# LEACTURE NOTE


## NAME: CHANDRASEKHAR DASH

## DESIGNATION: PTGF MECHANICAL ENGINEERING DEPARRTMENT


## SUBJECT: MECHATRONICS

## 2.1 Transducer:

- A transducer is an electronic device that converts energy from one form to another. The process of converting energy from one form to another is known as transduction.
- Some common examples of transducers include loudspeakers, microphones, thermometers, and LEDs.
- Determining the exact magnitude of physical forces such as temperature and pressure is difficult. But, if these physical forces are converted into an electrical signal, then their values can be easily determined using a meter.
- The primary function of transducers is to convert a physical force into an electrical signal so that it can be easily handled and transmitted for measurement.
- They are extensively used in the instrumentation field as instrumentation deals with measuring and controlling several variables like sound, flow, level, angle, etc.

**The transducer can be divided into:**

The transduction element is used to transform the output of the sensing element into electrical outputin two parts

- Sensing element
- Transduction element

The transduction element is used to transform the output of the sensing element intothe electrical output.

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The sensing element is a detector that is responsible for sensing the element or it is the part thatresponds to the phenomenon

**2.2 Classification of Transducers**

1. Primary and secondary type
2. Analog and digital type
3. Active and passive type
4. Transducer and Inverse type

**Primary and Secondary Transducer:**

- Suppose you need to measure pressure. In this case, we use the bourdon tube .so the bourdon tube act as the primary transducer it senses the pressure and converts pressure into the displacement of its free end.
- The displacement of the free end moves the core of the linear variable differential transducer which produces an output voltage proportional to the movement of the core which is proportional to the movement of the core which is again proportional to pressure.
- So, we can measure pressure. Here bourdon tube is the primary transducer and LVDT is a secondary transducer.

**Analog and Digital Transducer:**

- Transducers converting input quantity to analog output in form of pulses are analog transducers.
- Ex. Strain gauges, thermocouples, etc. digital transducers convert the input to electrical output in form of pulses.

**Active and Passive Transducer:**

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- Active transducer don't need a auxiliary power source to produce output.
- The energy required to producethe output signal is obtained from the physical quantity being measured.
- Ex. piezoelectric crystals, tacho-generators, etc.
- Passive transducers are those which need an auxiliary power source to produce output.
- Ex. linear potentiometer etc.

**Transducers and Inverse transducer:**

- Transducers, as mentioned earlier convert non-electrical quantity to electrical quantity whereas inverse transducer converts electrical to non-electrical quantity.
- This type of transducer convertsan electrical signal intothe required form.
- Ex. Piezoelectric Crystal. It converts electrical signalsinto mechanical vibration.

**Application of transducers:**

- In our mobile phone. Microphones, Speakers, and touch screens.
- In our Computer Mouse optical sensor/ transducer is available.
- In our Clock Piezo Crystal is working.
- In our Computer Hard Disk Magnetic Sensor is installed.

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## 2.3 Electromechanical transducer:

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- any type of devic tha either co vert an electrical signal into sound waves (as in a loud peaker) or converts a sound wave into an electrical signal (as in the microphone).
- Electromechanical transducers are used primarily as actuating mechanis ms in automatic control systems and as sensors of mechanical motion in a utomation and measurement technology.
- They may be classified according to the conversion principle used as resis tive, electromagnetic, magnetoelectric, and electrostatic types.
- Examples of electromechanical transducers are the measuring mechanism of a permanent

  magnet instrument, a loudspeaker, a microphone, and a piezoelectric trans ducer.

## 2.4 Transducer Actuating Mechanism

- It is the source of energy which can be a mechanical force,electrical force, hydraulic fluid pressure, or pneumatic pressure, and convert that energy into motion.
- An actuating mechanism not only changes the state of change of the object being controlled but also moves the control member according to a specified control principle with the minimum possible deviation.

## 2.5Displacement sensor

- A displacement sensor is a device used for measuring positional movement or detecting the movement of a given object, these movements can be either linear or rotary.

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- Displacement nsors, also k own as position sensors, are a very common type of sensor. They are used throughout many industries and can be found all around us.
- Displacement sensors are widely used: Some of the most common industries for displacement sensors are- Motorsport, automotive, industrial applications, agriculture, aerospace, robotics, and many more.

**Types of Displacement Sensor**

1. **Linear displacement sensors**: measure movements that occur along a single axis, this can be left to right or up and down. They use a range of technologies and have different outputs depending on the application requirements.
2. **Rotary displacement sensors:** are used for measuring turning movements. They transform rotary movements into output signals. Rotary displacement sensors can be used for either clockwise or anti-clockwise movements and can be the single turn for motion ranges under 360° or multiturn for larger movements than this.
3. **Contacting displacement sensors:** use a technology where the sensor encounters the given object and the components inside also come into physical contact with each other to measure displacement.
4. **Potentiometers** also known as "pots" are a contacting technology using a slider and a resistive track to monitor displacement. Potentiometers can be either linear orrotary.

**2.6Velocity sensors:**

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**5**



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A velocity receiver (v loci y sensor) is a ensor that responds to velocity rather than absolute po ition.

For example, dynamic microphones are velocity receivers. Likewise, many electronic keyboards used for music are velocity sensitive and may be

- passive motion ensors.

**a) Active sensors:**

Active sensors have both a transmitter and a receiver. This type of sensor detects motion by measuring changes in the amount of sound or radiation reflecting into the receiver.

**b) Passive motion sensor**

The passive motion sensor does not have a transmitter Instead of measuring a constant reflection, the sensor detects motion based on a perceived increase of radiation in its environment.

**Force sensor**

A force sensor is a component that converts the magnitude of force into related electrical signals. The force sensor can detect mechanical quantities such as tension, pressure, weight, torque, strain, and interior stress. It has become an indispensable core component of power equipment, engineering machinery, various working machines, and industrial automation systems.

Types of Force Sensors

- Load Cells
- Strain Gages
- Force Sensing Resistors (FSRs).

**a) Load Cells:**

Load cells (sometimes spelled as loadcells) are a type of force sensor/force transducer that converts an applied force into an output signal that can be used to measure forces such as compressive forces, most commonly weight.

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**b) Strain gages:**

Strain gages are a type of ensor element whose electrical resistance varies as a result of an applied force.

Stress is the term used to describe the internal resistance force that an object

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**b) Piezoelectric sensors:**

Its works by employing the piezoelectric effect. The piezoelectric effect describes the generation of an electric charge as a response to physical changes to the material. This effect is more evident in certain materials to a degree that can be measured. The charge created is proportional to the applied force. The sensor can measure and calibrate changes in the charge and display a corresponding pressure measurement.

**c) Manometers:**

The earliest devices used to measure pressure comprised glass tubes filled with liquid. Manometers are essentially a tube that uses liquid movement to compare the pressure experienced by their two surfaces. The most basic manometers are U-shaped with a liquid inside that is displaced by varying pressure differences.

**d) Bourdon tube:**

The Bourdon tube is an ingenious mechanical device that uses physical movements. It harnesses the surrounding force to drive a dial that is calibrated to display a pressure reading.

## 2.7 Temperature Sensors:

A temperature sensor is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record monitor or signal temperature changes.

**9**



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There are many different types of temperature sensors. Some temperature sensors require direct contact with the physical object that is being monitored (contact temperature sensors), while others indirectly measure the temperature of an object (non-contact temperature sensors).

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**Types of light sensors:**

- **Photovoltaic cells**
- **Photodiodes**
- **Photo-resistors**
- **Photo-transistors**

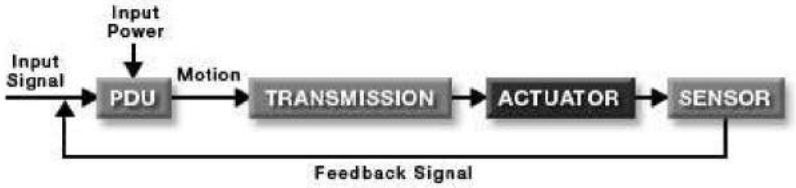
The phototransistor is a semiconductor device that can  ense light levels and alter the current flowing between the emitter and collector according to the level of light it receives.

Phototransistors and photodiodes can both be used for sensing light, but the phototransistor is more sensitive given the gain provided by the fact that it is a bipolar transistor.

### 3 Mechanical Actuators

A mechanical actuator functions to execute movement by converting one kind of motion, such as rotary motion, into another kind, such as linear motion. An example is a rack and pinion. The operation of mechanical actuators is based on combinations of structural components, such as gears and rails, or pulleys and chains.

Mechanical Actuators are used as a mechanism to translate mechanical motion (often rotary) into linear motion or with the help of gearing into rotary motion at a different speed.  These actuators are typically part of a larger system which includes a power drive, mechanical interconnects, and feedback devices to control the motion of multiple devices.



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## 3.1 Kinematic link

A kinematic chain is an assembly of rigid bodies connected by joints to provide constrained motion that is the mathematical model for a mechanical system. As in the familiar use of the word chain, rigid bodies, or links, are constrained by their connections to other links.

### Links

A kinematic link or element or link is a resistant body that constitutes part of the machine connecting other parts which have motion relative to it.

### Types of links

- Rigid links
- Flexible links
- Fluid links
- Floating links

### Rigid link:

A rigid link does not undergo any deformation while transmitting motion.

Ex: Crank and Connecting rod.

### Flexible links:

A flexible link is one in which transmitting motion is partly deformed in a manner not to affect the transmission of motion.

Ex: Spring, Chain, Rope, Belt, etc.

### Fluid links:



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A fluid link is deformed by having fluid in a closed ve sel and the motion is transmitted through the fluid by pressure.

Ex: Hydraullic Press, Hydraulic jack.

**Floating Link:**

A floating link is not connected with the frame.

**Kinematic Pairs**

A kinematic pair is a connection between two physical objects that imposes constraints on their relative movement.

**3.1.2 Mechanism**

Mechanisms are devices that can be considered to be motion converters, in that they transform motion from one form to some other required form.

e.g., linear motion to rotational motion.

Cams and Follower

A cam is a body thatrotates/ oscillates and in doing so imparts a reciprocating/ oscillatory motion to a second body, called the follower.



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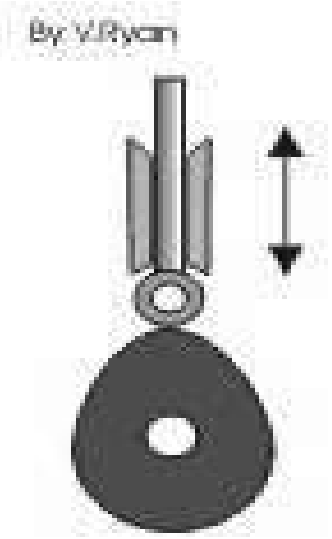
4 S

- As the cam rotates, the follower is made to rise, dwell and fall.
- The shape of the cam determines the length of time spent at each position.
- Rise section = drives the follower upward
- Fall section = drives the follower downward
- Dwell section = allows the follower remains at the same level (does not fall or rise)

The motion of the follower will depend on the shape of the cams and the type of follower used.



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- The shape of the cam is called the PROFILE
- Example of cam profiles

a) Pear-shaped cams are used on the shafts of cars. The follower remains motionless for about half of the cycle of the cam and during the second half, it rises and falls.

**5**



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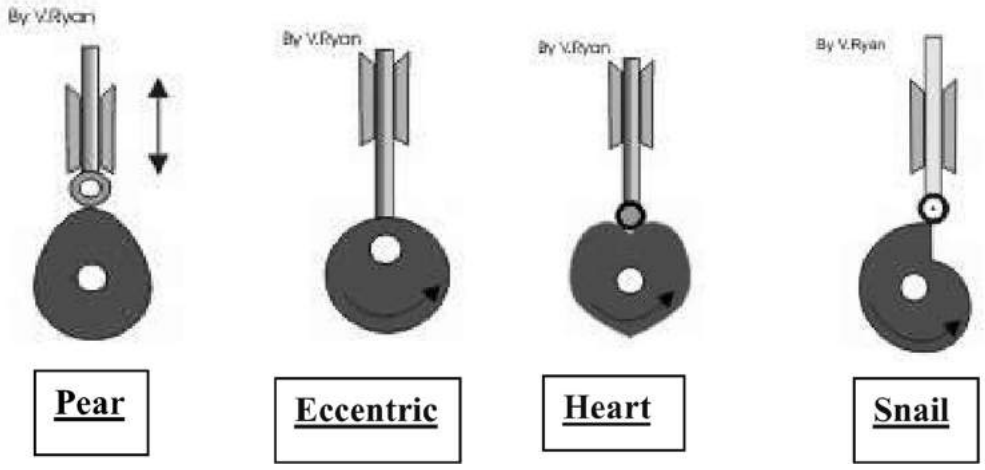
b) Circular cams or eccentric cams produce a smooth motion. These cams are used in steam engines

c) Heart-shaped cams allow the follower to rise and fall with 'uniform' velocity.

d) Snail/drop cams produce sudden drop or fall of the follower.



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**Crank and Slider**

- This mechanism is composed of three important parts:
- The crank which is the rotating disc, the slider which slides inside the tube, and the connecting rod which joins the parts together.
- As the slider moves to the right the connecting rod pushes the wheel around for the first 180 degrees of wheel rotation. When the slider begins to move back into the tube, the connecting rod pulls the wheelaround to complete the rotation.

**3.1.3 Gears**

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A gear is a rotating circular machine part having cut teeth or, in the case of a cogwheel or gearwheel, inserted teeth, which mesh with another toothed part to transmit torque and speed.

**Gear Drives**

**Gear drives**, sometimes referred to as gear trains and gearboxes, are mechanisms consisting of an assembly of gears, shafts, and other machine elements for mounting the rotating parts. They form a mechanical system used for transmitting shaft power from a driver such as an engine, turbine, or motor to a driven piece of machinery. Gear drives can alter the transmitted power by using different configurations of gears.

Gear drives can increase or decrease the rotational speed of the output shaft. A common use of gear drives is for reducing the speeds of motors and engines that typically run at thousands of revolutions per minute (rpm). These are known as speed reducers. By reducing the speed, torque is increased. This force amplification characteristic is one of the main functions of speed reducers.

Gears are the main components of gear drives. Gears are toothed rolling elements which mesh with one another by engaging their teeth. Because of the large dynamic forces involved, gears are made with alloyed steel. The properties of these metals are also modified by heat treatment to reach the right toughness and rigidity required for their application.

Other components of gear drives are the shafts, keys, couplings, bearings, housing, and flanges. The shafts are the components that connect the gear drive with the input and output systems. Keys and couplings are used to lock the shafts of the driver and drive equipment onto the gear drive. Bearings are the machine elements that support the shafts while reducing friction. The housing



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and flanges are usually made monolithic. The housing encloses and supports the whole assembly while the flanges are used for mounting.



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**Functions of Gear Drives**

- Changing the Speed of Rotation
- Increasing or Decreasing the Output Torque
- Modifying the Axis of Rotation.
- Reversing the Direction of Rotation.

**Types of Gears**

1. **Spur Gear:**

Spur gears are the most extensively used gear type. They are cylindrical with straight teeth formed along the lateral surface of the cylinder. Spur gears can be external or internal. An external spur gear is considered the usual type that has teeth on its outside surface. On the other hand, an internal spur gear is a hollow cylinder with teeth cut on its inner lateral surface.


**8**



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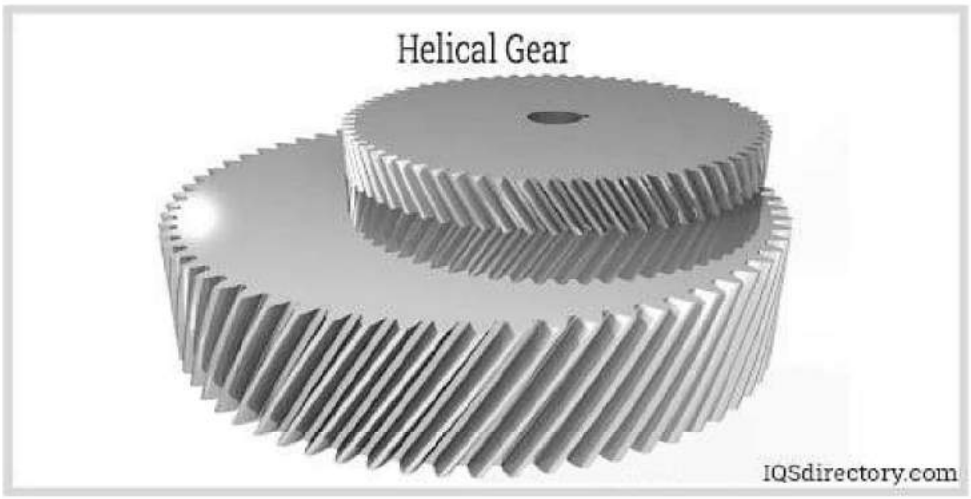
## 2. Helical Gear:

This type of gear has a cylindrical form similar to spur gears. The difference is their teeth which are cut in a spiral wrapping around the cylinder. Helical gears are




used because of their smooth and quieter operation. They are also stronger and have a longer lifespan than spur gears with similar ratings. However, the downside of using helical gears is the larger thrust load imposed on the supporting bearings.

**9**



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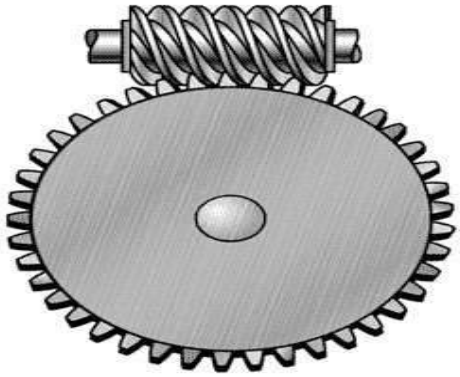
### 3. Worm:

This type of gear must not be confused with worm gears which are defined as the driven gear in a worm gear drive. A worm operates similarly to crossed helical gears. Both of these gear types have drivers that operate through screw action. However, a worm is modified such that its teeth mesh with a larger contact area.

These gears are used to transmit motion and power between non-parallel, non-intersecting shafts. They offer large gear ratios and capabilities for substantial speed reduction while maintaining a quiet and smooth operation.



### 4. Bevel gears

Bevel gears are cone-shaped gears with teeth placed along the conical surface. These gears are used to transmit motion and power between intersecting shafts in applications that require changes to the axis of rotation. Typically, bevel

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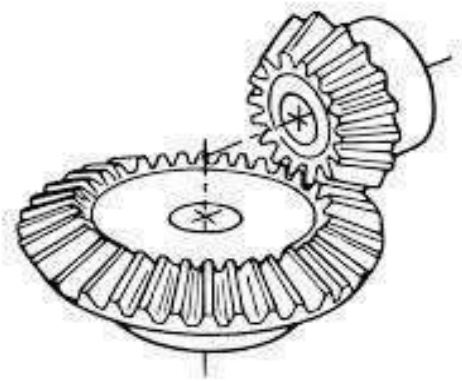
gears are employed for shaft configurations placed at 90-degree angles, but configurations with lesser or greater angles are also manageable.

There are several types of bevel gears available differentiated mainly by their tooth design. Some of the more common types of bevel gears include straight, spiral, and Zerol bevel gears.





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**Common Gear Drives**

**Parallel Gear Drives:**

Parallel gear drives use gear sets that transmit power through shafts with parallel axes. Spur, helical, and herringbone gears are used for this type of gear drive. Parallel gear drives are the most common and extensively used in industries involving mechanical equipment.

Parallel gear drives have higher power transmission efficiency than other configurations. They are also easier to manufacture. On the other hand, parallel gear drives use large output gears for attaining high-speed ratios. Thus, they are not suitable for compact applications. To reduce the size of the driven gear, multiple gear stages are employed.

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Multiple stages are used to create higher speed r[c]duction. These are attained using compound gears. A compound gear is composed of two or more concentric gears placed next to each other. These adjacent gears have a different number of teeth. Since these gears are coupled by a single shaft and have different pitch diameters, they have the same angular speed but different linear speeds.

**Worm Gear Drives:**

Worm gears are devices that transmit power through non-intersecting, non-parallel shafts. They are primarily used for high-speed reduction. Various mechanical equipment uses worm gears such as gates, conveyors, and elevators. Then again, the applications that make the most out of their unique characteristic are tuning and indexing mechanisms which require high-precision adjustments.

Worm gear drives have two main components: the screw and the wheel. The screw, or worm, is the driver gear while the wheel, or worm gear, is the driven gear. Rotating the screw by 360° turns the wheel by the number of worm threads. Worms with more than one thread are called multi-start worms. The speed reduction ratio is equal to the number of teeth of the driven gear divided by the number of worm threads.

**Planetary Gear Drives:**

Planetary gear drives or planetary gearboxes are an assembly of internal and external gears that can achieve multiple speed reduction ratios. By using internal gears, they are much more compact than gearboxes using external gears

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such as parallel and inline gear drives. This i don by locking one component, either the sun, planet, or annular gear.

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**Advantages of Gear drive**

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A belt drive is shown in the figure. It consists of two pulleys over which an endless belt it passed over them. The mechanical power or rotary motion is transmitted from the driving pulley to the driven pulley because of the frictional grip that exists between the belt and the pulley surface.

The portion of the belt which is having less tension is called the slack side and the one which has higher tension is called the tight side. The effective pulling power of the belt that causes the rotation of the driven pulley is the difference in tension on the slack and tight sides.

Sometimes in a belt drive, there is always a possibility of some slipping taking place between the belt and the pulleys which causes the driven pulley to rotate at a lesser speed, consequently reducing the power transmission. Hence belt drives are said to be not a Positive type of power transmission system.

**Types of Belts**

There are four commonly used types of belts are:

1. Flat belt
2. V belt
3. Circular

Flat belt:

This belt has a rectangular cross-section. These belts are capable of transmitting power over long distances between pulley centers. The efficiency of this drive is around 98% and produces little noise.

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V-belts:

v-belts are also used with grooved pulleys, V-belts are trapezoidal in cross-section. These belts permit a large speed ratio and can transmit higher power. Multiple drives are possible.

Circular:

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This type of belt has a circular cross-section and is used with grooved pulleys.

**Types of Belt Drives**

The following are the 5 main types of Belt Drives:

1. Open belt drive.
2. Crossbelt drive.
3. Stepped cone pulley or speed cone drive.
4. Fast and loose pulleys.
5. Jockey pulley drive.



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7



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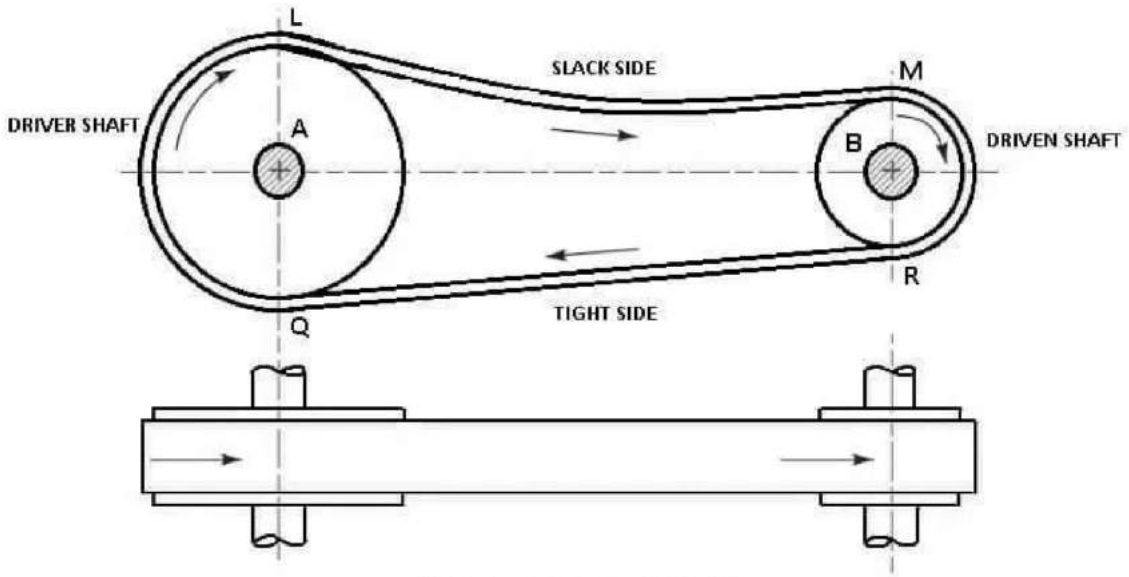
## 1. Open Belt Drive

- In these types of belt drive, the belt is employed when the two parallel shafts have to rotate in the same direction.
- When the shafts are far apart, the lower side of the belt should be the tight side and the upper side must be the slack side.
- This is because, when the upper side becomes the slack side, it will sag due to its weight and thus increase the arc of contact.




OPEN BELT DRIVE



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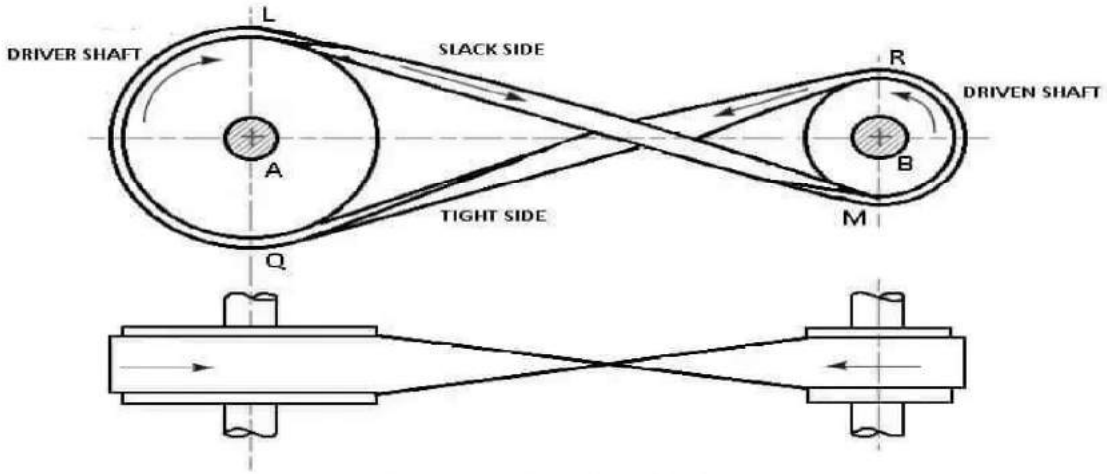
. **Cross Belt Drive**

- In These types of belt drives, the belt is employed when two parallel shafts have to rotate in the opposite direction. At the junction where the belts cross, it rubs against itself and wears off.

- To avoid excessive wear, the shafts must be placed at a maximum distance from each other and operated at very low speeds.




CROSS BELT DRIVE

**3.Stepped Cone Pulley or Speed Cone Drive**

A stepped cone pulley also known as a speed cone is shown in fig.



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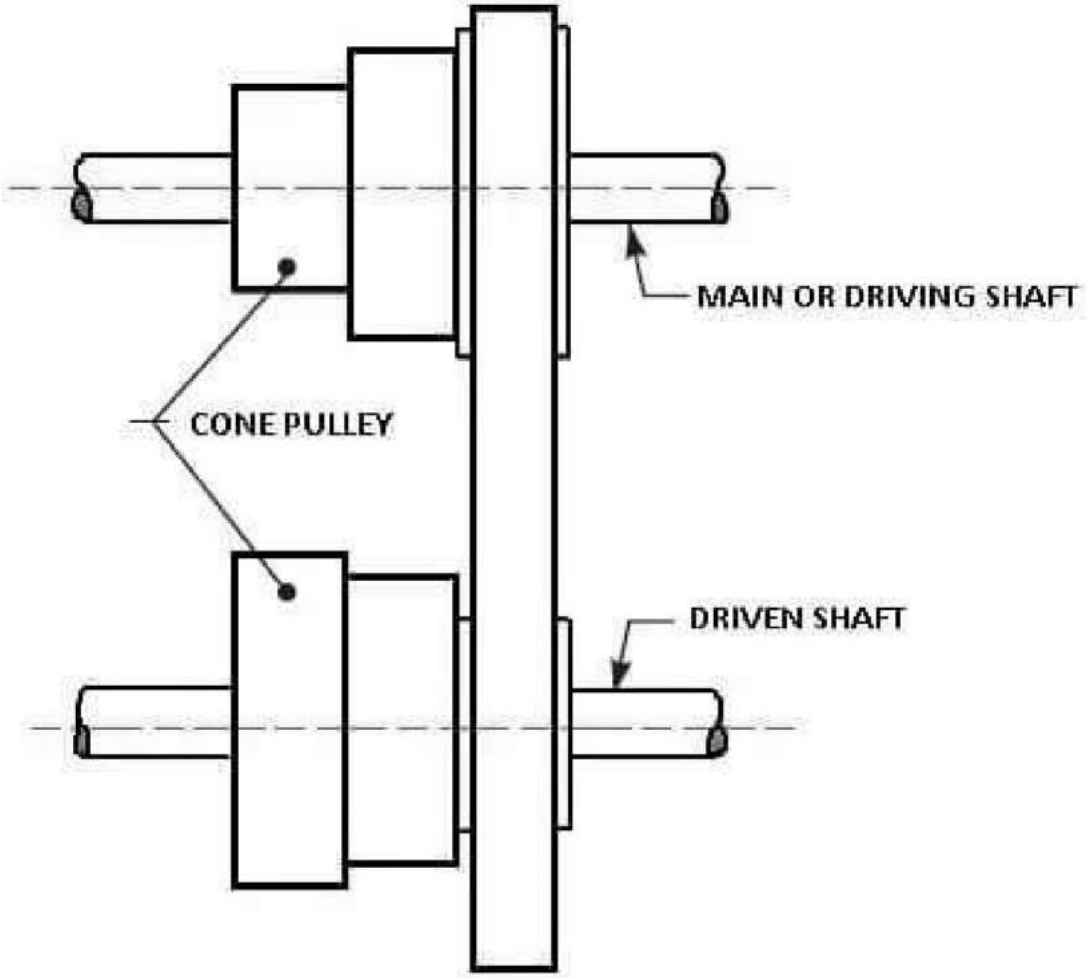


# STEPPED OR SPEED CONE PULLEY

- This type of belt driveis used when the speed of the driven shaft is to be changed very frequently as in the case of machine tools such as lathes, machines, etc.
- A stepped cone pulley is an integral casting having three or several pulleys of different sizes one adjacent to the other as shown in fig.
- One set of stepped cone pulleys is mounted in reverse on the driven shaft. An endless belt will be wrapped around one pair of pulleys.



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- By shifting the be t from one pair of pulleys to the other, the speed of the driven shaft can be varied.
- The diameter of the driving and driven pulleys is such that the same belt will operate when shifted on different pairs of pulleys.

**4. Fast and Loose Pulley Drive**

- These types of belt drives are used when the driven or machine shaft is to be started or stopped whenever desired without interfering with the driving shaft.
- A pulley that is keyed to the machine shaft is called a fast pulley and runs at the same speed as that of the machine shaft.
- A loose pulley runs freely over the machine shaft and is incapable of transmitting any power.
- When the driven shaft is required to be stopped, the belt is pushed onto the loose pulley using a sliding bar having belt forks.



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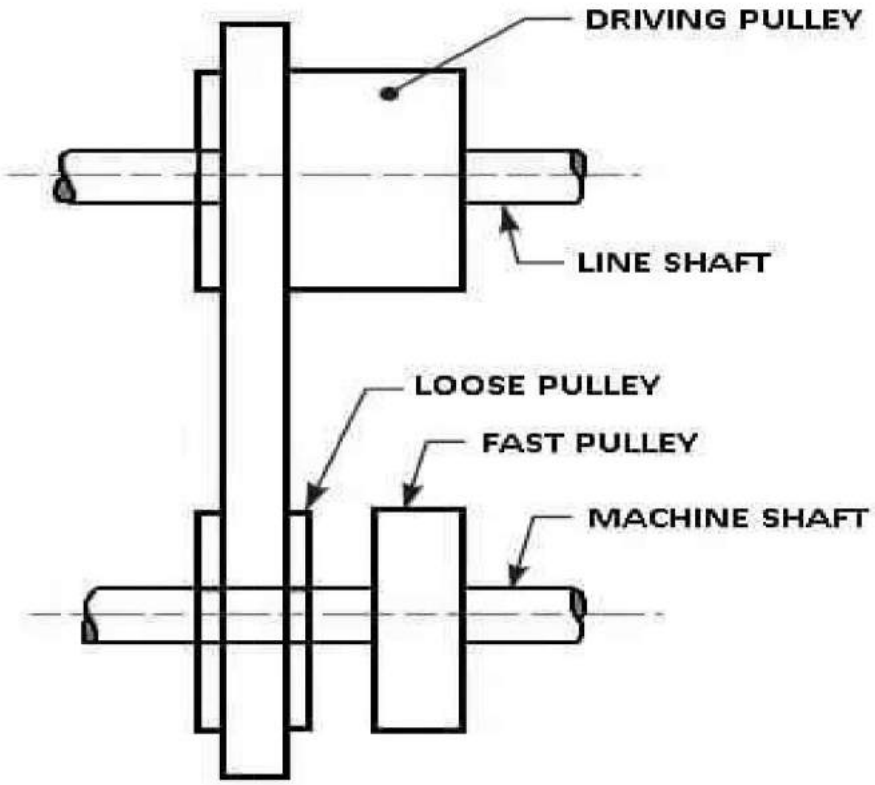
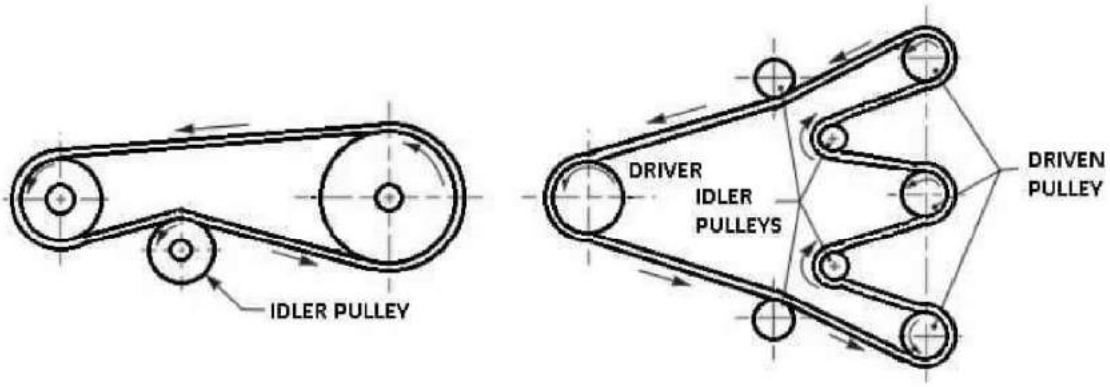



FAST AND LOOSE PULLEY DRIVE

**5. Jockey Pulley Drive**




JOCKEY PULLEY DRIVE

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- In an open belt drive arrangement, if the center distance is small, or if the driven pulleys are very small, then the arc of contact of the belt with the driven pulley will be very small, which reduces the tensions in the belt, or if the required tension of the belt cannot be obtained by other means, an idler pulley, called jockey pulley is placed on the slack side of the belt as shown in fig.
- Which increases the arc of contact and thus the tension which results in increased power transmission.

**Advantages of belt drive**

- They are simple and economical.
- They can transmit Power over a considerable distance.
- They can protect the machine from overloading by slipping the belt over a pulley.
- Belt drive can absorb shock and damp vibration.
- The operation is smooth and silent.
- They are durable and require very little maintenance.

**The disadvantage of belt drive**

- Limited Speed range.
- They are not compact.
- Considerable power loss.
- Short service life compared to other modesof power transmission.
- The velocity ratio may vary due to belt slip
- They inflict a heavy load on shafts and bearings

### 3.1.5 Bearing



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A bearing is a machine element that constrains relative motion to only the desired motion and reduces friction between moving parts.

Generally, all types of machinery are provided with supports for rotating shafts. The supporting device is known as a **bearing**. In other words, a **bearing is a machine element** that constrains relative motions and is used to reduce friction between moving parts.

Bearing employs to support, guide, and restrain moving the element. This is a stationary member, and it carries the load.

The part of the shaft supported by the **bearing is known as the journal,** which is a moving member.

The common applications of bearings are:

1. Shafting in workshops,
2. Spindles of a machine tool such as a lathe, drilling, milling machine, etc.
3. The crankshaft of engines, axles of automobiles, etc.

**Types of Bearings**

**1. Ball Bearings:**

The ball bearing is the most common type of bearing. It consists of small **metal balls** that are located between two metal rings which are known as **Races**. Balls are also kept in position using an assembly called **Cage**.

Since sliding friction is very high compared to rolling friction ball bearing provides less energy loss.



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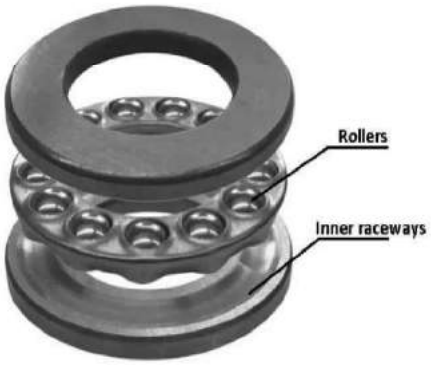
The inner Races and bal s are free to rotate, and the outer races are stationary.

The shaft is fitted inside the inner race and the outer race is fixed to a motor.

**2.Thrust Bearings**

**In thrust bearing**, the bearing pressure will be axial. The axis of the shaft may vertical or horizontal. If the axis of the shaft is vertical, the thrust bearing is known as the **footstep bearing**.

If the axis of the shaft is horizontal, the thrust bearing is known as a roller bearing.



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### 3.Roller Bearing

The roller bearings are intended to maintain accurate alignment of every part over a long period and can carry a heavy momentary load.

This renders them suitable for machinery which requires frequent starts and stops.

The rolling action of the bearings makes line contact with their races while the balls make point contact.

It has a higher load-carrying capacity. This bearing includes cylindrical rolling elements instead of balls as load-carrying between races.

### 4.Cylindrical Roller Bearing

These are roller bearings in which tiny cylinders are used as rolling elements instead of balls in ball bearings.

It utilizes line contact between the rolling elements and the raceway, which optimizes the distribution of stress factors at the point of contact.

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This contract means that the radial load rating of cylindrical roller bearings is very high. Depending on the structure, they can also transmit a limited amount of axial load.

Cylindrical roller bearings are used in mining, power generation, transmission, and metal recycling applications.

**5.Tapered Roller Bearing**

These roller bearings are designed to support axial and radial forces.

Tapered roller bearings are made of tapered raceways in the inner and outer rings with conical rollers.

Due to the contact angle, tapered roller bearings can handle high radial and axial forces in one direction.

Tapered roller bearings can provide low friction, long service life, and enhanced operational reliability.

Tapered roller bearings are commonly used in gearboxes, hoisting equipment, rolling mills, and machines in the mining industry.



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## 6.Needle Roller Bearing

A needle roller bearing consists of long, thin cylindrical rollers shaped like needles.

Standard roller bearings have rollers slightly longer than their diameter, but needle bearings typically have rollers at least four times longer than their diameter.

These bearings have high load ratings and are only

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suitable for radial forces.

If space is limited, needle bearings can be an excellent option. They are used heavily in automobile components such as rocker arm pivots, pumps,

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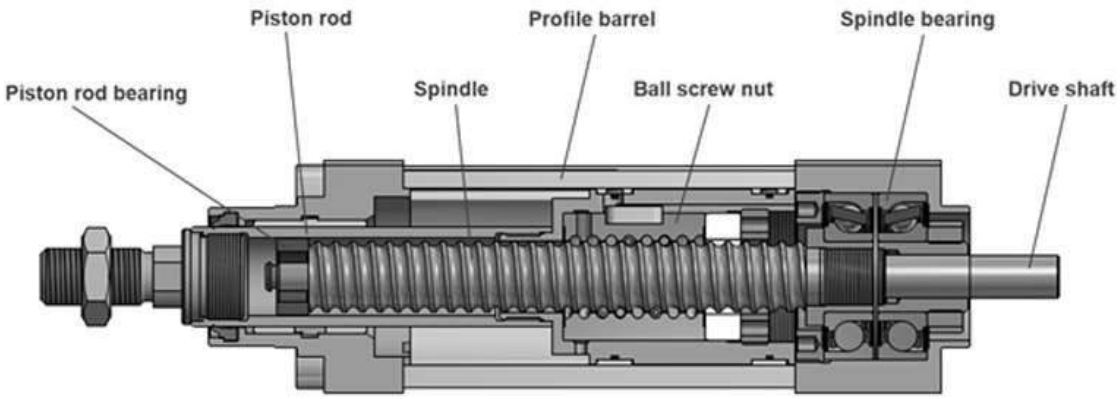




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An electric motor will create rotary motion as the spindle, or rotor rotates. The motor spindle is directly coupled to a helical screw, via the drive shaft, which in turn rotates in a ball screw nut.

As the spindle rotates the ball screw nut is driven forwards, or backward, along the helical screw.

A hollow piston rod is attached to the ball screw nut and this creates the linear motion out of, or into the linear actuator as the motor rotates clockwise or anti-clockwise.

The motor is controlled by an electric drive, which allows the rotation speed to be varied and, hence, the linear speed of the actuator.

A feedback mechanism gives positional information and the linear actuator can be programmed to move to a certain position, stop and then move on, or return to its rest position.

The power of the motor will determine the torque that can be generated and hence the force that can be put to useful motion through the actuator.

### 3.2.1 Switches and Relay

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A switch actuator is a mechanical component on a switch used to manually turn a circuit on and off. Switch actuators can also serve to visually indicate whether a circuit is ON or OFF.

The switch is an electrical device that is used to break or make an electrical circuit manually or automatically.

Pole

The pole within the switch is the controller. Generally, we use a single pole or double pole to explain how many separate circuits are controlled through the switch.

Throw

When the circuit is controlled through the pole then it is called a throw. Generally, we use single or double throw to explain how many different circuits will be controlled through a single Pole.

**Open**

If the pole is detached by a single throw, then the condition of this throw is known as an open or open state.

Close

If the pole is attached to a single throw, then the condition of this throw is known as the close or close state.

**Connections**

SPDT has three connections which are normally open, normally closed& common.



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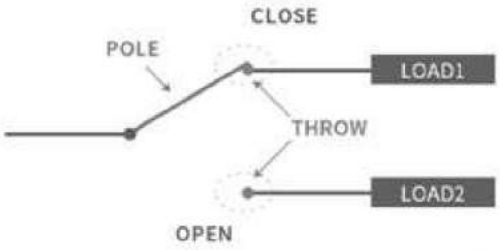


**Normally Open (NO)**

If the pole is detached from the throw circuit by default, then the circuit is called a NO circuit or N/O circuit. Similarly, the switch is known as the NO switch or N/O switch.

**Normally Closed (NC)**

If the pole is connected to the throw by default, then it is called an NC circuit or normally a closed circuit. Similarly, the switch is known as an NC switch or N/C switch,



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**The Common**

The common connection allows the flow of current to make the circuit either with the normally closed (NC) or the normally open (NO) contacts.

**Types of Switches**

The types of switches are classified into four types namely:

- SPST (Single Pole Single throw)
- SPDT (single pole double throw)
- DPST (double pole, single throw)

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- DPDT (double pole double throw)

**SPST (Single Pole Single Throw)**

The SPST is a basic ON/OFF switch, that is used to connect or break the connection between two terminals. The power supply for the owl circuit is given by this switch. A simple PST switch is shown below.




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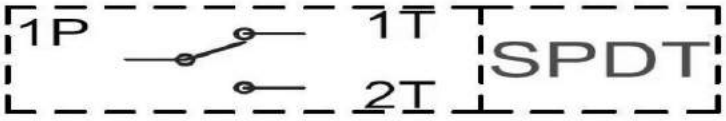
**SPDT (Single Pole Double Throw)**

The SPDT switch is a three-terminal switch, one terminal is used as input, and the remaining two terminals are used as outputs. It joins a mutual terminal to one or the other of two terminals. In the SPDT switch, instead of other terminals, just use the COM terminal. For example, we can use COM & A or COM & B.

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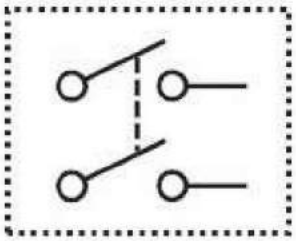
**DPST (Double Pole, Single Throw)**

The DPST switch consists of two poles which means it includes two identical switches located side by side. This switch is operated by one single toggle, which means that two discrete circuits are controlled at a time through one push.



**Symbol**

**DPST Switch**



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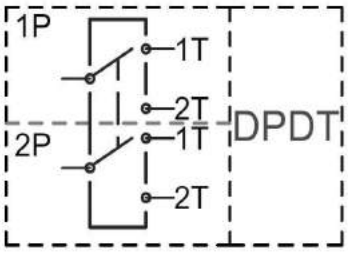
**DPDT (Double Pole Double Throw)**

This switch is equal to two SPDT switches, which means two separate circuits, connecting two inputs of each circuit to one of two outputs. The switch position controls the number of ways and from the two contacts, each contact can be routed.

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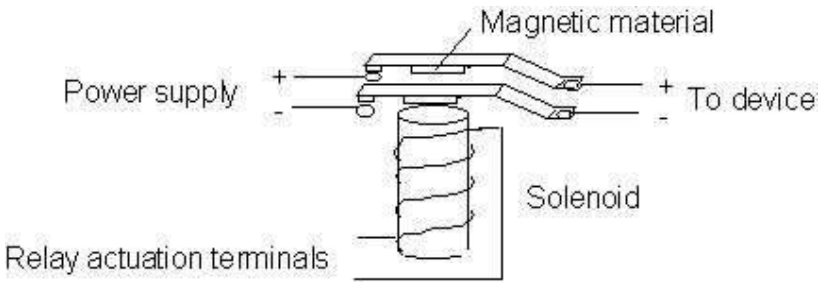
**Relays**

Relays are switches, which are turned on/off by the application of a low voltage across the relay terminals. They are universally found in automatic control applications since they can control equipment directly through electric signals instead of requiring a physical operation.

Relays may be Normally Open or Normally Closed.

The contacts are connected only when the actuation terminals are energized. In Normally Closed relays, the device is connected to the power supply when the relay actuation terminals are not connected. Relays with high current capacity (over 40Amps) are called contactors.




### 3.2.2 Solenoid Actuators

A solenoid actuator is a control device that uses electromagnetism to convert electrical energy into mechanical motion.

The movement of the solenoid may be used to close a set of electrical contacts, cause the movement of a mechanical device, or both at the same time.



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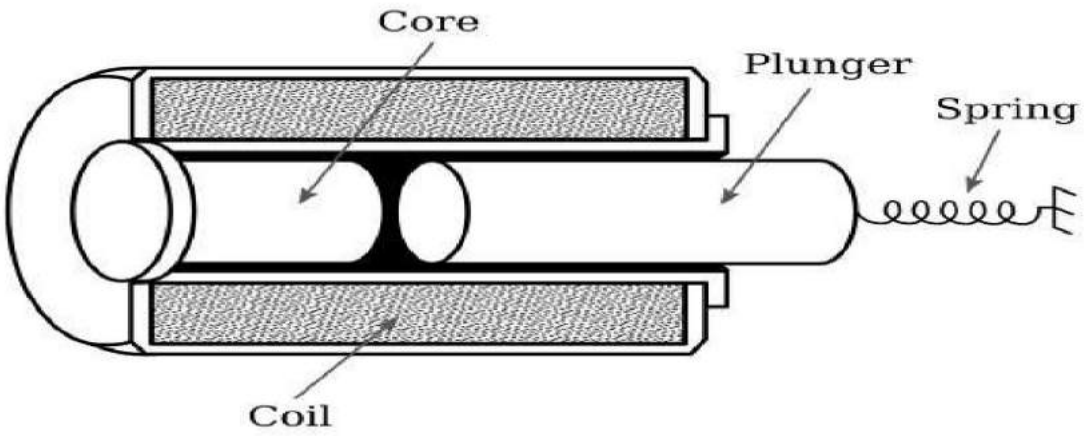


A solenoid is an electromagnet formed by a conductor wound in a series of loops in the shape of a spiral.

Inserted within this coil are a soft-iron core and a movable plunger.

The soft-iron core is pinned or held in an immovable position. The movable plunger (also soft iron) is held away from the core by a spring when the solenoid is less energized.

When current flows through the conductor, it produces a magnetic field. The magnetic flux produced by the coil results in establishing north and south poles in both the core and the plunger.

The plunger is attracted along the lines of force to a position at the center of the coil.

The de-energized position of the plunger is partially out of the coil due to the action of the spring.

When voltage is applied, the current through the coil produces a magnetic field. This magnetic field draws the plunger within the coil, resulting in mechanical motion.

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When the coil is de-energized, the plunger returns to its normal position because of spring action.

The effective strength of the magnetic field on the plunger varies according to the distance between the plunger and the core.

For short distances, the strength of the field is strong; and as distances increase, the strength of the field drops off quite rapidly.

While a solenoid is a control device, the solenoid itself is energized by some other control device such as a switch or a relay.

One of the distinct advantages of the use of solenoids is that mechanical movement can be accomplished at a considerable distance from the control device.

The only link necessary between the control device and the solenoid is the electrical wiring for the coil current. The solenoid can have large contacts for the control of high currents. Therefore, the solenoid also provides a means of controlling high currents with a low current switch.

### 3.2.3 DC Motors

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through direct current and convert this energy into mechanical rotation.



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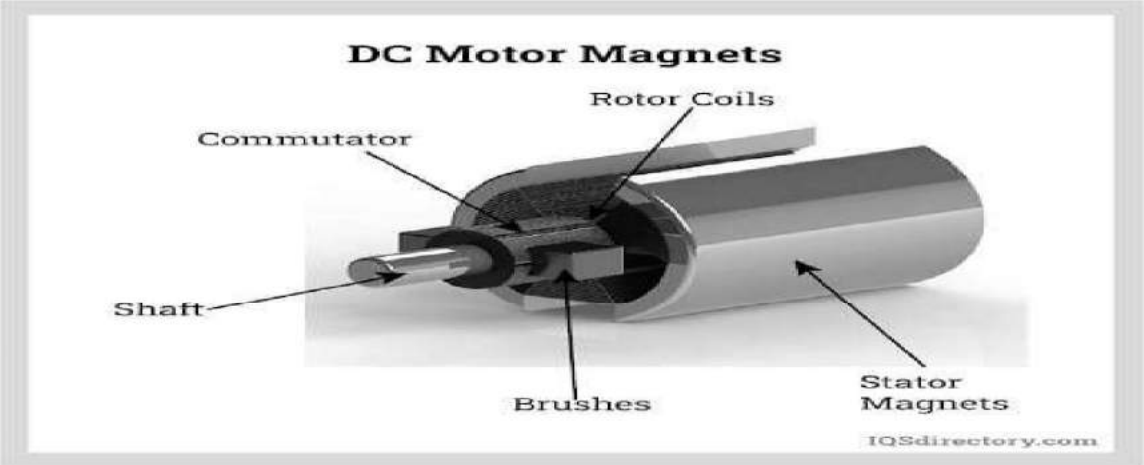


**Different Parts of a DC Motor**

A DC motor is composed of the following main parts:

**Armature or Rotor**

The armature of a DC motor is a cylinder of magnetic laminations that are insulated from one another. The armature is perpendicular to the axis of the cylinder. The armature is a rotating part that rotates on its axis and is separated from the field coil by an air gap.

**Field Coil or Stator**

A DC motor field coil is a non-moving part on which winding is wound to produce a magnetic field. This electro-magnet has a cylindrical cavity between its poles.

Commutator

The commutator of a DC motor is a cylindrical structure that is made of copper segments stacked together but insulated from each other using mica. The



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primary function of a commutator is to supply electrical current to the armature winding.

Brushes

The brushes of a DC motor are made with graphite and carbon structure. These brushes conduct electric current from the external circuit to the rotating commutator. Hence, we come to understand that the commutator and the brush unit are concerned with transmitting the power from the static electrical circuit to the mechanically rotating region or the rotor.

**Types of DC motor**

- Self-Excited DC Motor
- Separately Excited DC Motor

**Self-Excited DC Motor**

In self-excited DC motors, the field winding is connected either in series or parallel to the armature winding. Based on this, the self-excited DC motor can further be classified as:

- Shunt wound DC motor
- Series wound DC motor
- Compound wound DC motor



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| Type of Motor | Characteristics | Applications |
|---|---|---|
| Shunt | Speed is fairly constant and medium starting torque. | 1. Blowers and fans<br>2. Centrifugal and reciprocating pumps<br>3. Lathe machines<br>4. Machine tools<br>5. Milling machines<br>6. Drilling machines |
| Series | High starting torque.<br>No load condition is dangerous.<br>Variable speed. | 1. Cranes<br>2. Hoists, Elevators<br>3. Trolleys<br>4. Conveyors<br>5. Electric locomotives |
| Cumulative compound | High starting torque.<br>No load condition is allowed. | 1. Rolling mills<br>2. Punches<br>3. Shears<br>4. Heavy planers<br>5. Elevators |
| Differential compound | Speed increases as load increases. | Not suitable for any practical applications |

### 3.2.4 AC Motors

An AC motor is an electric motor driven by an alternating current The AC motor commonly consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft producing a second rotating magnetic field. The rotor magnetic field may be produced d by permanent magnets, reluctance saliency, or DC or AC electrical winding.

When an AC motor is in steady-state rotation, the magnetic fields of the rotor and stator rotate with little or no slippage. The magnetic forces between the rotor and stator poles create average torque, capable of driving a load at rated speed.

The speed of the stator rotating magnetic field and the speed of the rotorrotating magnetic field, relative to the speed of the mechanical shaft, must maintain synchronism for average torque production.

**The two main types of AC motors are classified as induction and synchronous.**

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**The Induction Motor**

always relies on a small difference in speed between the stator rotating magnetic field and the rotor shaft speed called slip to induce rotor current in the rotor AC winding. As a result, the induction motor cannot produce torque near synchronous speed where induction (or slip) is irrelevant or ceases to exist.

**Synchronous Motor**

The main function of a synchronous motor is to change the AC electrical energy into mechanical energy. This kind of motor works simply at a synchronous speed.

The synchronous motor working principle is, once the power supply is provided to the synchronous motor, and then a rotating field can be formed. So this field seeks to drag the rotor through it, although could not perform due to the inactivity of the rotor. Therefore, no starting torque can be generated. So basically this is not a self-starting motor.

**The advantages of ac motors include the following.**

- Design is easy & simple
- The power factor is good
- Inexpensive
- An AC source can be directly connected to this motor
- Good power-to-weight ratio
- Maintenance is less

**The disadvantages of ac motors include the following.**

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- The starting torque of this motor is very less
- At low speeds, it won't operate
- Poor positioning control
- Limited speed through the frequency supply

**The applications of ac motors include the following.**

- They are appropriate for projects wherever constant motion & permanent speed are not necessary.
- They are not appropriate for applications that need very fewer speeds.
- These motors are a very good choice for applications that need high performance & torque o/p.
- These motors are used in power tools, clocks, disk drives, fans, blowers, pumps, compressors, conveyors, audio turntables, home appliances, washing machines & industrial areas.

### 3.2.5 Stepper Motors

A stepper motor is an electromechanical device that converts electrical pulses into discrete mechanical movements.

The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence.

The motor's rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shaft rotation.

The speed of the motor shaft's rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied.

Types of stepper motors

- Permanent magnet stepper
- Hybrid synchronous stepper

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- Variable reluctance stepper

**Permanent magnet motors**

It uses a permanent magnet (PM) in the rotor.

It operates on the attraction or repulsion between the rotor PM and the stator electromagnets.

**Hybrid Synchronous Stepper Motor**

Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in small package sizes.

**Variable Reluctance Stepper Motor**

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.

### 3.2.6 Control of Stepper Motor

Stepper motors operate differently from DC brush motors.

It rotates when voltage is applied to its terminals.

Stepper motors effectively have multiple toothed electromagnets arranged around a central gear-shaped piece of iron.

The electromagnets are energized by an external control circuit.

To make the motor shaft turn, the first electromagnet is given power.

It makes the gear's teeth magnetically attracted to the electromagnet's teeth.

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At the point when the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet.

When the next electromagnet is turned ON and the first is turned OFF. The gear rotates slightly to align with the next one and from there the process is repeated.

Each of those slight rotations is called a step, with an integer number of steps making a full rotation.

In that way, the motor can be turned by a precise, Stepper motor doesn't rotate continuously, they rotate in steps.

There are 4 coils with 90o angle between each other fixed on the stator.

The stepper motor connections are determined by the way the coils are interconnected.

In a stepper motor, the coils are not connected.

The motor has a 90-degree rotation step with the coils being energized in a cyclic order.Which determines the shaft rotation direction.

The coils are activated in series in 1-sec intervals.

The shaft rotates 90 degrees each time the next coil is activated.

Its low-speed torque will vary directly with the current.

Stepper Motor Control by Varying Clock Pulses. A Stepper motor control circuit is a simple and low-cost circuit, mainly used in low-power applications.



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- The feedback loop is not used.
- These motors produce extremely high noise.
- Not easy to operate extremely at high speeds.

**Applications Of Stepper Motor**

- Stepper motors are used as paper feed motors in typewriters and printers.
- These motors are used for positioning print heads, and pens in X-Y plotters.
- Stepper motors are used in machine tools.
- Printers
- CNC machines
- 3D printers
- Laser and optics
- Industrial machinery

### 3.2.7 Servo Motors

A Servo motor is a rotary actuator or linear actuator. It allows for precise control of angular or linear position, velocity, and acceleration.

It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller. Often a dedicated module is designed specifically for use with servo motors.

It is an electrical device that can push or rotate an object with great precision. If you want to rotate an object at some specific angles or distance, then you must use a servo motor. It is just a simple motor thatruns through a **servo mechanism**.

If the motor uses DC power as a supply, then it is the DC servo motor. If the motor uses AC power as a supply, then it is an AC servo motor.

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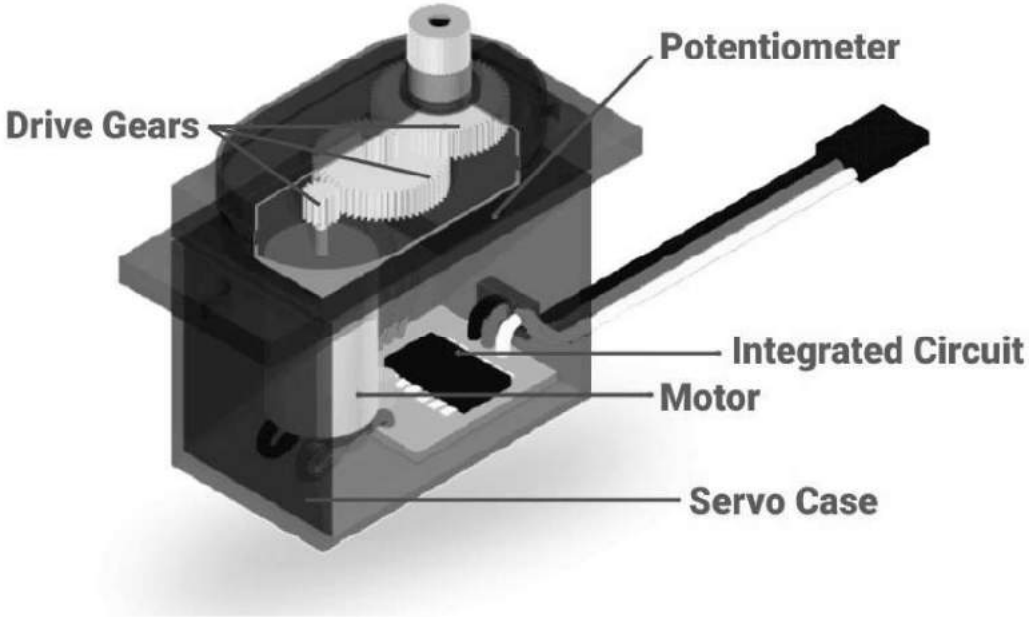
We can get a very high torque servo motor in a small and lightweight package. Due to these features, they use in many applications like toy cars, RC helicopters, planes, Robotics, Machines, etc.




This motor is a closed-loop mechanism that incorporates positional feedback to control the rotational or linear speed and position.

**This motor is an assembly of four things:**

- Normal DC motor- That is in charge of generating the motion through its shaft.
- Gear reduction unit/gearbox
- Potentiometer
- Control circuit

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The DC motor connects with a gear mechanism that provides feedback to a position sensor which is mostly a potentiometer.

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- Higher cost.
- When stopped, the motor's rotor continues to move back and forth one pulse. So, it is not suitable if you need to prevent vibration

**Applications of Servo Motor**

- Industries, used in machine tools, packaging, factory automation, material handling, printing converting, and assembly lines. In many other demanding applications robotics, CNC machinery, or automated manufacturing.
- uses radio-controlled airplanes to control the positioning and movement of elevators.
- In robots because of their smooth switching on and off and accurate positioning.
- In the aerospace industry to maintain hydraulic fluid in their hydraulic systems.
- uses many radio-controlled toys.
- used in electronic devices such as DVDs or Blu-ray Disc players to extend or replay the disc trays.
- used in automobiles to maintain the speed of vehicles



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## 4.0 Programmable Logic Controllers (PLC)

### 4.1 Introduction

PLC stands for Programmable Logic Controller.

A PLC is a computer specially designed to operate reliably under harsh industrial environments – such as extreme temperatures, wet, dry, and/or dusty conditions.

PLCs are used to automate industrial processes such as a manufacturing plant's assembly line, an ore processing plant, or a wastewater treatment plant.

A PLC candesign or improved digital computer that manages the electromechanical processes of an industrial environment.

PLCs vary in size and form factors. Some are small enough to fit in your pocket while others are large enough to require their own heavy-duty racks to mount.

Some PLCs can be customized with back planes and functional modules to fit different types of industrial applications.

PLCs are widely used in a variety of industries because they're fast, easy to operate and are considered easy to program.