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Course Title
Electronic Modules for Industrial Applications using Op-Amps

By
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Department of Electronic Systems Engineering

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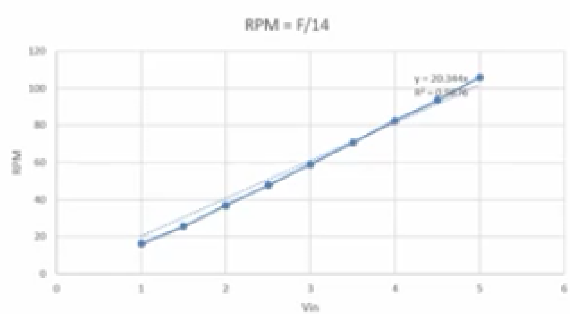
Experiment: Design and Build a Speed Control of a DC Motor using Op-amp

- Calibration:

Vin	Frequency (F)	RPM =(F/14)
1	227	16.21428571
1.5	357	25.5
2	515	36.78571429
2.5	668	47.71428571
3	827	59.07142857
3.5	989	70.64285714
4	1157	82.64285714
4.5	1310	93.57142857
5	1483	105.9285714



Get the plot between Vin and Frequency (RPM); RPM = Frequency / 14 (Since, 1 revolution corresponds to 14 pulses)

Welcome to the module, in the last module we have seen the relationship between Vin and the change in the frequency of the encoder, so we have also understood the working of driver circuit,
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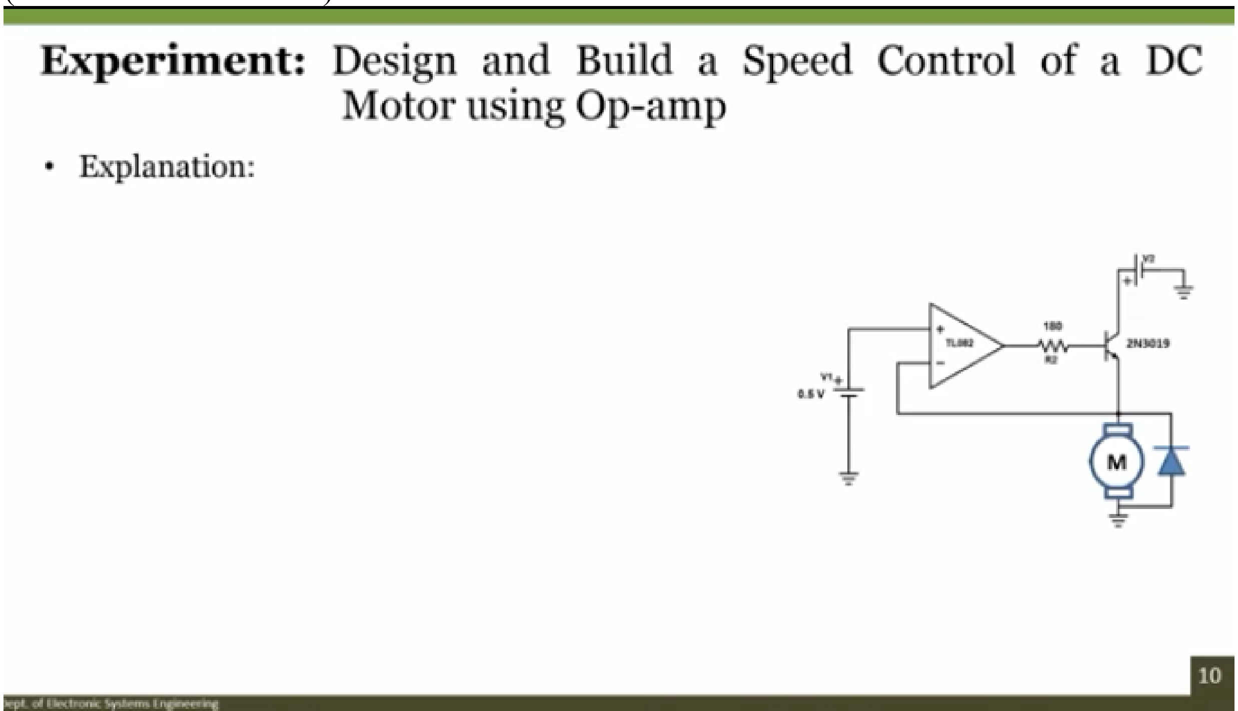

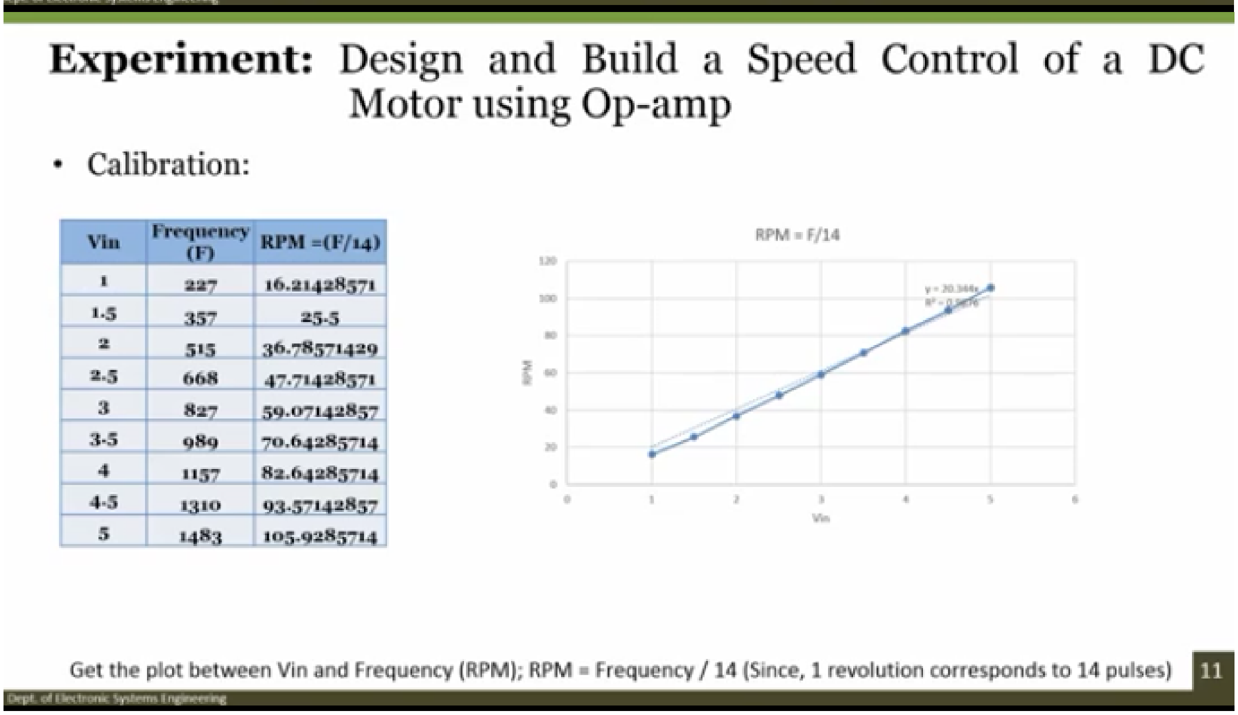

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5	1483	105.9285714

how exactly the driver circuit is working, and we have also seen the relationship between input voltage, that means input connecting to the positive terminal of operational amplifier, how the frequency of the digital pulses that we are getting from the encoder is keep on varying, so as we know that encoder depends upon the number of pulses that it is coming entirely depends upon the RPM of a motor, so increase in the voltage, increase is the RPM of the motor, so as a result the number of pulses that we are getting per minute is also increasing, so as a result we have also observed that the number of pulses that it is occurring or we are getting from the output of an encoder is also higher, so one way to visualize that is by looking into the frequency and we have also seen the frequency and we have divided the frequency that we obtained from the CRO using RPM that divided with 14, the purpose of this 14 is that when we looked into the datasheet,

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

- Calibration:

Please Note:
RPM = (Frequency x 60)/(No.of pulses x Gear reductior

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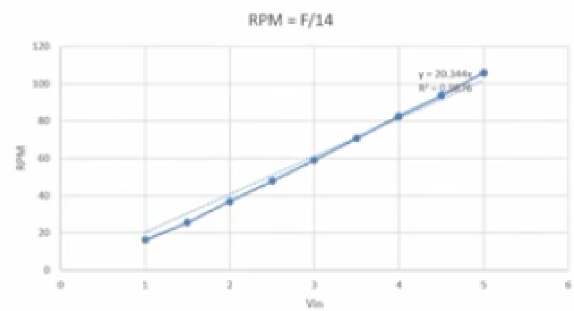

Get the plot between Vin and Frequency (RPM); RPM = Frequency / 14 (Since, 1 revolution corresponds to 14 pulses) 11

one revolution corresponds to total of 14 number of, 14 pulses, so we got an RPM.

So finally we made a graph between Vin and the RPM, and we understood that by plotting a tread line we understood that 1 volt is corresponds to approximately of 20 RPM, so what it means if I want motor to be rotated approximately of 20RPM, if I provide a set point of 1 volt it will understand that the motor has to be rotated at 20 RPM, so that is a scaling factor or a mapping factor that we have concluded from the yesterday's experiment.

So with this understanding we have also done the simulation of converting our,

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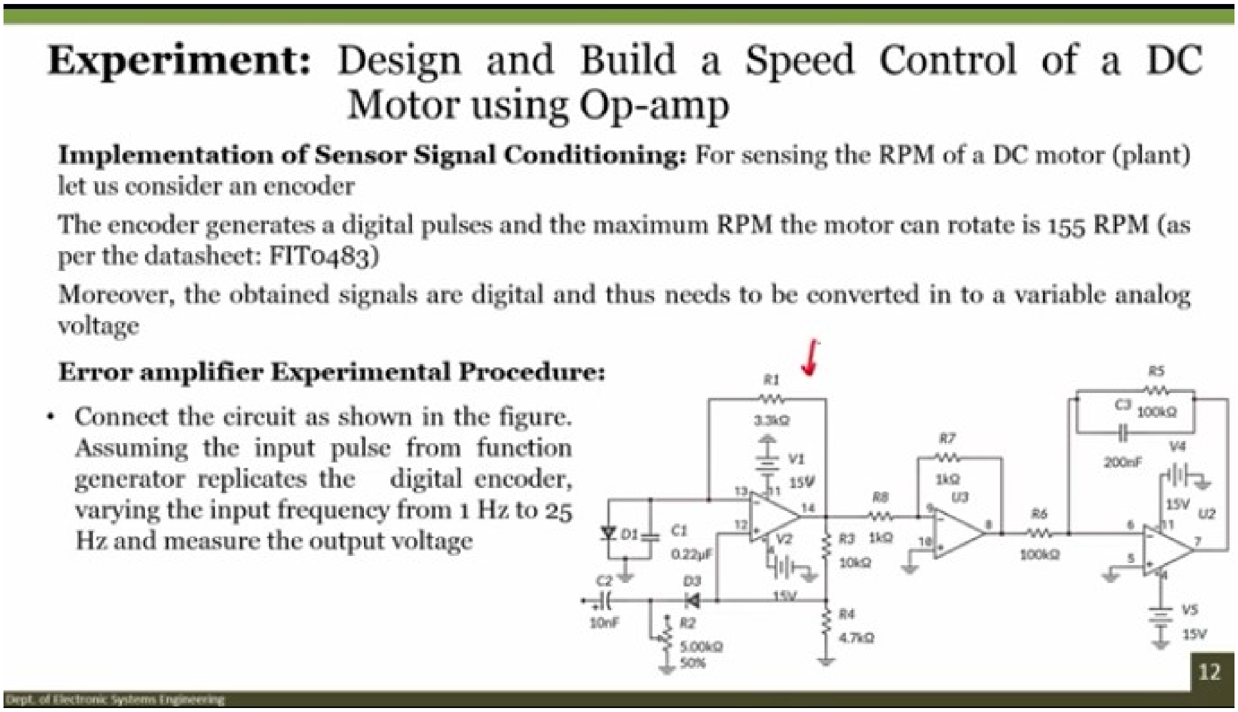

the input digital pulses into the constant width pulses by using a monostable multivibrator, so why do we require this? When we observed the excel which gives you the plotting which was, which gives the relationship between Vin and the frequency, along with the frequency we have also observed the on-time and off-time of the pulse that we are getting from encoder, so when we observed the both, the frequency term, the pulse width everything is keep on varying with respect to the input voltage, so if I directly integrate the input voltage it is very difficult to get a relationship between the output voltage and the input voltage, which is nothing but the RPM, so for that purpose what we have done, we have made one particular term as a fixed, so either we can make you know RPM as a, you know the frequency at which this particular thing is operating to be fixed and by varying the,

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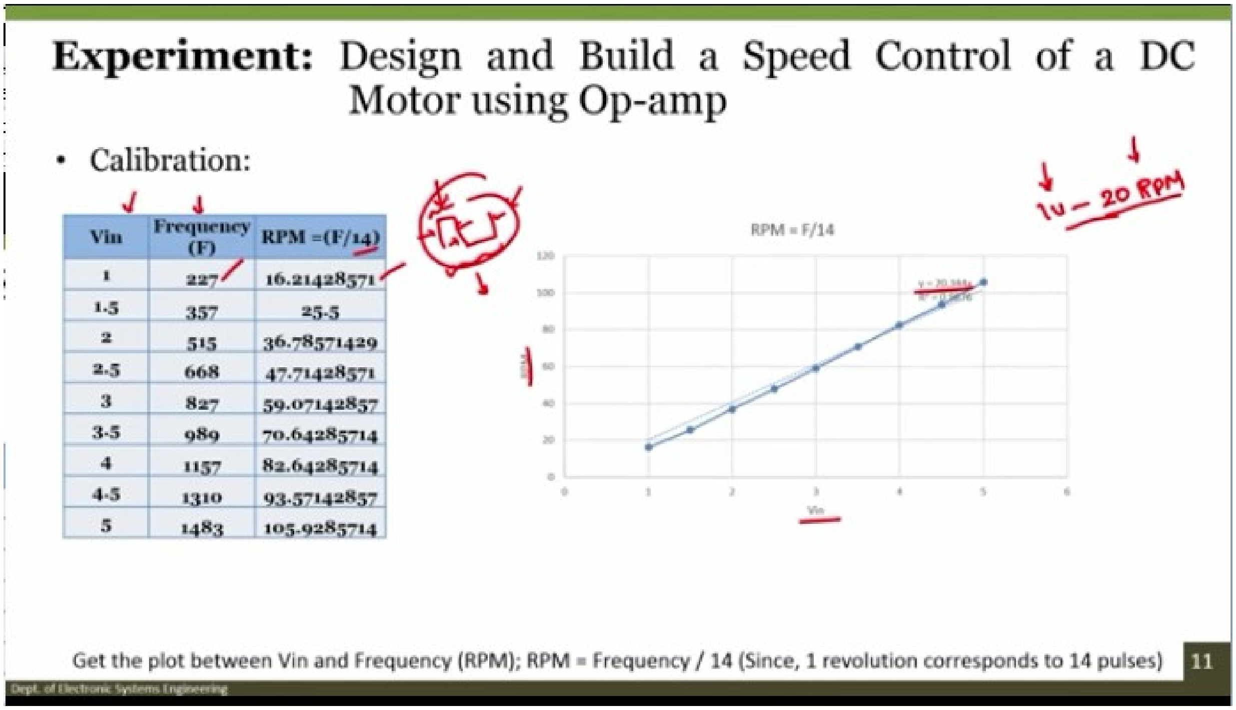

by changing the pulse width which is nothing but the PWM signal, we can also integrate that signal, we can understand, we can observe the varying output voltage with respect to the change in the pulse width, but since it will be a difficult what we have done is we have an interfaced or the output of the encoder has been integrated to a monostable multivibrator, so since it is a monostable multivibrator, whenever a triggering pulse is received, whenever there is a, whenever we receive a triggering pulse at this point we will get a constant duration pulse,

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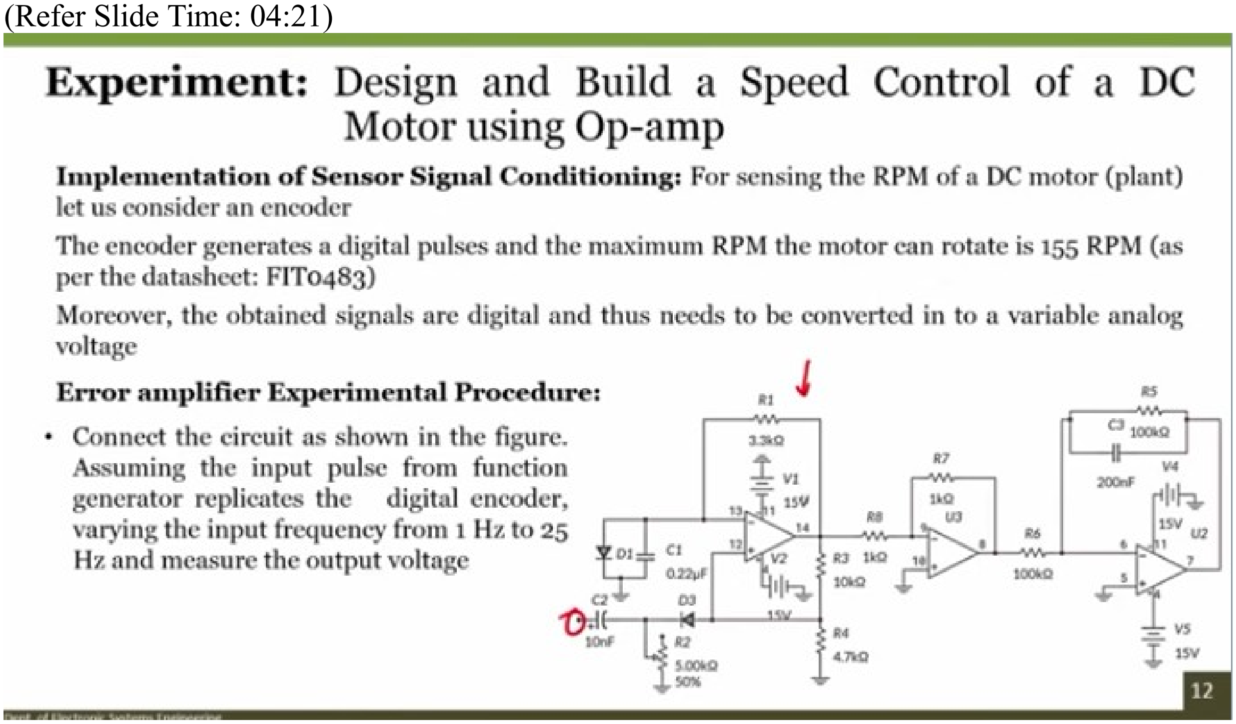

and this constant duration pulse either this or this one, so in this case so since it is a monostable that too operational amplifier based we got a pulse like this, and this duration of the pulse

entirely depends upon the parameters that we have set here, now would be, so it depends upon the beta, it depends upon R1 and C1, so those relations also we discussed yesterday, right.
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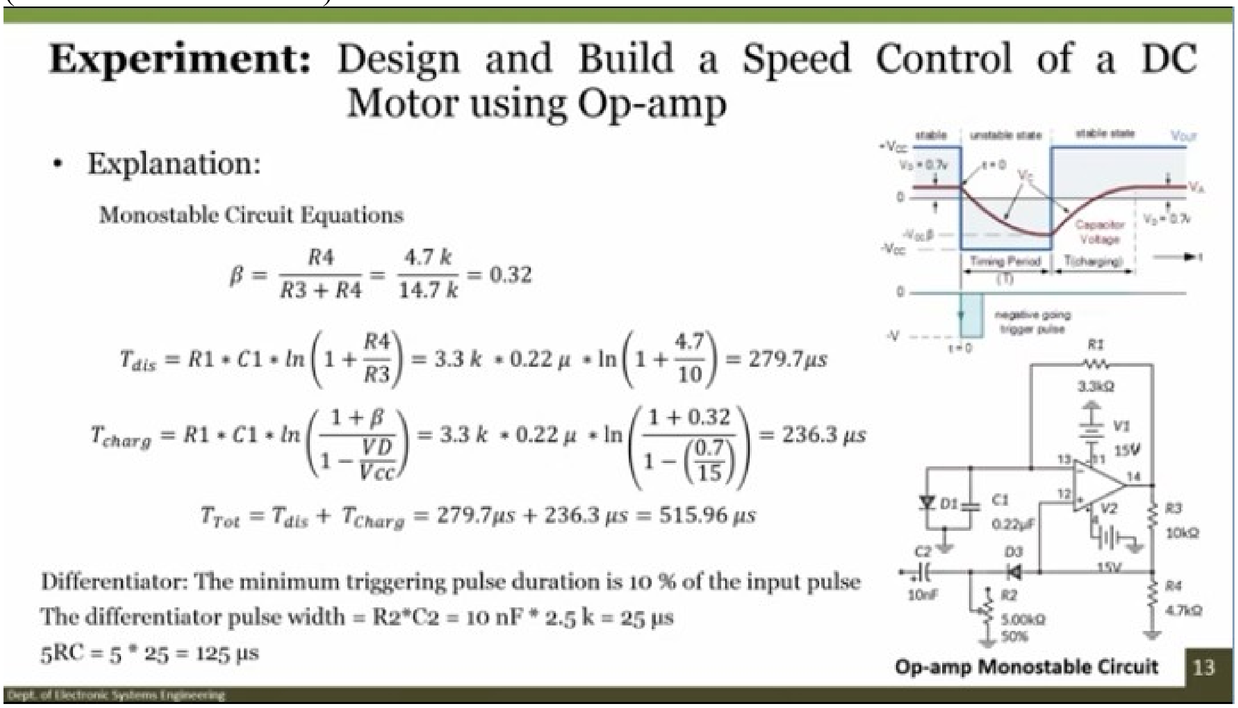

Then we have also seen how we have come out with the R1, C1 values as well as R3, R4 values in order to you know match with all the operating ranges of our input voltage, which means that when the motor is rotating with 0 to 5 volts, whatever the frequency, whatever the frequency the output encoder is providing the monostable multivibrator should work for all that operating range, all the frequency for that we have chosen such that the charging and discharging time of the capacitor should be always smaller than that of the monostable multivibrator pulse value, as well as should be smaller, sorry the charging and discharging of the capacitor of a monostable multivibrator should be smaller than that of the lowest value of the encoder signal that we received, since the operating voltage is of 5 volts max that we are using in this particular case study, so for 5 volts we observed what is an on-time, as well as what is an-off time, and if you know on-time and off-time of the pulse by adding both the things we will get the total time and this total time is higher, this total time is higher than the total time that we got from discharging and charging of a capacitor.

As a result this will work completely for that particular range of input voltage or particular, for this particular frequency signal, and also the discharging time of the capacitor which is decided by R1 and C1 should be smaller than that off the discharging time of the pulse, right, so with this understanding we have considered the R1 as 3.3 kilo ohms, C1 as 0.2 to microfarad, and beta instead of going with 0.5 for our requirement we have gone with 0.3.

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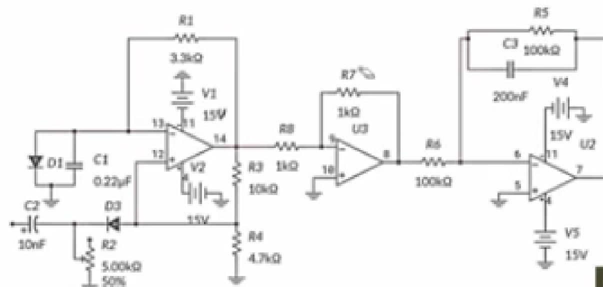
Experiment: Design and Build a Speed Control of a DC Motor using Op-amp

Vin	Vo1
1	
1.5	
2	
2.5	
3	
3.5	
4	
4.5	
5	



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So with this understanding now after conducting an experiment yesterday we understood that for all range of input voltages, of input voltages from to the motor which is 0 to 5 volts, the encoder change its frequency from approximately of 227 hertz to 1 to 5 volts, 227 hertz to somewhere around 1.5 kilo hertz, so for all this frequency we understood that the monostable multivibrator is working fine, and it is as per our expectation, but now what we have to see? Our intention was, our intention when we recall into, when we look into our complete closed loop control system block diagram the whole idea is that the system input should always mapped with the output that we get from the sensor, right now we have done a part of sensor signal conditioning,

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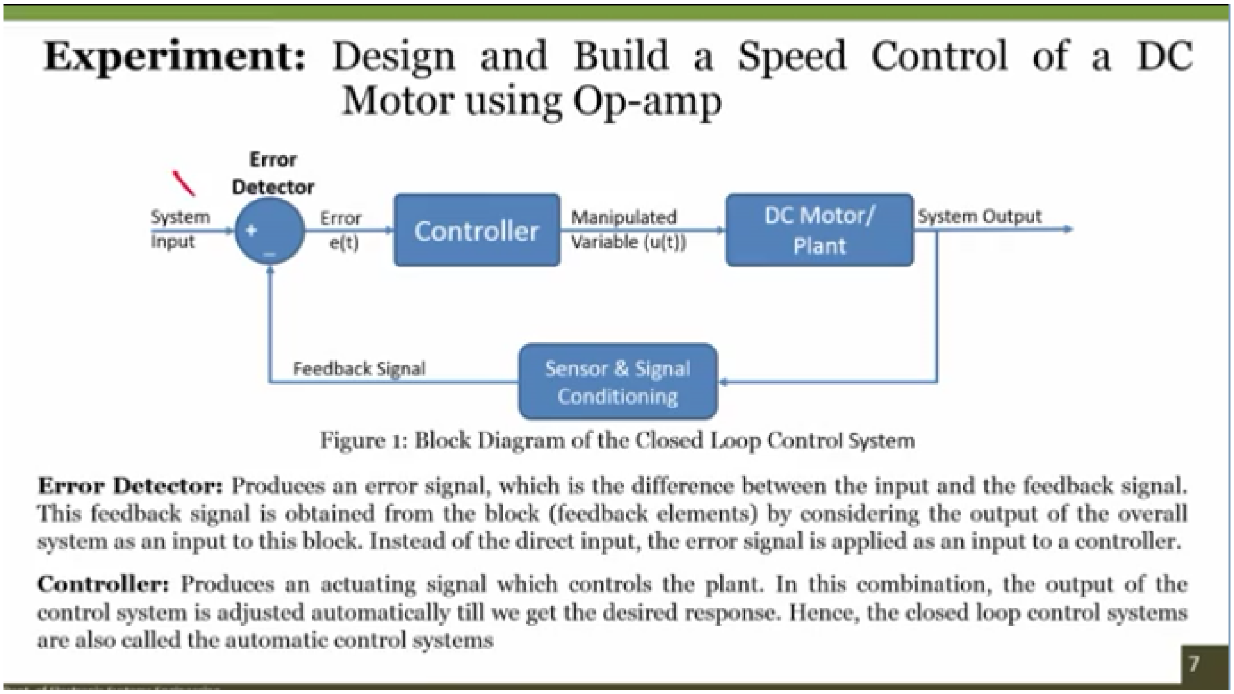

since we already have a sensor a part of sensor signal conditioning that part is designing a monostable multivibrator, so that after monostable multivibrator we got a fixed time duration of a pulse, either it is on-time pulse or off-time pulse, one particular pulse is always fixed.

And we have also seen that in order to make that the output of the encoder in this case which provides a triggering input to the monostable multivibrator should be always from 0 to -5 volts, right, so the next part is that, next part of signal conditioning is that this pulse has to be converted to output voltage, right, and after generating an output that too linear output voltage, what I mean is that by varying the, by varying the RPM of an DC motor which varies with respect to the change in the input voltage given to the DC motor, the output voltage also has to linearly increase, so which means if I say this is an RPM, and if I say this is sensor signal conditioning circuit, so based upon the RPM the sensor signal conditioning circuit output should also vary linearly, but at what rate? This rate at which it has to operate should be equal to the mapping factor of your system input, so in this case our mapping factor is 1 volt corresponds to 20 RPM approximately, so which means that 20/1 so 20 RPM for 1 volt, this is a sensitivity factor, sensitivity factor or the mapping factor that we have considered for this particular system, so whatever the output that we get from the sensor signal conditioning circuit should also maintain 20 volt per RPM, sorry 20RPM per volt, or 1 volt per 20 RPM,
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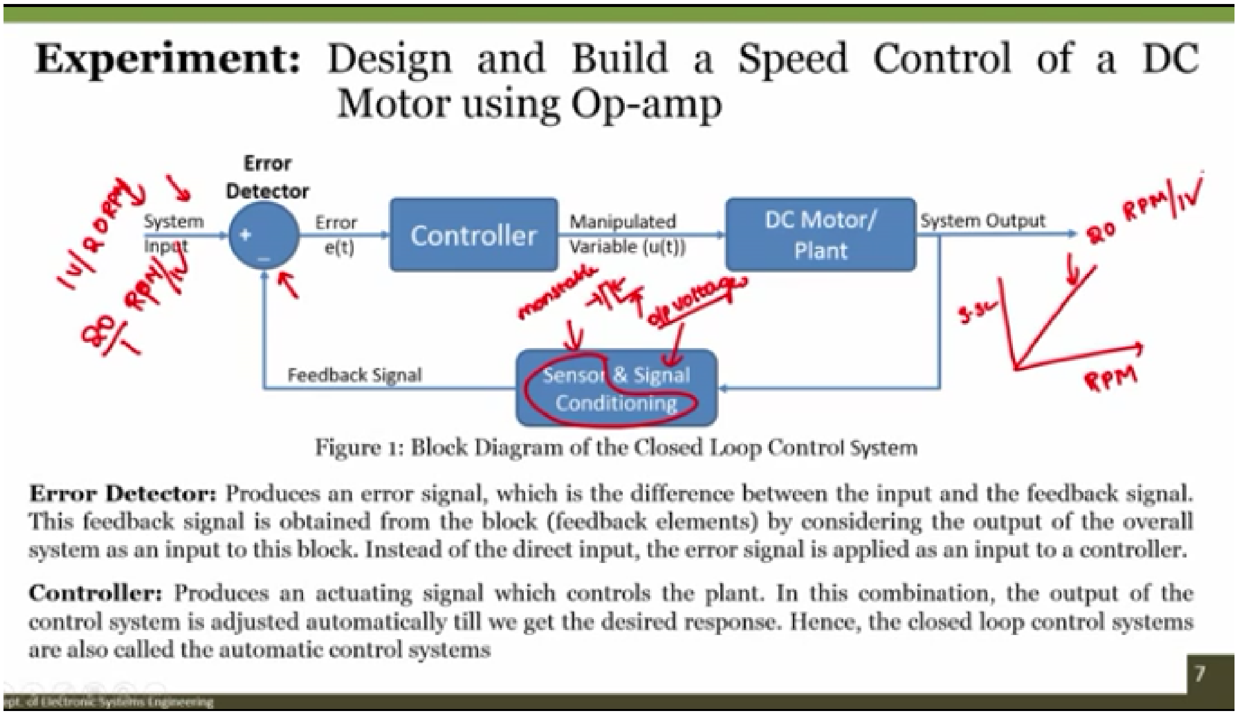

so in this case input is RPM, output is voltage so that's why it is 1 volt per 20RPM, then we consider as a sensitivity.

So as long as this condition is satisfy our signal conditioning part is done, but we have not still reached to this particular case, before this case we have to get an output voltage, but how do we get a linearly varying output voltage? So in order to do that today what we are going to see is that we are going to integrate the output whatever we get from the monostable multivibrator,
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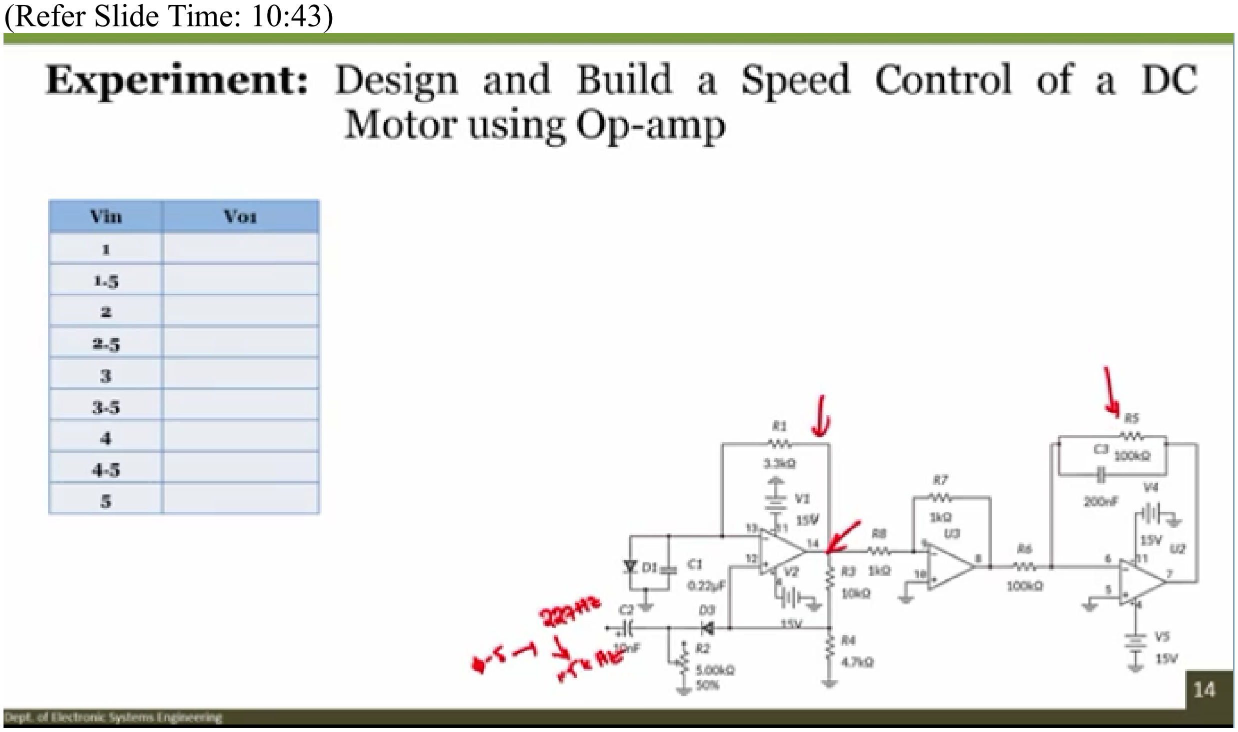

but instead of directly connecting it to integrator circuit we are connected through an inverting amplifier, but why do we require inverting amplifier? The reason is that yesterday in the previous session if you observe the output that we get from the monostable multivibrator meaning, when a triggering pulse is given like this, so this is from encoder output, right, so this is 0 volt, this is -5 volt, because we have reversed the clock pulse, and it has been given to triggering input of a monostable multivibrator,

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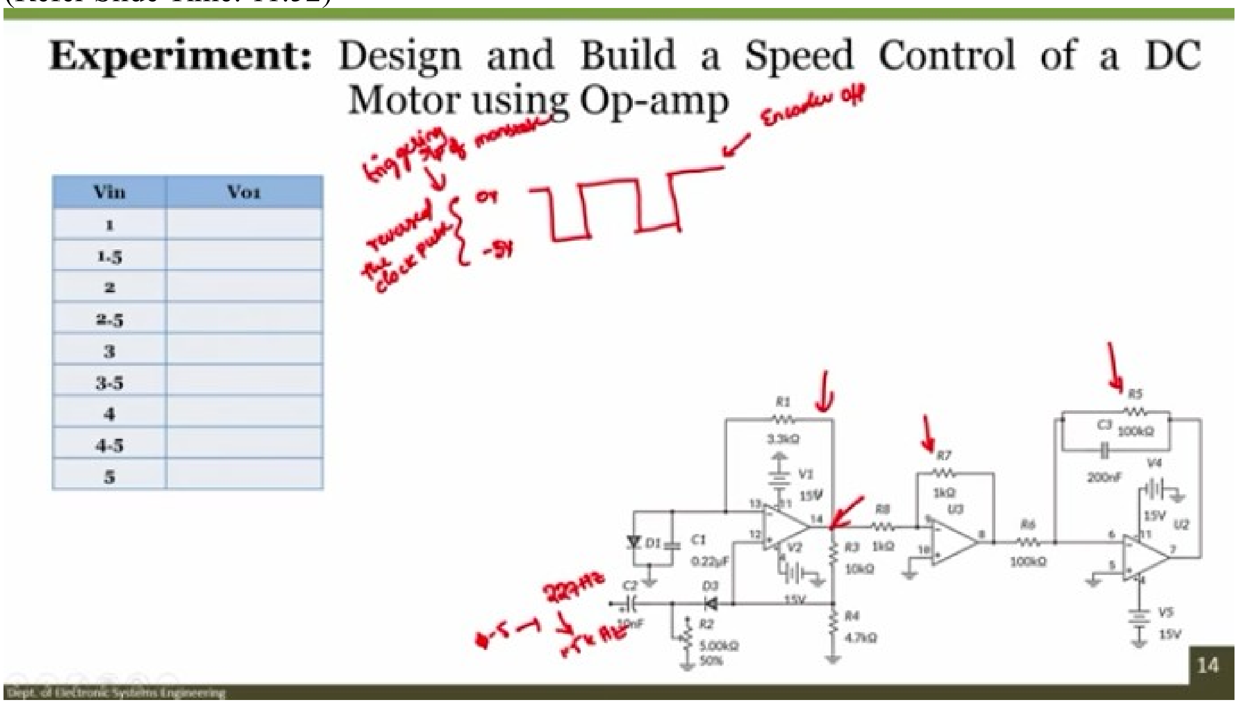

so we got an output such that the output will be always from +15 to -15 so we got something, so if I say this is +15 range, and if I say this is -15 range, -15 volts range, sorry, this is -15 and this is +15 range, we understood that whenever there is a negative spike we got, so in this case there will be a negative spike at this point, so we got a fixed pulse with a duration of 279, approximately 280 microseconds, so we got something,

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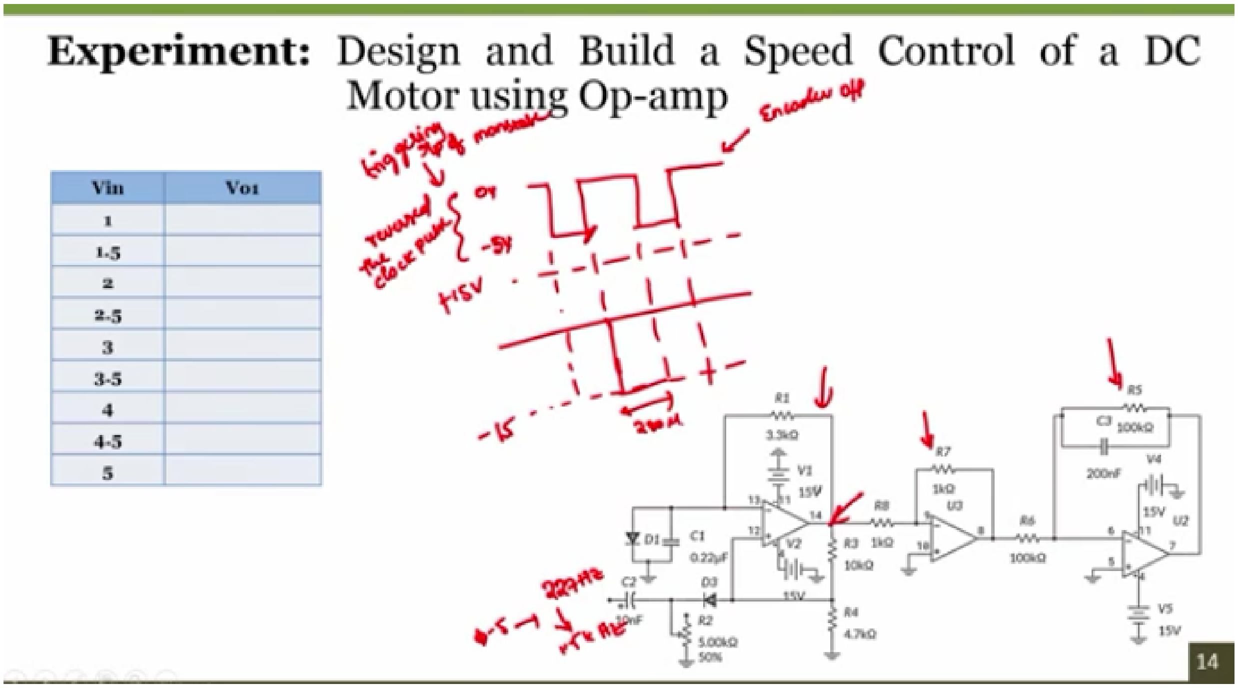

we got like this, this is 280 microsecond.

And till we get a next triggering pulse it was in stable state that means at +15, right, so this is the signal that we got, and the signal width is also smaller than that, smaller that of the complete signal, but ideally practically there will be always a difference, the reason is that when we see ideally we always consider that op-amp is, op-amp output voltage will be supply voltage, +15 and -15, but practically speaking the supply voltages will not be at +15 and -15, will be smaller than the supplied voltage.

As a result there will be small deviation in, there will be a small deviation in on-time, as well as off-time of the output of monostable multivibrator, but after considering everything we have given a very big room in this case where we required a total of 620 microsecond, but the complete ideally it is a 515, 516 microseconds is the time required for the capacitor to charge as well as discharge in this case, so we have plenty of enough time in this case for sustain for those practical problems, but even then but if you see during the negative cycle the output is very small, so what we have done is by passing through inverting amplifier the output will be a phase shift of, 180 degree phase shift of this particular signal that we have seen, so finally we get a signal of like this.

So whenever there is a negative triggering pulse, this particular width will be 280 microsecond and this will be based upon the previous state, next triggering cycle that we get, right, so this we have already, this will be the output of an inverting amplifier, for further it will support inverting amplifier, I suggest you to look into the previous course which was discussed by Professor Hardik Pandya.

Now so this is the practical integrator, the difference between a practical integrator and an ideal integrator is that the practical integrator should always have to have a resistance R5 parallel to the capacitor that we have seen here,

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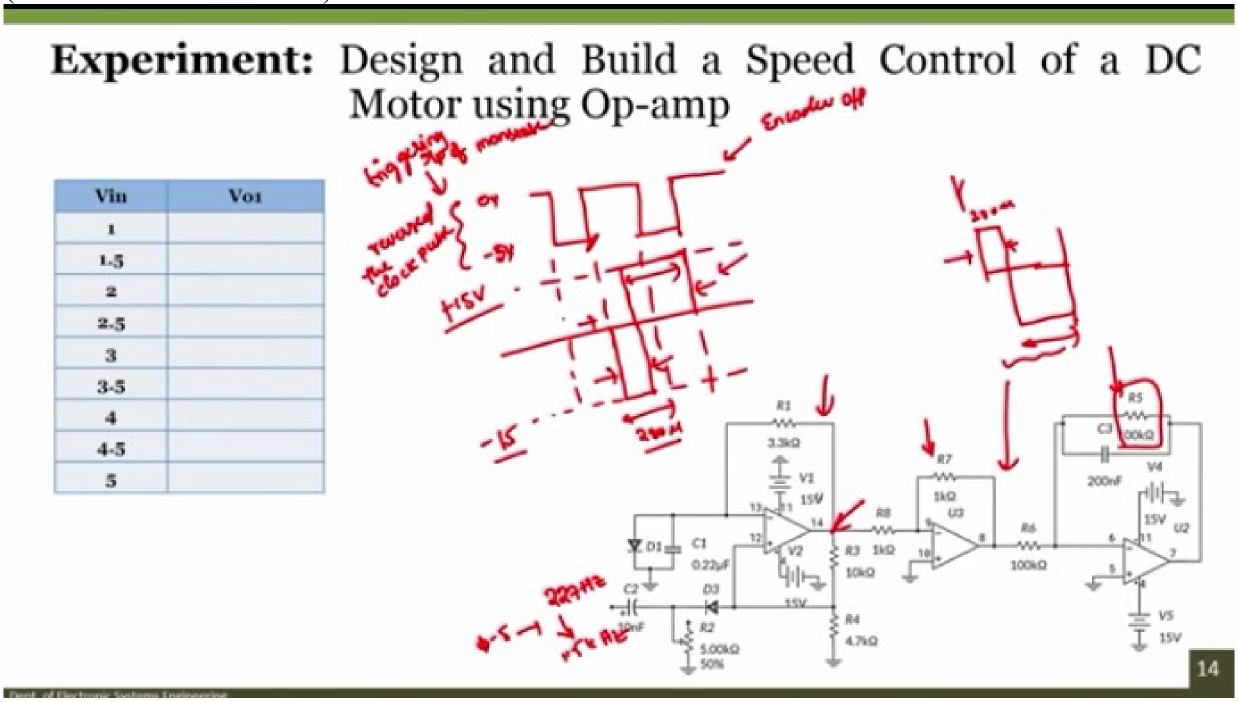

so even this integrator concept we have discussed in the previous lecture previous course, please have a look if you have any further information or you can even send as an query so that we can give you further more information about that.

Now we will see by varying this particular frequency, the encoder signal frequency which has given as an input to the monostable multivibrator whether we are getting a linearly variable output voltage or not, so whole idea is that it has to give a linearly variable output voltage based upon the change in the frequency,

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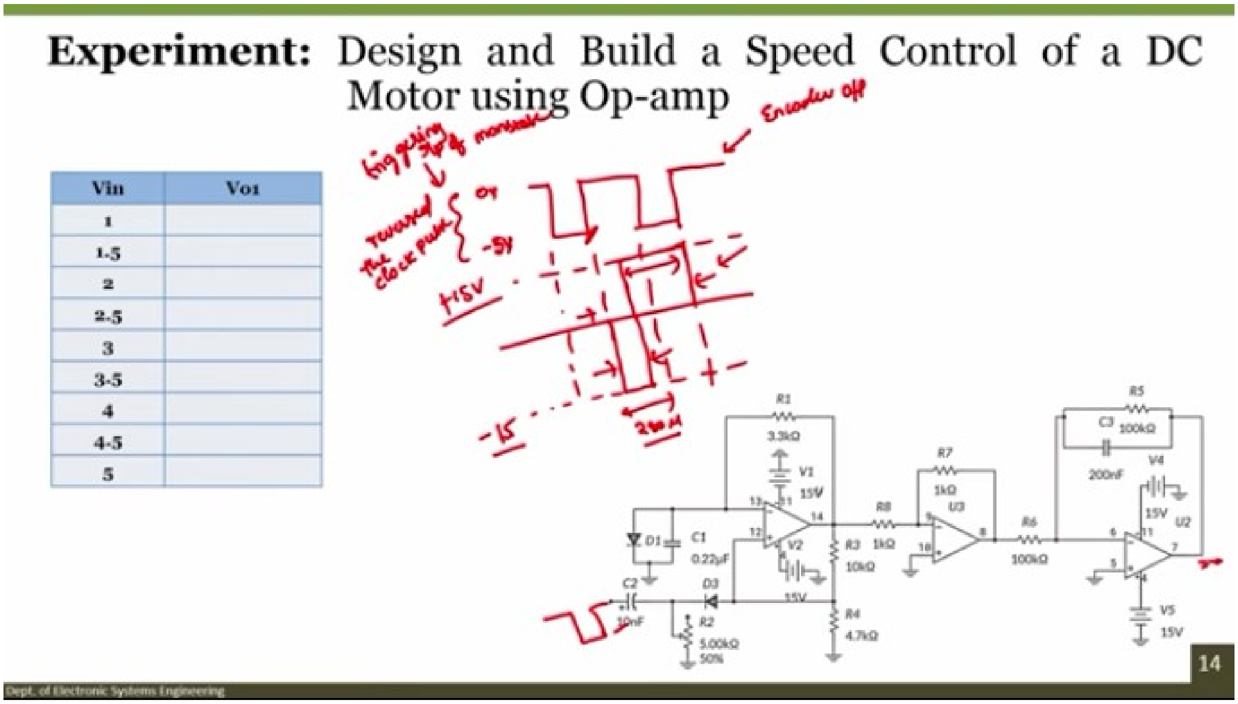

so we will see whether it is giving it or not, but what is an idea behind that? That in adding an integrator the output of a monostable will gives an linearly output voltage, the reason is that so when we look into the monostable multivibrator, we know that we are getting a fixed duration pulses, of on-time pulses, but generally it will be reversed since we passed it through a inverting output, this fixed duration will be on the positive side, say this is for one particular set of frequency, right.

Now for example say in this case we have seen only 3 pulses, 3 on-time pulses of fixed duration, suppose if the input voltage given to the, motor has been increase, what happens? For the same fixed time duration say this is time T1, for the same T1 we can see more number of pulses, right, you can see more number of fixed number of pulses, so because this constant is always fixed, and this entirely depends upon monostable multivibrator that we have designed, even in this case this is TX, this is TX this value, and this is also TX,
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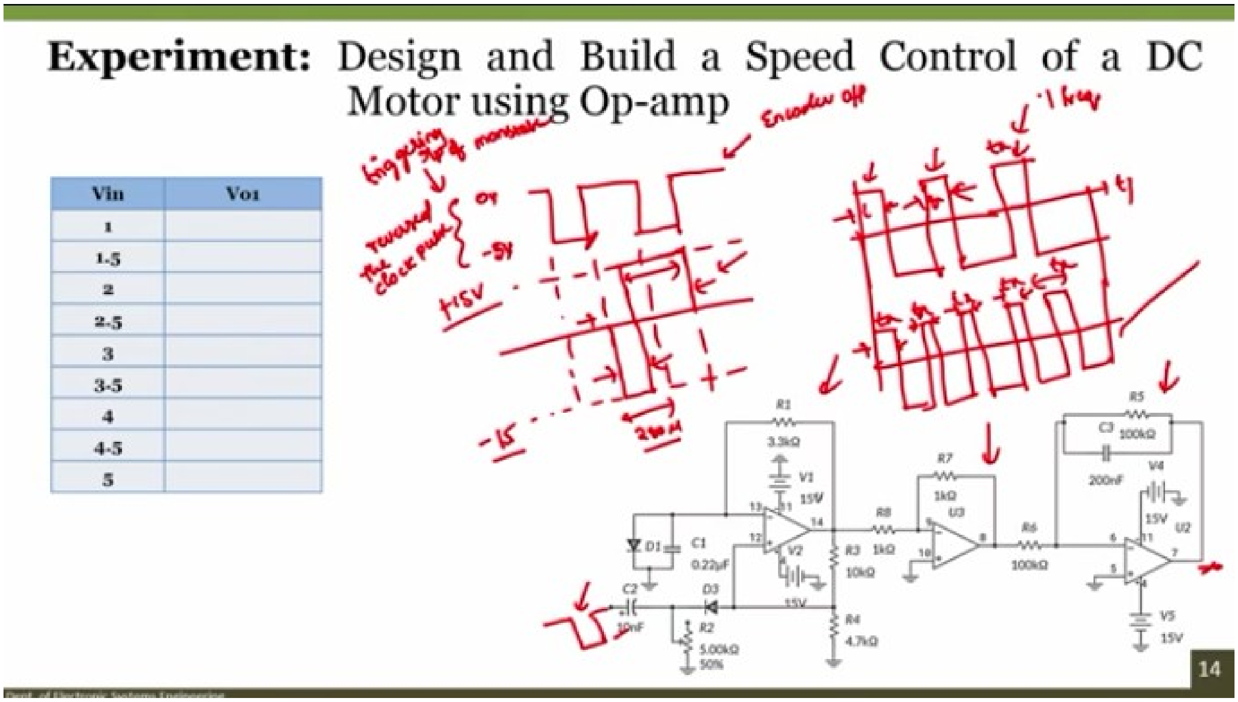

but the number of such TX this pulses occurring in higher frequency signal is higher than the low frequency signal, right, which means that for when the input voltage to the motor is higher we get more number of such pulses, when you integrate this particular curve, integrate this particular output voltage in this case the area under the curve will be smaller, in this case the area under curve is higher, but it entirely depends upon what is your +VCC as well as what is your –VCC too.

Since in our case +VCC is +15, and –VCC is -15, right, initially it may be at one particular value, it will be keep on decreasing because the magnitude of -15 is higher when compared to the magnitude of +15, so when the RPM is higher the magnitude of +15 is also increasing when compared to -15, so we may experience a negative slope curve, right, so we will see how exactly it is going to come.

So let me open multisim here, so yesterday we have seen the working of this particular block which is nothing but our monostable multivibrator, we have given an input signal which is similar to the encoder output that we receive, and this is our integrator circuit which we have seen at this point.

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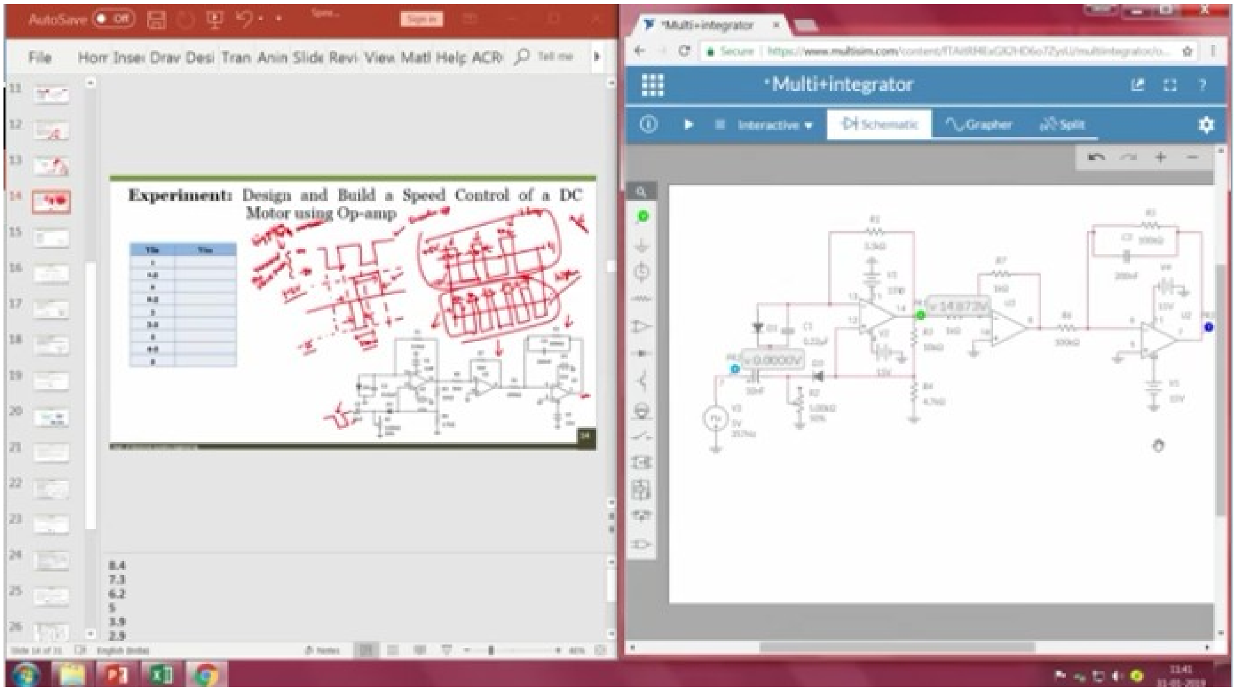

Similarly this is our inverting amplifier, so now what we are going to do is that I've already designed an integrate and kept it here, so this yesterday we have already seen in the previous module, just have a look on the previous module in case if you have not looked into that, so now we will vary a frequency at this point, so we have already noted different frequencies, the frequencies that we got from the yesterday's experiment, from the previous experiment, these are the frequencies that we received, we provide an input of these frequencies at this point, and we have also observed the output voltage is there yesterday in the previous course, in the previous module, now we will see whether the output is linearly varying or not.

We will do the simulation, then we will note down the values, then we will also experimentally verify whether we are getting a linearly variable output voltage or not.

Now what I will do is that, the first frequency, so these are the frequencies we got, first I will apply 227 hertz signal here, so this I will change it to 227 hertz, and I am running the simulation, I will go to grapher,
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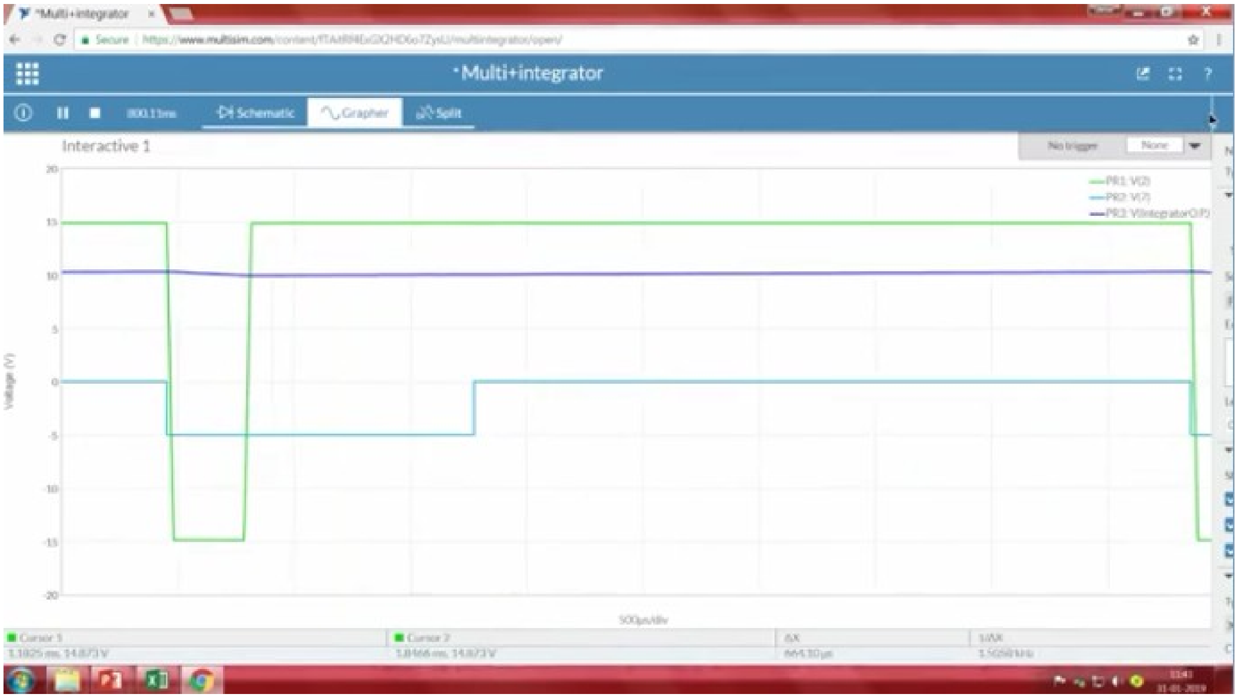

so our interest is only to the integrator output, so this is our integrator output we got somewhere around 10.215, let me note it down, so we got 10.215 because why I have given at input voltage of 1 because for input voltage of 1 we know 227 hertz, so that means when the motor is connected with 1 volt, the output we are getting from the integrator is 10.215 volts.

Next we will apply the another frequency, so the other frequency is 357, right, here we can see the output voltage is decrease,
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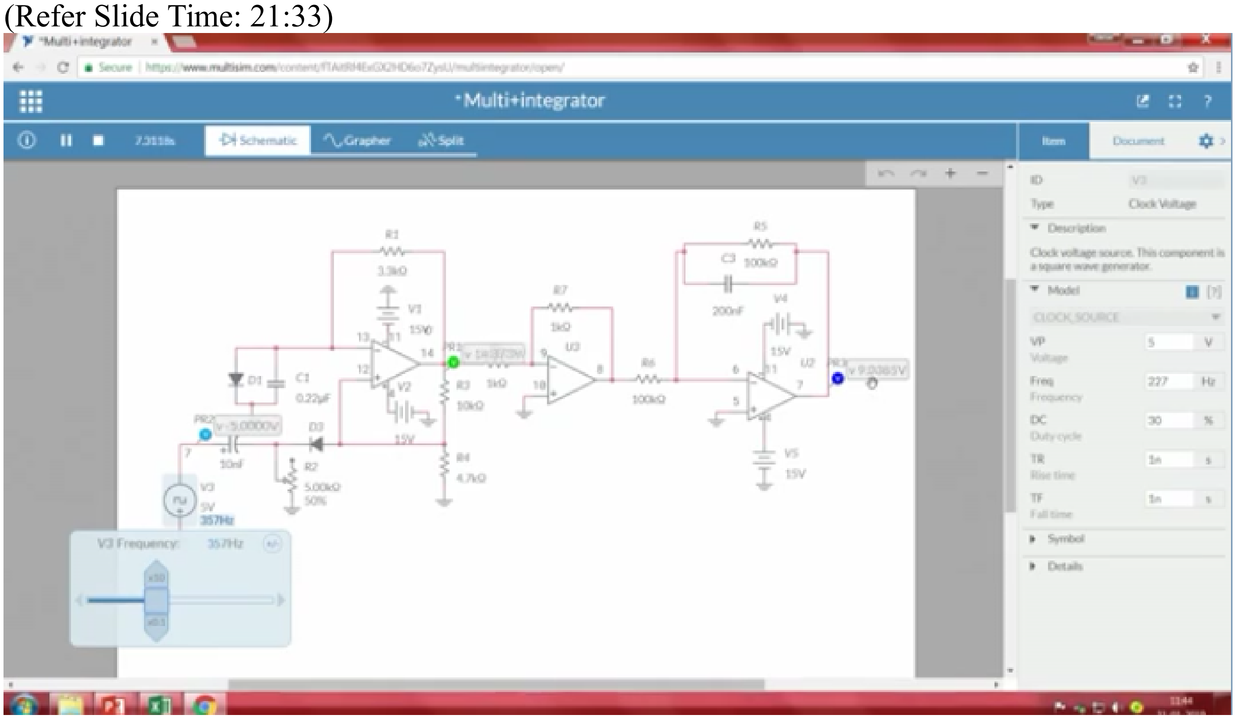

I hope now this is clear for you why the output voltage is decreasing so it is 9.11, 9.11 volt, then I will go with 2 volts, so 2 volts corresponds to 515 hertz, let me stop and run, so we will wait for one second, so right now it is in milliseconds range, so when I look into the value we got somewhere around 7.9, so we got 7.9 volt, I'll go with 3 volts now, let me stop, so 3 volts corresponds to 827 hertz, let me run, so I will wait till 2 seconds here, so that it is just like since we are using a capacitor it take some time to charge it too,

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so we got approximately of 5.2 volts, so let me write down 5.26 volts so not here, then we will go with 4 volts, so the 4 volts corresponds to 1.157 kilo hertz, 1.157K, we will wait for 2 seconds,

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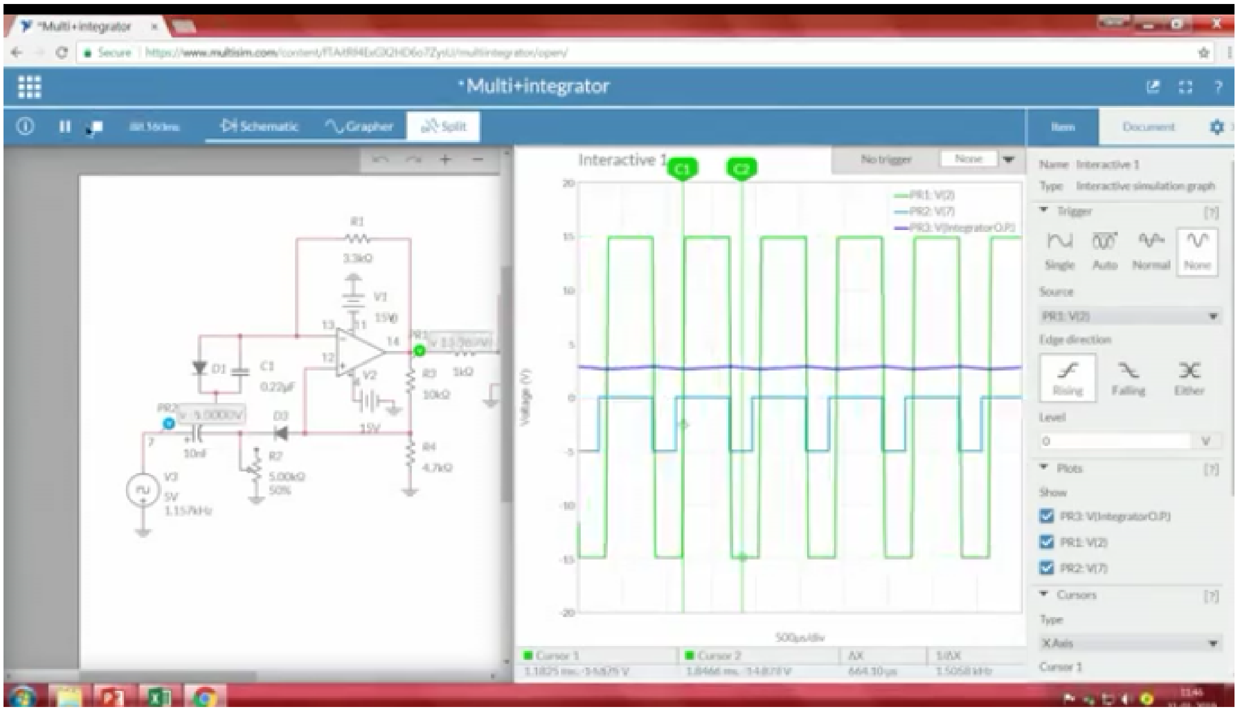

1 to 2 seconds because right now it is running at milliseconds range, so now it is 2.7, so I will write down 2.7 for 4 volts, then we will go with 5 volts, let me stop, so 5 volts corresponds to 1.483K that's what we have observed yesterday.

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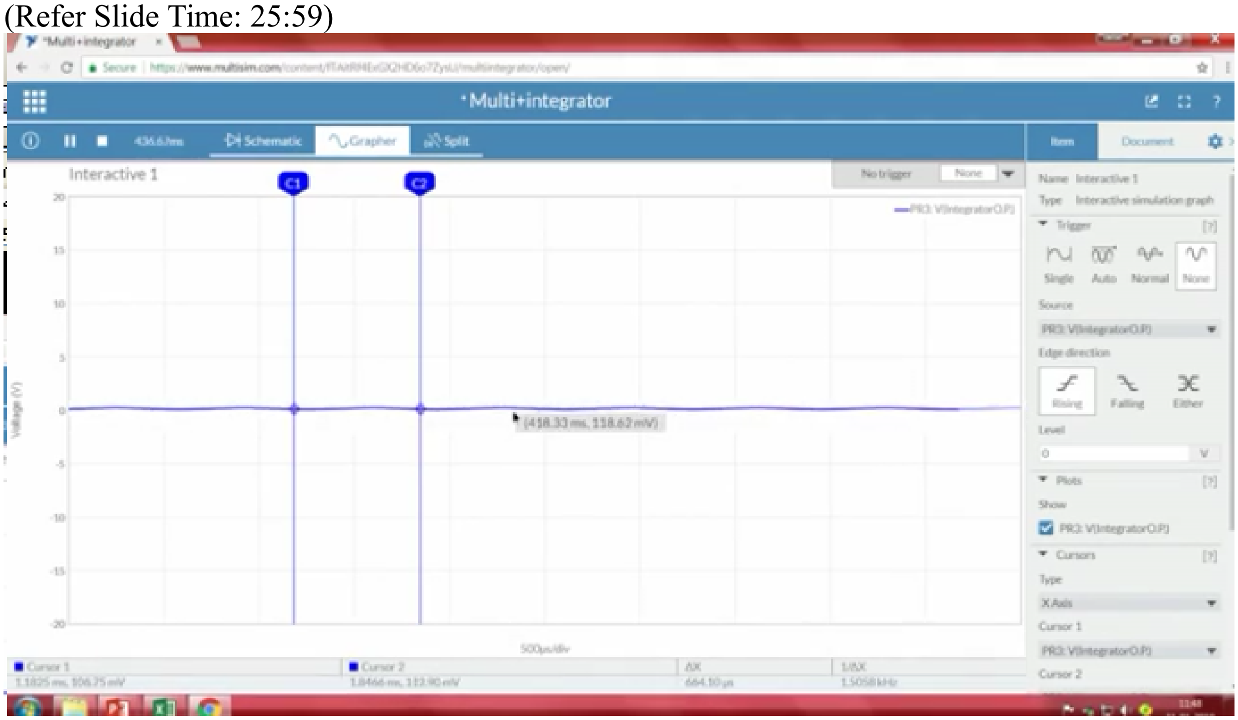

And let me run, okay, now if I notice it we got somewhere around 200 millivolt, but it is keep on fluctuating that is because of the capacitance value if you slightly increase the capacitance then the problem would be solved, so 200 millivolt, sorry, yes so let me change the capacitance to little higher value and observe, so here we can see approximately of 200 millivolts.

Now with this understanding, so these are the values that we got, let's plot this values in an excel, I will take one more sheet or I will take in the same sheet, let me keep it aside,
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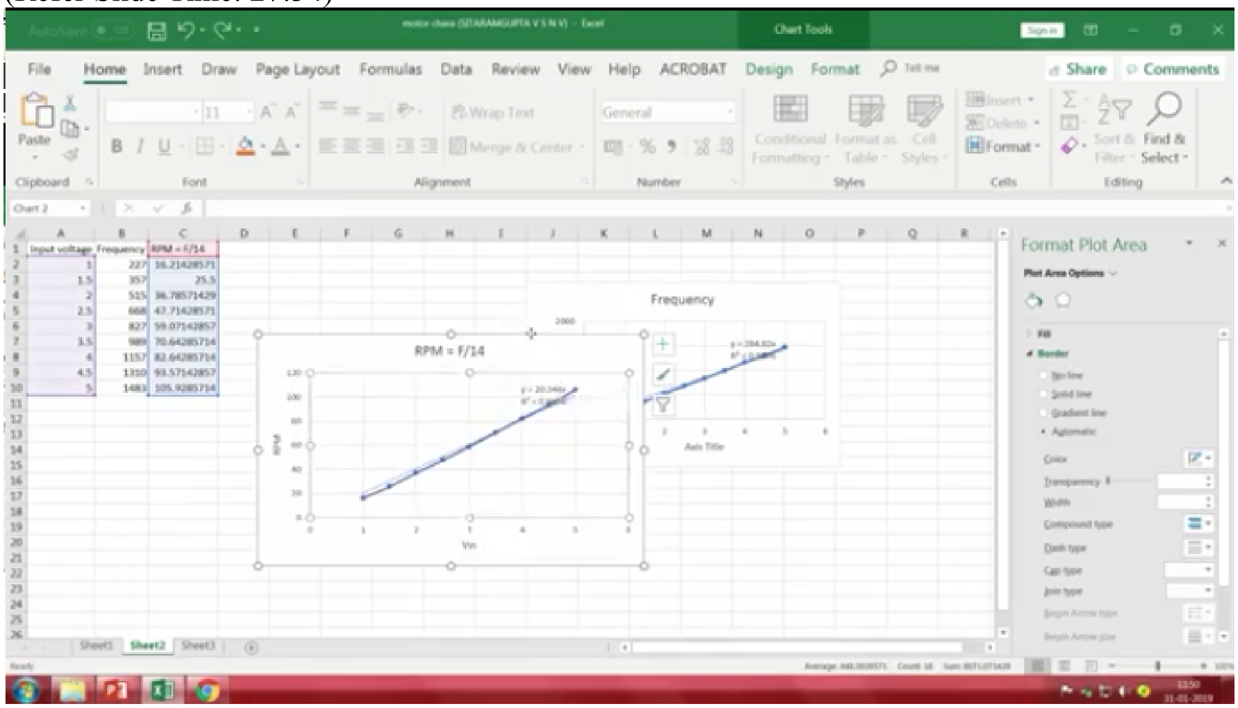

so this is for integrator output I am calling it as VO1, so we got 10.215 then for 2 volts we got 7.9, then for 3 volts we got 5.26, and 4 volts 2.7 volt, 2.7 volt then for this point 2 volt,
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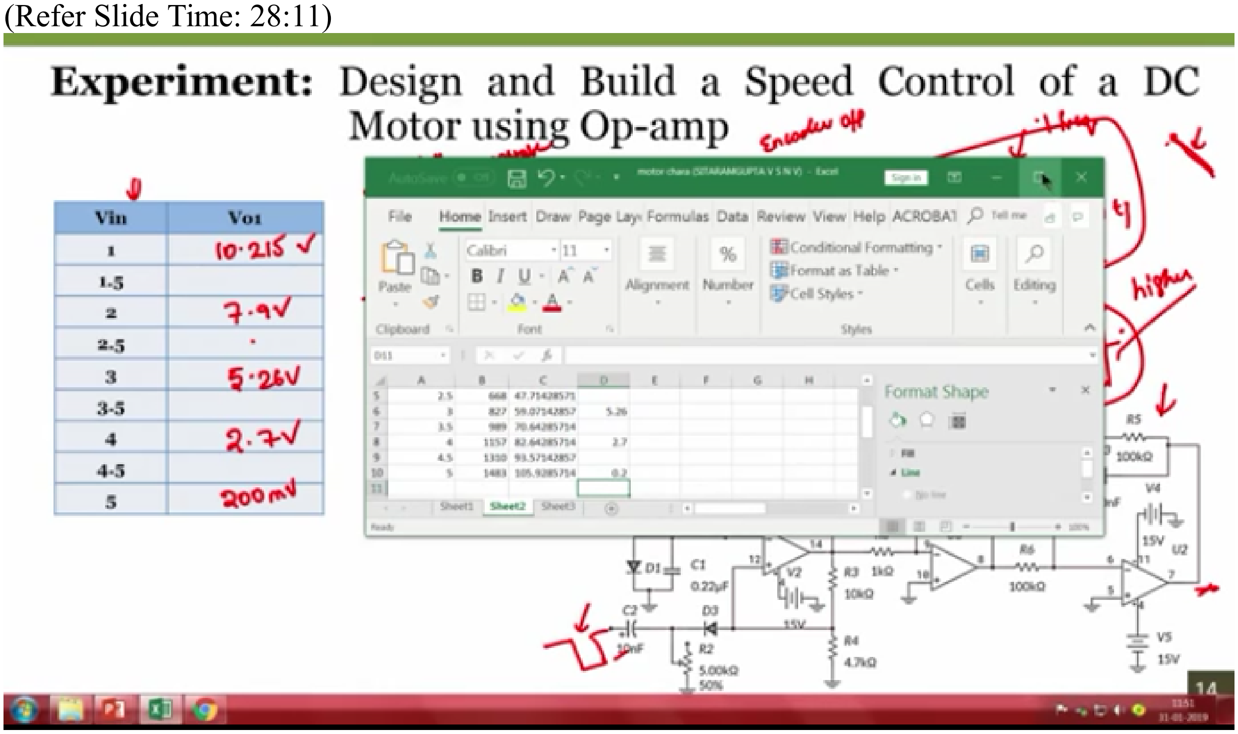

now let me plot the graph between input voltage and the VO1,
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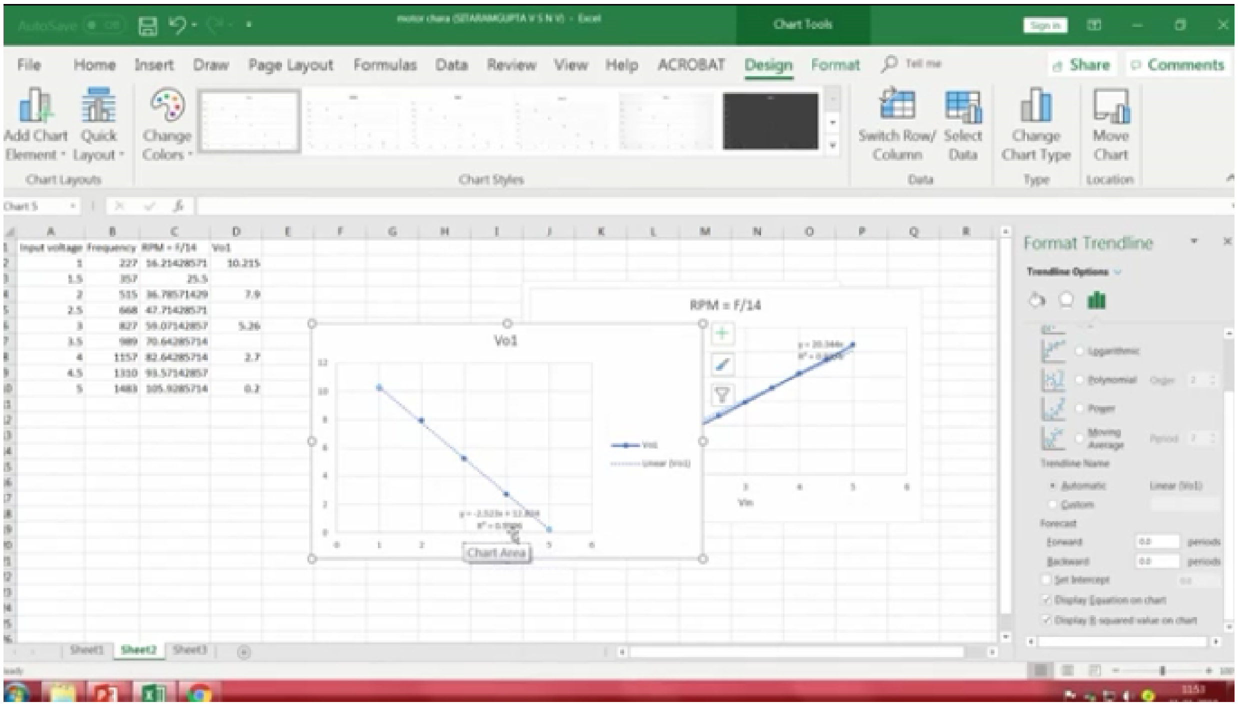

so here you can see we have R square value of 0.99 which means almost linear, but when we see the slope, the slope that we got is negative, which means that when the input voltage is keep on increasing, the output voltage from the integrator is keep on decreasing, that is what even we have expected from the previous graph, that indicates the slope is of negative, the reason why it is we are getting a negative slope is that when we look, when we have done analytics we have already showed that, we have already seen that the output from the monostable multivibrator as well as integrator pulses will always you know, will fluctuate from +15 to -15, right, and the magnitude of -15 the time duration of -15 is higher when compared to the magnitude of a +15 volts, so as a result when we do an integration which is nothing but area under the curve, the magnitude initially will be higher when the RPM is keep on decreasing as the magnitude, the time duration of the 15 volts is becoming higher and higher because of more number of pulses that we are getting it, so that the magnitude of the positive is higher when compared to the magnitude of negative resulting to decrease the output from the inverting integrator, so that we can even see at this plot itself, but what we require? We require the mapping factor of 20RPM per 1 volt, every 1 volt we have to get a output of 1 volt, but from this case we got somewhere around -2.53 X into X+12.84, let me write it down, -2.53X + 12.84, the slope of this line is -2.53, but we require a slope of 20 ports to 20,

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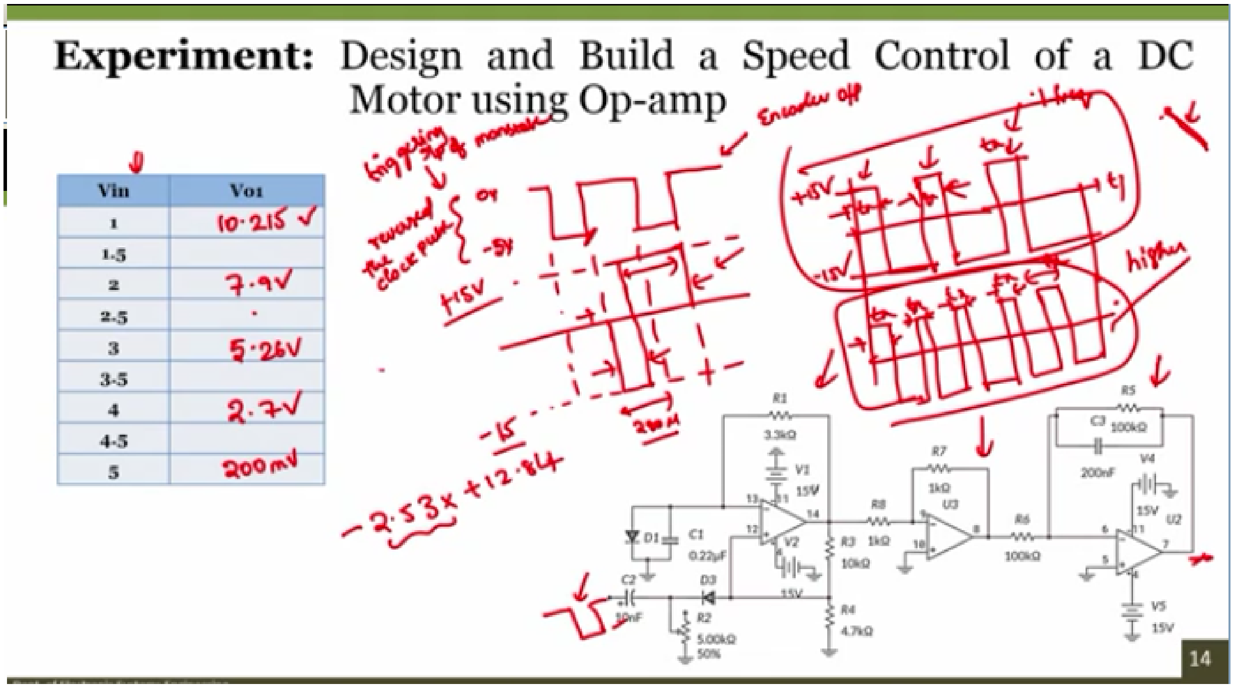

but how do we convert it? How do we convert it is the question mark, so that means we have not completely fulfill the requirement of output voltage of signal conditioning circuits, still we have to design another set of signal conditioning circuit in order to map the input set point to the output voltage of an integrator.