedded system.
* Examples : Pendrive
  Camera
  Smart Watch

Networked Systems,

* A group of physically separate electronic devices that perform a collective function.
* Examples : Home Automation system.

Structure of embedded system


User Interface
Sensor
Analog to Digital Converter
Microprocessor or Microcontroller
Digital to Analog Converter
Actuator
Memory

Hardware Components

The embedded system is not general purpose, so no need of adding all hardware to it. But we should have the minimum quantity required. Those are of-

① Power supply.

② Processor

CPU, DSP, Media processor, Application specific processor, Microprocessor, Microcontroller, Embedded processor, ASIP

③ Timers counter/Timer

Required to count the occurrence of things and carry out actions at regular intervals.

④ Memory

RAM → Random Access. Memory

ROM → Read Only Memory

⑤ The Communication Port

To communicate with other embedded systems via this interface. Example : UART, USB, Ethernet, RS-485; SPI_ SCI, I2C, SATA

⑥ The Parallel Port

Peripheral connections are made via a parallel port.

⑦ Input and Output

I/O will be used to determine the processor.

Software Components

① Editor

To design algorithms and creat applications on Operating system, Editor tool will be used.
Example : C, C++, Java, HTML, PHP, Python, Pascal etc_

② Emulator

This is a piece of software that enables to use the features of the host system.

* All the parts are controllable through the emulator.
* Use to debug the applications.
* Used to transmit code from the host system to the target machine.

③ Assembler

* A machine language is created from written code by the assembler tool.

* source code → Object Code → Machine language

* Assembly language program is converted to HEX Code, then burn the program code into chip

④ Compiler

* The creation of an executable application

* Source code of high level programming language → Low level programming language

⑤ Linker

* It is a link editor, that merges one or more object files into a single executable code.

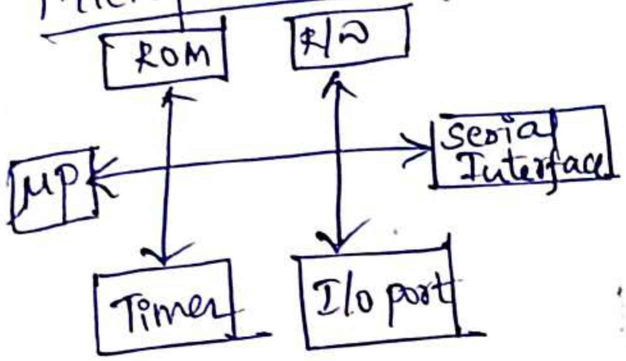
⑥ Debugger

* Used for testing and debugging
* Noting

Microprocessor Vs Microcontroller

Microprocessor (μP)

①



② Here memory I/o components have to be connected externally.

③ circuit is large.

④ Less efficient

⑤ Cost of the entire system increases.

⑥ Power consumption is high.

⑦ Most of the operations are internal instruction, hence speed is fast.

⑧ Less number of register, hence more operations are memory based.

⑨ Based on Von Neumann architecture.

⑩ Used in PC, Laptops

Microcontroller (μC)

①

μC	ROM	R/W memory
Timer	I/o port	serial Interface

② It is an external processor along with internal memory and I/o components.

③ Circuit is small

④ More efficient

⑤ Cost is low.

⑥ Power consumption is low. (Power saving mode)

⑦ Each instruction will need an external operation, hence it is relatively slower.

⑧ More registers, hence the programs are easy to write.

⑨ Based on Harvard architecture

⑩ Used in Washing machines, MP3 players.

Types of microcontrollers

* 8-bit microcontroller

Intel 8031,
8051,
PIC1X,
Motorola MC68HC11

* 16-bit microcontrollers

Intel 8051XA,
PIC2X,
Intel 8096,
Motorola MC68HC12

* 32-bit microcontrollers

Intel/Atmel 251
PIC3X

There are different microcontroller types
8051, PIC, AVR, ARM

Commercial Off the Shelf (COTS)

The products that are readily available in the commercial market and can be purchased off-the-shelf for use in various systems, including aviation, millitary and computing.

These are not specifically designed or developed for a particular application but are rather adapted aftermarket to meet the needs of the purchasing organization.

Examples : Microsoft office suite
Adobe creative suite
Microsoft operating system
Antivirus softwares

Advantages

1. Easy to install and interoperate with existing system components, which can result in lower cost.
2. Reduced development time, faster insertion of new technology
3. Lower lifecycle costs resulting from using readily available and up-todate products.

Limitations

① Ceasing of support.
② Security risks.

Microcontrollers

* It is a small and low cost microcomputer that is designed to perform specific tasks of embedded systems.

Examples : ① Displaying information on embedde devices.

② Receiving remote signals

General structure of a microcontroller

① Central Processing Unit (CPU)

* Responsible for carrying out instructions and decoding data to complete the allocated task effectively.
* Combination of electronic computing unit and logic unit.

② Memory

* Program memory & Data memory
* Volatile and Non volatile memories like RAM, ROM and EPROM.

③ Communication Interface

Serial and parallel Communication interface will be working in all general microcontrollers. In 8051, there is a built in UART with RXD (Serial data receive pin) & TXD (Serial data transmit pin) on PORT3.0 & PORT3.1 respectively.

(4) Input /Output peripherals

I/O ports

* The interface for the microcontroller to the external world by Input/Output ports.

* Input devices should provide information from the user to the CPU in the form of binary data.

[After receiving the data from the i/p devices, executes appropriate instructions and gives responce through o/p devices

Timers
Counters

* Provide the operations of time delay and counting external events.

* Provide function generation, Pulse width Modulation, Clock control etc.

System Bus

A group of connecting wire that connect the CPU with other peripherals like Memory, I/O ports & other supporting components.

Serial port

Provides microcontroller to communicate with other peripheral devices.

Interrupt Controls

Interrupt is a request for the processor to interrupt currently executing code, so that the event will be processed in a timely manner.

Df the request is accepted, the process will suspend ~~the~~ his current activities. It saves its state and execute a function called an interrupt handles. [Interrupt service routine]

Power supply

There are three main DC voltage source available to supply power for microcontroller boards.

1. Batteries
2. Wall adapters
3. USB port of a computer.

The power supply of a microcontroller can be either an independent power source in the form of a LiPo battery or power from a computer over the micro USB cable connection.

Reset

The reset used in the microcontroller,

1. Power On reset resets the microcontroller when power is turned ON,
2. Manual reset resets the microcontroller when a push button is pressed.

The various reset sources are:

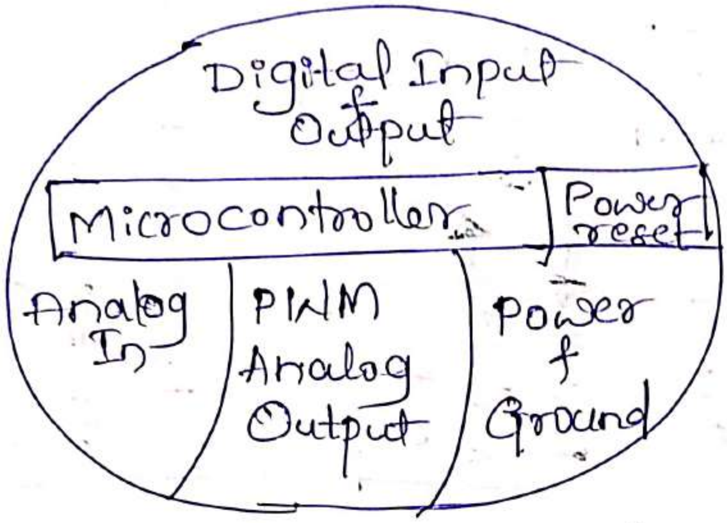
1. External Reset
2. Internal Low Voltage Detect (LVD) Reset
3. Internal Watchdog Reset.

A reset circuit consists of a capacitor & a resistor connected to the reset pin of microcontroller. A reset does not affect contents of internal RAM.

Microcontrollers on Arduino boards:

The majority of Arduino boards use Atmel AVR microcontrollers. [ATmega328]

Pins of a Microcontroller



* It has built in I/o cababilities, so it can read and write digital and analog values/states and connect directly to the real world.

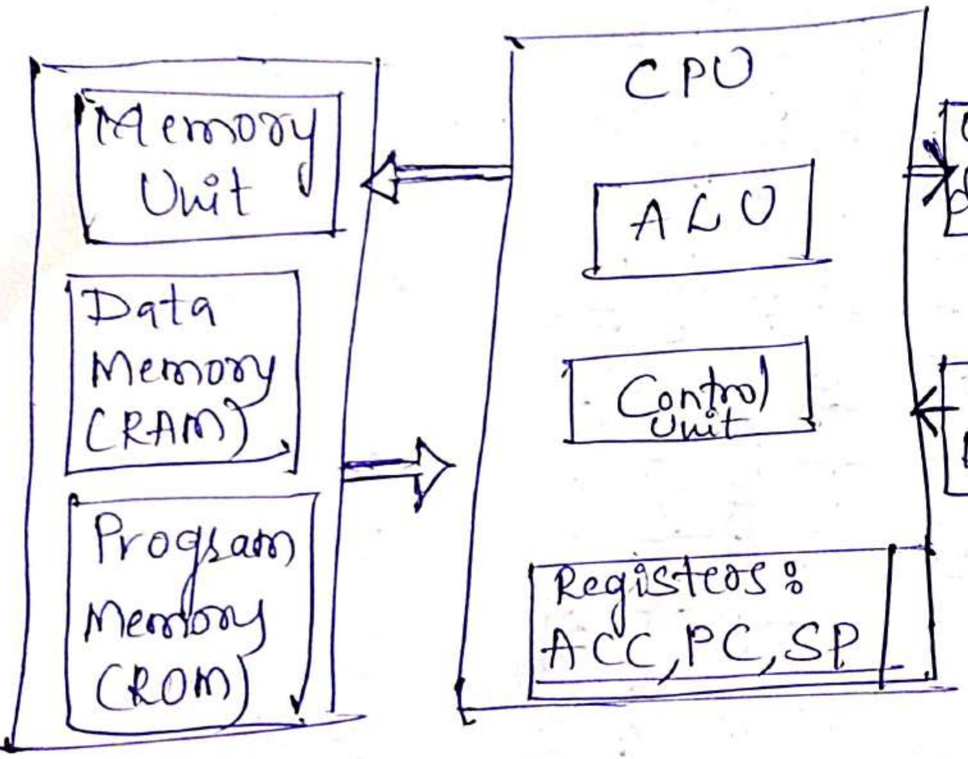
* These are generally used for low to medium complexity specific tasks in equipment. This contracts with the powerful, number-cruching microprocessors used in PCs, which handle a variety of software applications.

* These are often used in portable devices which run on batteries.

* The program in a microcontroller is usally stored in EPROM.

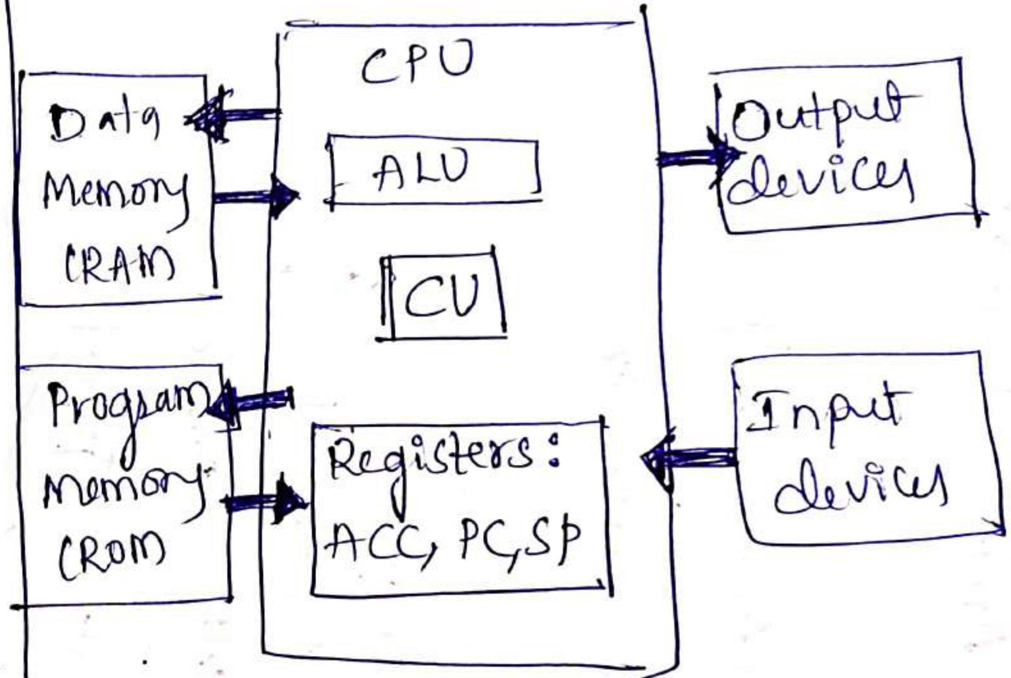
Memory organization

① Von Neumann Architecture



Program memory and Data memory are'tseparate. In a ~~sig~~ single memory both data and program execution will be stored.

② Harvard Architecture

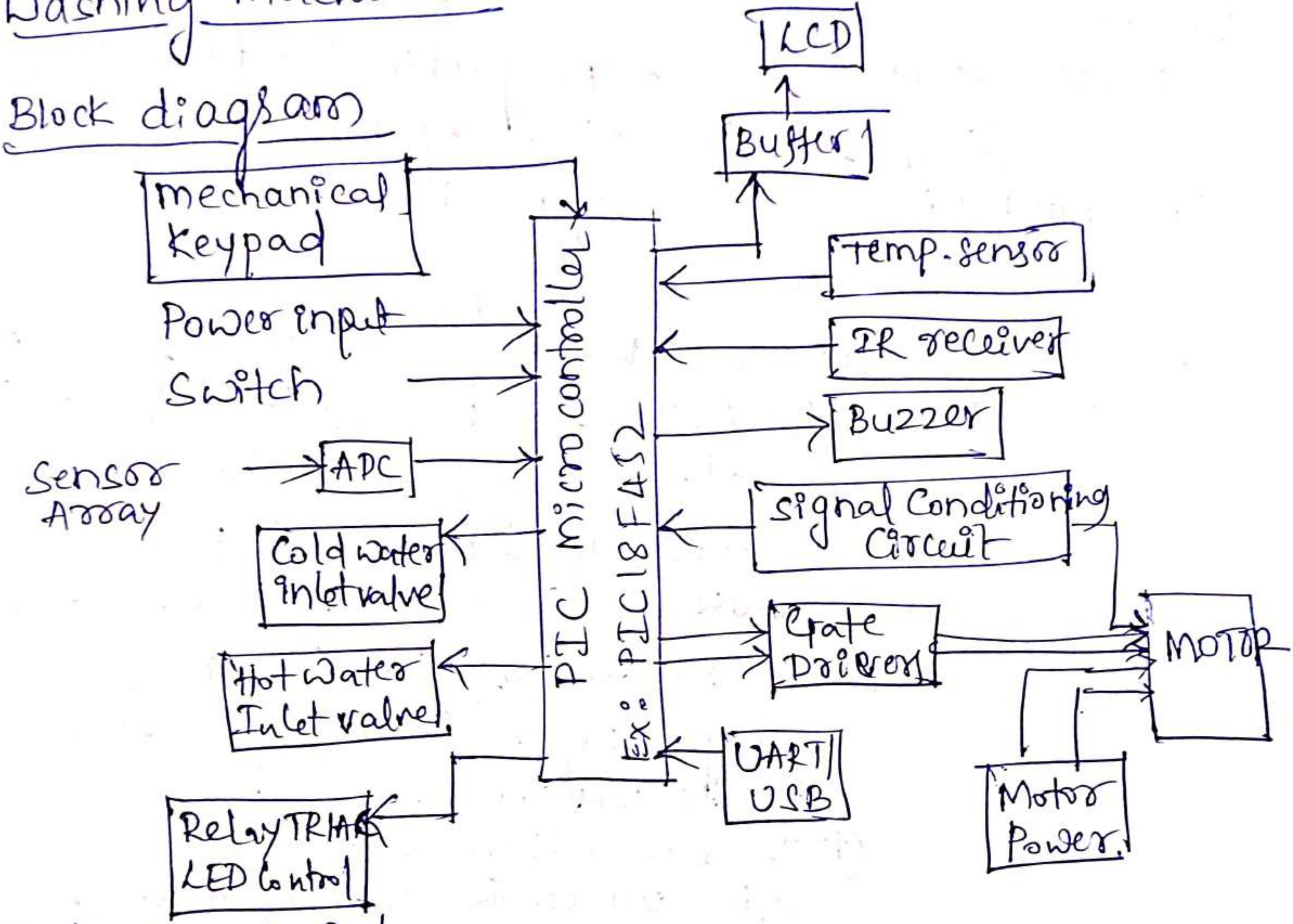


Program memory & Data memory are ~~not~~ separate. So in both the independent memory blocks the data storage and program execution will be done.

Case studies

Washing Machine

Block diagram



Working principle

Washing Machine has,

① Hardware : Buttons, Display + buzzer, electronic circuitry

② Software : It has a chip on the circuit that holds the software which drives controls & monitors the various operations.

③ Mechanical Components : The internals of a washing machine which actually wash the clothes control the input & output of water, the chassis itself.

The main principles behind the working of a washing machine are the centrifugal and Centripetal forces.

Where centrifugation helps quiken the process of sedimentation of different density particles to Clean the laundry in the washing machine.

It operates in two cycles.

① Wash cycle :- ① It involves the principle of centrifugal force. The forces direction is from inside to outside in the drum.

② Paddles are like ridges present on the drum's edge and helps move the clothes

③ Every part of the cloth is rinsed adequately in the soap water mixed in the machine.

④ There is a thermostat inside the machine, after turn on the device, it measures the tempurature and increases the heat according to its need.

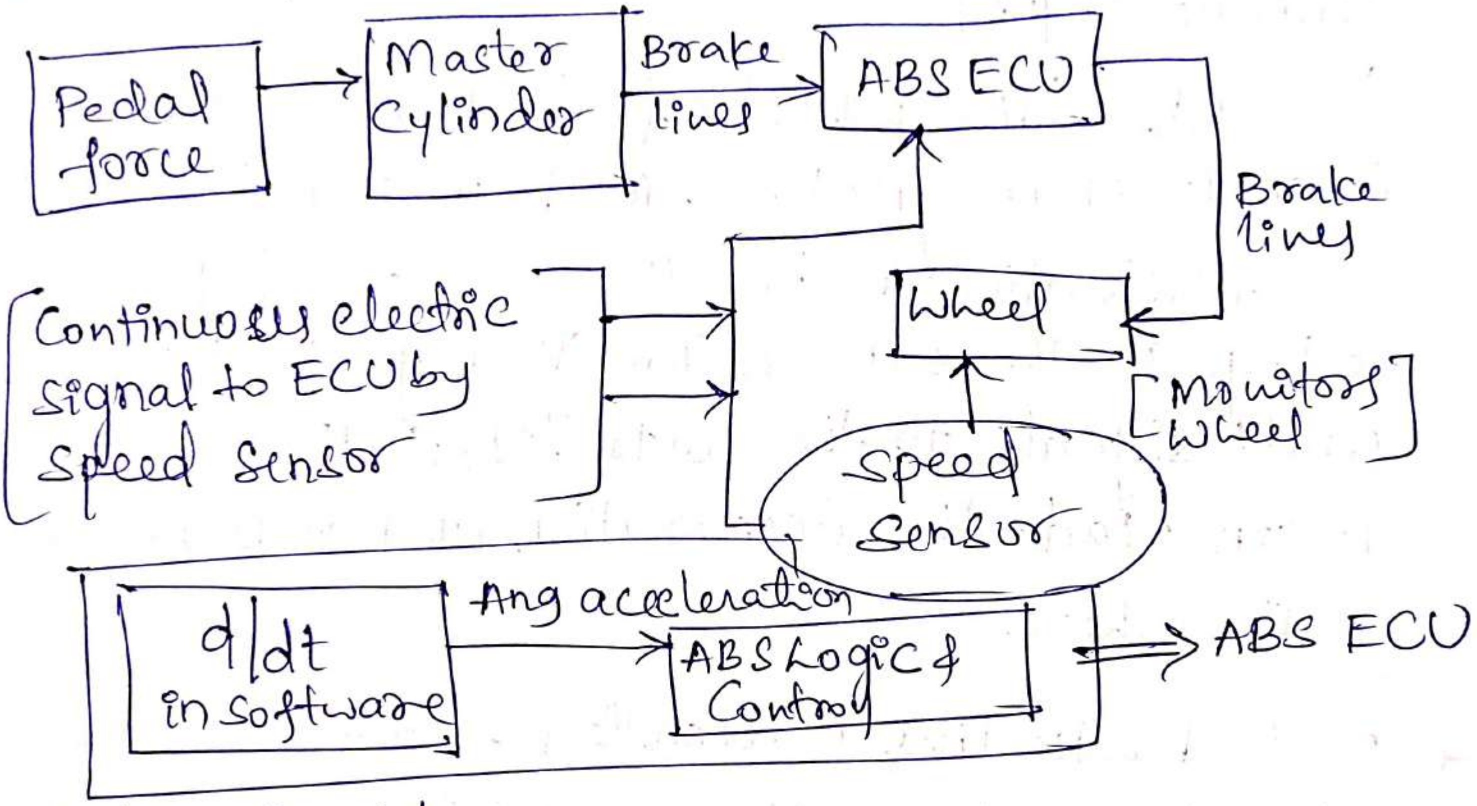
② Rinse cycle :- ① Involves the centripetal force. The force acts from outside to inside and creates a vaccum like space in the middle of the washing machine.

② When the water is enough for operati the inner drum rotates back and forth a time, mixing the cloth properly with soap water.

③ Programmes opens the valves and let the dirty water flow away, to allow clean water to come into the drum

Anti Brake Systems / Anti lock Brake system (ABS)

Block diagram



Working Principle

Anti Brake system has,

① wheel speed sensor
② Toothed sensor ring
③ Electronic Control Unit (ECU)
④ Hydraulic modulator
⑤ Vacuum boaster
⑥ Hydraulic lines
⑦ Wiring from ECU
⑧ Master cylinder with proportioner valve.

* Speed sensors are used to calculate the acceleration and deceleration of the wheel It consists of a toothed wheel and an electroma coil or a magnet and a hall effect sensor to generate signal.

When the wheel of the vehicle rotates, it induces magnetic field around the sensor The fluctuation in this magnetic field generates voltage in the sensor. This voltage generated sends signals to the controller, with this the it can reads the acceleration and deceleration of the wheel.

* Each brake line is controlled by the ABS has a valve. It works in three positions

Pos 1 → Valve Open

(Pressure from the master cylinder passed through it to the brake)

Pos 2 → Valve blocks the line and separates the brake from the master cylinder.

Pos 3 → some extra pressure released by the valve.

* Pump is used to ~~Restore~~ restore the pressure to the hydraulic brakes after the valve releases the pressure.

When the controller detects wheel slip, it sends signals to release the valve. After the valve releases the pressure supplied from the driver through pedal force.

* Controller (ECU) is receiving the information from each individual wheel speed sensors and if a wheel loses its traction with the ground the alarm signal sent to the controller, it limits brake force and activate the ABS modulator. ABS modulator actuates the braking valves ON and OFF and varies the pressure to the brakes.