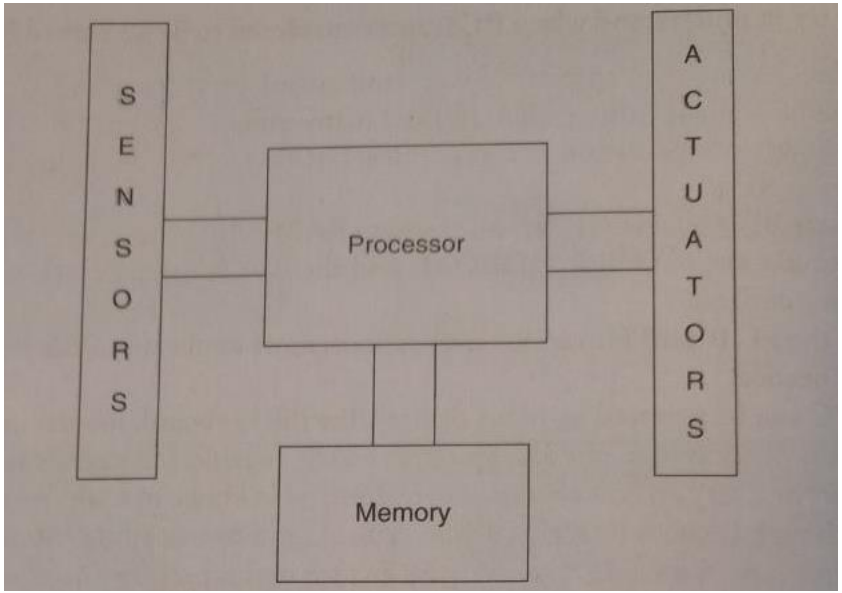
Chapter 3
Sensors and ADCs

General Model of Embedded System



Sensors

- Any embedded system needs sensors-depending on application, it may be just one sensor or many sensors.
- A sensor converts physical quantity to corresponding voltage.
- The data obtained from these sensors decide the course of action for actuators of the system.

General Model of Embedded System

- Sensor are input devices and actuators are output devices
- Output of sensors is in analog form but for using them with MCUs it must be converted to digital numbers which is done by ADCs
- If ADCs are not of good resolution and sensitivity, the whole point in using good sensor is lost

Different Type of Sensors

I. Temperature Sensors
II. Light Sensors
III. Proximity/Range Sensors
IV. Encoders
V. Humidity Sensors

Some other are gas sensor, smoke sensor, piezo-electric(for sensing stress and strain etc), touch sensor and so on. As per requirement of applications, sensors are used.

I. Temperature Sensor

a. Thermistor
b. Thermocouple

a. Thermistor

Thermally Sensitive resistor-

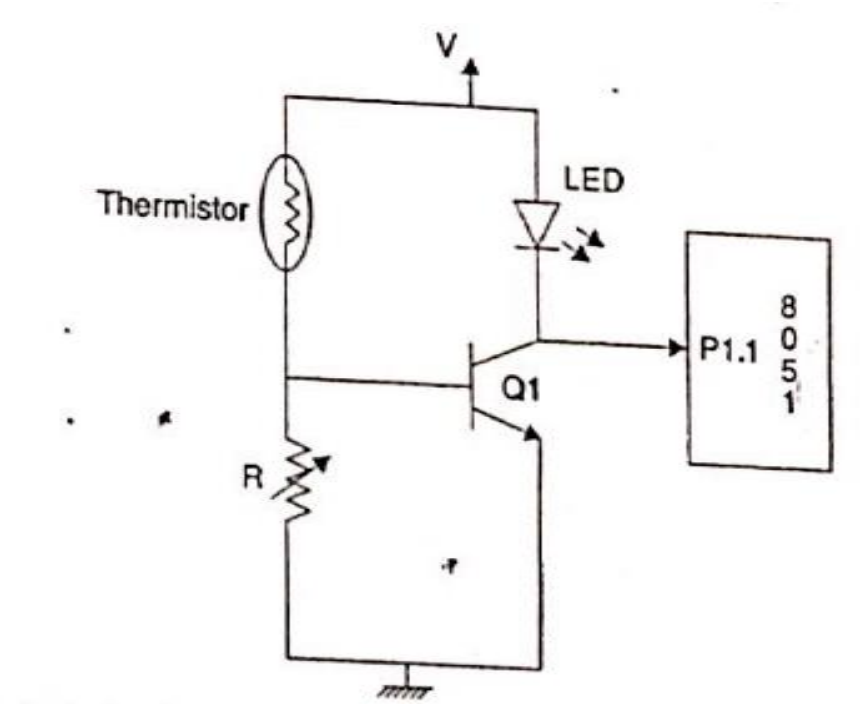
means that its resistance is affected by temperature variations around it. Thermistor are made up of semiconductor material

Two kinds of thermistor

- NTC(Negative Temperature Coefficient)
- PTC(Positive Temperature Coefficient)

In NTC, resistance of thermistor decreases with increase in temp. and PTC is just reverse

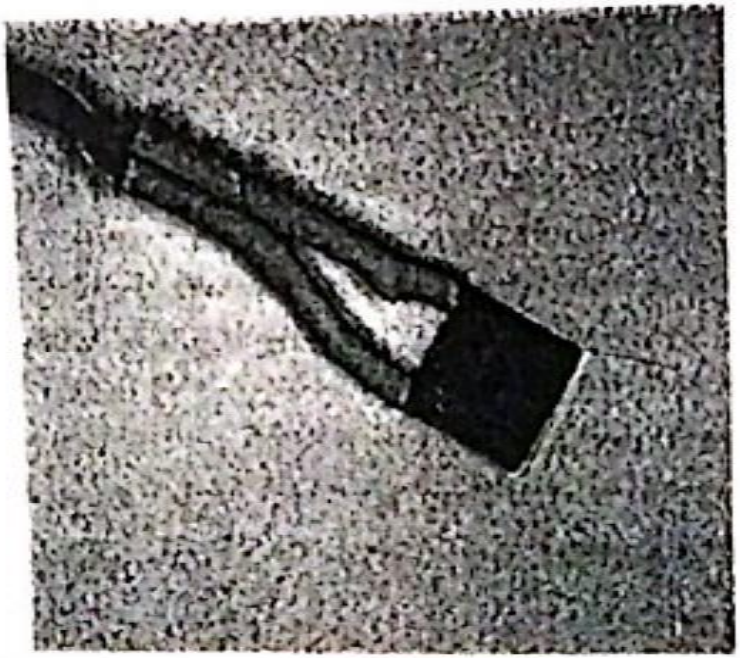
A Simple circuit using Thermistor(NTC)



A Simple circuit using Thermistor(NTC)

- The transistor is off, because high resistance of thermistor prevent it from getting the sufficient base current.
- When temp. increases the resistance of thermistor decreases and at certain value of thermistor resistance, the base current need to turn on the transistor is obtained. This switches the transistor ON.
- The collector voltage goes low and the LED lights up.

Photograph of Thermocouple



b. Thermocouple

- It is also sensor for measuring temperature
- There are two dissimilar metals joined together
- One junction is kept at constant temp called cold(reference) junction, While other is measuring junction called hot junction.
- When two are at different temps a voltage is developed across the junction
- Voltage is proportional to temp diff b/w two ends of pair of conductors.
- Used in many high temp applications like furnaces, turbines, engine temp measurement in industries and automobiles.

Light Sensors

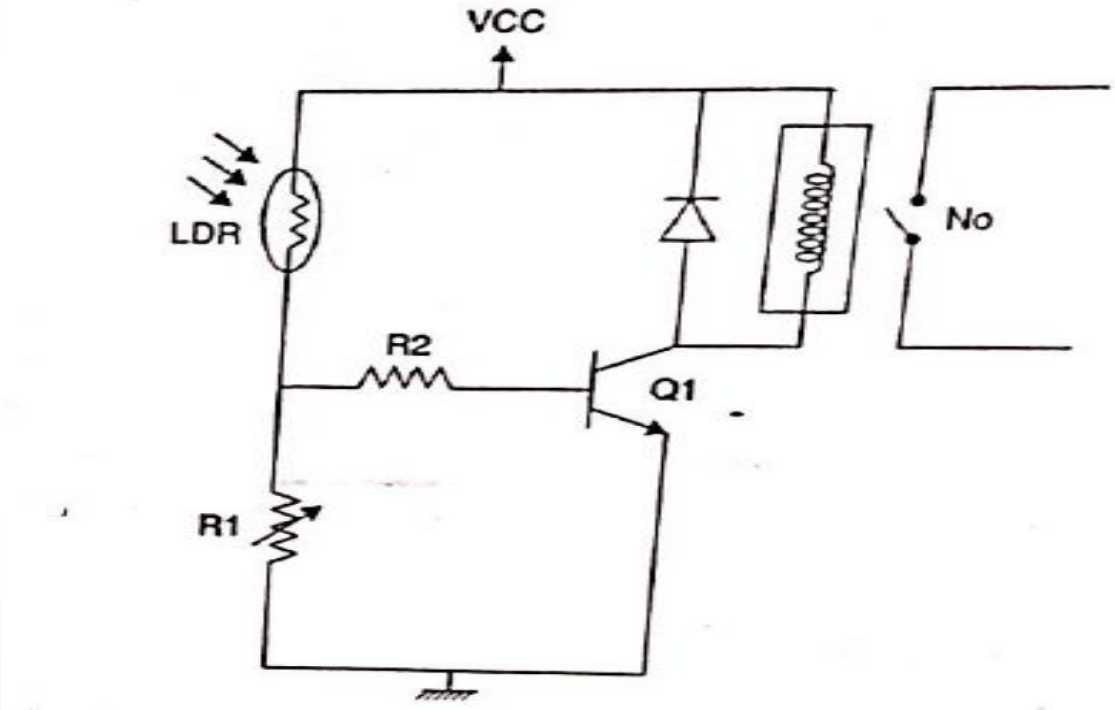
a. Light dependent Resistor (LDR)
b. Light Emitting Diode (LED)
c. Photo Junction Diode

. Light Dependent Resistor(LDR)

- Made up from cadmium sulphide
- The resistance of which changes with change in light intensity
- **In Dark** –resistance several thousand ohms
- **In presence of bright light** –resistance is few hundreds ohms
- When light fall upon it electron hole pairs created and conductivity increases.

Photograph of LDR

A Circuit Which uses LDR for sensing light



A Circuit Which uses LDR for sensing light

- When there is no ambient light relay contact is open(i.e. NO (normally open) contact)
- When current increases beyond a certain limit this contact closes.
- In the circuit shown LDR is used to sense the presence or absence of light.
- In absence of light , The LDR has resistance of Mega ohms so transistor does not get sufficient bias to be on.

A Circuit Which uses LDR for sensing light

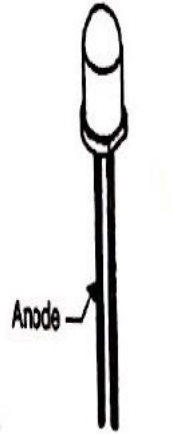
- When there is ambient lighting the resistance of LDR falls and transistor get bias current to conduct.
- The transistor switches ON and the relay gets energized –its contact closes.
- This closing can be used to activate some action, as needed.
- The amount of illumination required to cause the switching may be adjusted using variable resistance R1.

Disadvantages

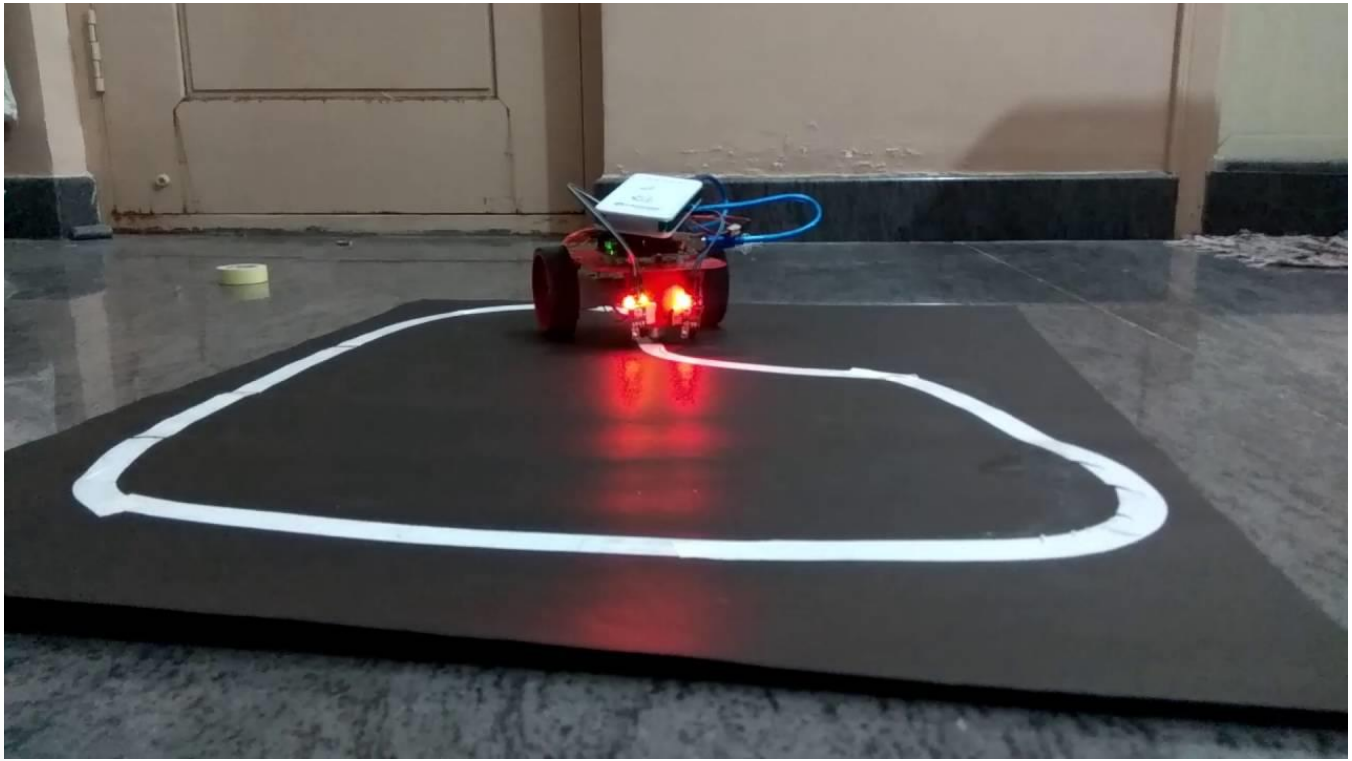
- Sluggish response time
- It takes quite some time to respond to change in illumination.

b. Light Emitting Diodes

- LEDs are light generating devices And as such do not act directly as sensor
- they can be made to emit light which is detected by photodetecting device.
- This detection can be used as sensor value.



A Line following Robot



A line following Robot

- A robot is made to move continuously on a white line .
- An LED is fixed under the robotics vehicle.
- The light from LED strikes the white line on the ground and reflects it back.
- there is a photo detecting circuitry to receive this, and the corresponding activation circuitry ensures that vehicle moves continuously on the white line.

A Line following Robot

- But when path becomes a curve , the moving vehicle will deviate from path defined by white line.
- This will be sensed by the photo detecting circuitry which no longer receives the reflected light, because the black background absorbs it all.
- this can be used to create necessary logic to bring the vehicle back on the white line, and due to this feed back mechanism, it is made navigate along the curve

Infra Red LED

- For many sensor circuits infra red LEDs are preferred as light source.
- Because it can be used in the same manner at day and night, as visible light does not affect its operation.

Photo junction Devices

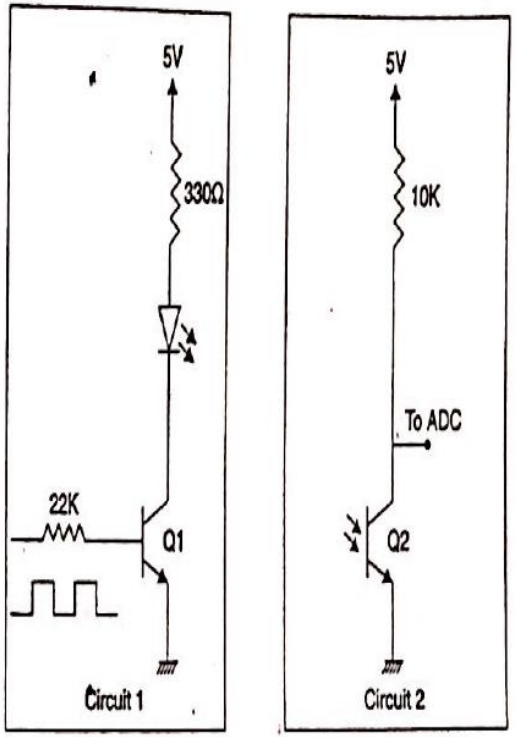
Photo Diode

- This diode is similar to regular semiconductor diode except that it is packaged with a window to allow the light to reach the sensitive part (PN junction).
- It is designed to operate in reverse bias so that reverse current flows
- Smart light sensors that can switch from ON and OFF in nanoseconds
- Used in TV remote controls, scanners, fax machines, copiers

Photo Transistor

- A phototransistor is basically a photodiode with gain.
- The phototransistor light sensor has its collector base PN-junction reversed biased and is also exposed to radiant light source.
- Any normal transistor can be easily converted into a phototransistor light sensor by connecting a photo diode between collector and base

An intrusion detection setup



An intrusion detection setup

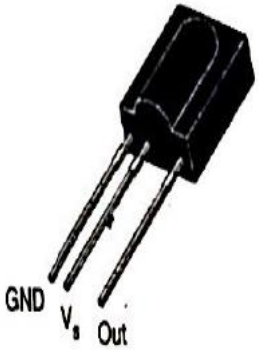
- An LED output is activated by astable oscillator is used to generate a pulse of some particular frequency. This LED in circuit1 is light transmitting circuit.
- This pulse is continuously detected by infra red detector in circuit2.
- When an intruder blocks the path of light (between circuits 1 and 2) the momentarily absence of light is sensed by IR sensor in circuit2 and this information can be used as an indication that an intruder has blocked the path of light.

An intrusion detection setup

- Any action can be initiated by this, for example, a relay ca be activated to trigger an alarm on sensing intruder.
- There is a standard IC acting as an infra red receiver and it is the TSOP series.
- For using this , the signal transmitted by IR LED should have a standard format.

TSOP Series IC

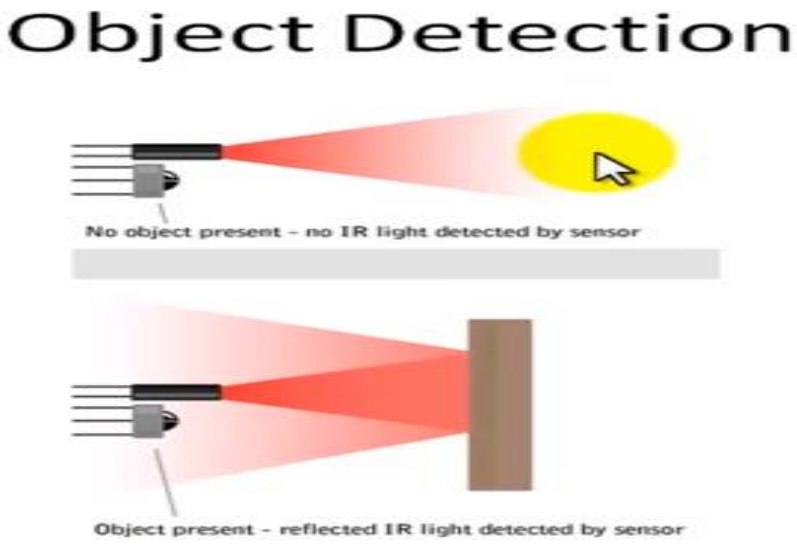
- TSOP package contains a PIN photodiode, a band pass filter and a demodulator which converts the signal to a format that a micro controller can use.
- Because of preamplifier and band pass filter inside, received signal is robust and free of noise.



Proximity/ Range Sensor

- Detection of an object and determination of its range are very important especially in field of robotics.
- Visible or infrared light can be used.
- To detect there is some object in the proximity, a beam of light is sent which the object will reflect back to the receiver.
- The reflected light is detected by photo detector , and information can be used to confirm that there is an object within the path of emitted light (within certain range)

Object detection by Proximity/ Range Sensor



Proximity/ Range Sensor

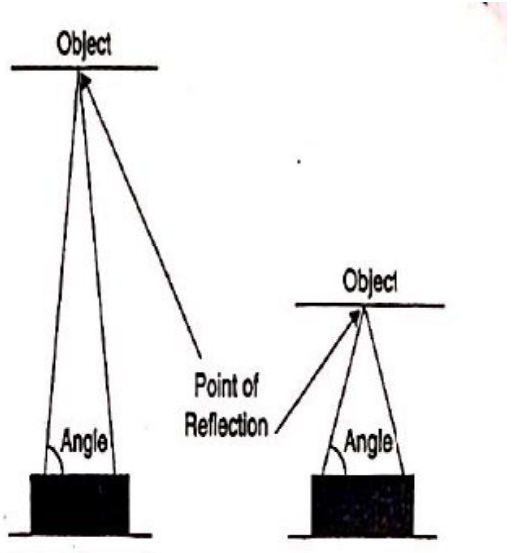
- Recently SHARP has produced a series (GP2DXX) of IR range finders ICs .
- The GP2DXX series have both proximity detector and range sensors.
- GP2D12,GP2D120, GP2Y0A02, GP2Y0A21 and GP2Y0A700 sensors offer true ranging information in form of an analog output.
- By contrast, GP2D15 and GP2DY0D02 offer a single digit value based on whether an object is present or not.

Merits

- Powerful
- Quite accurate
- Easy to use
- Affordable
- Small
- Good range measurement capability from inches to meters
- low-power consumption.

Range Sensing Techniques

- SHARP IR range finder works by the process of triangulation, which is technique in which region is divided into series triangular elements.
  - A pulse of IR is emitted and then is reflected back if it strikes the object in its path.
  - This method works by detecting **this reflected beam angle** –by knowing the angle distance can be determined.



Encoder

- Sensor for finding the **speed and direction (and position and distance travelled)** of a moving vehicle.

- This is an encoder which can be fitted to the shaft of wheel of the vehicle

- It uses optical principle and is called **optical encoder**

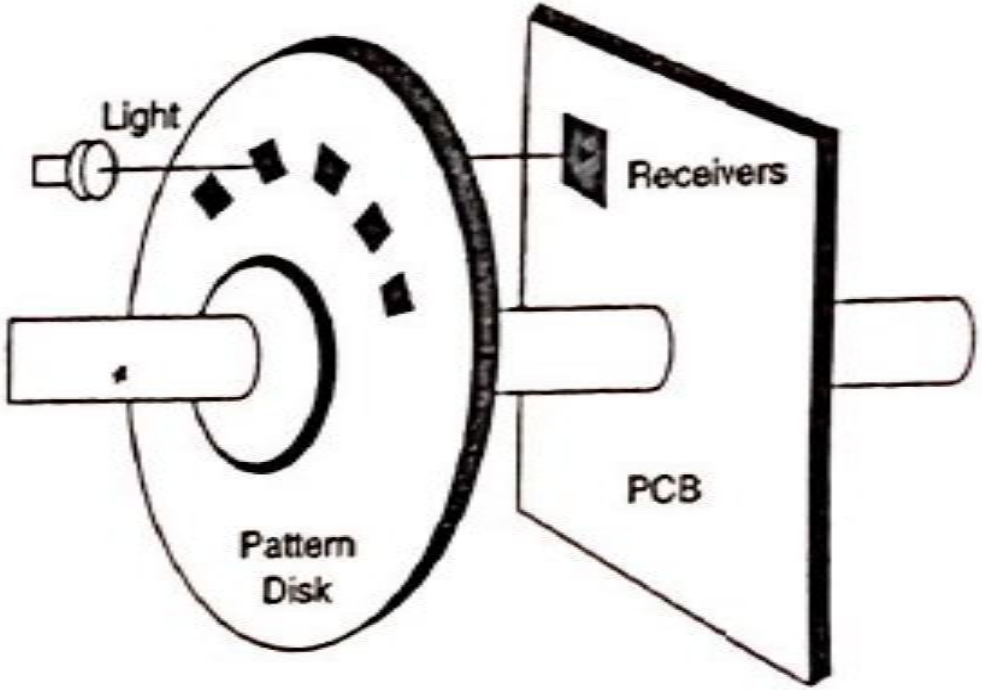
Pattern used in optical encoder

- This pattern has 12 black and 12 white blocks.
- If we consider black and white in terms of 0 and 1, we get a square wave.
- Assume this pattern is fitted to shaft of wheel and there is a sensor from which pulses can be obtained corresponding to pattern.

Pattern used in optical encoder

- If pulses are counted the no of rotations that have occurred can be found out.
- If wheel diameter known, circumference of wheel can be calculated, which measures the distance covered with one wheel rotation.
- By knowing how much is the angle turned for one received pulse is equivalent to distance travelled, and from this velocity can be calculated

An optical encoder transmitter and receiver



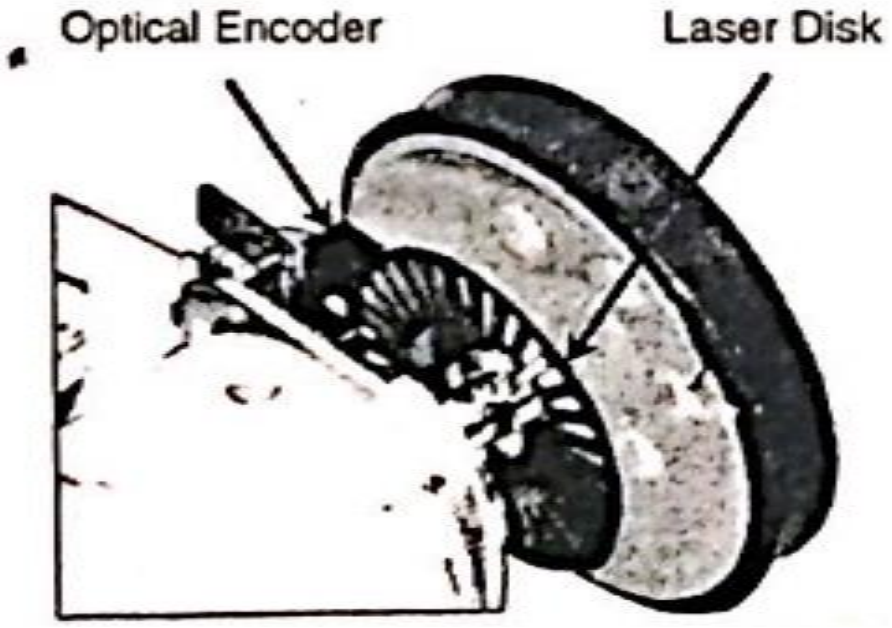
For optical encoder important components are

- **A disk** with a pattern as shown
- **An LED** which generates light which passes through hole in the disk or is blocked by disk
- **An optical** sensor which receives these light pulses and converts it to electrical signals.
- Fig shows a pattern disk with a few holes, which can be attached to shaft of moving wheel.
- As wheel rotates, the current passes through holes which is sensed by the receiver on PCB.
- The pulse obtained can be used to calculate the distance travelled

ICs

- ICs available with an IR LED and a photo detector in one package e.g. interruptor switch
- Such IC is H21A1/H21A2/H21A3series which consists of gallium arsenide infrared emitting diode coupled with a silicon phototransistor in a plastic housing
- The gap in a housing provides a mean of interrupting the signal with opaque material switching the output from ON to OFF state.

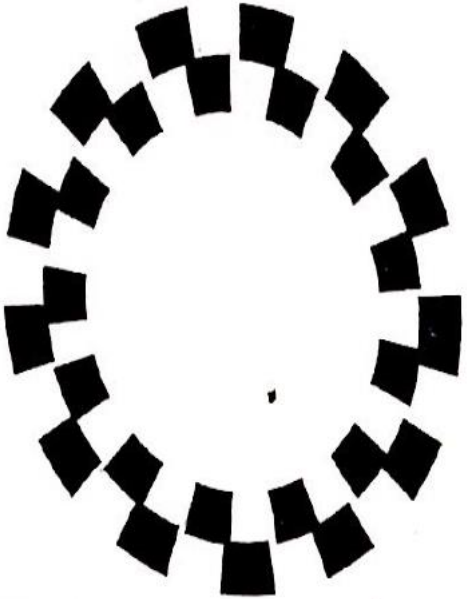
Optical encoder fixed to wheel of robot

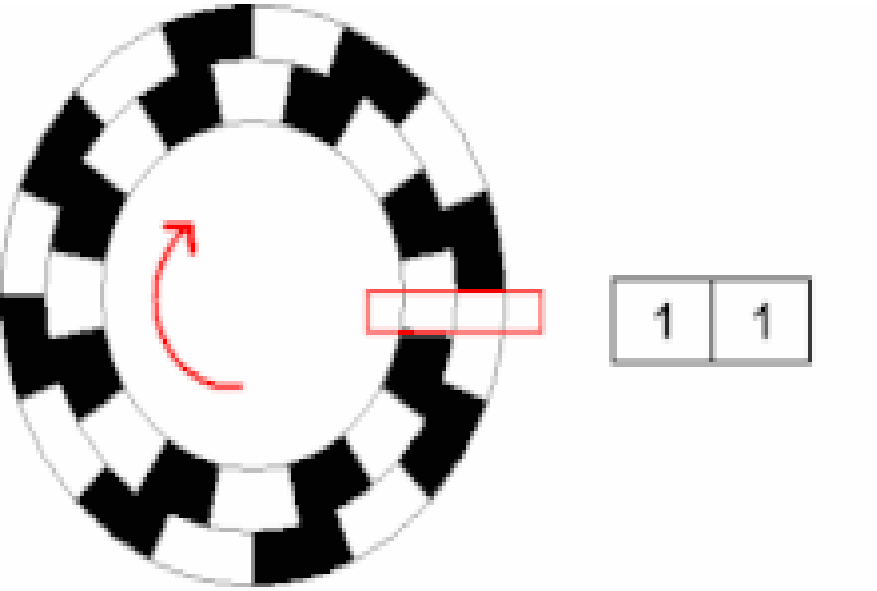


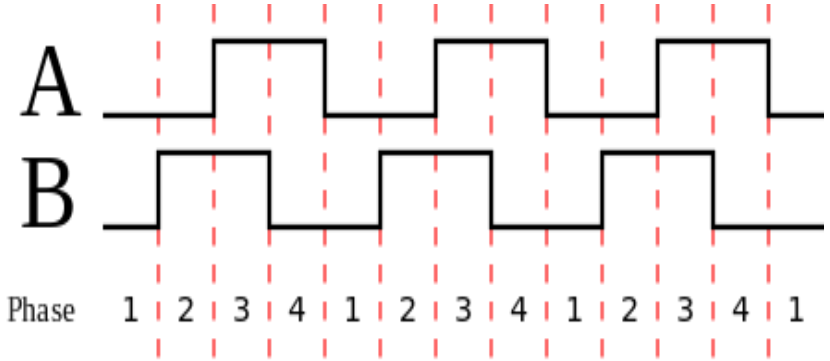
Directional Pattern

- Type of pattern disk just discussed is non-directional because it cannot decipher the direction of movement

- For directionality, a pattern with two sagged pattern is necessary, so that the system can tell which way the wheel is turning.







Two square waves in quadrature. The direction of motion is indicated by the sign of the *A*-*B* phase angle which, in this case, is negative because *A* trails *B*. This represent clockwise direction.

Humidity Sensor

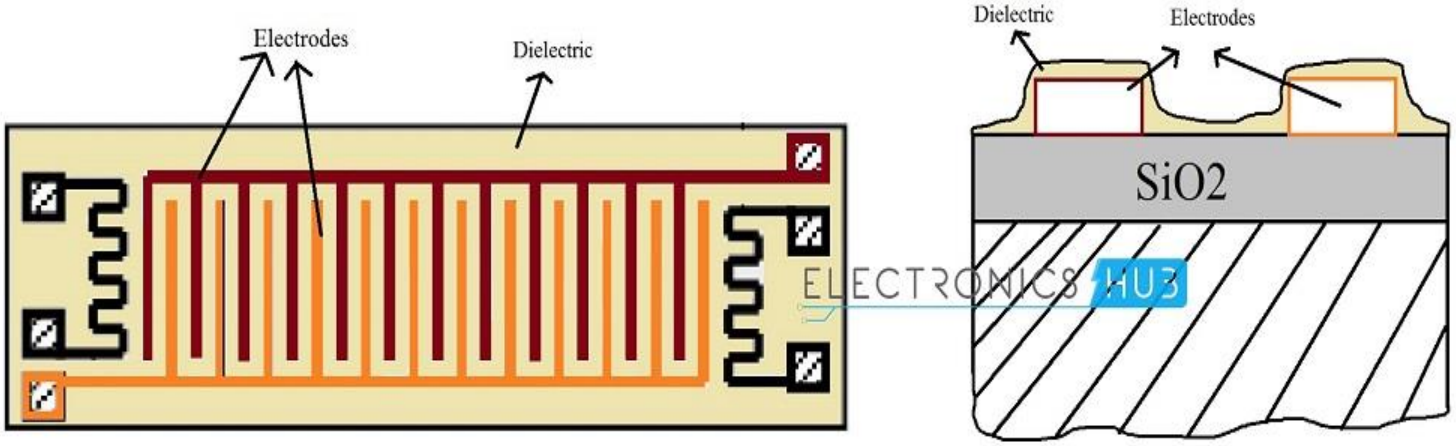
- Humidity is amount of water vapor present in air.
- **Absolute Humidity**: It is actual amount of water vapor present in air. It is mass of water vapor per unit volume of air.
- **Relative Humidity**: It is ratio of amount of water vapor in the air and the amount of water vapor that would in the air at the saturation.

Humidity Sensor Applications

- **Home automation system** :Humidity monitored to bring it to level which makes it a comfortable environment
- **In household**: intelligent control of living room, microwave cooking, laundry etc.
- **In semiconductor industry**: wafer processing
- **In automobile industry**: window de-fogging control

Capacitice Humidity sensor

- Generally sensing of humidity involves a change of impedance (capacitance, for example).
- Sensor element is consist of film capacitor on different substrates.
- The dielectric is polymer which absorbs and releases water proportional to humidity and thus changes capacitance of the capacitor, which is measured by on-board electronic circuit.
- Commonly available humidity sensor are: HS12P,HS15P series.



Top View

Cross Section

Analog to Digital Converters

- All sensors give an analog voltage proportional to the physical quantity sensed
- To convert it to digital number which an MCU can use Analog to digital converter (ADC) s used.
- Many MCUs like PIC, ARM, AVR(Alf and Vegard's RISC processor) have ADC inside the chip, while 8051 use an external ADC.

ADC Interfacing

- ADCs convert analog voltages into digital codes which can be processed by embedded systems
- ADCs are required for all systems that need to interface with real-world signals(analog).
- Two separate interfaces that are accessible to an embedded system are:

i. Control Interface

ii. Data Interface

Control Interface

- ADCs vary widely in complexity, performance speed.
- They have various modes and states which need to be managed to operate them in a way as needed
- ADCs might have different modes like 10-bit/12-bit/14-bit(resolution), various offset modes, power modes, latency modes, input clock cycles etc.

Control Interface

- E.g. SAR (Successive Approximation register) ADC might continuously convert the input signal, and generate codes and put them on the data bus

Two basic controls

- Register control
- Pin control

Register control

- All the modes and states are managed with the help of registers.
- Hence we need some way to write into and read from these registers. For this we depend on register interface

Various Industry standards exist for such interface like

- SPI (Serial Peripheral Interface)
- I2C (Inter-IC)
- UART (Universal asynchronous receiver-transmitter)

Pin Control

- For simple ADC no. of states and modes are not enough to justify the use of register interface. They might have simple pins which control state of ADC
- Typically, the no. of such pins will be less than or equal to 4, which allows us to select between 16 different states.
- Some such devices might have a simple state machine inside which allows the ADC to respond to the sequence of inputs applied at input pins.
- This is used in ADCs used for compact biomedical applications.
- The ADC might be combined with an AFE (Analog Front End) and transceiver

Data Interface

- ADCs vary widely in their speed of conversion, from a few samples per second to several GSPS (Giga Samples per Second)
- In case of slow ADCs separate data and control interfaces are not usually used.
- In such devices **register interface** is used for read and write both data and state information
- E.g. Most microcontrollers which have **builtin ADC has a register interface** through which both control signals like start/ stop conversation as well as data can be sent and read

Data Interface

- In high speed ADCs, control signals have to be sent without interrupting flow of data . In such cases, separate dedicated data interface is used.

Two types of interfaces used are:

i. Parallel

ii. Serial

Parallel Interface

- Each data word is transmitted over several physical lines with each line carrying one data bit.
- There is also a clock line which is used to latch the data when it is ready.
- Parallel interfaces are used mainly in applications where the resolution and/or speed is low.
- In such cases they can be directly transmitted without a lot of digital manipulation by the ADC and directly read by the controller where as serial systems require a SEDES(Serializer Deserializer) for data transfer.
- Parallel interfaces can be classified based on different parameters

I. clock edges used for latching data

i. **Positive Edge**: data is latched on positive edge of clock.

ii. **Negative Edge:** data is latched on negative edge of clock.

iii. **Dual Edge:** data is latched on positive and negative edges of clock. This is known as DDR (Double Data Rate) scheme. This can reduce no. of data lines by half and increase the speed by two.

II. Based on no. of lines used to transmit a single bit

i. **Single ended**: A single line is used to transmit one bit and the voltage is referred to the common ground.

ii. **Differentia**l: A matched pair is used to transmit one bit. One line carries bit +V and other bit –V.

This improves the noise immunity. Differential system require twice the no. of lines as single ended.

III. Based On Voltage Level

i. **CMOS:** Modern ADCs have digital modules consist of MOS technology so this voltage level is commonly used by ADCs for signalling

ii. **TTL(5V)**

iii. **LVDS(700mV peak to peak):**Low voltage differential signalling is used in differential systems. Both bit + and bit- lines have swing of 350 mV peak to peak each.

ICs are available which are capable of translating between voltage levels and signal modes.

Serial Interface

- Instead of each data line carrying 1-bit of data word, all the data bits are sent over single line.

Advantages of Serial Interface over Parallel

i. Fewer no. of physical connections
ii. Smaller die size made possible by reduced pin count
iii. Size is big advantage for higher resolution ADCs.
iv. Serial interfaces can operate differentially as the **increase in no. of wires is minimal**. This drastically cuts down noise pick up and allows for lower signalling voltages.

Serial Interface

- The **EMI generated by a balanced differential pair is much lesser than by a large** no of single ended parallel data lines. This is because opposing currents in pair cancel out the magnetic fields caused due to each other.
- The **lower signal swing made possible by common mode noise rejection** in a differential system reduces power consumption.

Serial Interface

- Serial interface allows for features like clock recovery. This makes it unnecessary to have a separate clock line. The clock is recovered from the data. **This is possible because serial interfaces switch at a much higher speed than parallel buses.**
- Quite a **few high-quality serial interface standards are there which allow for easy interoperability.**

Serial Interface Disadvantages

i. Requires a deserializer to convert the serial data to data words.

ii. Parallel data has to be converted to serial data and a high speed clock generated inside the device.

Serial Interfaces can be classified as

- **Single-ended**: There is only one data line and signal voltage is referred to common ground. The zero crossings are susceptible to noise. But no. of lines is less. Single-ended interfaces come with different signalling levels. A couple of them are
- CMOS(1.8-3.3V)
- TTL(5v)

Serial Interfaces can be classified as

- **Differential:**

Data is transmitted over a matched differential pair . This reduces noise and EMI generation. Signal swing can be lower because of improvement in noise. This can save power. These systems require special interfacing ICs to convert differential signal into single ended one for use in embedded system.

Differential system based on voltage swing can be classified as:

a. Rail-Rail Swing(e.g. USB)
b. LVDS(Low Voltage Differential Signalling 700mVpp)

Actuators

Introduction

- Actuation means
  - something is made to happen
  - this happening may be in form of a motion, display, alarm, transmission to a distant unit etc.
- When actuation is motion – motors are used.
- When data to be displayed display devices are used.

Displays

Some sort of display is necessary

Displays like LEDs, LCDs etc are common

LED

- works just as ordinary semi conductor diode
- It is usually made of Gallium Arsenide and is available in different colours.
- It can be used
  - as indication of activation of signal
  - Can act as alarm

LED

Advantages

- Easy to use
- Very bright and pleasing display which can be viewed equally well from all angles.

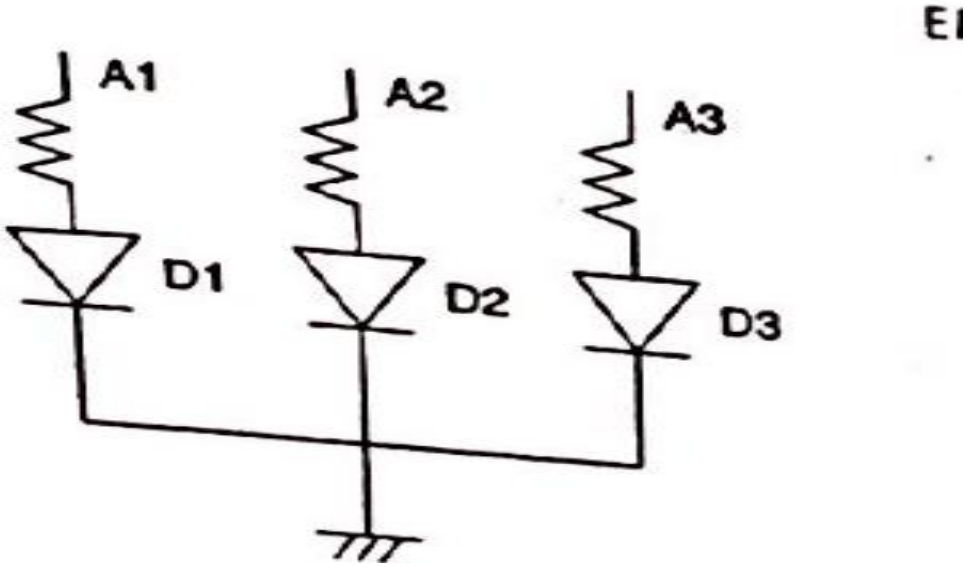
Drawbacks

- High amount of current

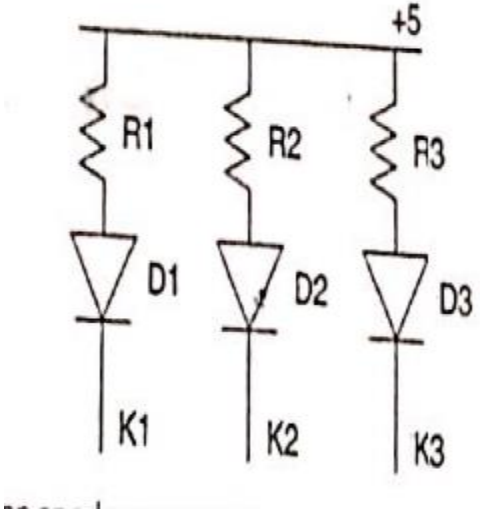
Common Anode Connection

- In case we need no. of LEDs we use only one power source for all of them.
- They are connected together in either common anode or common cathode connection

Common Cathode connection

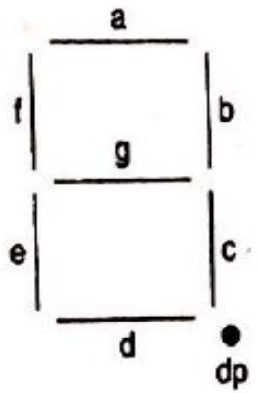


Common Anode connection



- If we want to light up only first and third then 0 (ground) is applied only at K1 and K3.

Seven Segment LED



Data Byte for seven segment LED

D7	D6	D5	D4	D3	D2	D1	D0
0	1	1	1	0	1	1	1

Seven Segment LED

Find the seven segment codes to be used for displaying

a)Assuming common cathode type of display

i)8

Sol: 0111 1111 i.e. 7FH

ii)A

Sol: 0111 0111 i.e. 77H

iii) b

Sol: 0111 1100 i.e. 7CH

Seven Segment LED

b) Common anode display

i)8

Sol: 1000 0000 i.e. 80H

ii)b

Sol: 1000 0011 i.e. 83H

Static Seven Segment Displays

- To display a number
  - sent from 8051 port to the display module.
- Send the code corresponding to the segments of the LED .
- This code gives the information as to which segments are to be lighted up for display of specific character.
- E.g. if 77H is outputted through a port, the character ’A’ is displayed on segment LED connected to port lines.

Static Seven Segment Displays

- To display a digit some of segments to be ‘ON ‘ and some to be ‘OFF’ .
- Either way, as long as module is ON the module draws its required current from power source.
  - Range from 5 to 30 mA for a single segment to be lighted up.
- This display is on all the time hence called static display.

Static Seven Segment Displays

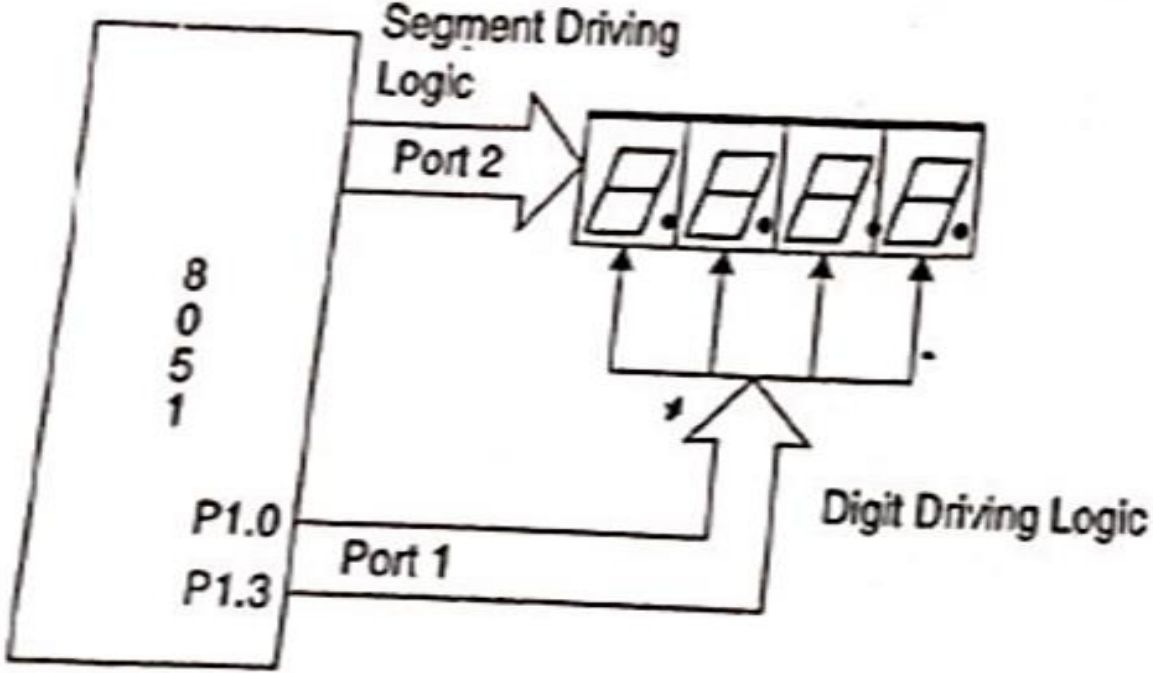
- To display 8-digit
  - For static display the current drawn is multiplied by eight and this becomes quite a large amount
  - as 7*25*8 mA

- For this reason static displays are not preferred for multiple digit display.

Dynamic Displays

- Array of digit display units
  - Say 4 seven segment LEDs arranged in a digit form a row
  - Continuous display can be obtained by lighting up just one digit at a time.
  - The next instant this digit is switched off and next one is lighted up.
- This is done continuously and cyclically from digit 1 to 4 and repeated at a rapid rate.
- **Because** of the persistence property of eyes, an illusion of continuous display is obtained.
  - This is called multiplexed display

Dynamic Displays



Dynamic Displays

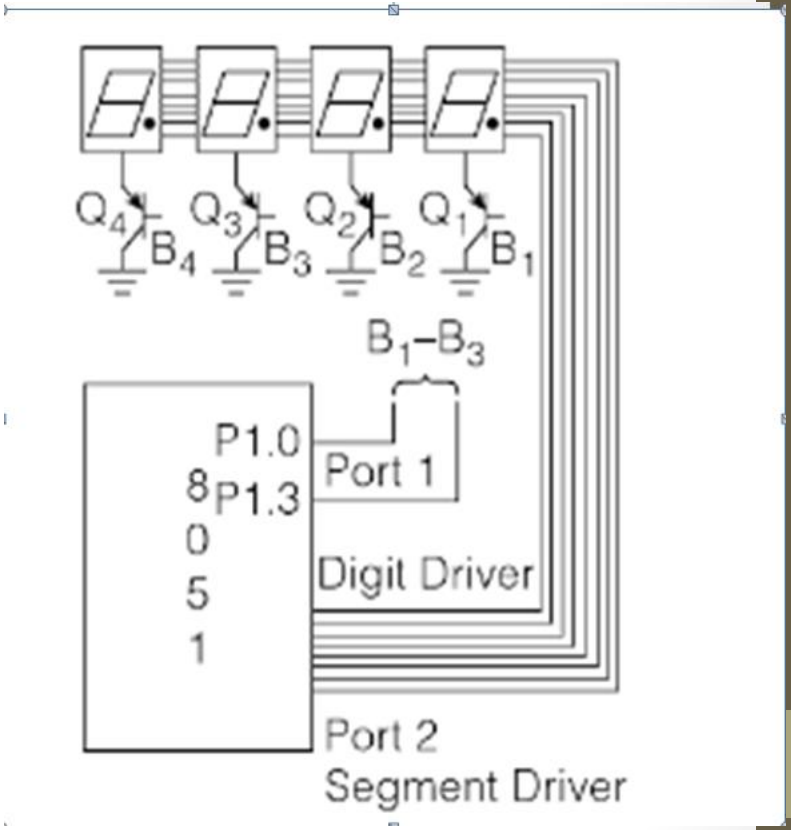
Key Points

i. The common anode/cathode of a digit to be activated

ii. At a time only one digit is ‘ON’.

iii. After specified delay digit is switched off and segment of next digit are on

iv. Consecutive digits to be switched on in cycling manner and the segment information should be supplied.



Advantages

- Unlimited viewing Angle
- Low power consumption
- Fast response Time
- Bright and more brilliant picture
- They require no back light as for LCD
- Fabrication process is easy, devices are thinner than fabricated by CRT display technology.

Disadvantage:

- Organic material have shorter life span
- It is sensitive to water too

Liquid Crystal Display(LCD)

Advantages

- Low-power dissipation
- Ease of use

Two types:

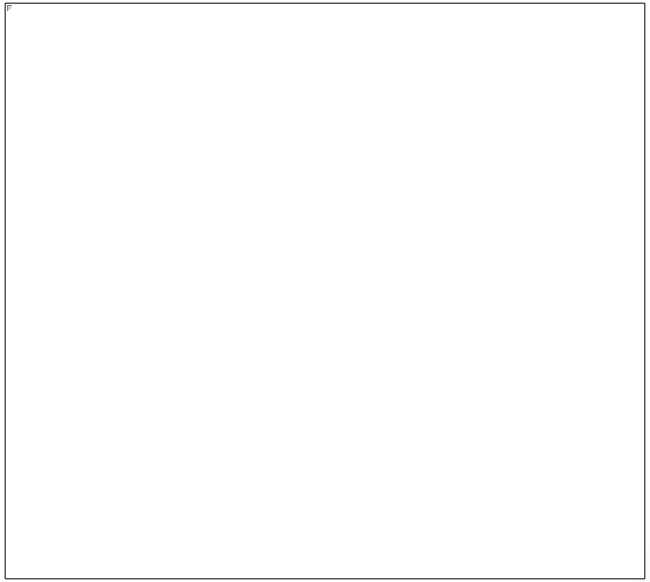
- **Character LCD(For** displaying ASCII characters)
- **Graphical LCD(Contain** display elements as dots or pixels which can be illuminated, to display any pattern)

Disadvantages

Display is not equally clear at all viewing angles

Character Liquid Crystal Display(LCD)

- Character LCD modules of different specifications
  - differ in number of lines
  - number of characters per line and so on
- Example: 16*2 character LCD
- Use registers to control and display data
  - Control and data registers



Liquid Crystal Display(LCD)

MOTORS

- Motors are used for rotational motion or which can be converted to linear motion when application calls for it
- In embedded systems, the rating(voltage, current, torque etc) of motor to be used depends on the application.
- E.g. i. We might use a motor to open/close a door. this might require a motor depending on weight of the door

ii. In robotics, where vehicle movement, arm movement etc are required. Motor used in robotics is small.

MOTORS

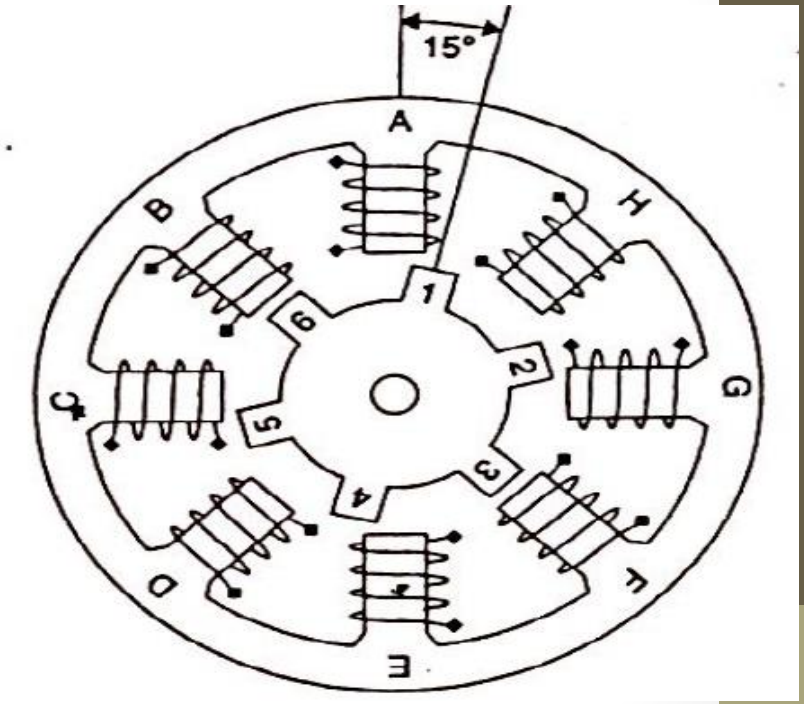
- **MCUs** are used in motors **for controlling** the motor.
- MCU can be **programmed to generate the driving logic for motor movement**.
- Motor are made to rotate clockwise/ anti-clockwise at different rpm or it may be a movement by small angle.
- But **motors cannot driven directly by MCU because current output from an MCU is relatively small so there should be arrangements to get higher driving currents and additional circuitry is usually necessary.**
- **Two types of motors**
  - **Stepper Motors**
  - **DC Motor**

Stepper Motors

- A stepper motor is electromechanical device which converts electrical pulses into discrete mechanical movements.
- When electrical current is applied to it, the shaft of the motor rotates in steps and this type of movement give the motor its name.

Principle of operation

- Stepper motors have multiple toothed electromagnets arranged around a central gear shaped piece of iron.
- The **electromagnets are energized by an external control circuit** which send pulses to the motor



Principle of operation

- To turn the motor shaft, one of electromagnets is given power first, which makes the gear's teeth magnetically attracted to electromagnet's teeth.
- When one tooth of gear is thus aligned to the energized electromagnet, others are slightly offset from corresponding electromagnets.
- When next is turned 'On' and first is turned 'off', gear rotates slightly to align with next one and the process is repeated.
- Each those slightly rotations are called step with integral no. of steps making a full rotation. In this way motor can be turned by a precise angle.

Principle of operation

The rotation of motor is related to sequence of input pulses:

i. The **order in which a particular sequence is applied decides the direction of rotation**(clockwise or anti-clockwise)

ii. The **speed of stepping** depends on frequency of the pulses applied

Higher the frequency, faster the stepping motor

Uses

- It is used where the movements need to be finely controlled. Because motor moves in steps and steps can be quite small in size.

E.g. If each step-2 degree

i. One complete rotation(360 degree)- 180 steps required.

ii. For 90 degrees rotation- 45 pulses

- They are used in applications such as

Printers, plotters, hard disk drives, medical equipment fax machines and automotive and industrial applications Where precise and controlled rotation is required. Robotics is another area where it is used.

Driving a Stepper Motor

- **Full Step Drive**: Both the phases are always ON. The motor will have full rated torque which is achieved by sequence of 1s and 0s.
- For clockwise sequence to be applied :. 09,0C
- For a

Step No.	A	B	$\overline{A}$	$\overline{B}$
1	1	0	0	1
2	1	1	0	0
3	0	1	1	0
4	0	0	1	1

Full step Drive

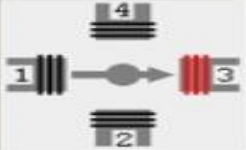
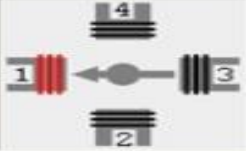
Step	Coil 4	Coil 3	Coil 2	Coil 1	
b.1	on	on	off	off	
b.2	off	on	on	off	
b.3	off	off	on	on	
b.4	on	off	off	on	

Wave Drive

- In this drive only a single phase is activated at a time . It has same no. of steps as full step drive but motor will have significantly less torque
- For clockwise sequence is 8,4,2,1
- For a

Step No.	A	B	$\overline{A}$	$\overline{B}$
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1

Wave Drive

Step	Coil 4	Coil 3	Coil 2	Coil 1	
a.1	on	off	off	off	
a.2	off	on	off	off	
a.3	off	off	on	off	
a.4	off	off	off	on	

Half stepping

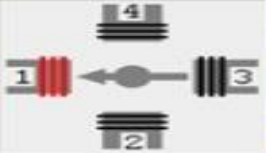
- When half stepping drive alternates between two phases ON and single phase ON.

Step No	A	B	$\overline{A}$	$\overline{B}$
1	1	0	0	1
2	1	0	0	0
3	1	1	0	0
4	0	1	0	0
5	0	1	1	0
6	0	0	1	0
7	0	0	1	1
8	0	0	0	1

Half Stepping

Step	Coil 4	Coil 3	Coil 2	Coil 1	
a.1	on	off	off	off	
b.1	on	on	off	off	
a.2	off	on	off	off	
b.2	off	on	on	off	

Half stepping

Step	Coil 4	Coil 3	Coil 2	Coil 1	
a.3	off	off	on	off	
b.3	off	off	on	on	
a.4	off	off	off	on	
b.4	on	off	off	on	

Other issues regarding stepper motor

- There is a chance of back emf produced during the de-energization of the coils. This can damage the circuits producing the sequence and hence diodes are connected which block these spikes. Such diodes are called flywheel, flyback, free wheeling or snubber diodes
- Darlington pair transistor are used for producing high current required to drive motors , diodes are connected to block emf.
- Such a diode is also in-built within the motor driving IC ULN 2003.

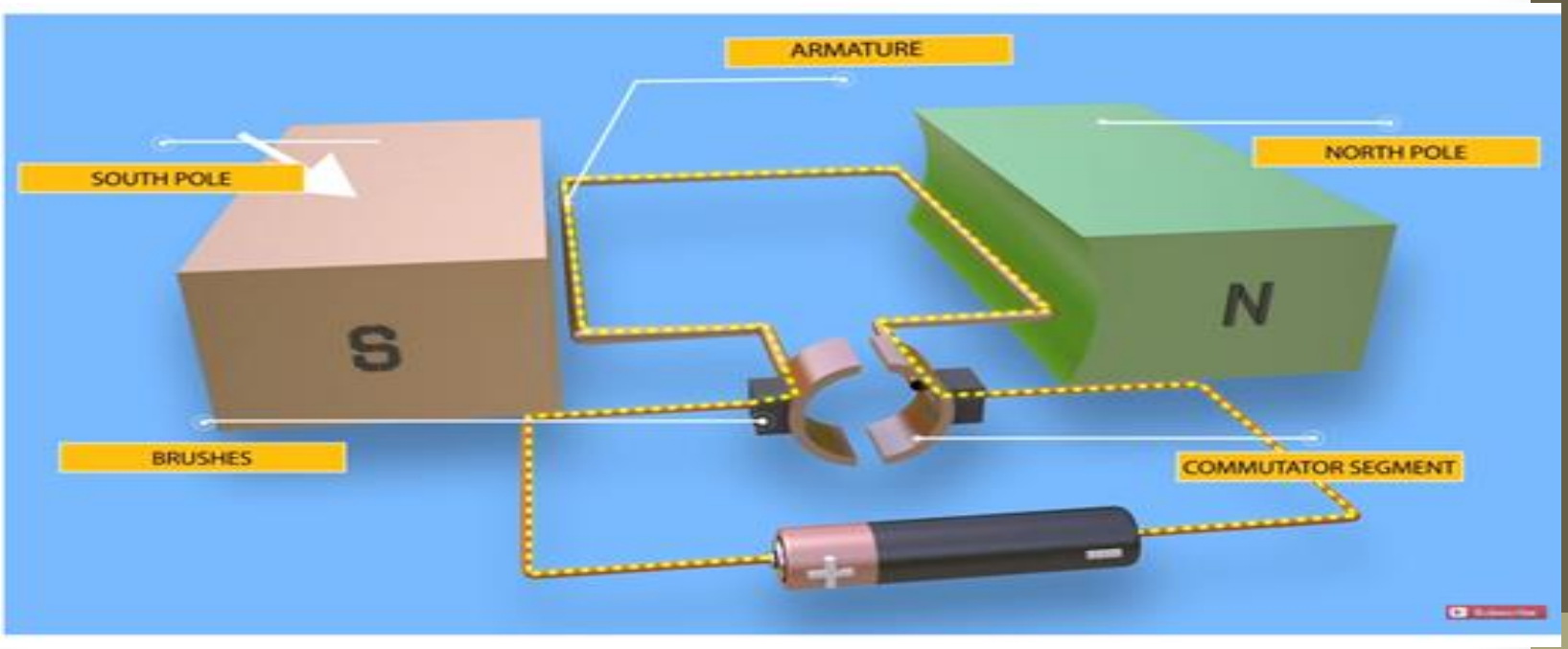
DC Motor

- This is type of motor which operates on direct current and is very commonly used in embedded system, when continuous movement is needed
- Speed and direction of movement can be changed as per the requirements of the application
- Dc motors are widely used in Robotics.
- Any type of movement is possible to be achieved with dc motors.

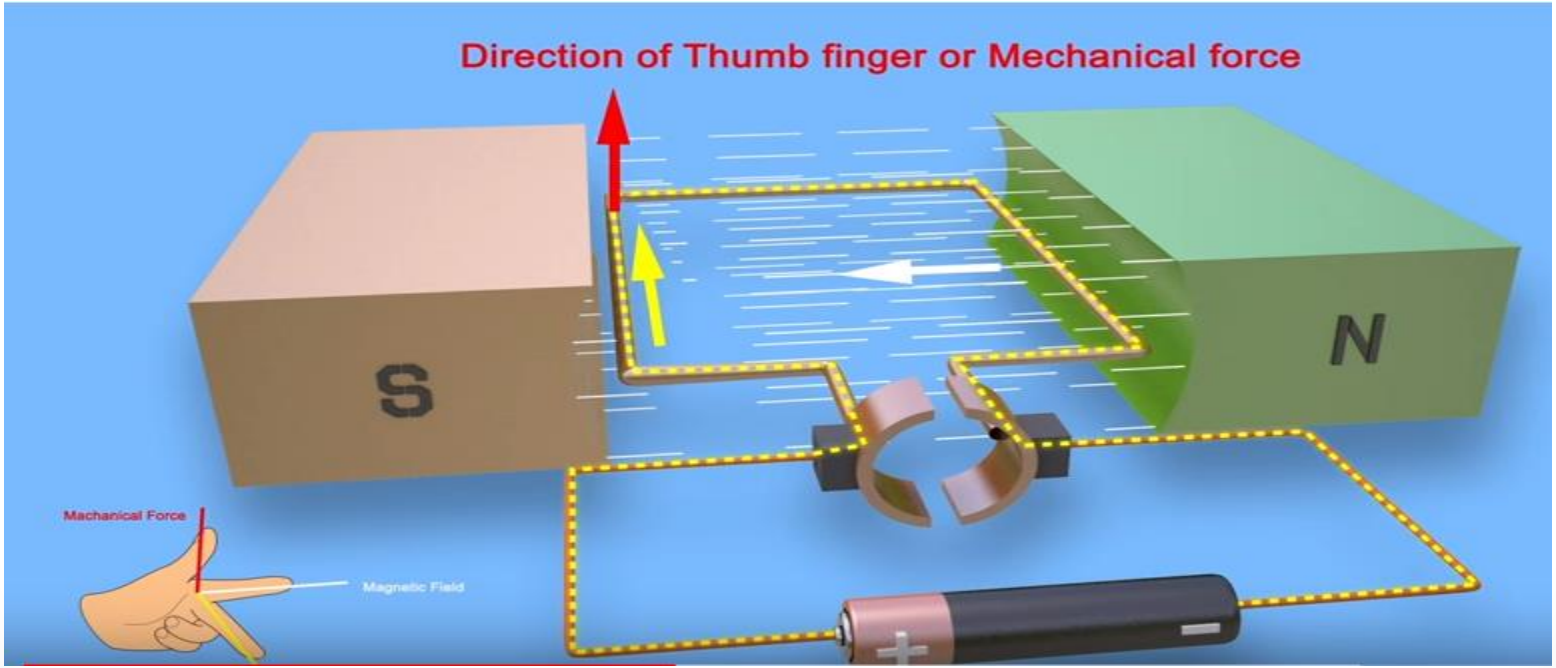
Principle of Working

- Dc motor has two basic parts
  - **Armature**: rotating part
  - **Stator:** stationary part

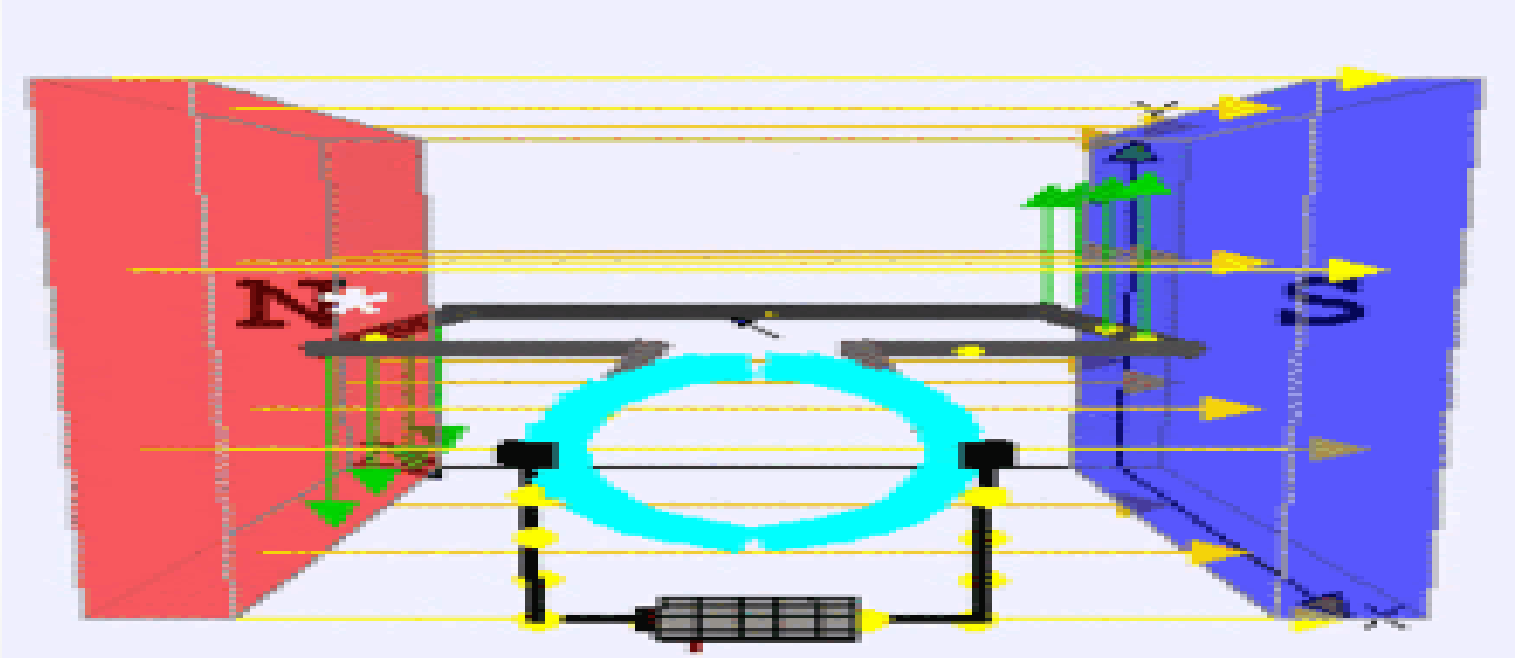
DC Motor


ARMATURE
SOUTH POLE
NORTH POLE
S
N
BRUSHES
COMMUTATOR SEGMENT

DC Motor


Direction of Thumb finger or Mechanical force
S
N
Machanical Force
Magnetic Field

DC Motor



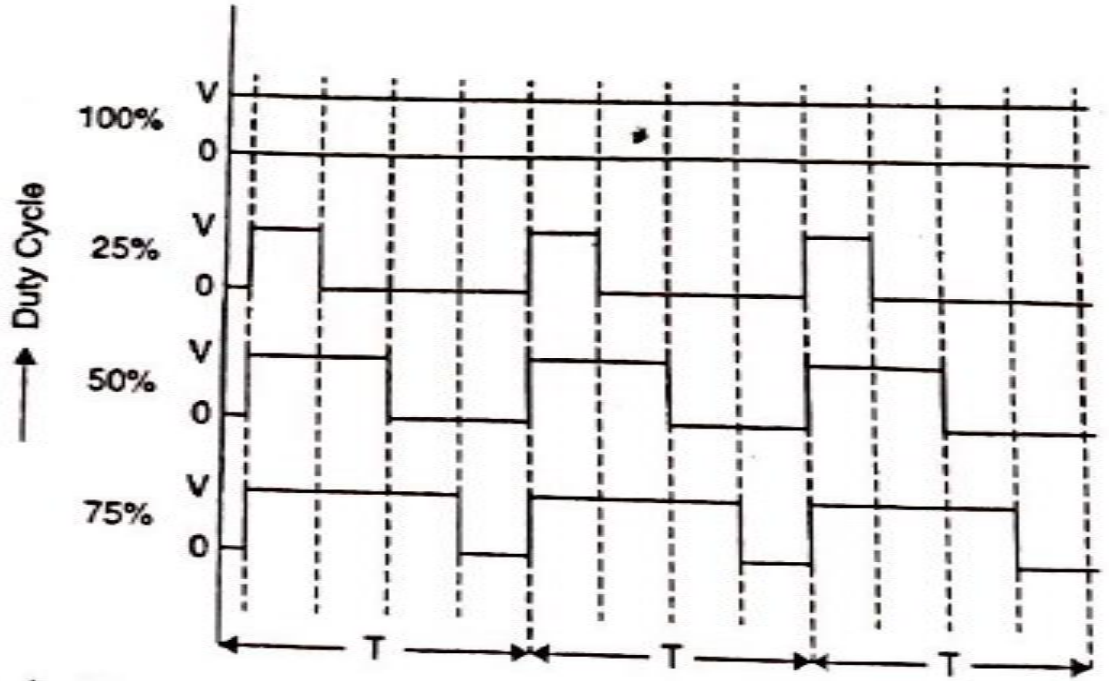
Characteristics of DC motor

- **non-polarized**: this means that its power supply voltage can be reversed
- **Speed varies with applied voltage:**
- running a motor at different speeds by increasing or decreasing supply voltage.
- In Dc motor, PWM is method used for varying motor speed.
- Apply a pulse train to power terminals of motor. The average voltage obtained at terminal is then proportional to duty cycle of pulse train, which is proportional to speed of rotation of motor.

Characteristics of DC motor

- As duty cycle increased the motor RPM increases and vice versa.
- When power supply is constant, it runs at 100% of its power rating
- As duty cycle reduces , the speed reduces

PWM at various duty cycles



Characteristics of DC motor

- An MCU can be used to generate PWM waveform based on some criteria or based on sensor values.
- Many MCUs have PWM unit as integrated peripheral –the user just specify pulse repetition time(T) and duty cycle.
- 8051 does not have PWM unit-but such a waveform can be generated by a simple program

Characteristics of DC motor

- **Torque varies with current:** torque of motor is rotary force produced. Torque *increases with increase in power supply voltage.*
- **Reversal of polarity of supply voltage causes reversal of direction :** i*mportant in many applications especially robotics, when the motor needs to reverse its direction of rotation.*

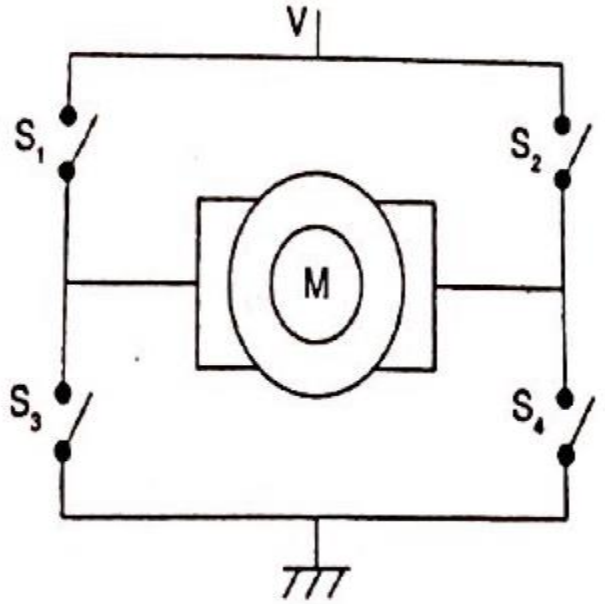
e.g. a robotic vehicle needs to reverse motion when an obstacle comes in its path. To do this dynamically, controlling switch is necessary called H-bridge

H Bridge

- It is called so because it has four switching elements at the limbs of the H and motor forms the cross bar.
- There are two switches at the top and two at the bottom named S1,S2,S3,S4.

H Bridge

- When motor is not expected to rotate, all the switches are kept open.
- When S1 and S4 are closed, motor rotates in clock wise direction
- When S2 and S3 are closed rotation is anti-clockwise
- When top two or bottom two switches are closed motor gets short circuited and should not be allowed.



Valid states of Switches

Table 3.8 | Switch status for direction of motor rotation

S1	S2	S3	S4	Motor Rotation
1	0	0	1	Clockwise
0	1	1	0	Anti-clockwise

Mechanism to realize H bridge

- To drive DC motor from an MCU output, the best would be a motor driving IC with H bridge.
- IC L293 D is dual H bridge IC which also provides sufficient current to drive a small motor
- L 293D IC is dual bridge , so with one IC two DC motors can be driven which can be controlled in both clockwise and anti clockwise directions.
- For applications that don’t need reversal of direction four output pins can be used for driving four separate motors.
- For protection of circuit against back emf flywheel diodes are included within the IC

Relays

- Switches which can be turn ON and OFF without manual control constitute a relay.
- Relay can be used to connect and disconnect between points in a circuit by using electrical control logic.
- Relay allow one circuit to switch a second circuit which can be completely separate from first.

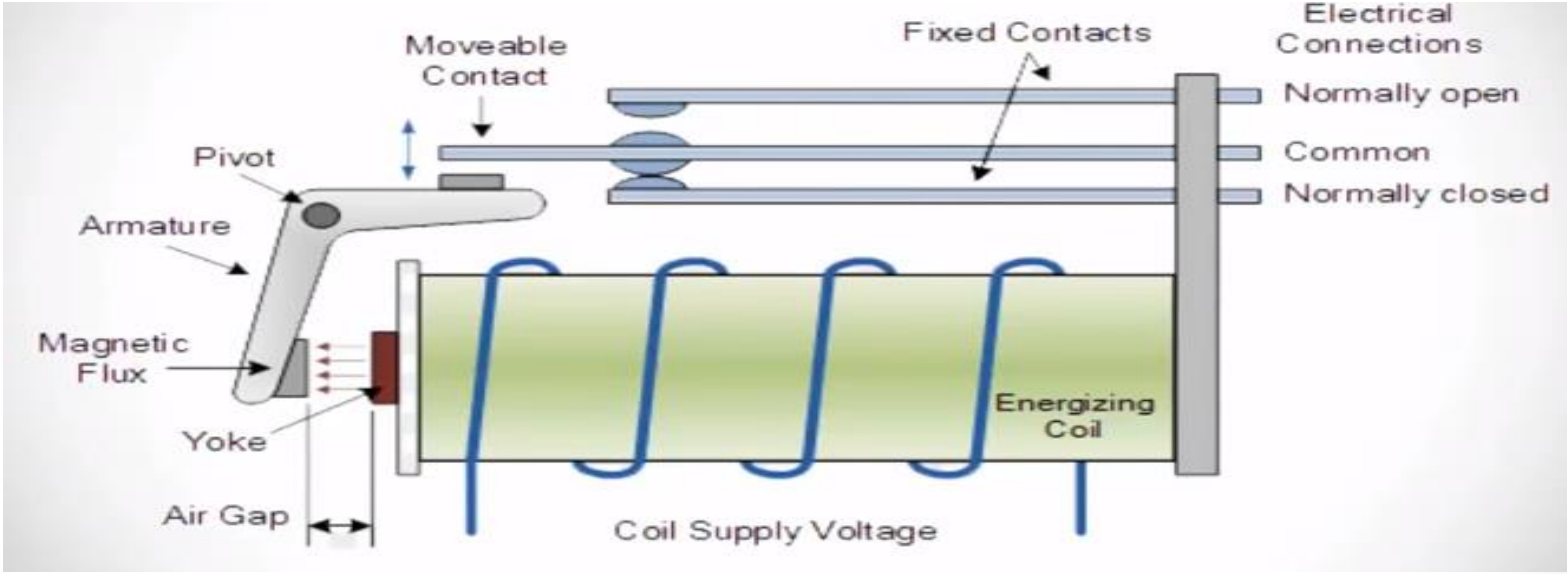
Relays

- E.g. a low voltage circuit can use a relay to switch a high voltage circuit.
- There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.
- Such relays are electro mechanical

Electromechanical Relays

- By using low voltages and currents, relays can make and break connections in higher voltage currents.
- Electro mechanical relays convert a magnetic flux created by an external signal into a mechanical force. This mechanical force causes a switch to open or close.

Electromechanical Relays



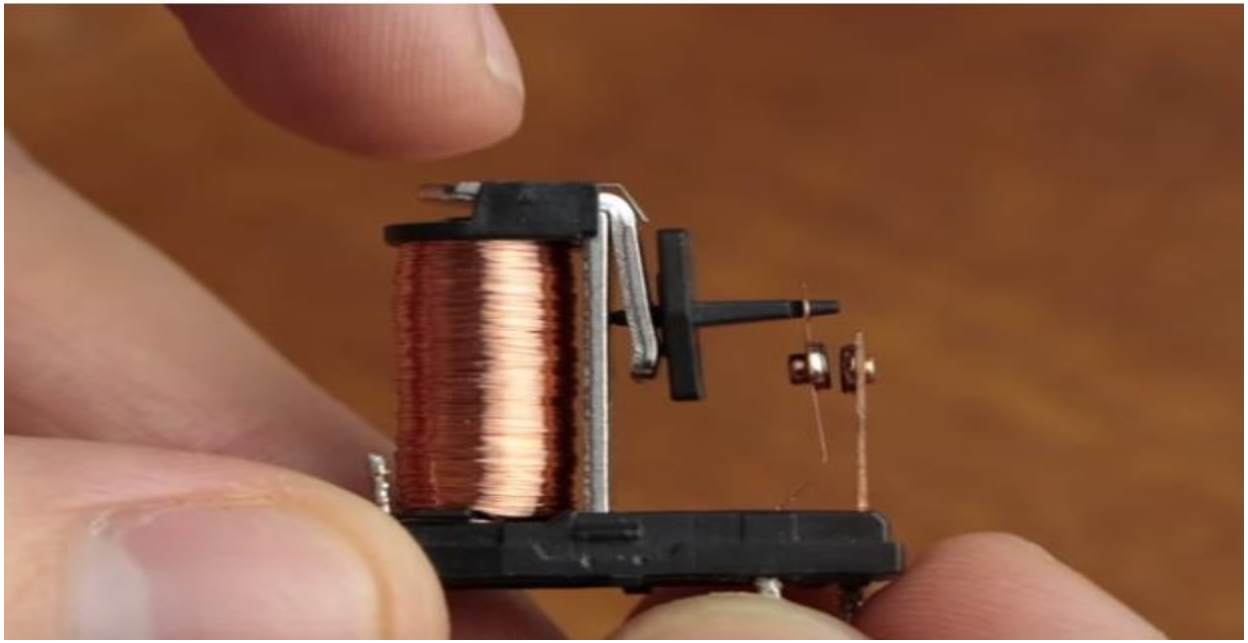
Electromechanical Relays

- Fig shows a coil around a permeable iron core.
- one end of iron is fixed(yoke), while other end is free and spring is loaded and is called armature
- Armature is hinged to yoke and mechanically linked to one or more sets of moving contacts.
- When coil is de-energized there is an air gap in the magnetic circuit.
- In this condition one of two sets of contacts in relay is closed and other set is open.

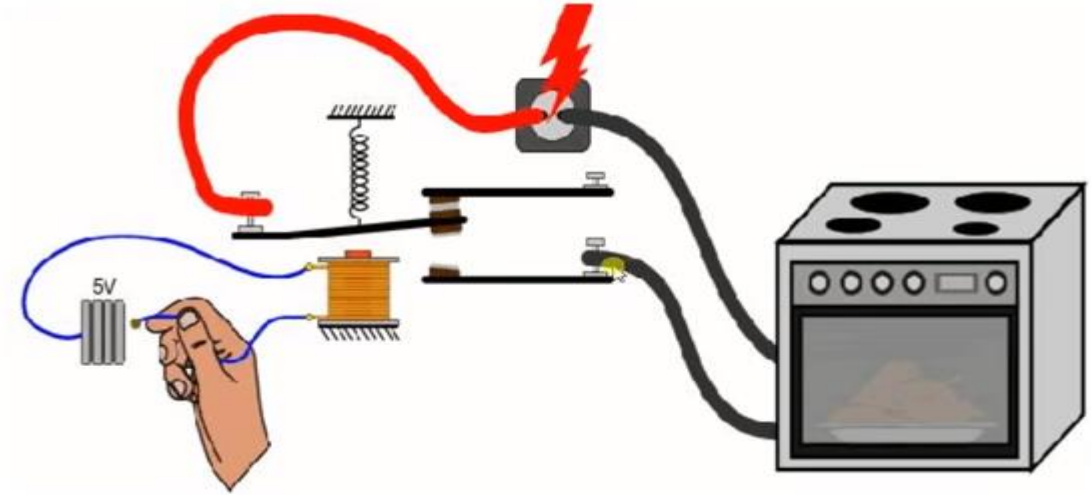
Electromechanical Relays

- The contacts which are open when coil is de -energized are called ‘Normally Open(NO)’ contacts- similarly there are ‘Normally Closed(NC)’ contacts.

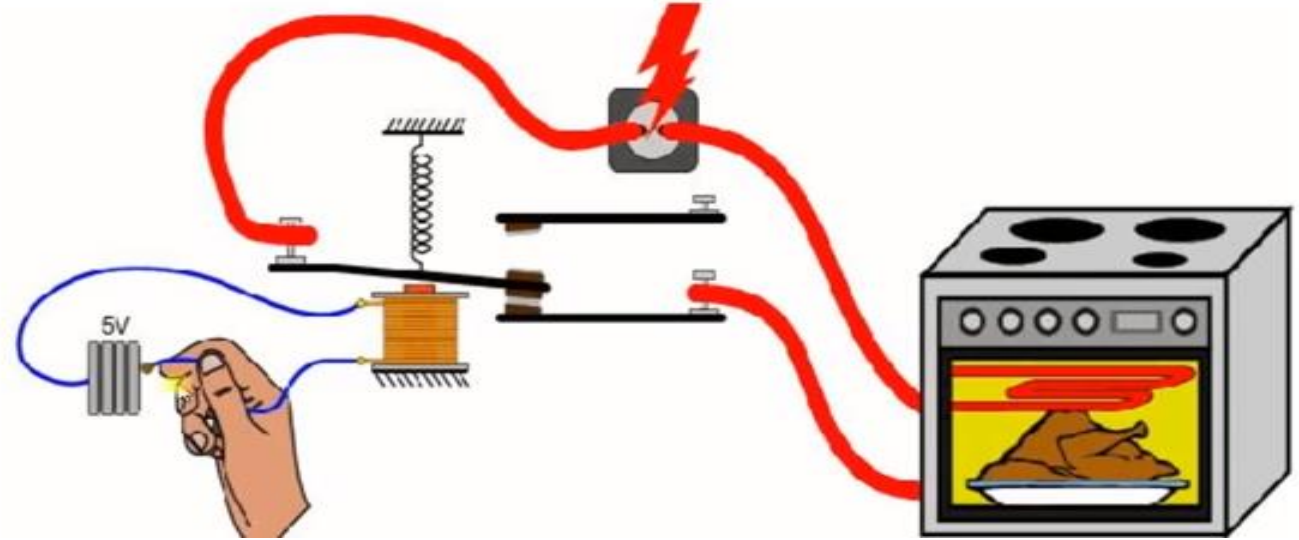
Electromechanical Relays



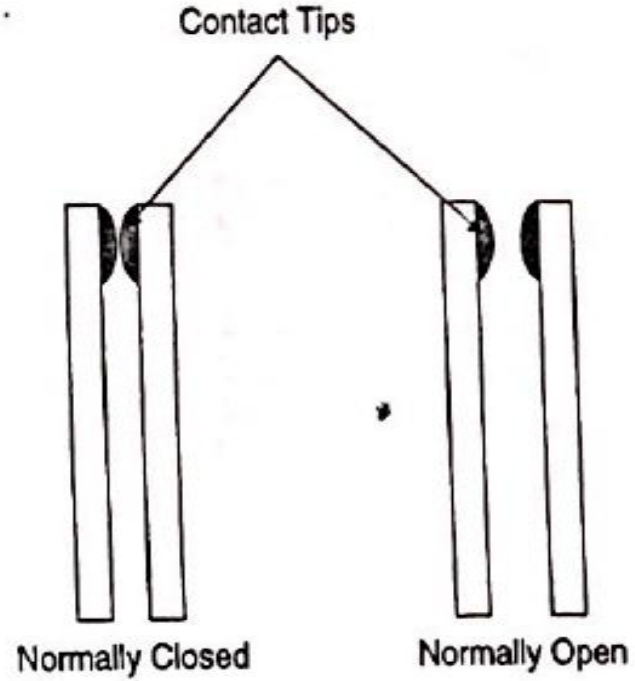
Electromechanical Relays



Electromechanical Relays



NC and NO contacts

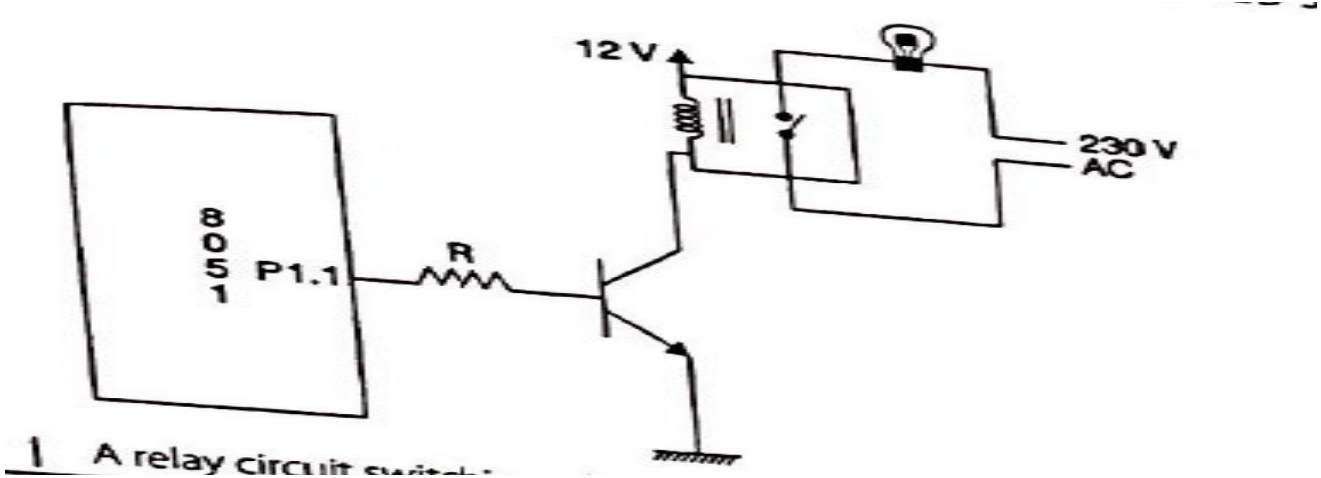


Contact Types

- The energization or de-energization of a rely can open or close one or more switch contacts.
- Each contact may referred to as a ’pole’.
- Many of these contacts or poles can be connected or thrown together and this give rise to description of contact types as SPST, DPST and DPDT.

A simple relay circuit

- A diode is connected across relay which saves transistor from getting damaged when there is back emf in the coil



1 A relay circuit switch

A simple relay circuit

- Relay in embedded system is connected to output pins of MCU.
- It is used to control high power circuits i.e. high voltage/current, by using lower voltage levels in the MCU.
- Fig shows a relay used to control switching of a bulb.
- In this case contact of relay should be able to withstand the high current passing through it.

Solid State Relays

- Electro mechanical relays have problems such as physical size and mechanical parts which tend to wear out with time.
- solid state relays are solution to these problems.
- Solid state relays have semiconductor switching elements like diode, transistors etc. Most of them have optoisolator incorporated internally, so as to isolate input and output.
- they are smaller, noiseless, bounce free and more reliable.