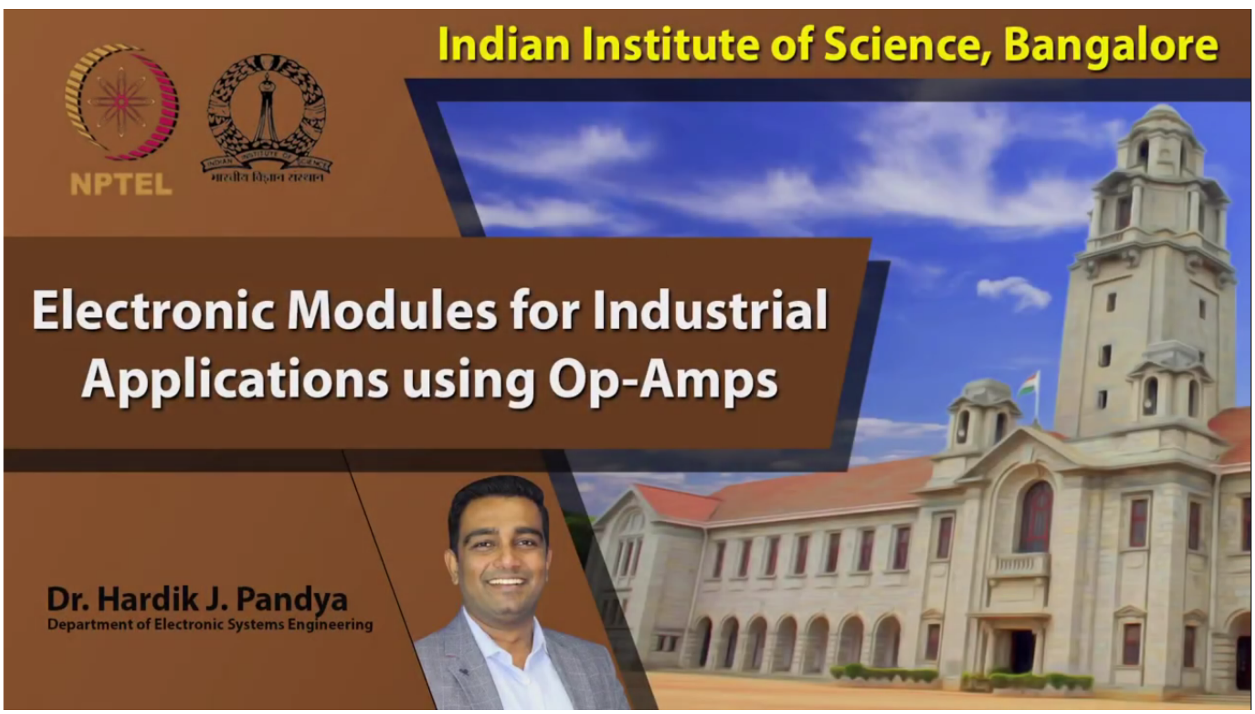
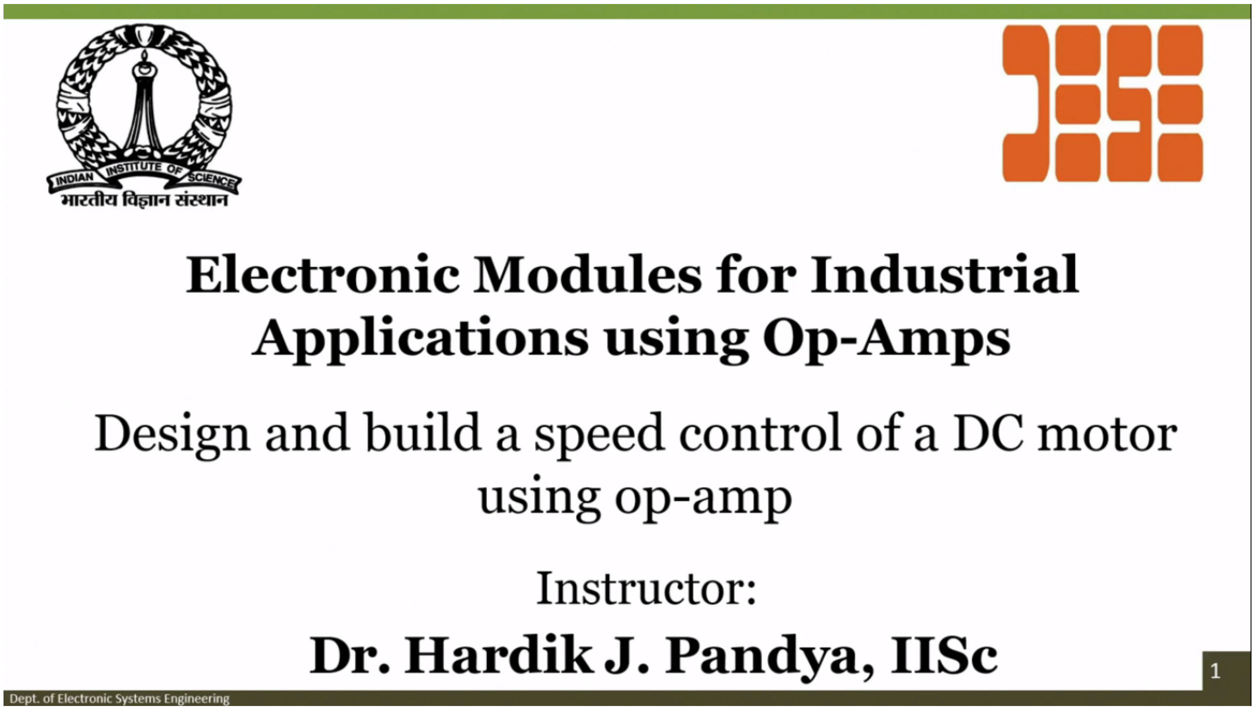
Indian Institute of Science
भारतीय विज्ञान संस्थान





Welcome to the module. So now we will see the setup and what we do is that we will slowly increase the voltages at the step of 0.5 and we will observe at what frequency the encoder is rotating. So before doing that let's see the connections. So what I have done here is that we have total force applied. So this case this particular RPS has total three. So the middle part if you observe it has plus 15 dedicated plus 15 and minus 15 channel here. This particular position. So for powering the op-amp we are using plus 15 the red one and the minus 15 the green one with the common ground black. Whereas this particular channel we are giving to power transistor and this channel we are powering encoder. So whereas the input to the positive terminal is powered by using this particular power supply.

So in this case we are using this particular channel, the first channel. So here you can see the channel one. The channel two is off. But the output is also on right now but the output is – the output from this channel is zero to this channel one.

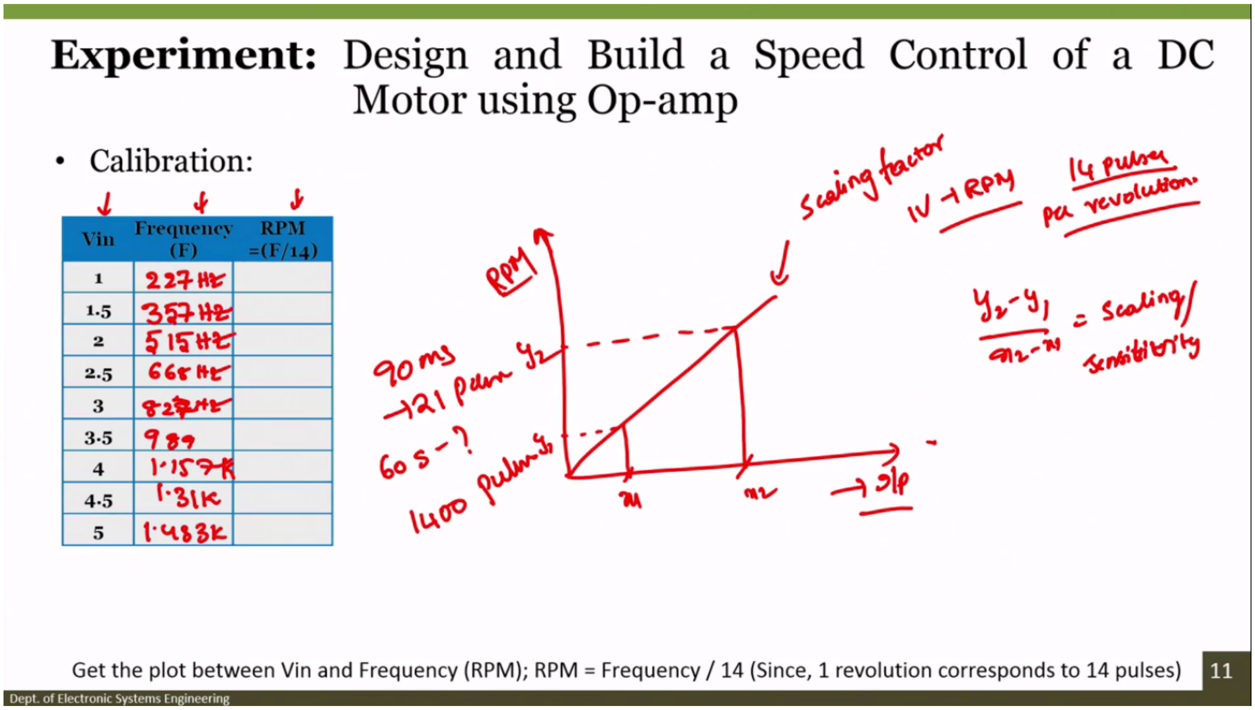
So what we are doing is that this one we have given as an input to the positive terminal of an operational amplifier. So if you see this is a transistor which we are using 2N3019 which is NPN transistor and this is our 56 ohm resistor which is connected in series with in between the ammeter of the transistor to the input of a motor such that it will allow not – it will not allow higher current to pass through the motor.

Similarly, here if you see this is a TL072 again we are using TL072 in negative feedback amplification mode basically an inverting mode so that any voltage that is being applied to the input of a positive terminal will be generated across the output of motor. As a result whatever the output the controller is giving the same output will be across the motor but the current required to drive the motor will be taken from this transistor and the output of this – the output of the operational amplifier is connected to the base of transistor by using the another resistor here which is 180 ohms to 220 ohms. The only idea of having this resistor is to limit the current flow through the transistor.

This is the motor that I was discussing about. This is our microgeared motor and the backside if you see it has encoders connected to this. Now if you see the pin configurations of this DC motor the top one is the motor input. The bottom which is connected to the red wire M2 which indicates with an M2 is your other terminal of the motor input. So whereas the second pin is a ground. And the C1, C2 are nothing but the inputs to the outputs from the encoder.

So in order to understand whether the motor is rotating in clockwise direction or anti-clockwise direction by observing the phase shifter between C1 and C2 we can estimate the rotation of the motor and the RPM will be determined based upon how many number of pulses the encoder is giving per minute. The fifth terminal is VCC which is nothing but the power to the encoder. So basically the max input voltage given to the encoder is 5 volts. And the motor will be the maximum voltage that is required for the motor to operate is of somewhere around 6 volts.

So now along with this it also has other signal conditioning circuits which I will be discussing in next coming sessions. Now to the [00:04:36] one input is connected to the [00:04:40] one channel, the first channel is connected to the first channel of this voltage which is nothing but the input voltage that we are giving it to operational amplifier. Whereas other channel the channel two it is being connected to the output of the encoder. But the channel two grounds are completely separated the reason is that in next case we require to have a negative triggering pulses. Because of that in the digital pulses that we see at this point will be always five to zero. Not to zero to five. It will be zero to minus five because of that shifting. So now what we do is that we will apply input voltage of one volt so here we can see I am slowly increasing the voltage. So apply the input voltage of one volt. And here we can see the pulses. So the yellow line corresponds to the input voltage which by using the channel 1 RPS that we are doing. The blue line indicates the output from the encoder pulses. The reason why we are getting zero to minus five volts is because of our shifting. We have made reverse connections at the output of the encoder for the future purpose. I will let you know why exactly. So it is being powered with the 1 volt right now.



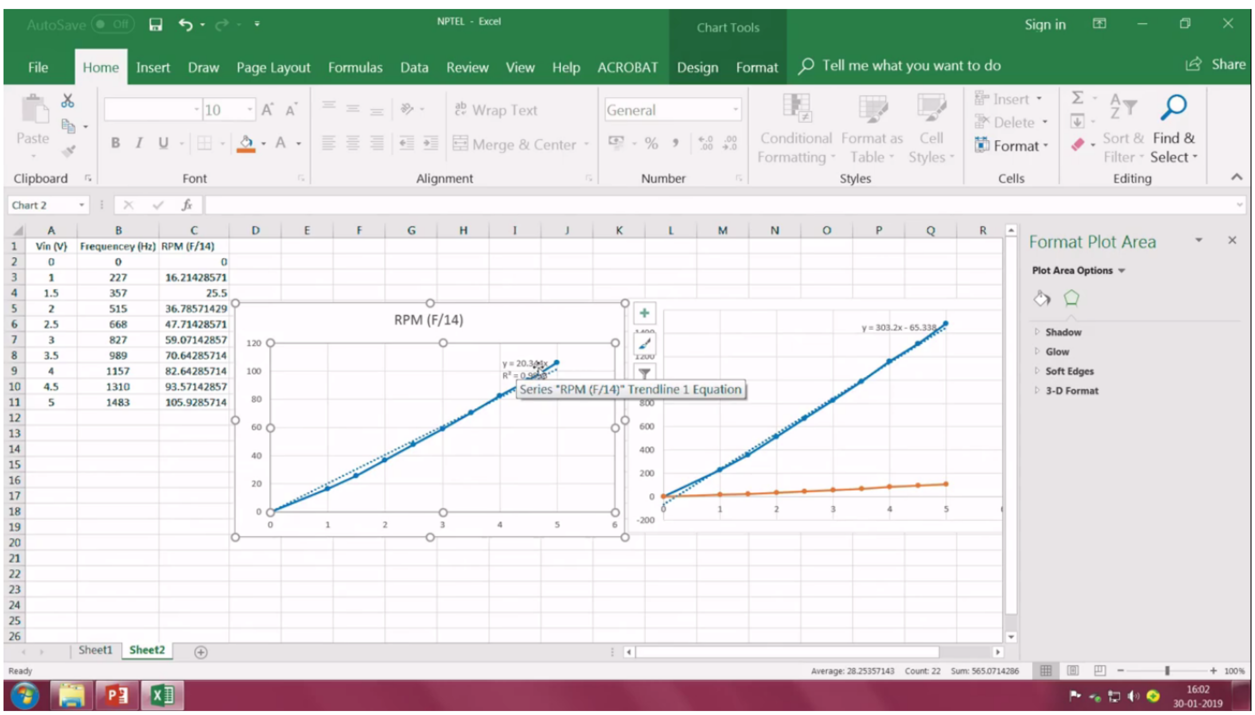
So in order to understand how many number of pulses the RPM of motor what we have to see is that we have to count how many number of pulses that we are getting per minute but right now the scale is at somewhere around 10 millisecond scale and if you count we have a total of 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 pulsed approximately 21 pulses in total of 1, 2, 3, 5, 6, 7, 8, 9 blocks. Each blocks correspond to 10 millisecond. So that means for 90 millisecond we are getting 21 pulses. 90 millisecond we are getting 21 pulses which means that if I want to calculate per minute so it will be 60 into 21 divided by 90 millisecond so which will be 1400 pulses.

So one thing it is clear that by looking into how many number of pulses that we are getting either we can compute in terms of an RPM R rather than that we can also notice the frequency at which it is coming. So when you look into the frequency we are getting approximately 235 hits. So one way is by looking into the how many number of pulses or another way of looking is by looking into the frequency. So right now the blue color one is enabled with the frequency. So it shows somewhere around 227 heads. So that means one thing is clear that for one volt we are getting 227. So we'll change it to 1.5 and we'll see. So right now it is on one. I am slowly tending to 1.5. So I've powered with 1.5. Now if I see the frequency at the output side, it is 357. So 375 heads. You can also notice the motor is rotating.

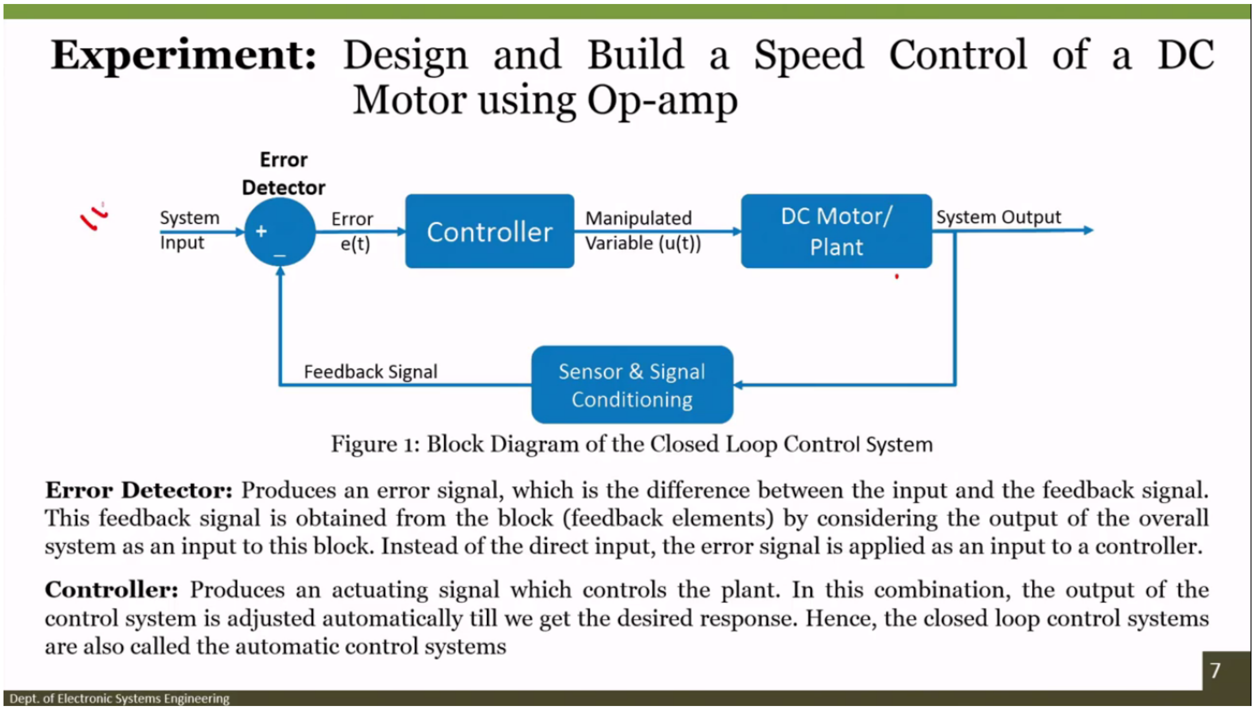
So for 1.5 it is 357 heads. Now, I will increase to 2 volts. Now the frequency is 515 heads. So for two it is 515. So slowly I'm increasing for every value. So 2.5, 668. then 3, 827.

So we can easily understand that it is the frequency is slowly increasing. So we'll observe. Now I'll go with 3.5. You can hear the noise. Now the frequency is 989 Hertz. So I will go to four volts. 1.157. Then 4.5. When I see the value, it is 1.31 K. This is K. This is Kilo Hertz. Then I'll go with 5. So it is a rotating at a maximum RPM. This is operated at six volts. So right now for five volts it is 1.48 kilohertz. 483, 4.483 kilo. So we understood the frequency but until and unless we plot it on excel or we plot it like graph we cannot understand whether it is linear or not. So what I'll do is that I will open an Excel. So I will enter the values . Now so since I have to do fby 14 what I will do is that this divided by 14, this is the Hertz. So at five volts it is clear that it is rotating at 105, 106 approximately RPM. So we also know that the maximum RPM it can rotate is 155 RPM. Now we'll plot a graph between both frequency and the input voltage as well as RPM versus input voltage So this is RPM. So I'll select these two. Insert. This is one graph. So one thing for zero it should be zero. So I will insert one more for zero, zero Hertz and and zero RPM. Okay.

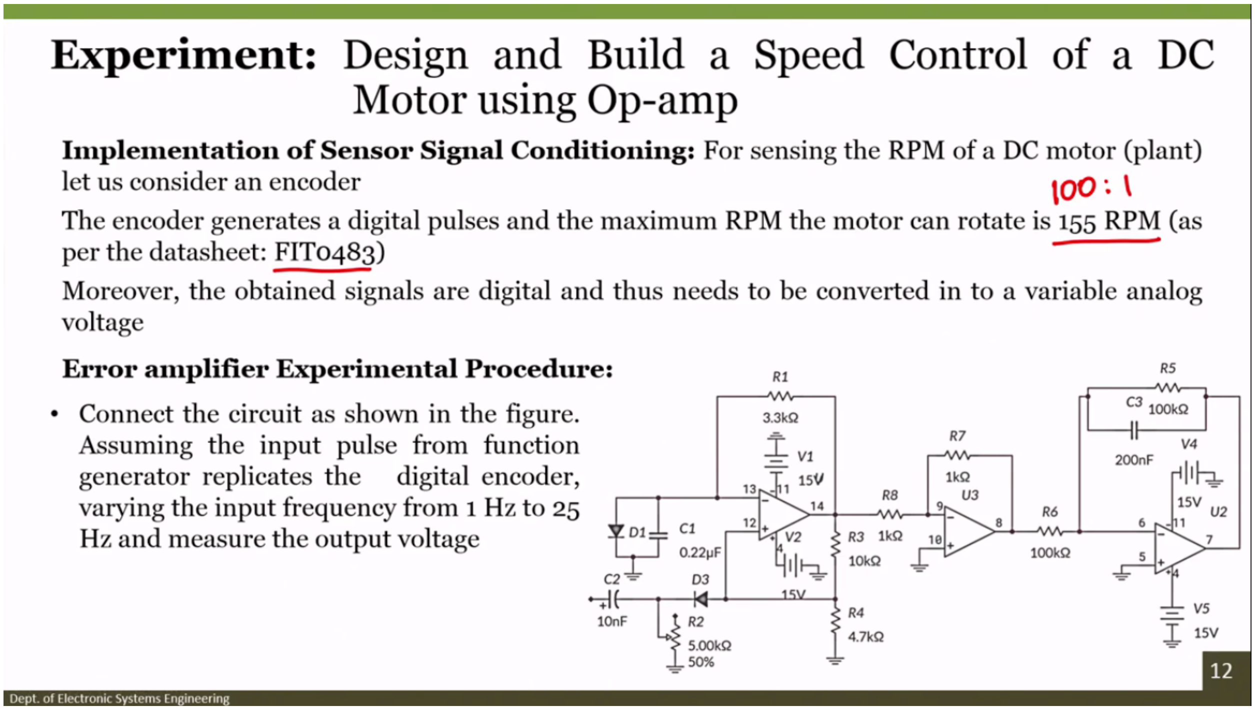
So let me rewrite. Okay let me plot for everything. Okay. Now I will also insert a straight line to understand whether it's straight or not. Okay. Almost same. So let me see the more options here. Then I'll go with the display equaltion on chat. So for frequency it is showing somewhere around 303. So for every voltage it is changing a frequency of 300, approximately, 300 Hertz. Now if a plot with respect to the RPM, so what I will do is that I will go with I'll add new sequence, select data. So this, I rename it as frequency versus Vin. So I will add new sequence which is RPM Vs. Vin. So the sequence X sequence is this particular value whereas Y sequence is this value. Now when I see the graph I got but I do not know because of this magnitude it's a really higher so what I will do is that I'll take another chart and I plotted on that.



So this versus this I want. I'll go to Insert, I will go to new chart. Yes. So this is RPM chart as well as this is frequency chart. So both curves look similar. Of course it should look similar. Now I will add straight line to this. I'll go to the More options then make. Okay. so I am selecting the straight line, going to More options, display R value as well as the equation. So one thing it is clear that even though it is a approximately not linear, but the linearity error is very small. One thing it is clear that R square value is really high so we can consider it as a linear and the Y value is we are getting somewhere around 20.3 approximately. If you are considering the offset at zero intercept as -- offset as zero so the changing RPM value is 20 which means that for every one volt we'll get approximate RPM of 20 plus or minus 10%. So one thing is clear, the sensitivity factor of this, sensitivity factories 20 RPM per volt approximately. So from the graph it is clear 20 RPM per one volt is the sensitivity factor.

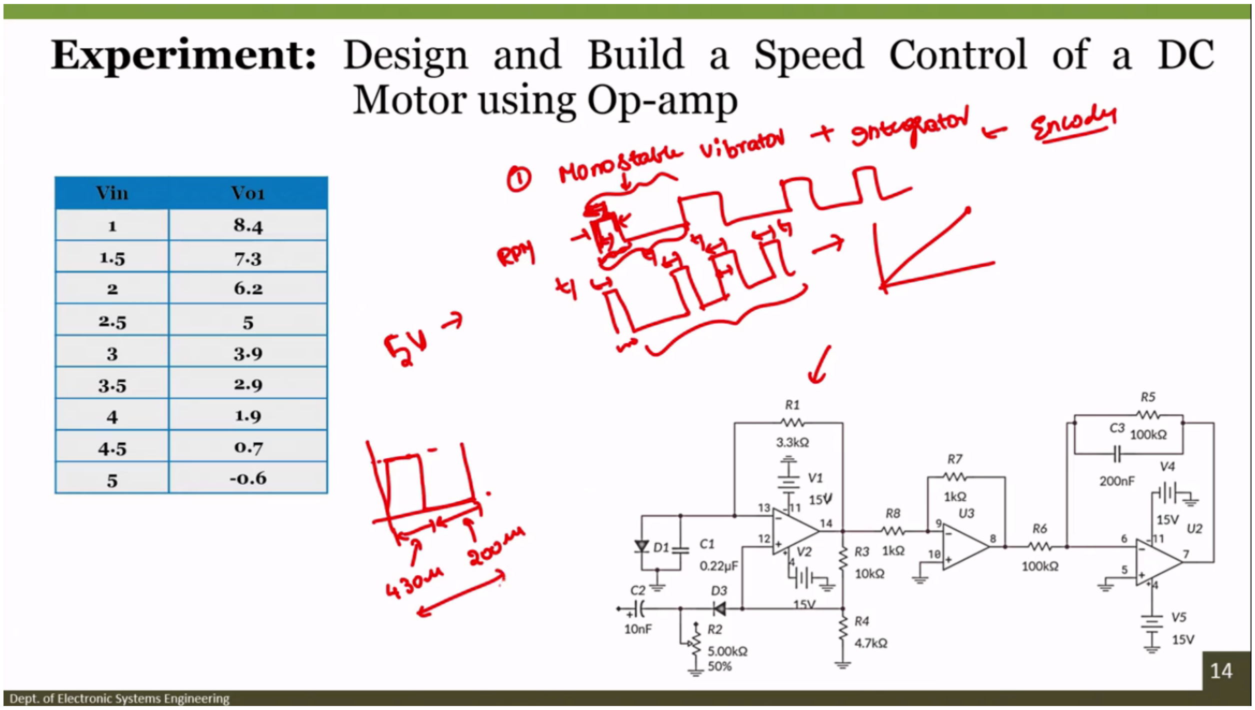


So with this understanding we know that we will go with the sames sensitivity factor as 20 RPM per one volt but system will not understand one volt whether one volt is 20 RPM or 100 RPM but this is only for our reference but system what will it will try to understand is that whether the feedback signal is also one volt or not. It looks for the system input value magnitude is matching with the system output magnitude provided these two should be of same units. So far that in order to have the same unit we are saying one volt corresponds to 20 RPM approximately. So this particular block is done. Driver part of the DC motor and the working with this is done. Now the major part is designing a sensor signal conditioning circuits and interfacing the output of a DC motor to sensor signal conditioning circuit. So one thing it is clear that for one volt we are getting 20 RPM. So this part is clear. So let me make it to zero. Okay. I made two zero. Now the next step. Implementation signaling conditioning. Why do we require.



Now it is clear that whatever the input that we see in the [00:18:44] is completely in the pulsating. So we are getting generally speaking we should get from zero to five volts. But in this case when we absorbed into the [00:18:53] we are getting zero to minus five volts. The reason is that the clock pins, we have reverse the clock pins. So if you see the connections of a mortar, which we have already seen, we know that we have for the encoder, we have a different values. V1, VCC, ground as well as C1 and C2. So what we have done is that we have done VCC connector with the five volts ground to ground. But instead of C1 connecting it to [00:19:26] we met this particular part to ground and this particular part we have connected to [00:19:31]. As a result, we will see a reverse signal image 180 degree image of the signal or flip signal of the actual signal. Why we have connected we will come back to the next one why it is required. So that's why the [00:19:47] output it is shown as zero to minus five volt but frequency remains same. What changes is duty cycle.

The next part what do we have to observe, how exactly the convert this digital pulses into analog signals. Analog signal with same scaling factor as one volt per 20 RPM, 20 RPM per one volt, the same scaling factor. How do we do that?

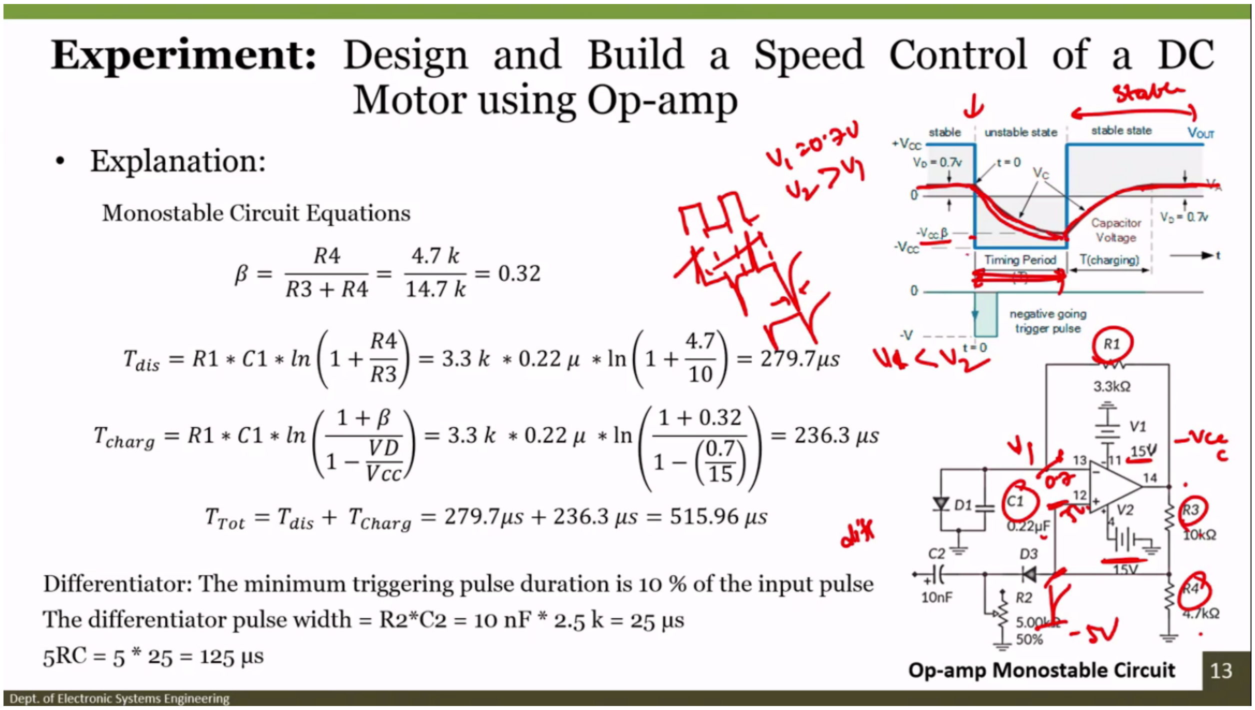


Vin	Vo1
1	8.4
1.5	7.3
2	6.2
2.5	5
3	3.9
3.5	2.9
4	1.9
4.5	0.7
5	-0.6

So for that the only idea is that by using one mono stable multi vibrator and integrate. So why do we require a mono stable multi vibrator? The reason is that in this particular case based upon changing the RPM, the frequency of the signal is keep on varying it. And moreover, since it is based upon number of pulses and when you look into the working of our encoder, it is based upon how much time duration that particular wheel or toothed wheel is in contact with respect to the hall effects sensor use this duration of time, which means that the pulse width of the PWM signal and entirely depends upon the RPM too, which is not constant. But if I make by using a mono stable multi vibrator if I maintain a fixed duty cycle or fix on time pulse such that whenever the RPM is changing, the number of such pulses are also higher. But this pulse widht will always remain constant. If I maintain then integrating over a period of time gives the average output voltage and moreover, if the motor is rotating within a higher RPM, the number of pulses that we are also getting will also be higher as a result, the more number of on time signals we observe and the integration output will be higher. So with that understanding we have designed a mono stable multi vibrator and practical integrator. Recall the working of a mono stable multi vibrator also the working of a practical integrator. I will also explain why exactly we are using inverting amplifier here, but just recall our previous lectures about the understanding of a mono stable multi vibrator as well as understanding of practical integrator.

Now. So the complete purpose of going with the mono stable multi vibrator is to provide a fixed duration pulses, to provide a fix duration of voltage but how do we generate it on, on what basis we select this is the fixed duration. So in order to understand that one thing what we have to know is that at a higher voltage, higher working voltage in this case so in this case the higher working voltage is five volts, what is the minimum pulse width that we are getting from the encoder and what is the total time that you are getting if you know, and if you make the mono stable multi vibrator output the pulse width should be smaller than this particular value as a result we will generate a pulse and we can design mono stable multi vibrator for that particular. What I mean to say is that so what we have done this for a different input voltages we have absorbed the on time as well as an of time from one volt to five volt with the step of 0.5 itself. So one thing it is clear that when we are operating at one volt the on time is 2.7 millisecond after it is 1.2 milliseconds. So totally put together 3.9 milliseconds and the frequency is 256 which corresponds to the same what we have also seen in the – in our previous recording experiment. Now when we see as the voltage is keep on increasing the frequency is also increasing, which means that on time and off time values are decreasing because the frequency is inverse of time. So when we want to design a mono stable multi vibrator the on time, the charging time of the capacitor as well as the discharging time of the capacitor should be smaller than that of the on time and off time of encoder. So in order to understand to what particular t1 on time the mono stable multi vibrator has to be designed we have to look for on time and off time of the lower on time and off time values of encoder. So when we look into this table, it shows that under five volts we are getting a 430 microseconds of on time and 200 microseconds of off time and total time of signal pulses 0.63. What I mean is that when we look into encoder output signal at five volts because only at the five volts we'll get a lower value, low time value. This particular time is 430 micro and this particular value is 200 micro. So the total time signal time is 630 microseconds. That corresponds to 1,587 Hertz. So what we also got is approximately of 1.48 approximately the same. So whatever we are planning to design the mono stable mult vibrator the on time should be smaller than that the on time of encoder.

So that what happens if it is higher? If the on time of the mono stable multi vibrator is higher at that particular frequency, there are chances of missing the pulses. So because of that reason, we have to consider the on time of mono stable multi vibrator should be smaller than that of the on time of this pulse. So in this case if you see the total pulse on time here is 430 microsecond, so the t1, the on time of mono stable multi vibrator should so be less than 430 microseconds. Not only that, another important factor that you have to consider when you're designing a mono stable multi vibrator is whether enough charging of a capacitor, enough charging time of a capacitor. So this tells us about the discharging time of the capacitor. And enough charging when during this time whether we have enough time for the capacitor to go 0.7. So before understanding that, just recall the working of a mono stable multi vibrator. So this particular block, if you consider this particular block is completely differentiated.



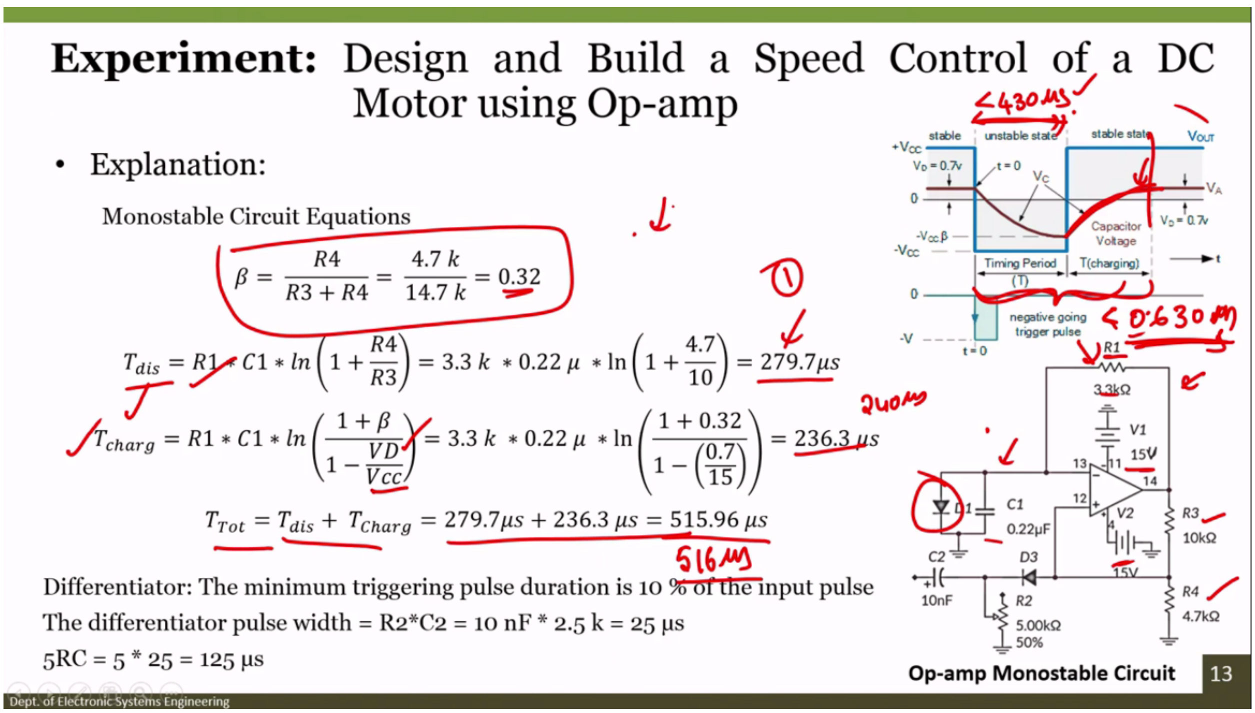
So C&R correspond and differentiator and this diode so when we give a clock pulse signal at the input of this particular portion here we get spikes. Wherever you have a positive, you will get a positive spike wherever you have a negative, you get negative spikes like this. But for mono stable multi vibrator to work, we require only a negative spike. Why do we need only a negative spike we will come to that. So in order to have only a negative spike by passing through the diode in reverse in this configuration that VC so only during the negative time the D3 will be in forward batch condition as a result this particular piece will be eliminated. Finally we will get this way at this particular point. But why do we need it? Now if you recall, the working of a mono stable multi vibrator so we have capacitor even, we have diode even, we have R1 and R3 and R4 corresponds to our beta. So how does it work? Initially if you consider, so since it is extinction of your [00:28:52] we know that we always have a positive feedback in this case. So because of the positive feedback, the operational amplifier will always either go at plus VCC state or minus VCC state. Imagine right now the output is at minus VCC state so what happens through this R1 and capacitors C1 this capacitor start charging, charging, charging if I don't have this particular diode, it's supposed to charge till beta VCC plus beta VCC but because of the diode, when this capacitor voltage is greater than 0.7 or VD the cutting voltage of a diode then the diode will be in a forward bias condition and it will not allow the capacitor to charge more than 0.7. That is nothing but a capacitor charging voltage. So here we can see from here so initially when it is a plus VCC state, sorry, I made it in [00:29:52], whenever it is in plus VCCC state the capacitor start charging, starts charging, charging, charging, and it goes to plus VCC state. So whenever it suppose to go to beta plus VCC but because of this diode this cannot go more than 0.7 volts. So it will stop charging at 0.7 volt. So this region is called stable state. because until and unless this voltage is greater than this particular voltage this value will be always plus VCC. The reason is that when you see the voltage here so 10 kilo on on 4.k and here it will be 15 volts plus VCC meaning if it powered at plus 1, minus 15 so this voltage is always restricted to 0.7 volt. This voltage is higher than so say this is V2, say this is V1 in this case V1 is 0.7 volt and V2 is higher than V1 so it will be always in plus VCC state until V2 becomes lower than that of V1.

So if I want to make V1 state if I want to go to the next state which is an unstable state which is a fixed duration state so that means output to go to minus VCC. So then V2 has to be provided with the smaller voltage than that of V1, But how do we provide it? So in this case it is not possible. So since it is not possible, what we can do is that if I can make at this point provided some negative triggering pulse. If I can provide a negative trigger pulse at V2 terminal as a result since it is a negative smaller duration triggering pulses this particular voltage at that moment will be smaller than V2 because say this is minus five volt, so this is 0.7 this particular voltage this is minus five for particular duration. As a result, this goes to minus VCC state now. So since the output is minus VCC then the capacity starts discharging. So right now you're in this state, it starts discharging, discharging, till what time? Till it reaches to minus beta into VCC. So the complete calculation for mono stable multi vibrator as well as a stable multi vibrator working experiment we have already seen in the previous course. You can just look into that. But I hope now it is clear that if we understand that it will discharge only for particular time duration and this particular time duration entirely depends upon what is an r, what is C1, and here R3, R4 too. So this tells you how fast your capacitor will start charging and this R3, R4 tells you till what value the capacitor will go up to. So that minus VCC into beta. So even the minus voltage that we are providing, the VCC that we are providing is also very much important in this case.

So this state where it goes to minus VCC and in one particular point the capacitor value will be higher than that of minus VCC value. Then it goes to the next step, which is nothing but stable state. So this duration is nothing but unstable state and the duration of this entirely depends upon R1 and C1. How do we design it? So in this case, if you observe we have to design the same pulse, but the duration of this should be smaller than 430 microseconds and the complete cycle should be lesser than 0.630 millisecond. since it is 0.630 millisecond or 630 microsecond. So that means if I know the formulas are related to that, it is easy for me to do that. But now it is clear that way. we require t4o d design less than 430 microsecond because if the pulses, if the on time pulse of this is greater than 430 microsecond, there is a chance when the motor is rotating at a higher RPM at one particular moment there are chances of missing few pulses. So in order to not to have, in order to not to change the accuracy of the system, we will be limiting to less than 430 microseconds. And another reason why the complete charging and discharging of complete pulse should be less than 630 microsecond because for the capacitor to do charge also requires some time and that time the complete discharging and plus charging time should be within the range of 630 microseconds. So when you look into the equations relevant to the mono stable multi vibrator now if you see this is R4 and R3 based upon that we have considered beta so the beta is nothing but 0.32. So this is not 0.5 This is-- if we consider R3 and R4 as either 10K our 4.7K, then beta would have been five volts 0.5 but in this case we have considered different R3 and R4 resistors. So the value is 0.3.

Now so for the design calculation R1 and C1 even if I see that time discharge, the formula for that is R1 C1 into log one plus R4 by R3. So if you see that the value will be 280 approximately 280 microsecond.

So if you see this is 430 microsecond, but the pulse that we are getting is 280 microseconds, which is smaller than 430. So one particular design criteria is met. Other one, charging, the total time should be smaller than 630 micro. So if I want to understand the total time, I also want to know what is a time for a capacitor to charge. Because before the signal, I should not get any, I should not get the next pulse. Next encoder pulse. So because of that, we also have to see what is the time taken for the capacitor to charge. If you miss this particular charging time, there are chances of getting errors because you are not providing enough time for the capacitor to charge it. So when we calculate the capacitor charging time, which is nothing but R1C1 log one plus beta by one minus V2 into VCC where VD is nothing but the cutting voltage of the diode that we are considering it here as well as VCC, what is the power supply that you are considering. So when you substitute all the values, so we are taking IN1007 we can calculate it as approximately of 240 microseconds. So the total time, which is nothing but discharging time as well as charging time is 516 microsecond. But what is the room that we have with the higher RPM when we are rotating at five volts we have a room up to 630 microseconds. But here in this case, we require a total of 516 microseconds, which is smaller than that of 630 microsecond. So whatever we have designed, the particular resistance that we have chosen, R1, C1, R3, R4 is good enough in order to not to miss any pulse, which means that it can count for all the pulses. It will not miss anything. So the accuracy will be good enough. So I hope this is clear.



So this particular resistors and capacitors have been selected by doing different permutations and combinations here. So we have done – here we can observe the different set of values that we have tried in order to match with our requirement. So we have gone with different capacitors, different registers, and we have seen what is an on time for each capacitor, whether everything is within our limit or not by adding these two whether these are within our limit or not. So we have done different calculations in order to match the resistance and capacitance value.

So finally we have come out with the R as 3.3 kilo and capacitor as 22 Microfarad, which is meeting our requirement. And another important thing, what we have to do is that whatever the differentiator time period that we are considering should be the pulse duration of the differentiators circuit which is nothing but this particular circuit or this particular triggering pulse should be 10% minimum of 10% of the input pulse. So in this case the input pulse is somewhere around 280 microseconds. So 280 microseconds into 10% approximately of 28 microseconds of pulse we require. So by using this particular resistor, by fixing this particular 10 nanofarad capacitor, by varying this resistor, we are achieving the pulses that we require.

So I hope now it is clear why we are using the negative pulse at this point instead of doing zero to five volts, we are given minus zero to minus five volts. The reason is that we require only the negative spike. We don't need any positive spike. So in order to get this negative spike, that triggering input provided should be always zero to minus give volts otherwise all the spikes will be greater than that. So for that intention, we made, we reverse the output of the encoder instead of measuring with respect to the ground, we measured everything with respect to five volts so that the output will be zero to minus five volts. So I hope this is clear right now.