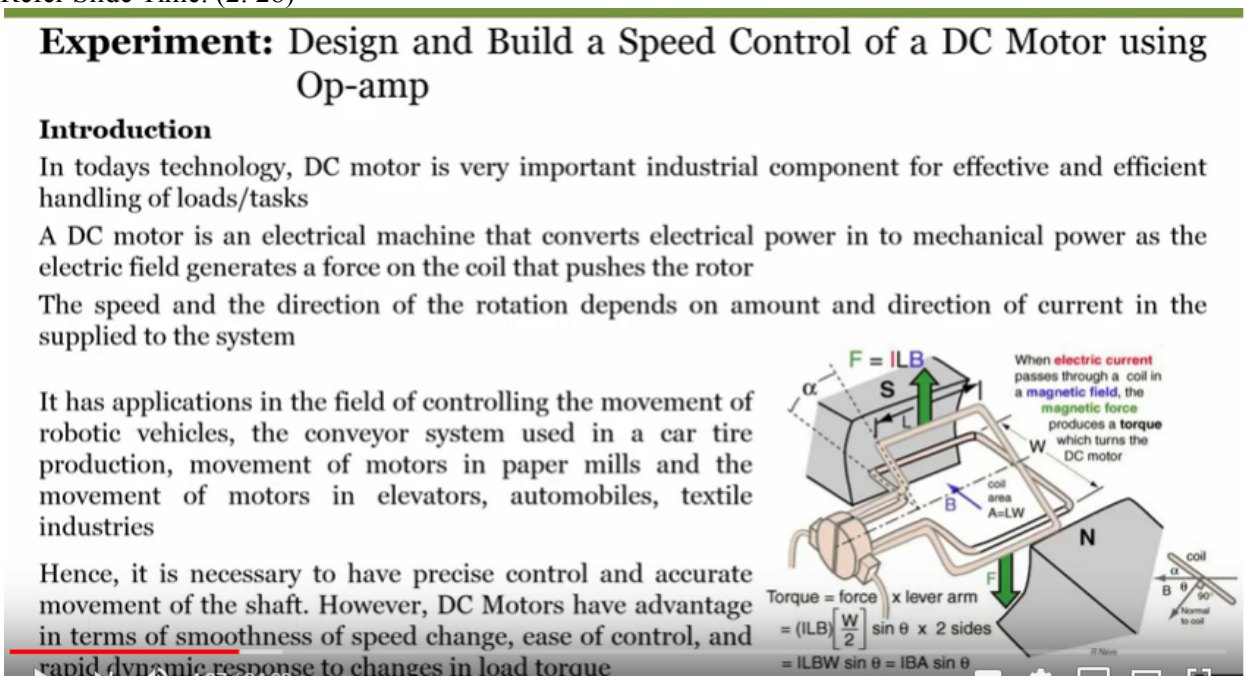
Lecture 21

Design of Speed Control of

DC Motor Introduction

Hi, welcome to this particular module. So, we have seen several applications of operational amplifier, to developed electronic modules. Right? And those electronic models, we have been showing you different applications for industry. Now, one of the very, important electronic module or the design that you need to learn, is how to control, a speed of a DC motor. Now, why this DC motor is really important and how it will help us, you see most of the toys in the home like a small robots, if you see at the home, a small, small fan working, you know in your office, how does it work, like a small table fan you have seen, in this or maybe this is, the fan in the system, your computer. Right? How this thing's works, is there a motor required for rotating, the rotor or it rotates on some other effect. So the point is, there are several kind of motors and starting with the static motor, we have ac/dc and then we have different kind of sub parts where you can say the series, DC motor, it is a shunt DC motor and then each of those, have their own specific advantage and, and of course there are disadvantages for example, if you talk about series motor and you talk about shunt motor, then you will see that is the series motor can be started faster, I'm talking about DC motors. Okay? If it is a series motor, it speeds up rapidly but, if you keep on adding the load, then the performance goes down. But, if you talk about shunt motor, then even you the starting speed, the speed is slow, but if you keep on adding the load, the performance does not degrade. So, depending on what kind of applications you are looking at, you need to select that particular type of motor. AlRight? So, today basically, we are talking about a DC motor and in DC motor, how we can design an electronic module to control this speed.

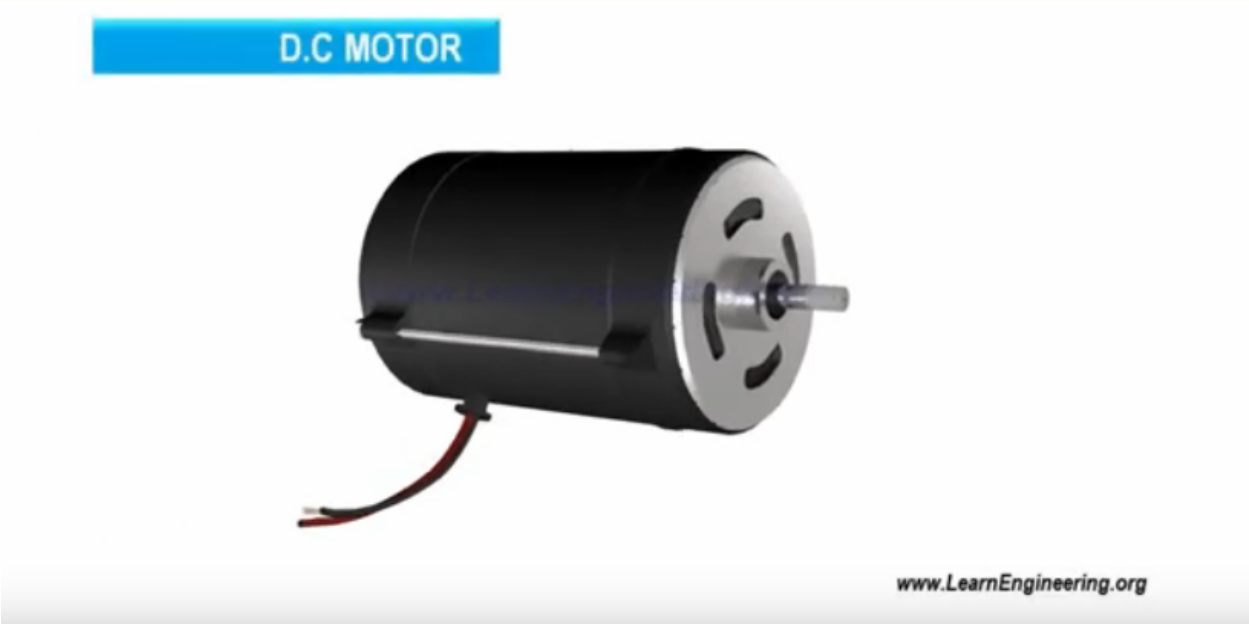
Refer Slide Time: (2: 28)



So, if you see the screen, we will start with the introduction and I have two videos for you, so that you understand, what kind of how the DC motor is constructed. But, but if we talk about today's technology, then DC motor is extremely important from industrial component for because, while it's efficient and effective handling of loads, DC motor is an electrical machine that converts in the taker power into mechanical power, wherein sir for rotating the you know, blade as well as the electric field generates a force in the coil that pushes the rotor. You see there's a electric field now, you see there are two coils here. Right? But and then there are a static magnetic field here, as at the south and north, poles you can see and

then, there is a electric field generated, on to these particular coils. Now, there is a reason why we use two, one coil not only one coil, but multiple coils and is keep on increasing the number of coils, the performance of a DC motor increases, if you just use a single coil, what happens is that at, at a particular rotation, angle the, the upward and the downward moment of the magnetic field, becomes canceled each other and therefore that's why, it is a kind of a jerk, so, so the moment is like this and then it is a jerk and then it again starts, to avoid that, if we have two coils, then that can be taken care of, you will see in the video, how that what does that mean. But, the point is, the speed and direction of rotation speed depends on amount and direction of current in the supplied system. And it has several applications, in the field of controlling the moment of robotic vehicles, the conveyor system used in the car tyre production, movement of motors in paper mills, moment of motors in elevators, automobiles textiles industries and so on and so forth. Thus it is extremely important to have a precise, control and accurate moment of the shaft, shaft is you, you, you know it, how, however DC motor have advantage in terms of smoothness of speed change, ease of control and rapid dynamic response to change the same d load torque. So, this is a schematic, where you can see: that when an electrical current is passing through a coil, a magnetic field is produced, which turns the motor, because of the torque generated. Right?

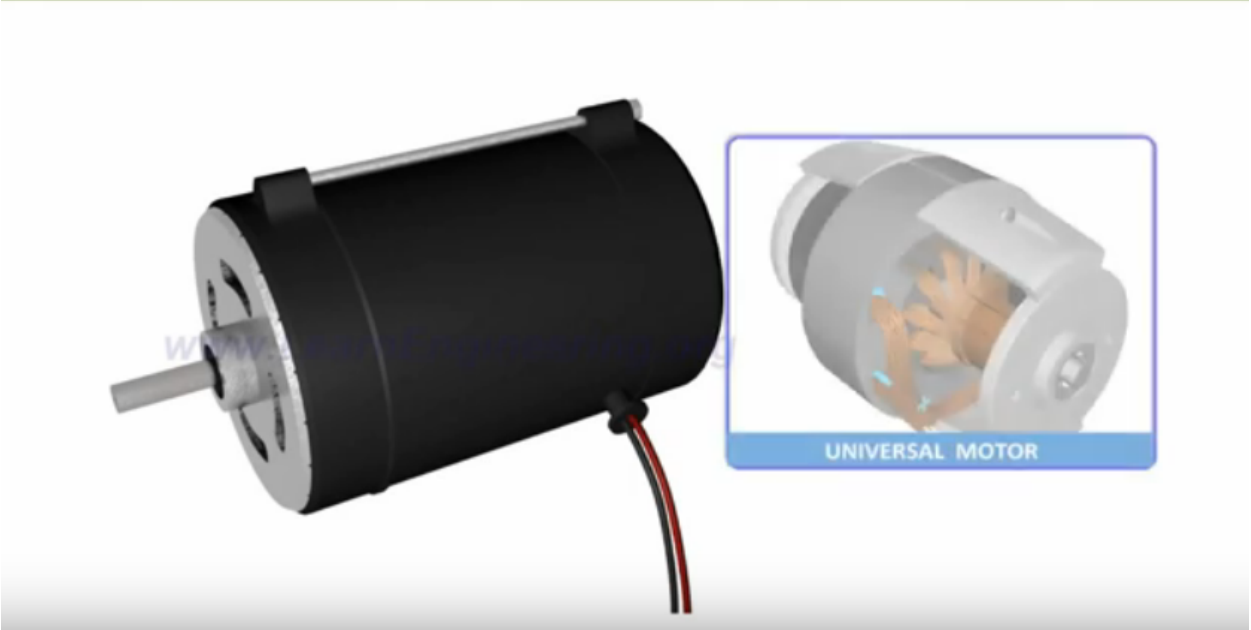
Video Start Time: (4: 50)



And if I show you the video, then you will understand more, what exactly that DC motor is and how it was, let me play the video, you can find DC motors in many portable home appliances, automobiles and types of industrial equipment, in this video, we will logically understand the operation and construction of a commercial DC motor. let's first start with the simplest DC motor possible, it looks like this, the stator provides a constant magnetic field and the armature, which is the rotating part, is a simple coil, the armature is connected to a DC power source, through a pair of commutator rings, when the current flows through the coil, an electromagnetic force is induced on it, according to the Lorentz law. So, the coil will start to rotate, you will notice that as the coil rotates, the commutator rings connect with the power source of opposite polarity, as a result, on the left side of the coil, the electricity will always flow away and on

the right side, electricity will always flow towards, this ensures that the torque action is also in the same direction throughout the motion. So, the coil will continue rotating. But, if you observe the torque action on the coil closely, you will notice that, when the coil is nearly perpendicular to the magnetic flux, the torque action near zero, as a result there will be irregular motion of the rotor, if you run such a DC motor, here is the trick to overcoming this problem, add one more loop to the rotor, with a separate commutator pair for it, in this arrangement when the first loop is in the vertical position, the second loop will be connected to the power source. So, a motive force is always present in the system, moreover the more such loops, the smoother will be the motor rotation, in a practical motor the armature loops are fitted inside slots of highly permeable steel layers, this will enhance magnetic flux interaction, spring-loaded commutator brushes, help to maintain contact with the power source, a permanent magnet stator pole is used only for very small, DC motors most often an electromagnet is used, the field coil of the electromagnet is powered from the same DC source. The field coils can be connected to the rotor windings in two different ways, parallel or series, the result is two different kinds of DC motor constructions, a shunt and a series motor, the series wound motor has good starting torque. But its speed drops drastically with the load, the shunt motor, has a low starting torque but, it is able to run almost at a constant speed, irrespective of the load acting on the motor, unlike the other electrical machines, DC motors exhibit a unique characteristic. The production of back EMF, a rotating loop in magnetic field, will produce an EMF according to the principle of electromagnetic induction, the case of rotating armature loops is also the same, an internal EMF will be induced that opposes the applied input voltage, the back EMF reduces armature current by a large amount, back EMF is proportional to the speed of the rotor, at the starting of the motor back EMF is too low, thus the armature current becomes too high, leading to the burnout of the rotor, thus a proper starting mechanism that controls the applied input voltage is necessary, in large DC motors. One of the interesting variations of the DC motor, is a universal motor, which is capable to run under both AC and DC power sources, to know more about it please check the next video. Thank you. Okay.

Video End Time: (9: 36)

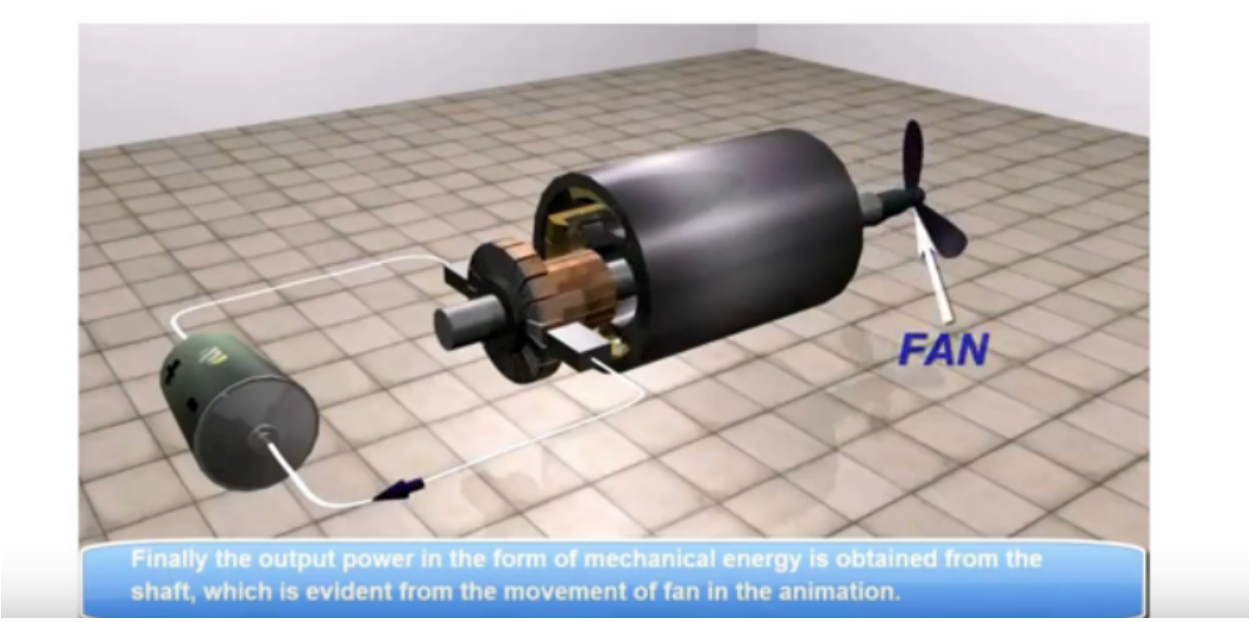


So, let me play another video, where you will see the, the construction of DC motor and how it works and in fact it is a really nice video, because you can see the blob diagram, the internal structure of the DC motor, how the coils are placed, why we cannot use a static magnetic electromagnet electrostatic, magnet and how does it really help. So, let me play that video also, for you

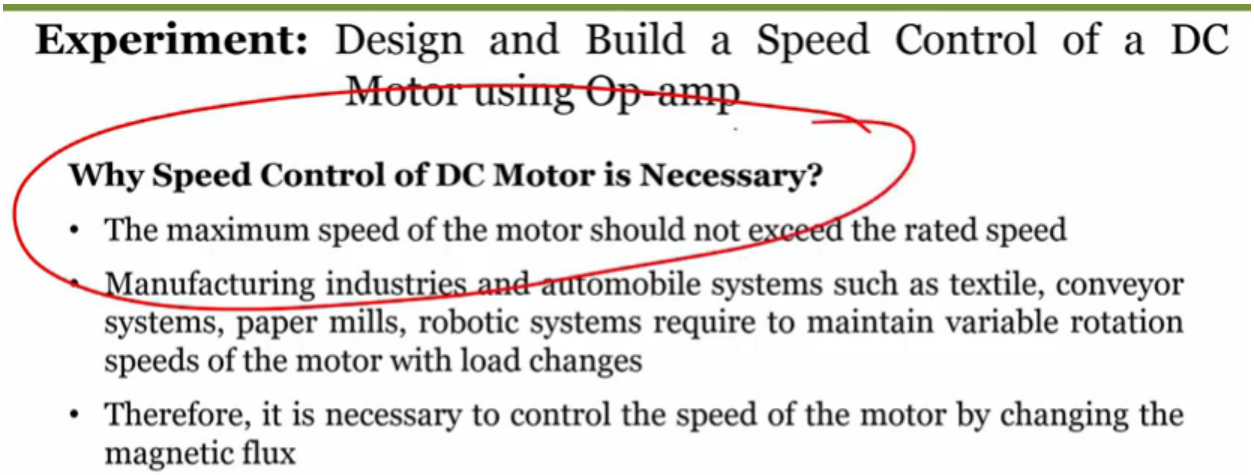
Video Start Time: (10: 03)

Construction and working of DC motor. Have you ever wondered, how the electric shaver works? How electric toys like small robots, toy cars etc work? The answer, to all the above questions, is DC motor or DC motor is the device: that converts DC electrical energy, into mechanical energy, in order to understand the working of a DC motor, we have first explained, the construction and assembly, of a DC motor. Let's first understand, the construction of a DC motor, magnetic frame or Yoke this part acts as a protective cover for the machines and protects the machine, from any outside disturbances, it houses field system and supports the armature through bearings, stator magnets, they are basically electromagnets, with such an arrangement. So that adjacent poles, have opposite polarity, they perform the function of producing the magnetic field. Armature, it is a system of conductors or coil, which is free to rotate on the supported bearings. The armature consists, of various parts, we will take each part one by one. To start with we have, armature core, it is made up of high permeability thin silicon content steel laminations. And the outer periphery of the core, has slots to carry armature windings. Next is armature winding, it is generally made up, of copper wires and is wound over the armature core. Commutator, the commutator is cylindrical in shape and is made of copper, it performs two basic functions: one being, collecting the current from the armature conductor and the other being, converting the alternating current of the armature into the unidirectional current, in the external circuit with the help of brushes. Brushes they are usually made of carbon or graphite. And the main function of brushes is to collect current, from moving commutator. Shaft, shaft is a rotating part of DC motor: we obtain the final output in the form of mechanical energy from the shaft, the armature is mounted over the shaft. Now, we will see the assembling of DC motor, we can now observe in the animation how this motor is practically assembled. Now, after the construction and assembling of DC motor, we will discuss the working in detail. Now, when the battery is connected to the DC motor, the current starts flowing through the armature. A force is developed in the armature, due to the influence of magnetic field of the stator, whose Direction is given by Fleming's left hand rule. Now, due to the development of this force, in each armature conductor, the armature will rotate, in the clockwise direction and as a result, the shaft will also rotate. Finally the output power in the form of mechanical energy, is obtained from the shaft, which is evident from the movement of fan, in the animation.

Video End Time: (15: 00)

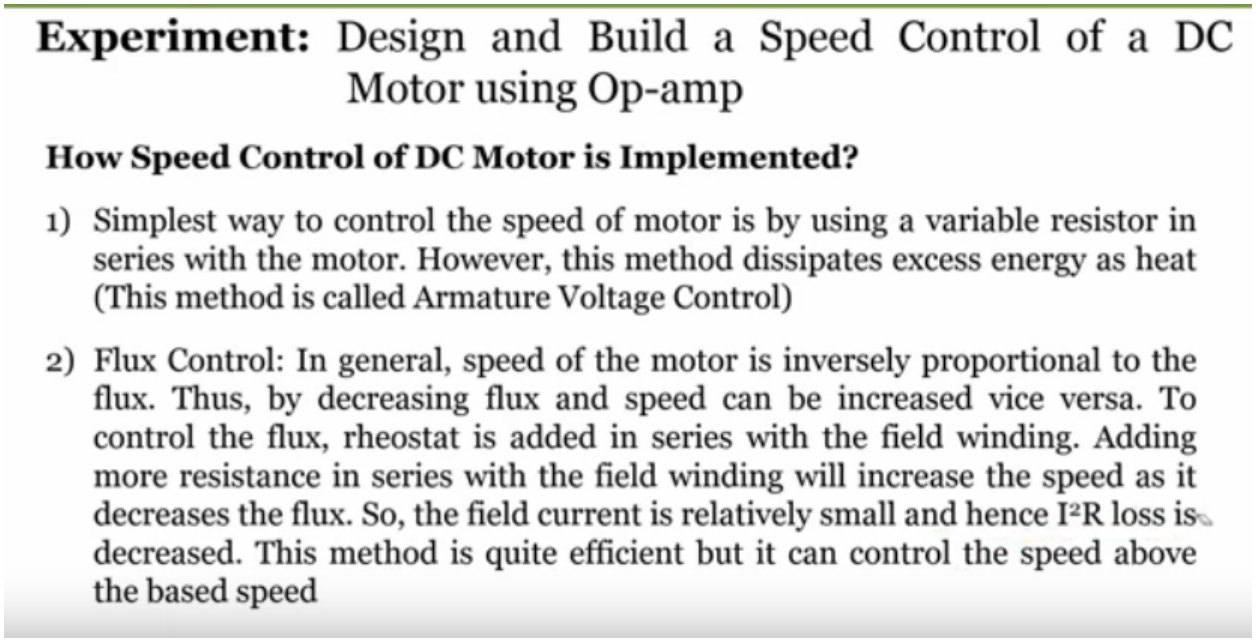


Refer Slide Time: (15: 02)



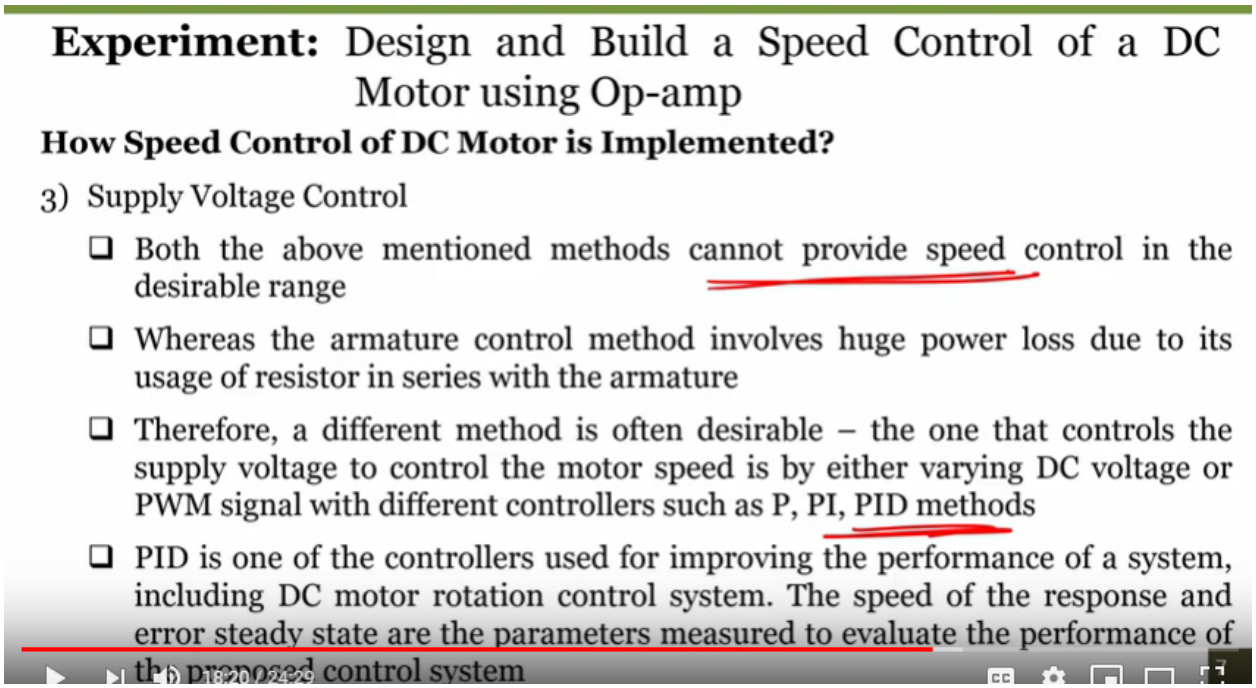
In both the videos you have seen, how DC motor works. Right? And how is the construction of DC motor, is there. Now, let us come to our experimental part, where we will see how we can design and build a speed control of a DC motor, using operation amplifier. But, before that, let us see, why speed control of DC motor is necessary? AlRight? So, the maximum speed of the motor, should not exceed the rated speed, we all know that, if you have a motor and if there is a radial speed, you cannot increase the speed of a motor more than the maximum rated speed. Second thing is, manufacturing industries and automobile industries, if you see this slide, as I says textile, conveyor systems, paper mills, operating systems, required to maintain a variable rotation, with load changes. That is very important, with load changes there should be a variable rotation speed, therefore it is necessary to control the speed of a motor by changing the magnetic flux. And that's why, we have to understand how can we control the speed of a DC motor.

Refer Slide Time: (16:01)



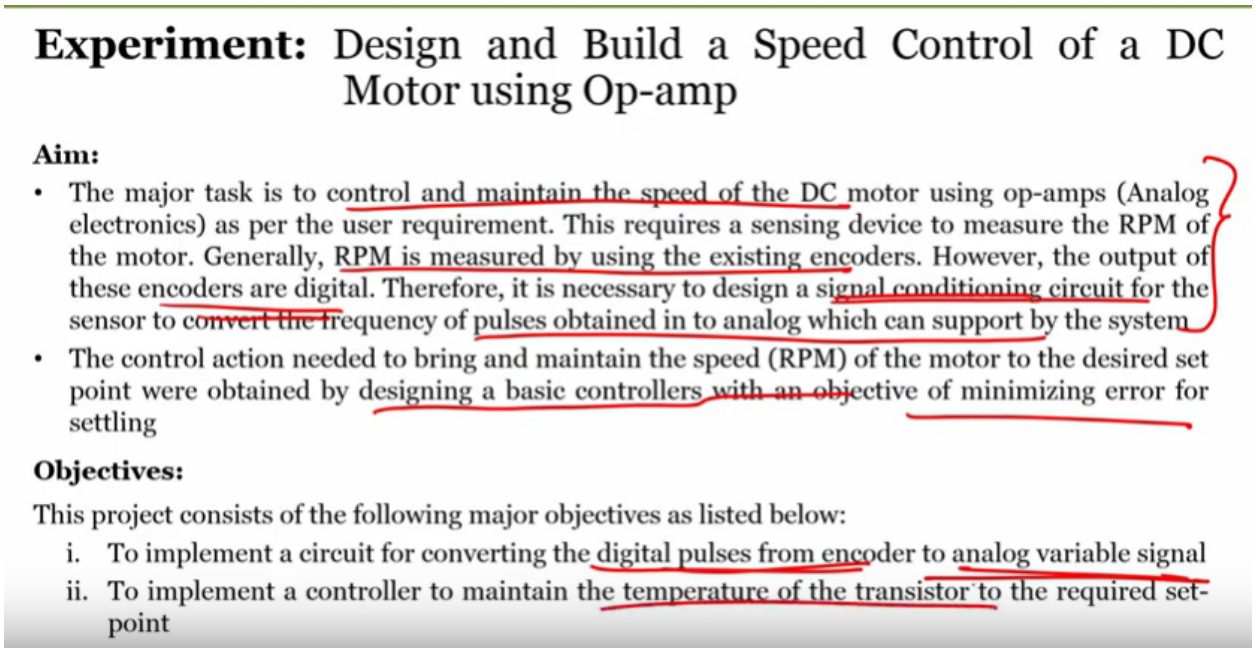
Now, the simplest way to control the speed of the motor is by using a variable resistor, in series with the motor: However, the method dissipates energy as heat and these are method is also called, ‘Armature Voltage Control’. We will see, the in experiment how we are designing this op-amp, based speed controller. But, before the let us understand, what is the second way of controlling the speed, which is flux, control in flux control the speed of motor is inversely proportional to the flux, thus by decreasing flux and speed can be increased vice versa. So, if I decrease the speed, the speed can be increased. But, if I decrease the flux, speed can be increased, if I decrease the speed flux can be increased. So, it's a vice versa we can do that, the control of the flux rheostat is added in series with the field winding, adding more resistance in series with the field winding, will increase the speed as it decreases the flask, like wear and like I said and so, the field current is relatively small and hence, your I square R loss, is small. This method is quite different but, you can control the speed above the base speed.

Refer Slide Time: (17: 05)



Now, the third one is supply voltage control. If I change the supply voltage then the speed of the DC motor can be controllable. So now, for supply voltage control, we had use both the above-mentioned methods which is you're, controlling the speed of murder by using variable register and flux control these are both the methods that we have discussed, cannot provide, speed control in the desirable range. So, whereas the armature control method involves huge power loss, which is our first method I said that there is a energy dissipation, excess energy as a heat, which is a power loss, due to a series of resistors in series with the armature. Therefore, a different method is often desirable, the one that controls supply voltage, to the control, to control the motor speed is by either, wearing the DC voltage or pulse width modulation signal, with different controllers such as, proper a proportional controller, proportional integrator controller, proportional integral differential methods. So, there are several methods that we can use now, PID is one of the most used, most preferred method, in all among, among all three methods, which is PPI and PID so, PID is one of the controllers used for improving the performance of a system, including DC motor rotation control system. The speed of the response and the study, error steady state are the parameters, measure to evaluate the, performance of the, proposed control system.

Refer Slide Time: (18: 24)



Experiment: Design and Build a Speed Control of a DC Motor using Op-amp

Aim:

- The major task is to control and maintain the speed of the DC motor using op-amps (Analog electronics) as per the user requirement. This requires a sensing device to measure the RPM of the motor. Generally, RPM is measured by using the existing encoders. However, the output of these encoders are digital. Therefore, it is necessary to design a signal conditioning circuit for the sensor to convert the frequency of pulses obtained in to analog which can support by the system
- The control action needed to bring and maintain the speed (RPM) of the motor to the desired set point were obtained by designing a basic controllers with an objective of minimizing error for settling

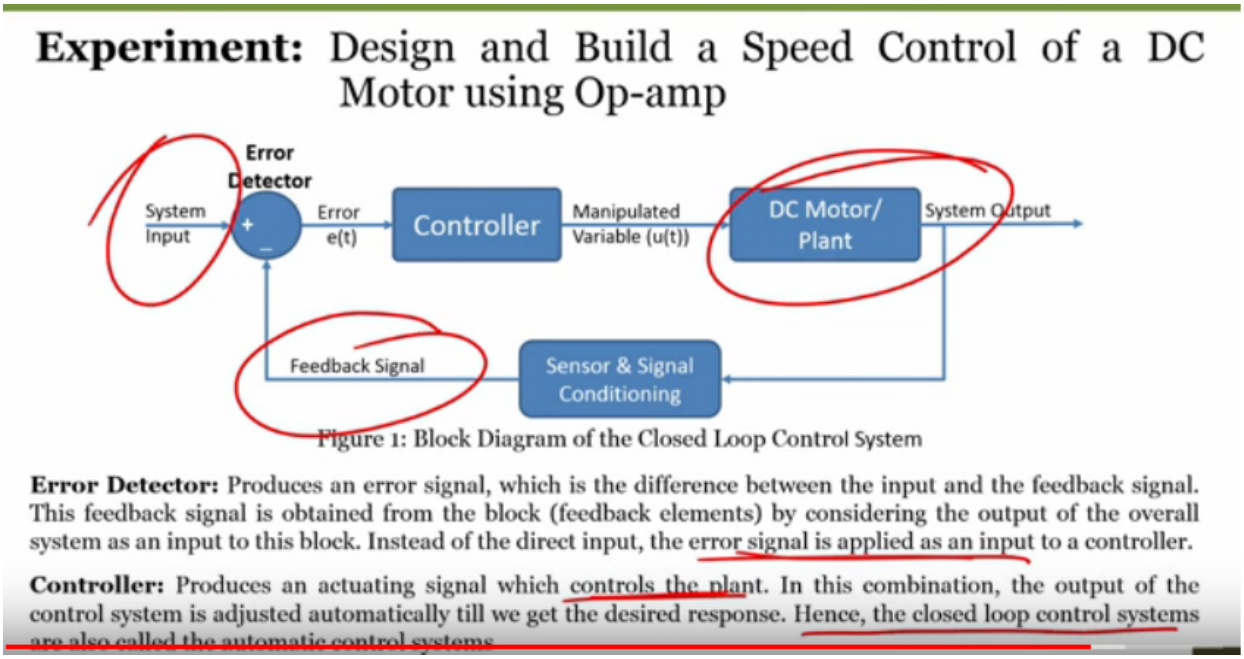
Objectives:

This project consists of the following major objectives as listed below:

i. To implement a circuit for converting the digital pulses from encoder to analog variable signal
ii. To implement a controller to maintain the temperature of the transistor to the required set-point

Now, so far, what is the aim of our experiment? The aim is that the major task is to control and maintain the speed of the DC motor, using op-amp that is our analog electronics, as per the user requirement. This requires a sensing device to measure the RPM motor generally, RPM is measured by using the existing encoder. So, we want to measure the speed of a DC motor, when to control the speed of a DC motor and flow understand, what is the rotations per minute we require encoder. However, output of these encoders are digital, therefore it is necessary to design a signal conditioning circuit, for the sensor to convert the frequency of pulse is obtained into analog, which can support the system. So, the, the if you see the aim is not so easy to understand, but if you, focus then you will understand that what we want? We want to control and maintain the speed of the DC motor and then we have to, we have RPM measurement with a help of encoders. However, the encoders are digital and that's, what we requires in organizing circuit, to convert the frequency of pulses into analog which ends about the system. Okay? Now, the control action needed to bring and maintain the speed of the motor, to the desired set point, would be obtained by designing a basic controllers, with the object you are minimizing error. So, what are other objectives? There are few objectives, the first one is, to implement a circuit for converting the digital pulses from encoder to analog variable signal, because the encoders are giving us an output in form of digital signals, to implement a controller to maintain the temperature of transistor to require the set point.

Refer Slide Time: (19: 55)



So, there are two objectives that you see here and for that, what we will do? We will see the block diamond of the closed Loop control system, again this experiment will be taken care of by the TA. But, let us quickly, see the theory part of it so, if you see the block diagram of a closed loop control system you can see that, the system input and there is an error detector, which detects the error with the help of the feedback signal, which is our sensor the signal conditioning sells it, we have a controller, to control and the speed of the DC motor and the whatever system output is there, there is feedback with the signal conditioning circuit, back to the error detector, whatever the errors are there, it will be taken care of and according to that the controllers can maintain the speed of the DC motor. So, we will discuss this thing in detail the, the role of error detector here, is to produce an error signal which is a difference of the system input, which is here and the feedback signal, which is from the sensor and signal conditioning circuit. This feedback signal is obtained from the block, which is we have shown see sensor and signals. So now, many talk about signal conditioning circuit, we also had to understand sensors and that's why, if you remember we have taken a topic, on Hawaii sensors are important, how can design sensor? How you can fabricate those sensors? Right? So, sensors are very, important and then once your sensor the sensing data can be further you know, you can, you can do the acquisition of that and you can control that, you can do the sudden signal conditioning that, with the help of the operational amplifiers and relevant components. So, instead of by direct input, the error signal is applied as an input to the controller. Finally, what is the role of controller? Controller produces an actuated signal, which controls the plant. Right? So, plant or DC motor that is a one and the same thing, in this combination the output of the control system is adjusted automatically, till we get the desired response. Hence the closed loop control system, are also called, 'Automatic Control Systems'. Okay? So, this is a closed loop control system.

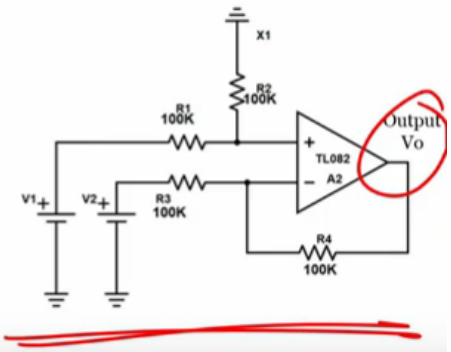
Refer Slide Time: (21: 53)

Experiment: Design and Build a Speed Control of a DC Motor using Op-amp

Implementation of Error Detector: Measures the difference between the input and the feedback signal

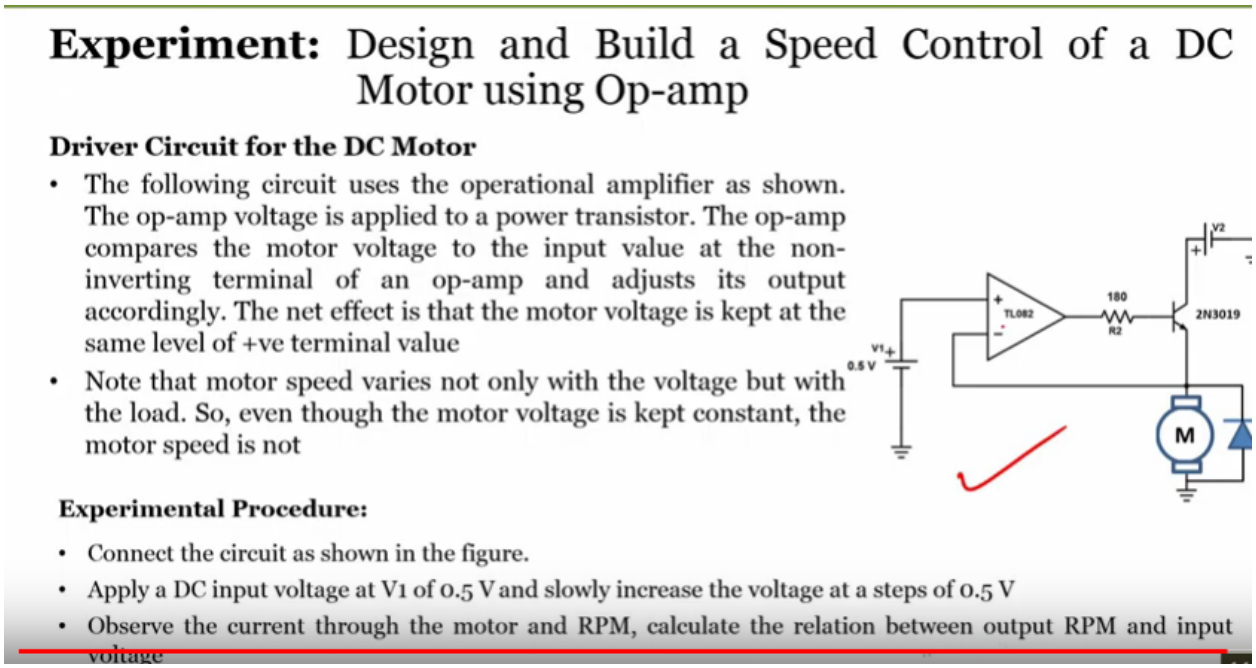
Error amplifier Experimental Procedure:

- Connect V1 and V2 (V1 = V2) to the inputs of Error amplifier at R1 and R3 resistors as shown in the figure. Measure the output at Vo. This is the common mode operation. Calculate its common mode gain
- Connect the V1 input to the signal high and the V2 input to the signal low and measure the output. This is the differential mode operation. Calculate its differential mode gain
- Calculate the CMRR and the differential gain of the system



Finally, there is a two more thing that we need to understand, which is implementation of error detection, which measures the difference between input and the feedback signal and error amplifier experimental procedure is, if you see this particular circuit, then we need to connect v1 and v2, to the inputs of error amplifier and r1 as resistors, shown in figure. Right? Which are of 100k, so what we had to do? We had to measure the output V o. Alright? And here's a common mode operation, so calculate common Mode gain, you already know, how to augment common Mode gain, because we have seen the operator operational amplifier parameters in our studying of the this particular course and then what we are to do? We are to connect v1 to the input and a v2 to the signal low and measure the output, there's a differential mode operation so you can, have differential Mode gain. Now, if you have common mode gain, if you have differential mode gain, what you can find? You can find common mode rejection ratio. Right? That is what we have to do in this experiment.

Refer Slide Time: (22: 49)



Again we will discuss about experiment in detail, in the in the back experimental class. If you want to design you know, driver circuit for DC motor, it is a DC motor a driver circuit, then we can use the following circuit, which is here. Right? And the op- amp voltage, is applied to a power transistor, which you can see here. Right? The op-amp compares the motor voltage the input at the non-inverting terminal. Right? The this is, at the non-inverting terminal, the input is applied to the non terminal and here we are inverting terminal, which is compared. So, the net effect is that water is kept at the same level of the positive terminal and note that, the motor speed varies not only with the voltage, but with the load as well. If you change the voltage the speed varies, if we change the load this speed will, vary. So, even though, the motor voltage is kept constant the motor speed, may not. So how can we do the experiments? We can't connect the circuit as shown in figure and then we apply a DC voltage of 0.5 volts, at point v1 and slowly increase of voltage, with a step of 0.5 volts, then what we can find or we can find the change the current of the motor and the rotations of the motor and then we can calculate the relation between output RPM and the input voltage. Right? So we will see these details in the circuit, this is just last slide for this particular lecture and I and the TA will show it to you, the experiment that we are designed, for controlling the DC motor. So, I just go through this particular slides, ask an equation if you have any doubts, through forum and we will be very happy, to answer your questions. Till then, you take care. Have fun. Bye