Mechatronics
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Lecture - 08
Displacement, Position and Proximity Sensors – II

I welcome you all in today's lecture on Displacement, Position and Proximity Sensors part II. In the earlier lecture, we have seen this type of sensor; today I will be elaborating some more these type of sensors. First one is the optical encoder. It is a device actually that converts a linear or angular displacement into a sequence of pulses.

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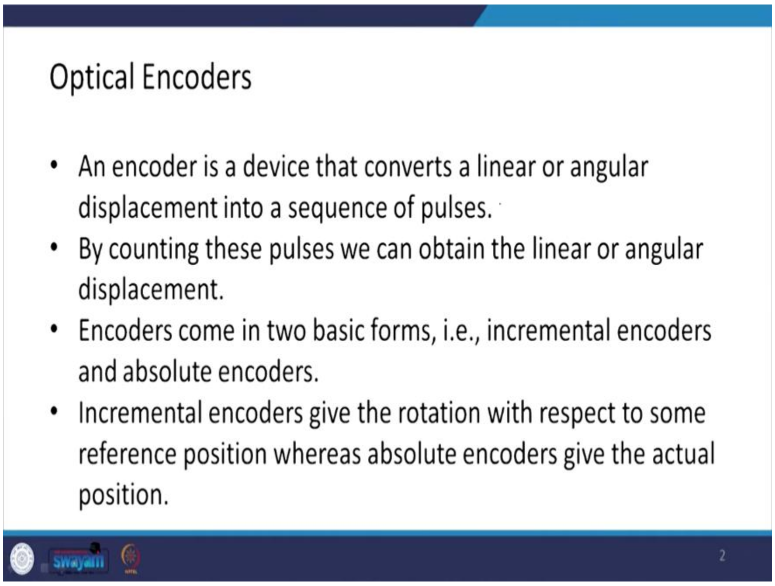

And by counting these pulses, we can obtain the amount of linear or angular displacement. And these optical encoders come in the two form, first is the incremental encoders and second is the absolute encoder.

As the name itself indicates, incremental encoder gives the rotation with respect to some reference position, whereas the absolute encoder gives the actual position.

Let us see the absolute encoder first. The absolute encoder is used for the measurement of angular displacement.

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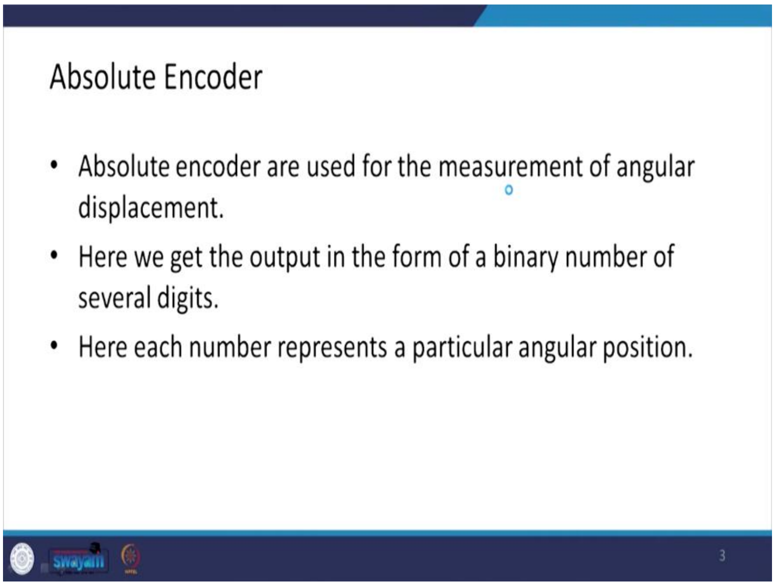

Or this is the one which I am going to talk about. Here we get output in the form of binary number of several digits and here each number actually represents a particular angular position and that is how we measure the angular displacement.

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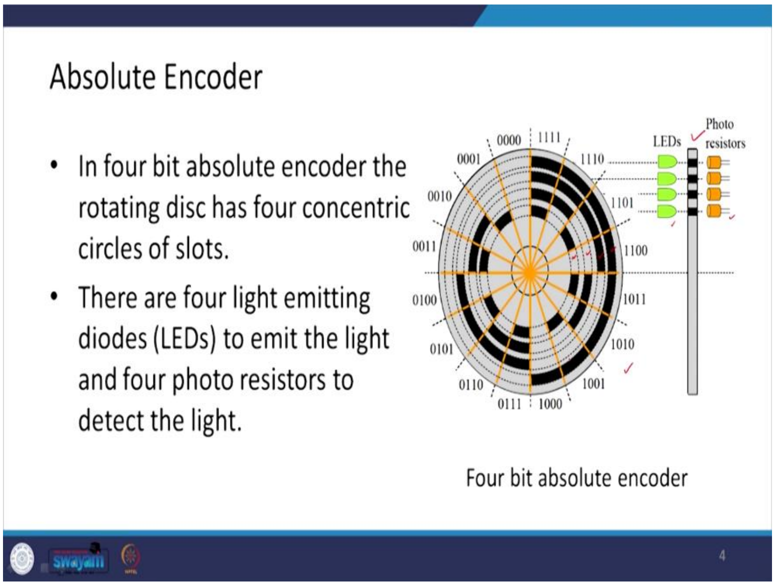

Here in the schematic, suppose there is a disc with holes are there indicated in the side view over here. There are four LEDs this side and there are four photo resistors to sense these LEDs light at the other side.

Now, in four-bit absolute encoder, the rotating disc has got four concentric circle as you can see, the first, second, third and fourth. These four concentric circles are having slots. And as I said there are four light emitting diodes or LEDs to emit the light and four photo resistors to detect the light. What these numberings are I will be talking about little later.

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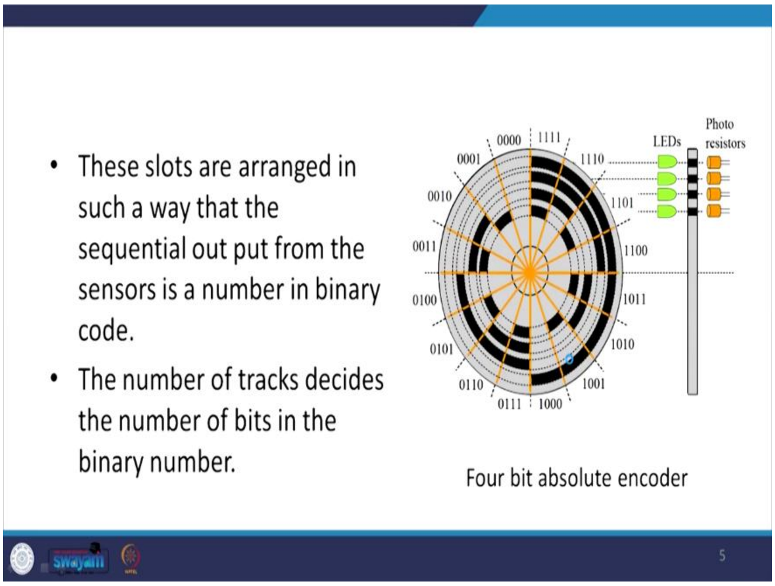

So, now these slots are arranged in such a way that the sequential output from the sensor is a number in the binary code and the number of tracks decide the number of bits in the binary code.

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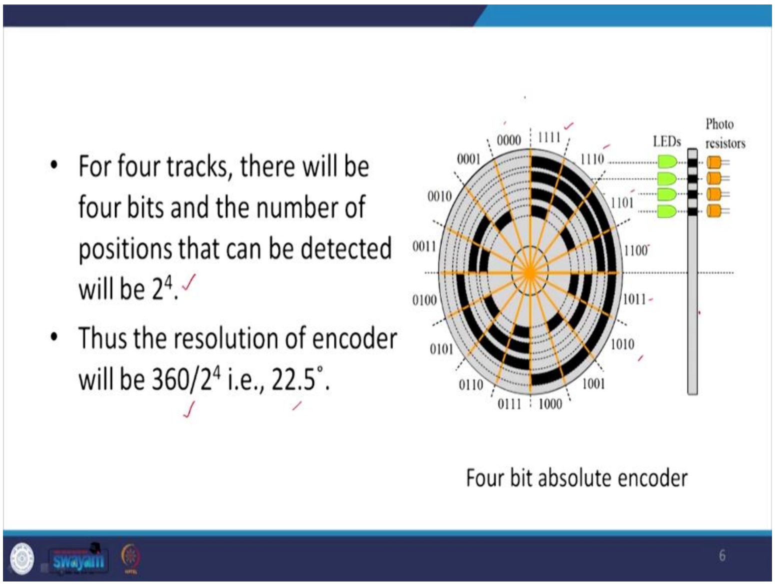

For example, in this one, you have 1111, then again 1110 and so on. For a four track as I was telling you, there will be four bits and the number of positions that can be detected will be 2 to the power 4 and this 2 to the power 4 positions will be around all these 360 degree.

The resolution of the encoder can be given by 360 divided by 2 to the power 4 that is 22.5 degree. We have is that these 2 to the power 4 number of positions are say this one 1, 2, 3, 4, 5, 6 to 16 over here.

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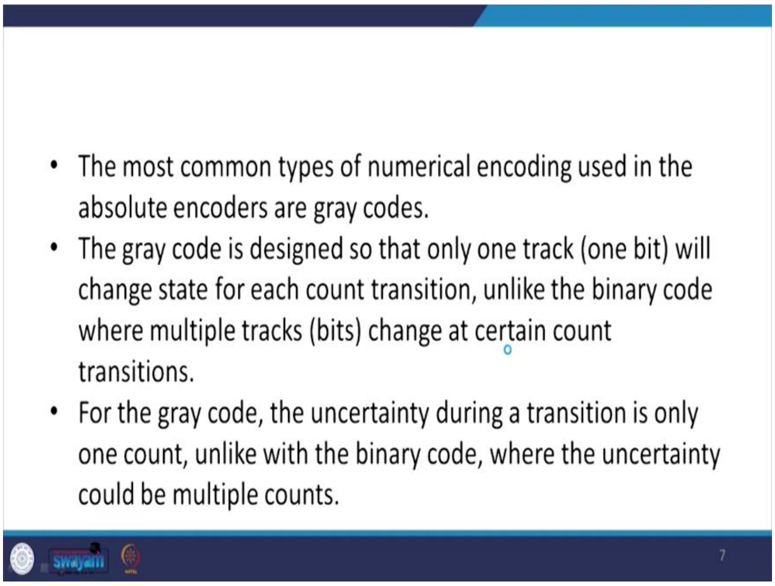

The most common type of numerical encoding used in the absolute encoders is gray codes. Now, before this, let me just explain this coding. So, here you see that there are four slots through which light passes and you had code 1111. The light is obstructed and light passes through these three. So, this is 1110 and similarly, this is 1101 and this is 1100.

So, likewise, we can have this binary representation for all these possible positions. Now, the most common type of numerical encoding is used in the absolute encoder are the gray codes.

Now, the gray code is designed so that only one track that is one bit will change the state of each count transition, unlike the binary code where multiple tracks change a certain count in the transition.

So, I will be talking about it a little later. Now, for the gray code, the uncertainty during a transition is only one count; because at a time only one binary digit changes, unlike in the binary code where the uncertainty could be the multiple counts. So, let us take this table.

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Decimal code	Rotation range (deg.)	Binary code	Gray code
0	0-22.5	0000	0000
1	22.5-45	0001	0001
2	45-67.5	0010	0011
3	67.5-90	0011	0010
4	90-112.5	0100	0110
5	112.5-135	0101	0111
6	135-157.5	0110	0101
7	15.75-180	0111	0100
8	180-202.5	1000	1100
9	202.5-225	1001	1101
10	225-247.5	1010	1111
11	247.5-270	1011	1110
12	270-292.5	1100	1010
13	292.5-315	1101	1011
14	315-337.5	1110	1001
15	337.5-360	1111	1000

So, for this, there are 16 positions see from 0 to 15, and the degree range which this absolute encoder measures that say 0 to 22.5 one, second is 22.5 to 45 and so on; the last one 337.5 to 360 degree. Now, in the binary code, let us look at the binary code for this say 0000 0001 0010. Now, here you see that the binary code there are two bit changes here; one is that is this 0 is tending to is changing to 1, whereas this 1 is tending is changing to 0.

Now, in the case of gray code what we do is that we change only one bit at a time. So, for example, here you see, this is 0001; so this 1 remains as it is, and from 0 to 1 there is only one change here and others are 0 0 only. So, this way in the gray code, there is only one bit change; whereas in the case of binary code, you may have more than one bit changes.

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Now, these are the commercially available optical rotary encoders. So, from the orange brand, you can see the rotary encoder and this is the incremental optical rotary encoder, whereas this one is an absolute rotary encoder. So, these are the commercially available encoders, which can be procured from the market.

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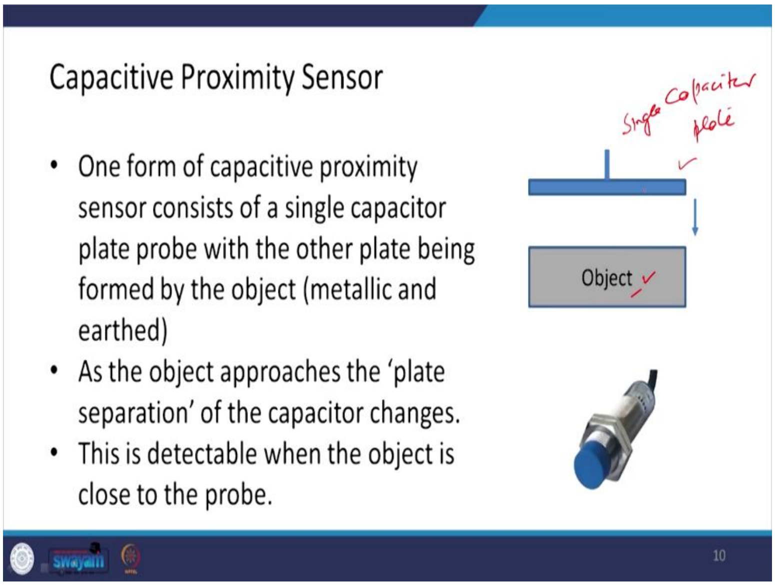

The next type of sensor is a capacitive proximity sensor. Now, one form of capacitive proximity sensor consists of a single capacitor plate probe with the other plate being formed by the object, which is metallic and earthed. So, if we look at this figure, the schematic is there just to explain you.

So, this is what we call the single capacitor plate. This is the single capacitor plate and this is the object. So, you can see based that based on the distance between them the capacitance will be changing and that is the indication of whether the object is near to this plate or not.

So, as the object approaches the plate, the separation of the capacitor changes and this is detectable when the object is close to the probe.

And this is how it looks like. In the market, you will get this capacitive proximity sensor in this form.

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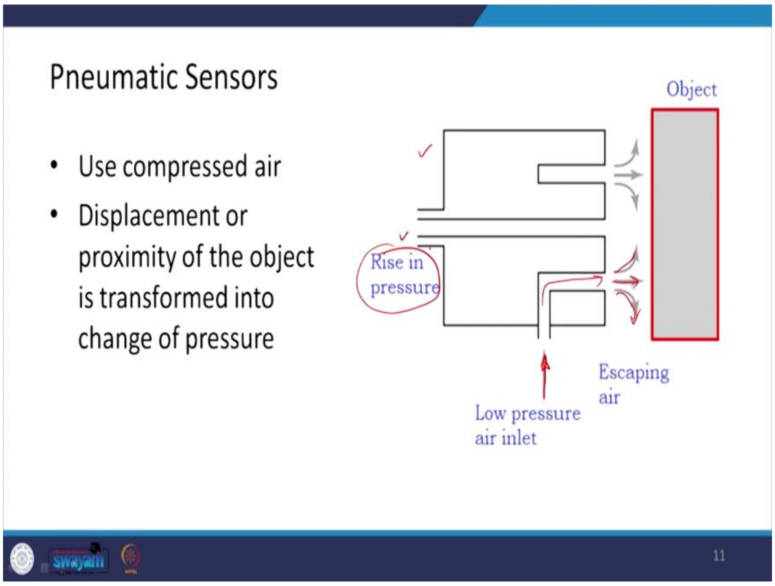

Next, let us look at the pneumatic proximity sensors. As the name indicates pneumatic proximity sensor uses compressed air and the displacement or proximity of the object is transformed into the change of pressure. Suppose this is my pneumatic sensor and here is a low-pressure air being supplied from, this pressure goes here and you have an object, alright. When the object is closer to this sensor then high pressure will be formed and you will be noticing the rise in pressure value here. So, this rise in pressure value is an indication of some object has come near to the sensor and this is how the proximity is identified.

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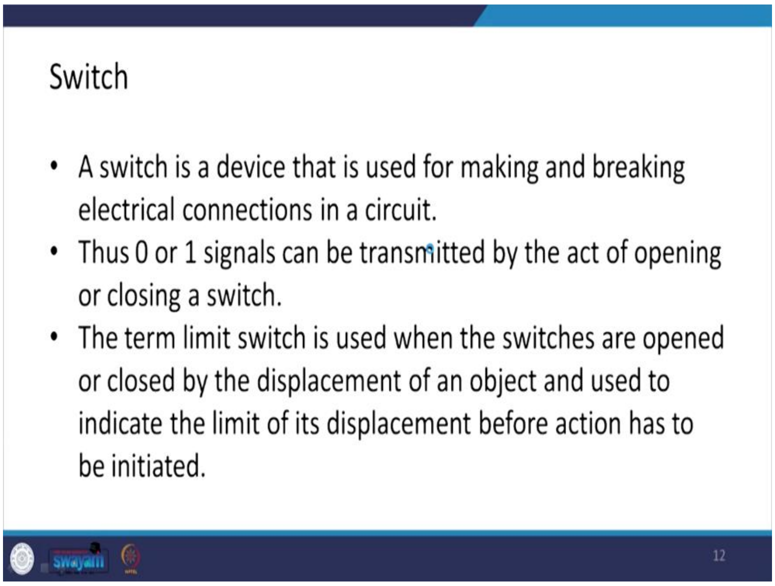

Another form of proximity sensors are switches and switches are in fact very cheap sensors. These switches are very similar to what we use in our house electrical connections. A switch is a device that is used for making and breaking the electrical connection in a circuit.

So, 0 or 1 signal can be transmitted by the act of opening or closing of the switch. So, if the switch is opened; so it is 0 and if the switch is closed, it is 1.

Now, the term limit switch is used when the switches are opened or closed by the displacement of an object and used to indicate the limit of its displacement before action has to be initiated. So, as the name indicates, the limit switches are used to indicate the limits of displacement.

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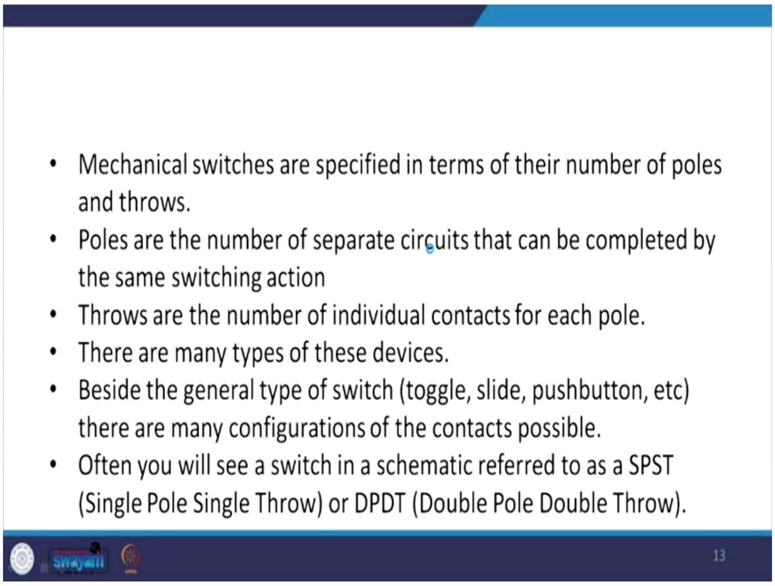

Now, coming back to the mechanical switches, the mechanical switches are specified in terms of their number of poles and throws. Now, you may be interested in knowing what are these poles and throws. So, basically, the poles are the number of the separate circuit that can be completed by the same switching action and throws are the number of individual contacts in each pole. There are many types of these devices and besides the general type of switch, which is say toggle type or slide type, or push-button type; there are many configurations of the contacts which are possible.

Often you will see a switch in a schematic figure being referred to as SPST or DPDT. The SPST basically means that it is a single-pole, single-throw; whereas the DPDT means that, double pole and double throw. The schematic is here.

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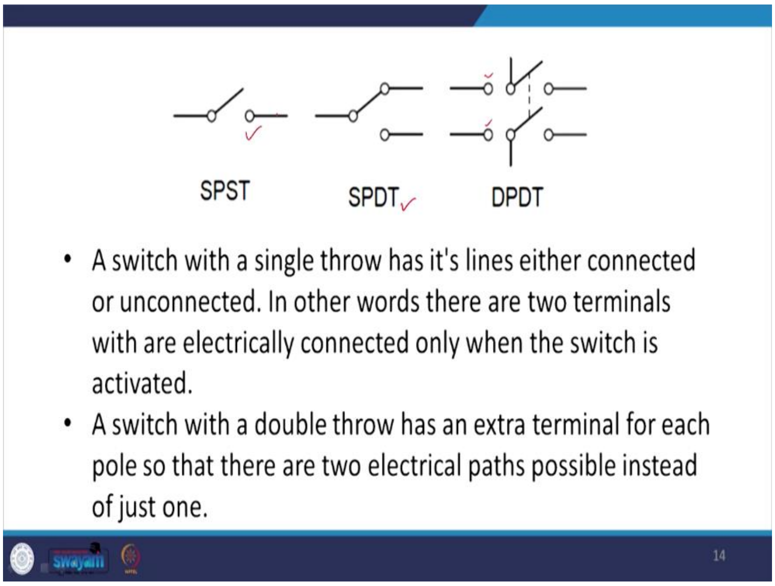

Here you can see that you have the single pole and the single throw, and here you have the single pole and double throw. There are two types of configurations that are possible in the double throw and here you have the double pole and double throw. With each the two configurations are possible.

So, a switch with a single throw has its line either connected or unconnected here as we can see. In other words, there is two terminals with are electrically connected only when the switch is activated, which are electrically connected only when the switch is activated. And a switch with a double throw has an extra terminal for each pole so that there are two electrical paths possible instead of just one.

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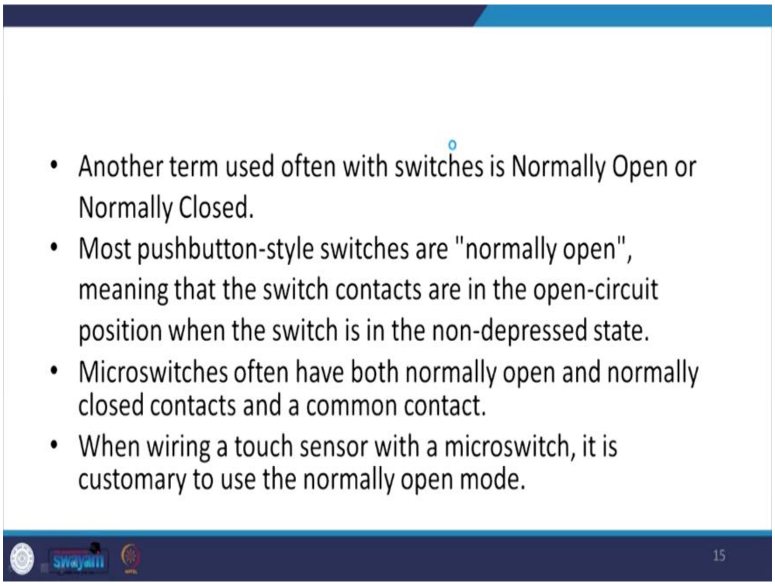

Now, another term which is often used in case of switches is normally open or normally closed. Most push button style switches are normally open it means that the switch contacts are in the open circuit position and the switch is in the non depressed state.

Now, micro switches are often have normally open, normally closed contacts and a common contact. While wiring a touch sensor with a micro switch, it is customary to use the normally open mode.

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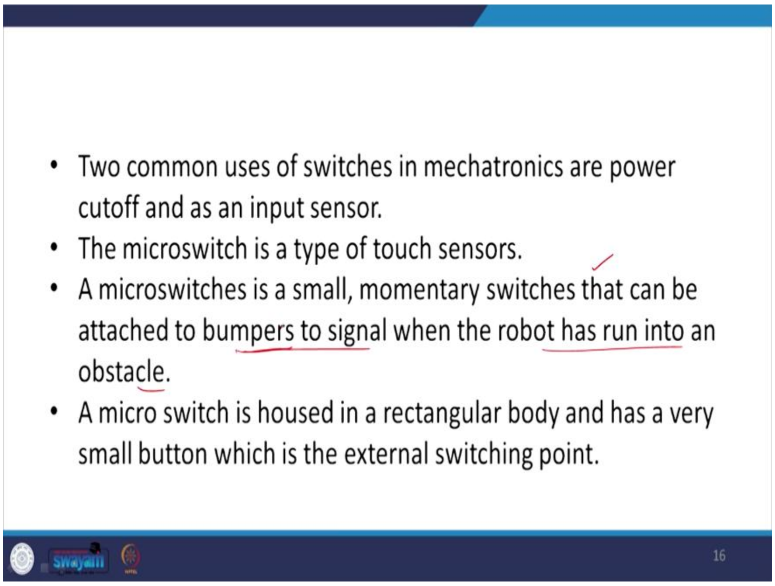

Now, two common uses of switches in the mechatronics are for the power cutoff and as an input sensor. The micro switch is a common type of touch sensor and which can be used in a small legged robot. If your robot touches some unknown obstacle then the presence of that obstacle can be detected.

A micro switch is a small momentarily switch that can be attached to a bumper to signal when the robot has run into an obstacle. This micro switch is often called as the bumper sensor. A micro switch is housed in a rectangular body and has a very small button which is the external switching point.

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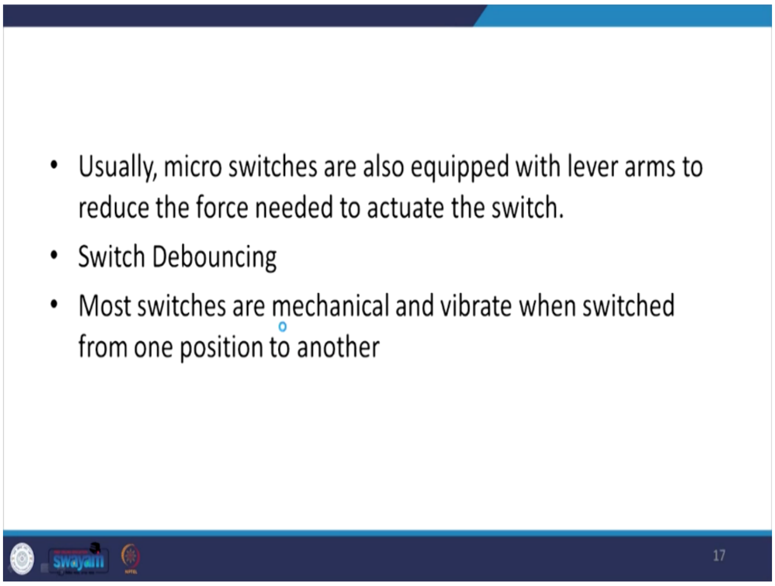
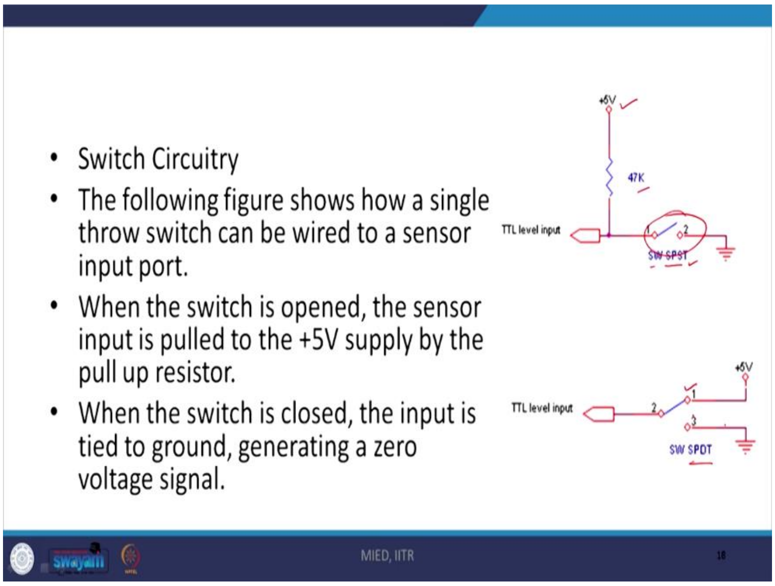


Usually, micro switches are also equipped with lever arms to reduce the force needed to actuate the switch. It is a simple mechanism if we want to amplify the forces.

In case of switches, there is a problem what we call it as the switch debouncing. Most of the switches are mechanical and they vibrate when switches from one position to another position, and this is what we call it as the switch debouncing. (Refer Slide Time: 19:25)



This figure shows how a single throw switch can be wired to a sensor input port. Here you can see that, this is switch single pole single throw, and when the switch is open as it is shown over here the sensor input is pulled to plus 5-volt supply by the pull up resistor. When the switch is closed the input tied to the ground generating a zero voltage signal.

Now this is the actually the single pole double throw switch, where you have the two types of configuration possible.

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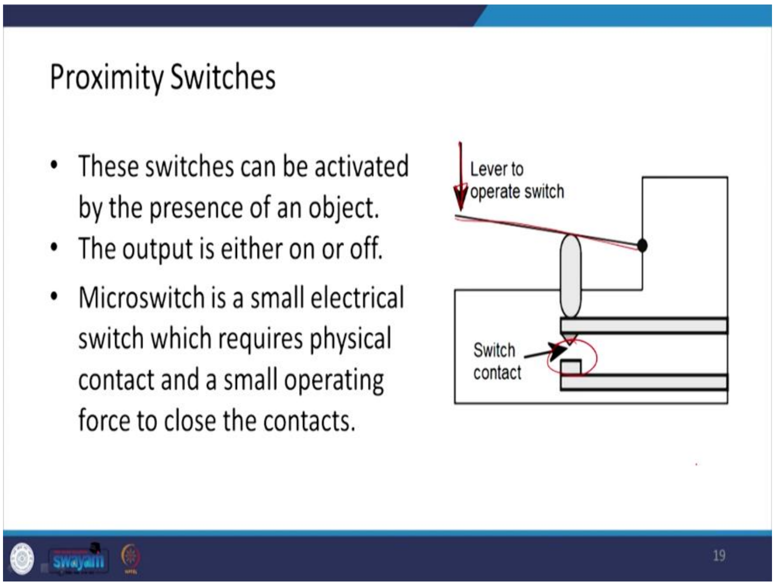

Next let us see the proximity switches. These switches can be activated by the pressure of an object. Here you can see that, the switch contact and to activate this contact we have arrangement like this and there is a lever and we can apply a force here to in order to operate the switch. The output is either on or off in this case and as I said, micro switch is a small electrical switch which require physical contact and a small operating force to close the contact.

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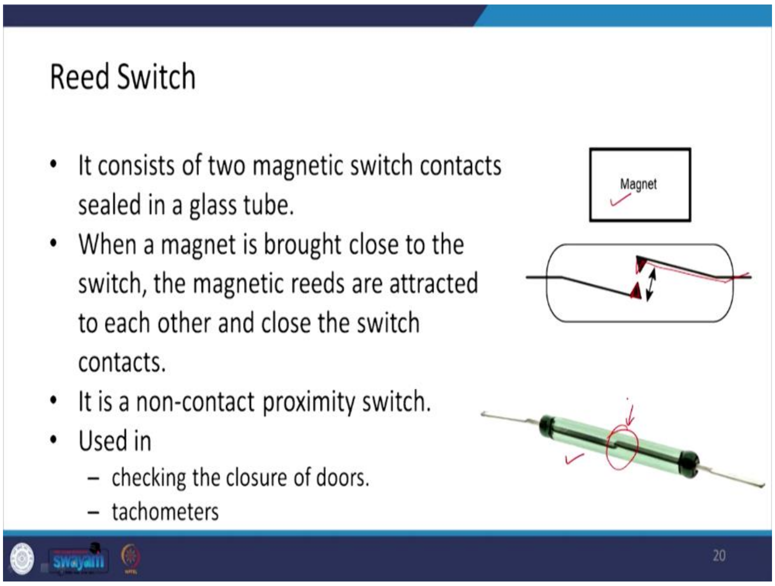

There is other type of switches called reed switches. It consist of two magnetic switch contact sealed in a glass tube. You can see this is how it is commercially available. There are two magnetic switch contacts and an arrangement is something like this as you can see that. These two can be allowed to made a contact with the help of this magnet. This is how it is assembled and sold in the market. Now, whenever a magnet is brought closer to it, there is a contact made, and that information can be passed on to rest of the circuit. The magnetic reeds are attached to each other and close the switch contact whenever a magnet is brought. It is a non-contact proximity switch because you see that the magnet is not going to make contact with the switches. They are primarily used in checking the closure of the doors as well as in the tachometers.

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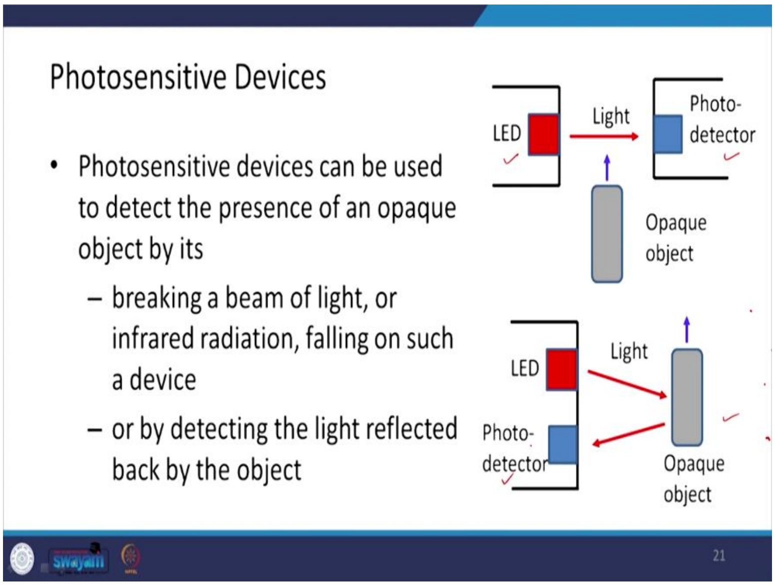

Next let us see the photo sensitive devices. These are again a type of sensors. These photo sensitive devices can be used to detect the presence of an opaque objects by its breaking the light or infrared radiation, falling on such a device. Suppose I have got a LED here and there is a photo detector over here. As this opaque object is moved here and it obstructs the path of the light that can be detected by the photo detector. It's another configuration could be the reflection that is, here the photo detector is at the other side of the LED and the object is in between the photo detector and LED obstructing the light path. Another configuration could be the opaque object being put at the other side and the LED and photo detector are on the same side. So, the proximity of this opaque object can be detected by the reflection of light from the opaque object and detected by the photo detector.

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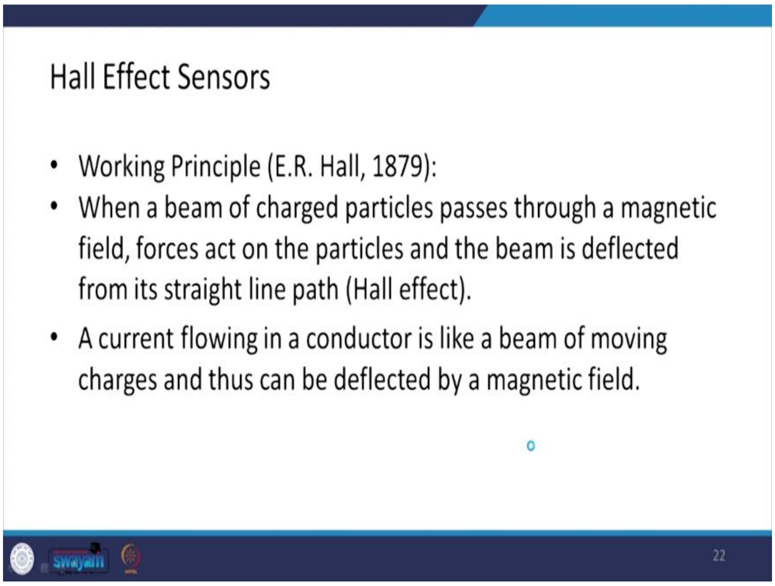

Next, let us see the Hall Effect sensors. These are again a very important sensors and used with mortars. The working principle was given by E. R. Hall in long back 1879. The Hall principle is that, when a beam of charged particle passes through a magnetic field, forces act on the particle and the beam is deflected from its straight line path, this is what is known as the Hall Effect. A current flowing in a conductor is just like a beam of moving charges and thus can be deflected by a magnetic field. So, this concept is used in this one.

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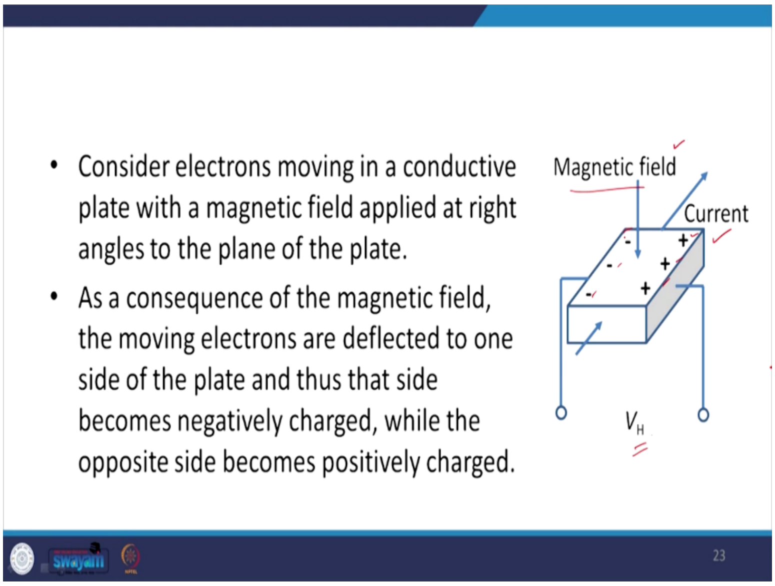

Suppose this is a current carrying conductor and when there is a magnetic field applied, these charges get deflected. At one side you have the positive charge and other side you have the negative charge and a voltage get generated across the terminal. Consider the electrons moving in a conductive plate with the magnetic field applied at the right angle to the plate, as it is shown over here as a consequence of the magnetic field, the moving charges are deflected to one side of the plate and thus the side become negatively charged, while the opposite side become the positively charged.

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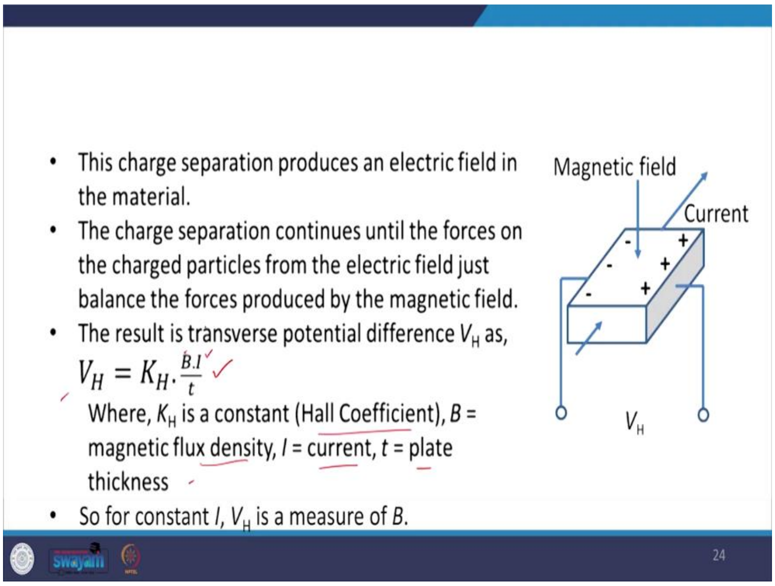

We can get this value,

$$V_H = K_H.\frac{B.I}{t}$$

where K_H is a Hall Coefficient, B is the magnetic flux density, I is the current through conductor and t is the thickness of the plate. For a constant value of I actually, V is the measure of B. This is how we can measure B. There are two types; one is the linear one, other is the threshold one. This can be used to measure displacement position as well as the proximity.

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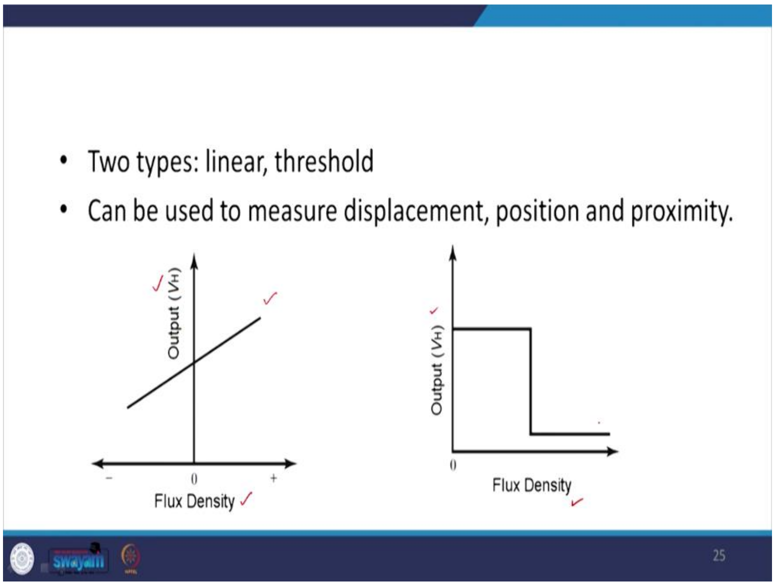

This is the type of characteristic which we can get for the linear, that is the flux density; there is a plot between flux density and the V_H that is the output voltage, it is linear. The threshold characteristic looks like this. After a certain value, there is going to be a fall in the output.

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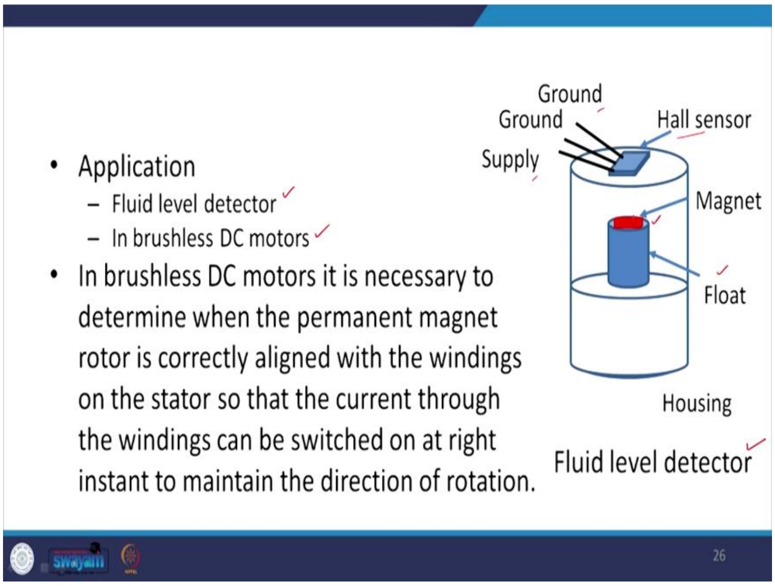

If we talk about the application of these sensors, these are used in brushless DC motors and they can also be used for the fluid level detector. This figure explains how they can be used for the fluid level detector.

So, we have the hall sensor put over here, there are ground terminal and supply is there and there is a magnet over here and this magnet is put on the float. As the magnet moves closure B changes and so the V_H changes and this V_H can be measured. This is how this Hall Effect sensor can be used for the fluid level detector.

In case of brushless DC motor, it is necessary to determine when the permanent magnet rotor is correctly aligned with the winding in the stator. The current through the winding can be switched on at right instant to maintain the direction of rotation. For that purpose, the Hall Effect sensor is used.

Now, let us look at some of the sensors, which are used to measure the linear and angular velocity and thus detect motion.

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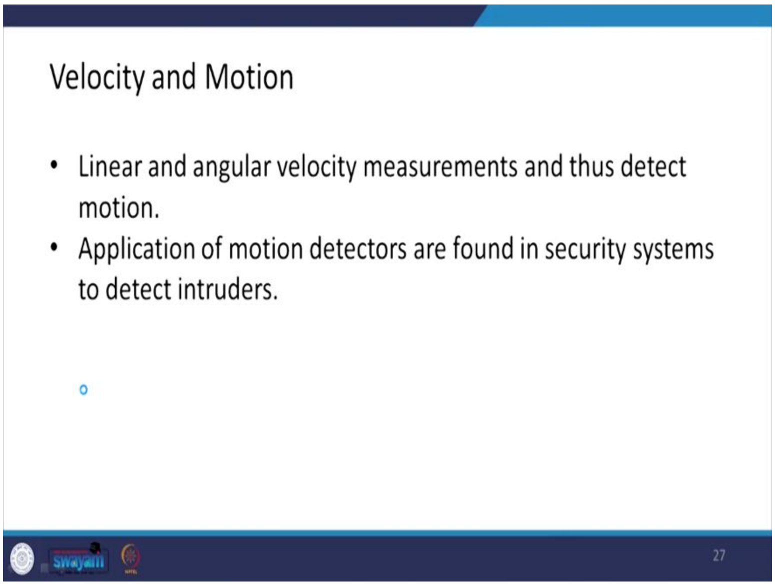

The application of these type of sensors or the motion detectors is found in security system to detect the intruders. The incremental encoders can also be used for the detection or calculation of the velocity.

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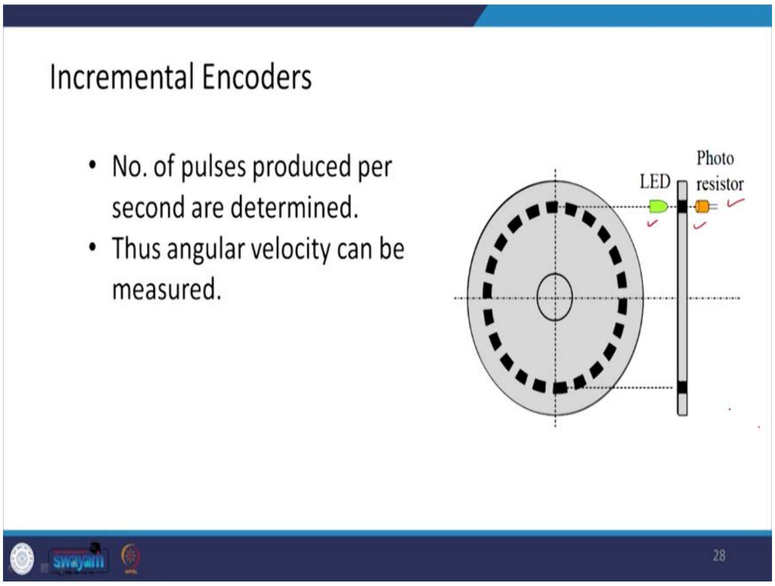

Here we have talked the principle of the encoders. We have a slotted disc here, there is a LED and there is a photo resistor over here. So, we can count the number of pulses per second and then from that, you can calculate the angular velocity.

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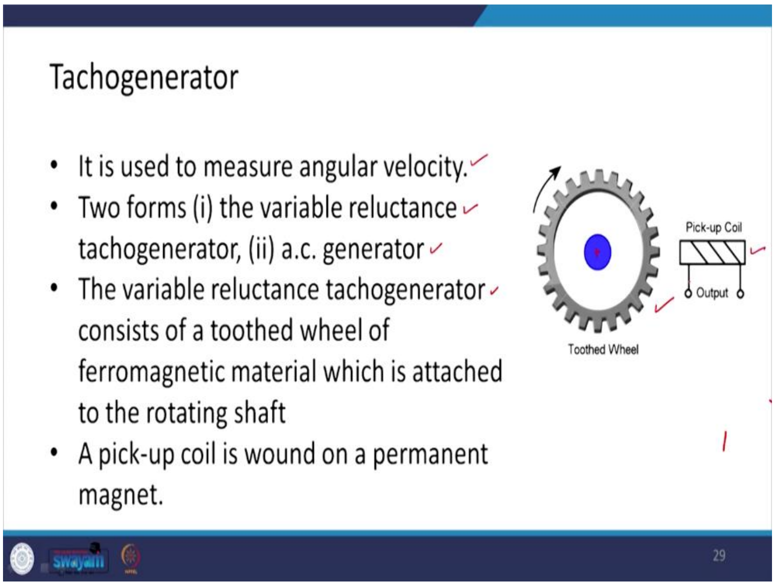

Tachogenerator is also used to measure the angular velocity. There are two basic forms available, one is the variable reluctance tachogenerator and another is the AC generator. In case of variable reluctance tachogenerator, consist of basically a toothed wheel as you can see over here of ferromagnetic material, which is attached to the rotating shaft over here. There is a pickup coil is wound on a permanent magnet.

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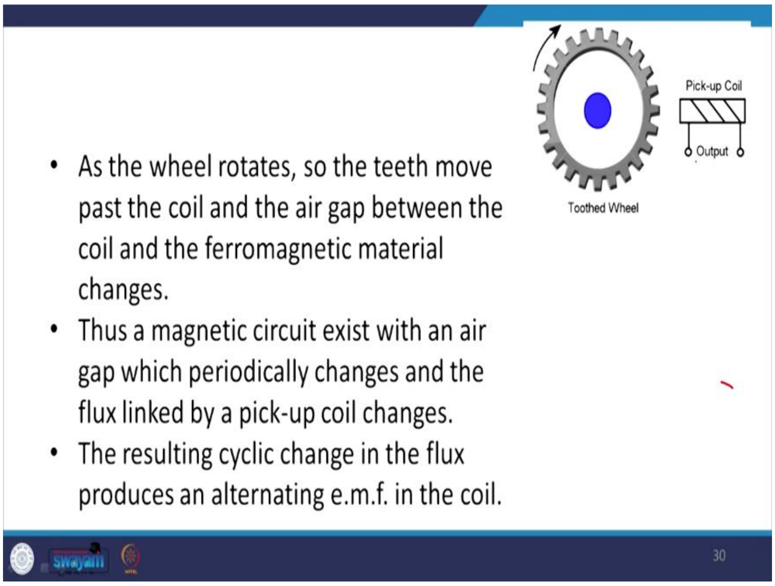

As the wheel rotates, the teeth move past the coil and the air gap between the coil and the ferromagnetic material changes. Thus, a magnetic circuit exists with air gap which periodically changes and the flux linked by the pick-up coil changes and the resulting cyclic changes in the flux produced, it produces an alternating **emf** that is electromotive force in the coil.

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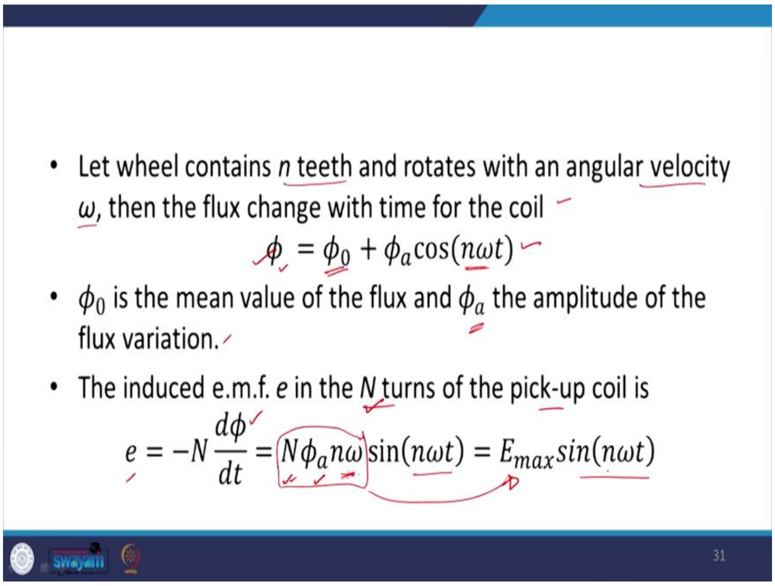

We can find out an expression over here. Suppose the wheel contains is having n number of teeth and that wheel rotates with the angular velocity ω, then the flux change with time for the coil can be given by,

$$\emptyset = \emptyset_o + \emptyset_a \cos(n\omega t)$$

where $\emptyset_o$ is the mean value of the flux and $\emptyset_a$ is the amplitude of the flux variation. The induced emf in the N turns of the pickup coil can be given by

$$e = -N\frac{d\emptyset}{dt} = N\emptyset_a n\omega \sin(n\omega t) = E_{max} sin(n\omega t)$$

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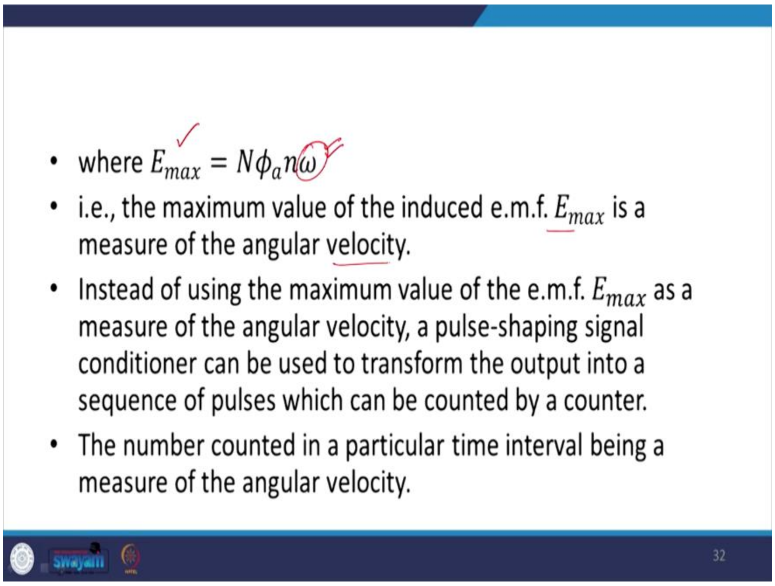

The maximum value that is,

$$E_{max} = N\emptyset_a n\omega$$

The maximum value of the induced emf that is E max is a measure of the angular velocity. E max is the measure of this angular velocity.

Instead of using the maximum value of the emf, E max as a measure of the angular velocity. A pulse shaping signal conditioner can be used to transform the output into a sequence of pulses which can be counted by a counter. The number counted in a particular time interval is the measure of the angular velocity.

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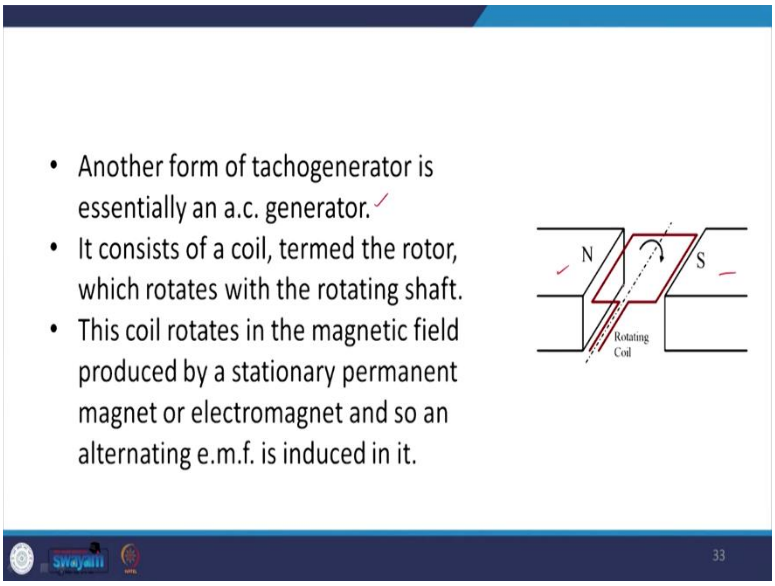
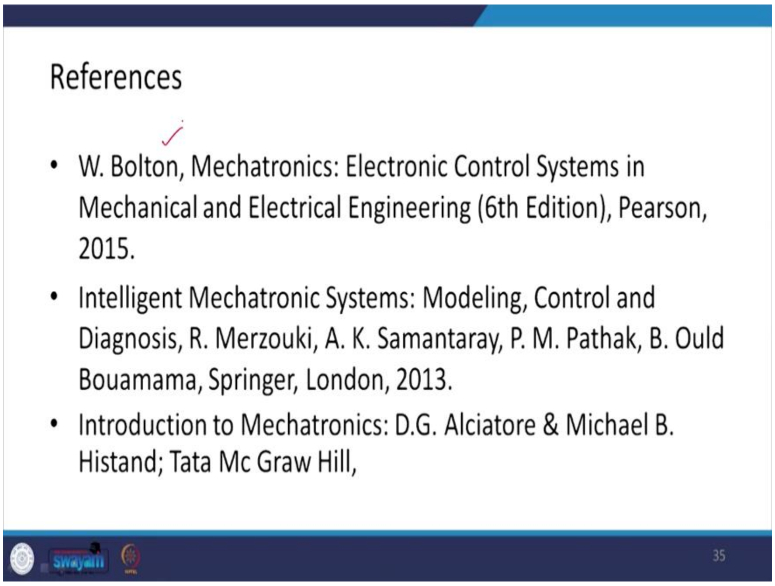


Second form of the tachogenerator is essentially an AC generator. The principle for this is simple, you have a say magnet over here and there is a rotating coil over here, which rotates in a magnetic field and because of its rotation, the number of flux linkages changes and e m f is generated.

It consists of a coil, which is termed the rotor. It rotates with the rotating shaft and the coil rotates in a magnetic field producing a stationary magnetic field and so you have the induced e m f. The amplitude or frequency of this alternating emf can be used as a measure of the angular velocity of the rotor. The output may be rectified and can be used to give a DC voltage with a size which is proportional to the angular velocity. (Refer Slide Time: 36:23)



For further reading, you can refer the book by Bolton and a book on Intelligent Mechatronic System. You can also refer the Introduction to Mechatronics by Alciatore and Histand.

Thank you.