INDIAN INSTITUTE OF SCIENCE, BANGALORE

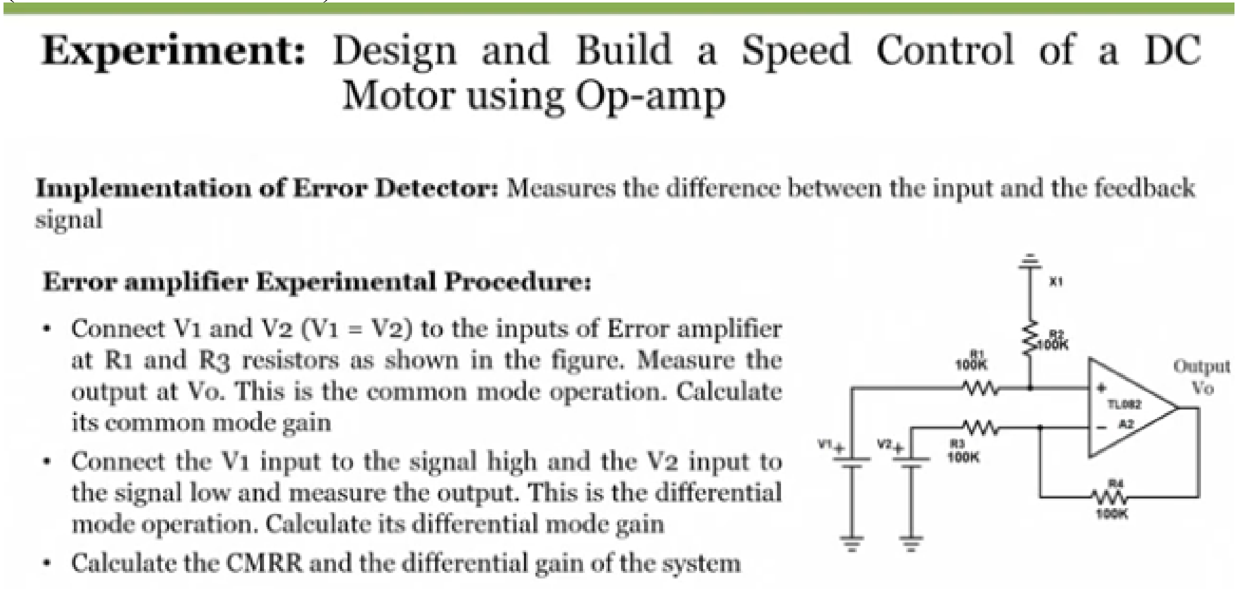
NPTEL

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

Course Title
Electronic Modules for Industrial
Applications using Op-Amps

By
Dr. Hardik J. Pandya
Department of Electronic Systems Engineering

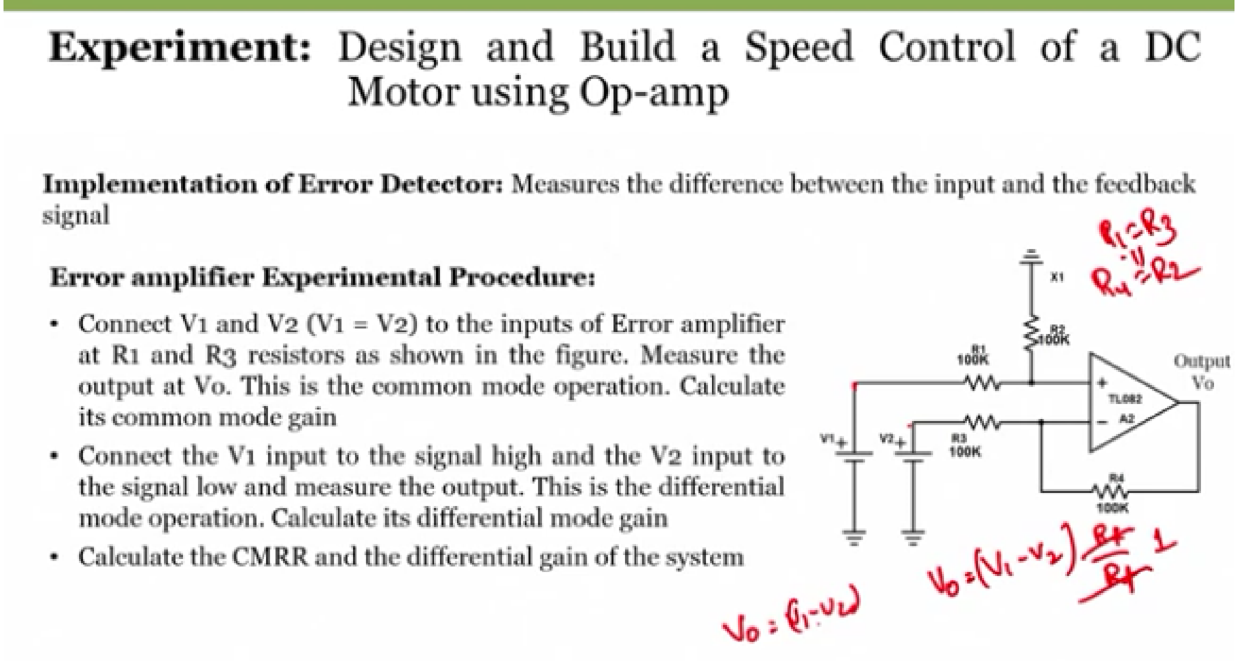
(Refer Slide Time: 00:33)

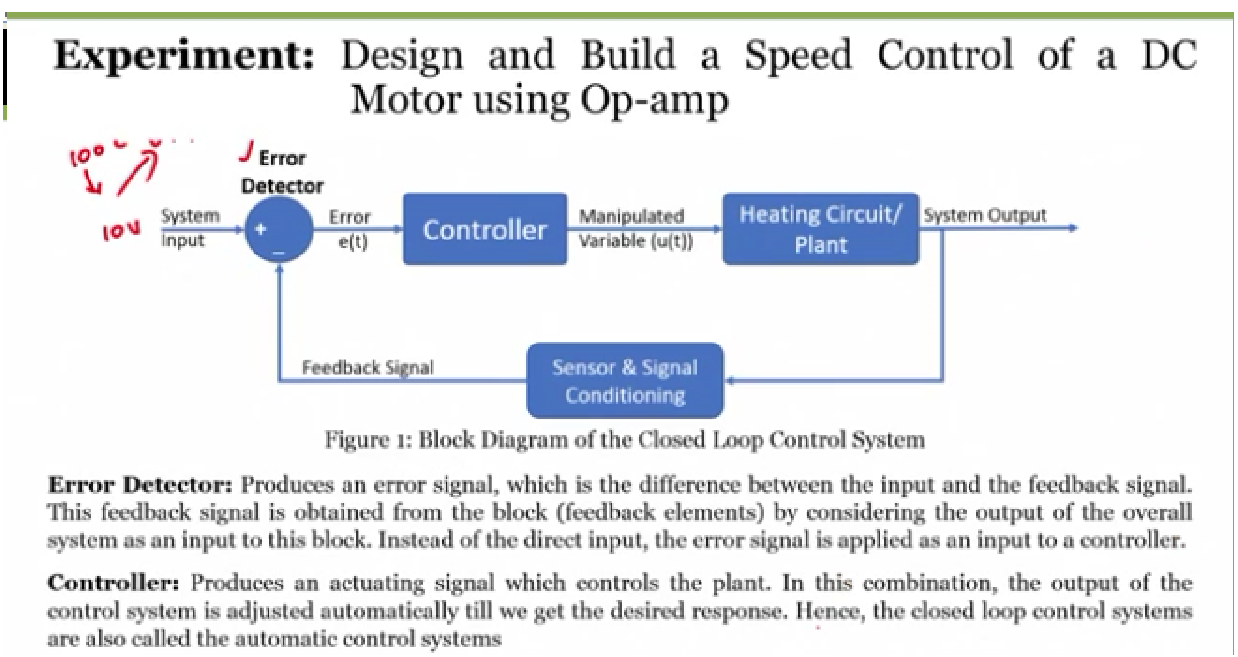


Welcome to the module, in this module we will see simple error detector, we'll start with the simple error detector which is nothing but the difference amplifier.

When we see right, so this is the differential amplifier circuit right, one input will be connected to the R1, R2 pair, resistor pair, other input is connected to the negative terminal which is input of R3, so the output will be, so if you recall the working of a differential amplifier the output is nothing but V1-V2 into RF/R1, RF/R1 this is the case when if R1 = R3, and R4 = R2, since in this case both R1 = R3, R1 = R2 = R3 = R4, so RF and R1 values are same, so the gain of the system is 1, so the V naught is V1-V2, that is what even we required,

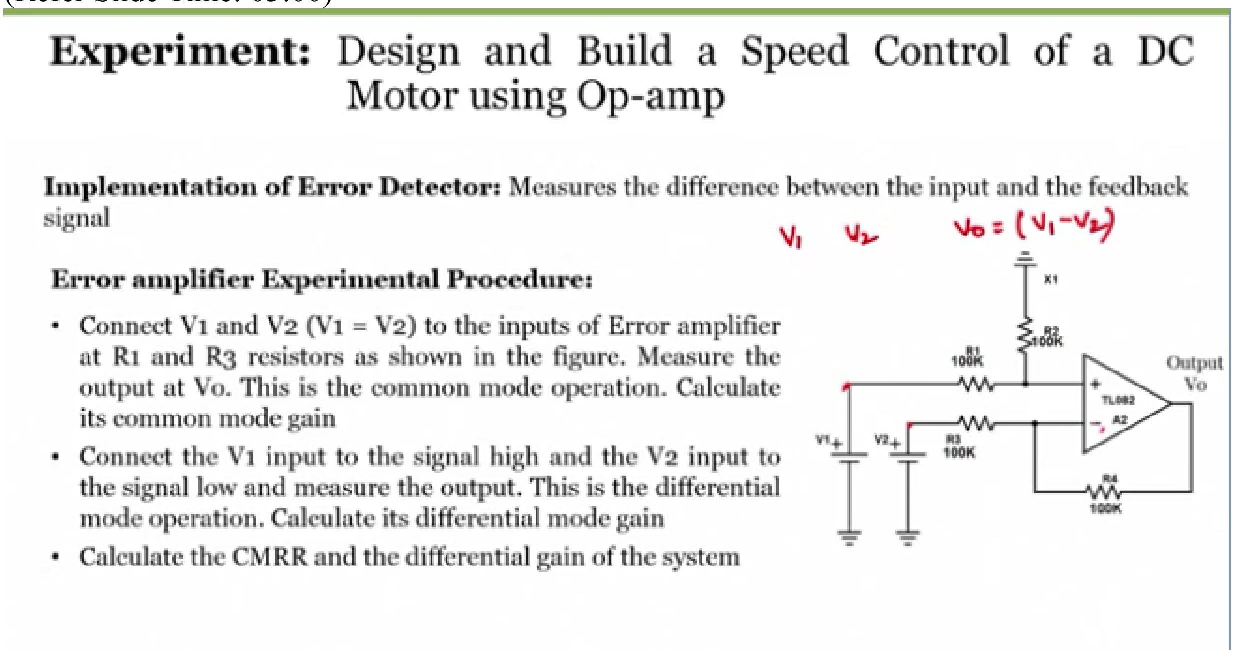
(Refer Slide Time: 01:35)



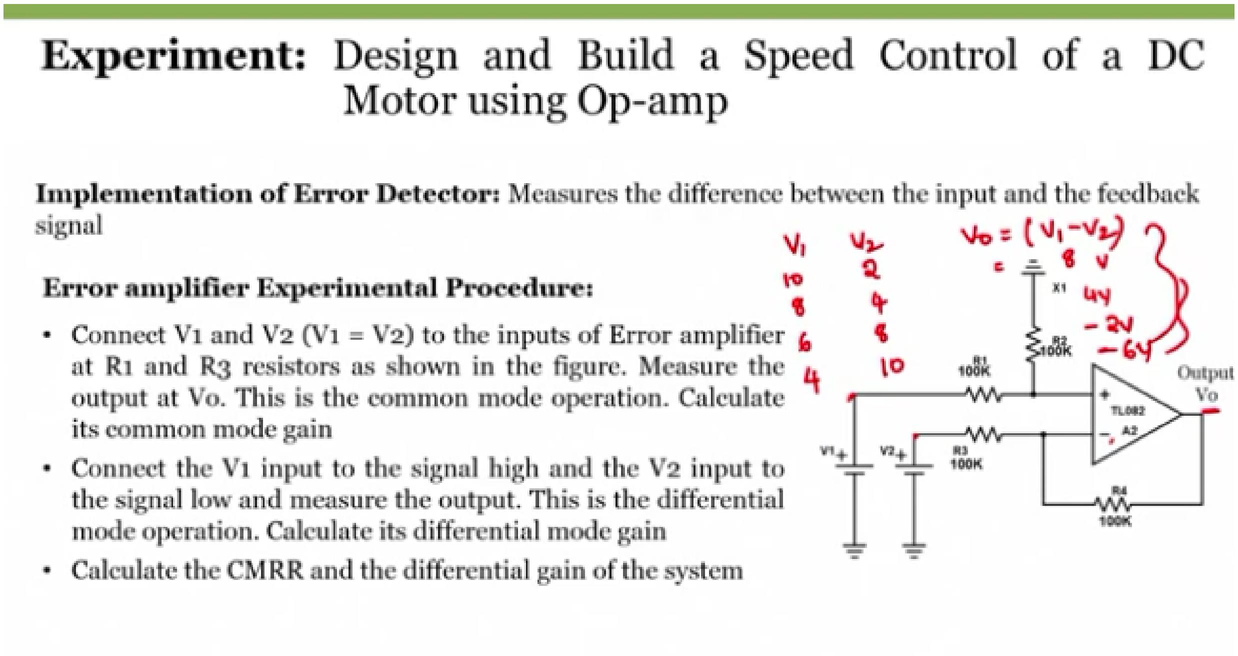


right, when we recall our system we don't have to apply any gain, whatever the input I have, it has to be subtracted with a feedback signal, and I have to get an output, that output we call it as an error, right, so in order to give that I don't need any gain, so since I don't need any gain I'm using all the resistance of same value, so that's maybe the problem with instrumentational amplifier, so few instrumentational amplifiers will have a gain starts from 5, the commercially available monolithic instrumentational amplifier for IC the minimum, the gain that will have this 5, so since it is not possible in this case what we have to do is either we have to go with a high input impedance differential amplifier, right, so I understood how exact, so we already know how does it works.

So let me quickly look into the simulation, so in order to understand about the simulation whether it is working fine or not, what we will take is we will take different points, so let's say I'll take V1 and V2 and I will calculate V naught, so V naught when you recall it is nothing but V1 – V2, the input that I'm applying it at this point and this point, right,
(Refer Slide Time: 03:00)

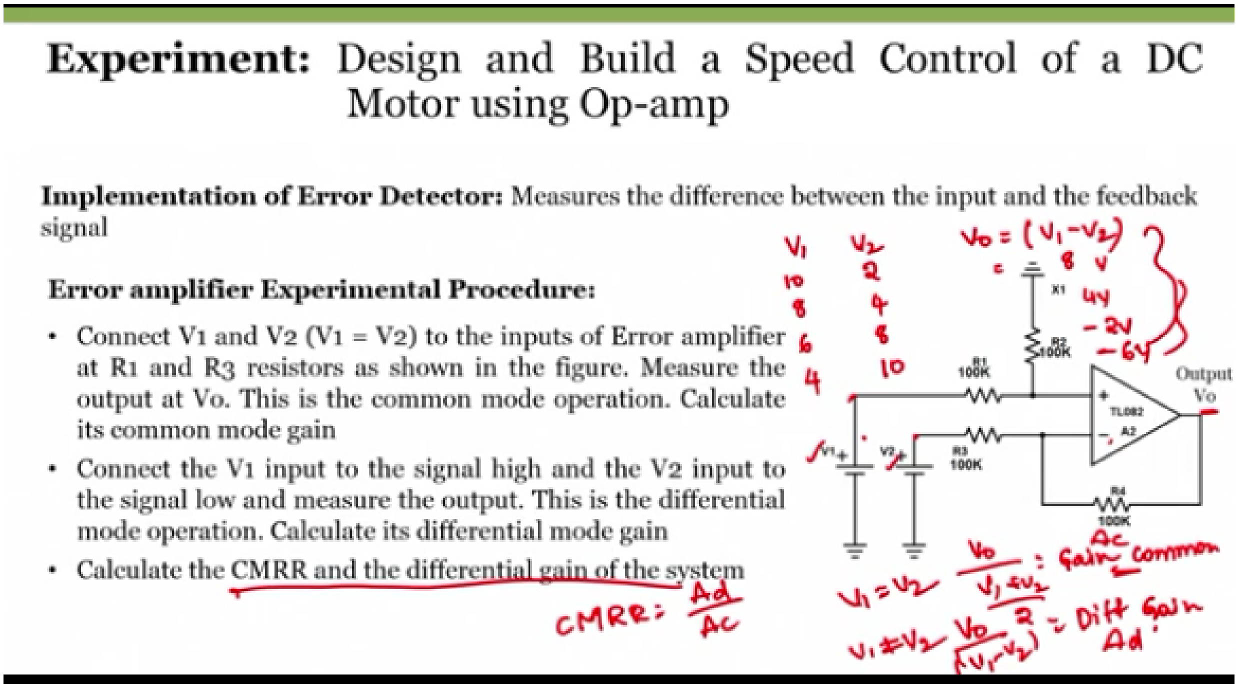


so let me take one input as 10, V1, another input as 2, so that means 100 degree and 20 degree, so what will be V out? V out will be 10-2, 8 volt, I should get an output as 8 volt, right, so this I'm taking 8, this is 4, so V out will be 8-4, 4 volt, 6, 6, so I will go with 8 in this case, I should get -2 volt, right, and 4 and 10, I should get -6 volt.
(Refer Slide Time: 03:50)



Let me see whether I am getting this values, if it is in a practical system, now in order to understand about the gain what we do is that, we will in order to you know practical as well as theoretically to calculate the gain as well as the CMRR value of the system what we can do is that, we can apply same signals at V1 and V2 and we will see what is an output voltage we are getting, so we know that V out by the input voltage that we do, that we connect is nothing but a gain of your system, right, when we connect the same signals V1 + V2/2 will be the common mode gain, because at this point we are taking V1 = V2, we will get common mode gain.

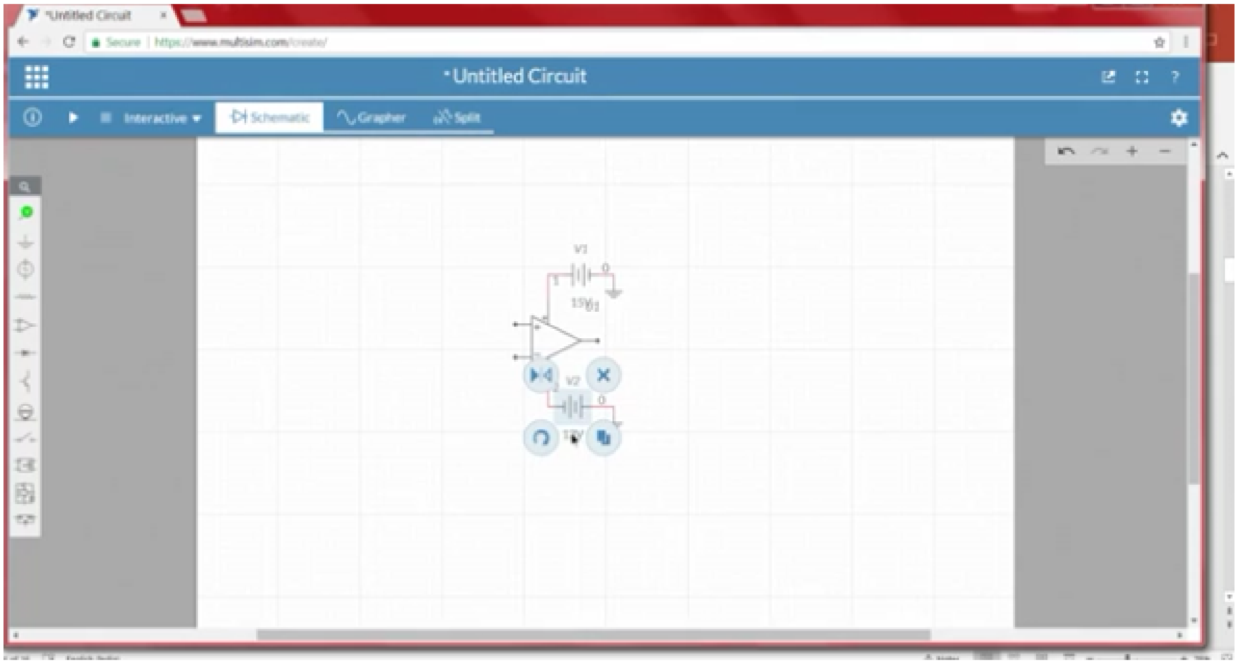
Now we will take different values of V1 and V2, and we will calculate what is an output and divided by V1 – V2, this is nothing but our differential gain, now if I want to calculate my CMRR, so CMRR is nothing but differential gain by common mode gain, so whatever the gain that I am getting, this is AC and this is AD, this divided by this if I do, I'll get the same CMRR of the circuit, we will see theoretically now, and then we will compare with practical too.
(Refer Slide Time: 05:07)



Excuse me, so to understand that what I will do is that I will open a multisim, so let me create a circuit, so we are using multisim from so many experiments I don't have to explain about how exactly this works and what are all the different functionalities and different system that it has, so our only thing is that how do we implement it that we will see, so we will connect according to our input signal, so what I will do is that I'll take the 5 terminal because the +VCC and –VCC are very much important to understand whether it goes to the saturation or not, so that's a reason I'm taking this value +VCC and –VCC too, and I'll take a voltage sources, DC voltage and I want to operate my system with 15 volts changing settings to the input voltage to 15, so positive is connected to the positive terminal, and other terminal should be connected to the ground, so I'm connecting it to the ground.

Now I have to take another voltage source, because op-amp has to be provided with a difference volt to different voltage sources, this is not a single source we have to always take 2 sources, two independent sources basically, so the negative of the power supply is connected to the negative terminal, so since negative 12, so it is the amplitude is 12, since the negative is connected here the values -12 volts,

(Refer Slide Time: 06:59)

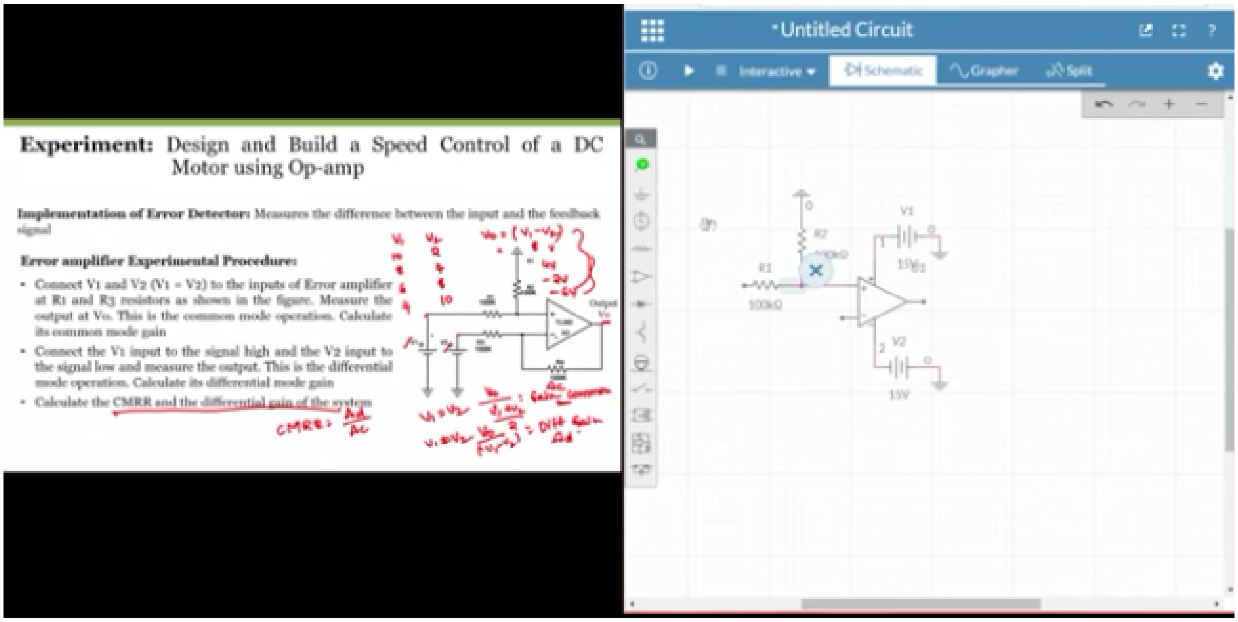


so since we require -15, so this does our requirement.

Now what we have to do? We have to connect one resistor at this point, so in order to not to have a mismatch between both this as well as our design in multisim, what I will do is that this is R1 I will consider, and this I will say 100K, in fact you can also take any resistance value but it should be all resistance whatever we used should be same one, same one but higher the resistances, right, more the input impedance of the system.

More higher the resistance is, more noise into the system, noise is always proportional to the resistance value, or resistance prefer, so that's a reason we have to moderately select between 10k to 100k, but 1k if I select is even we can select 1k but it will have slight loading effect to the previous stage of your system, loading effect on the previous stage of your system.

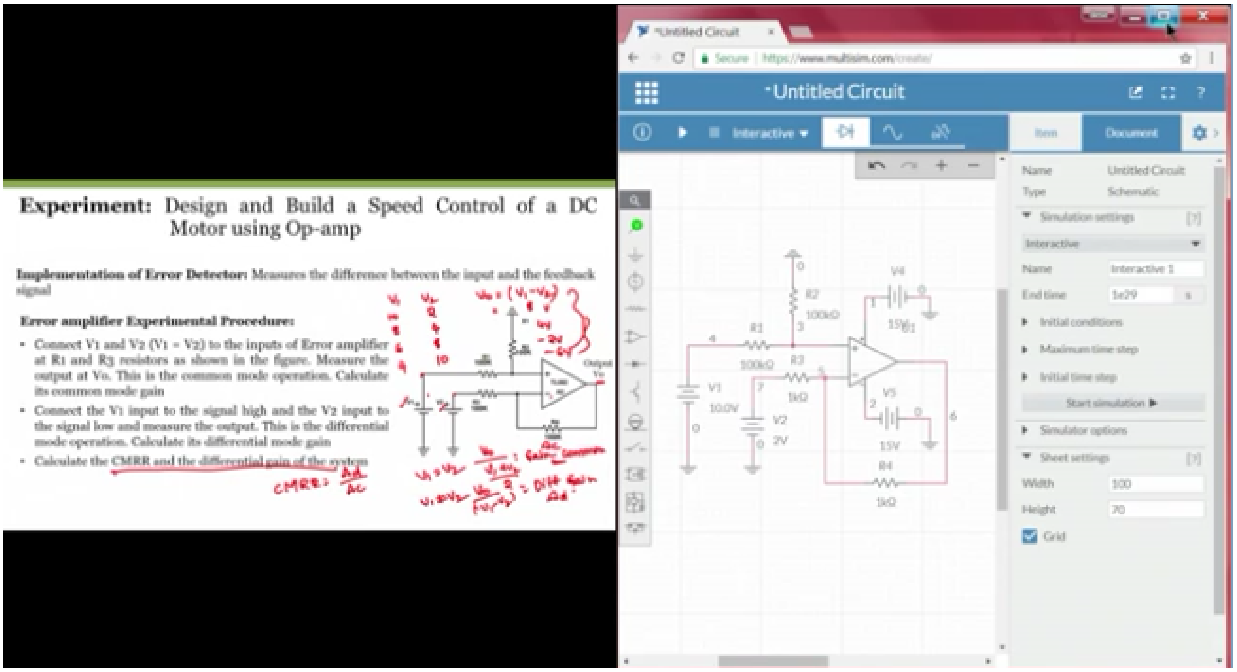
If I go more than 1k, 100 ohms it will have more loading effect on the system, so in order to not to have that we are considering somewhere around 10k to 100k, so in this case I'm considering 100k, so I need to take one more resistor and this is my R2, so this R2 part is done, so this part I have to connect it to the ground, so the ground terminal I have taken I'm connecting it here, okay, and this part should be connected to here and this part also connected to the positive terminal, so this is nothing but V1,
(Refer Slide Time: 08:47)



so I will take one more DC voltage source connecting this point, right, what I will do is that? This I will make it as the name of this, I will make it as V4, because V1 notation we are giving it for the input value, so this I'll make it as V1, now so V1 is ready, so this value, make it to 10, max is of 10 we are looking it, so 10, other terminal should be connected to the ground so I'm connecting it to the ground, so this part is done.

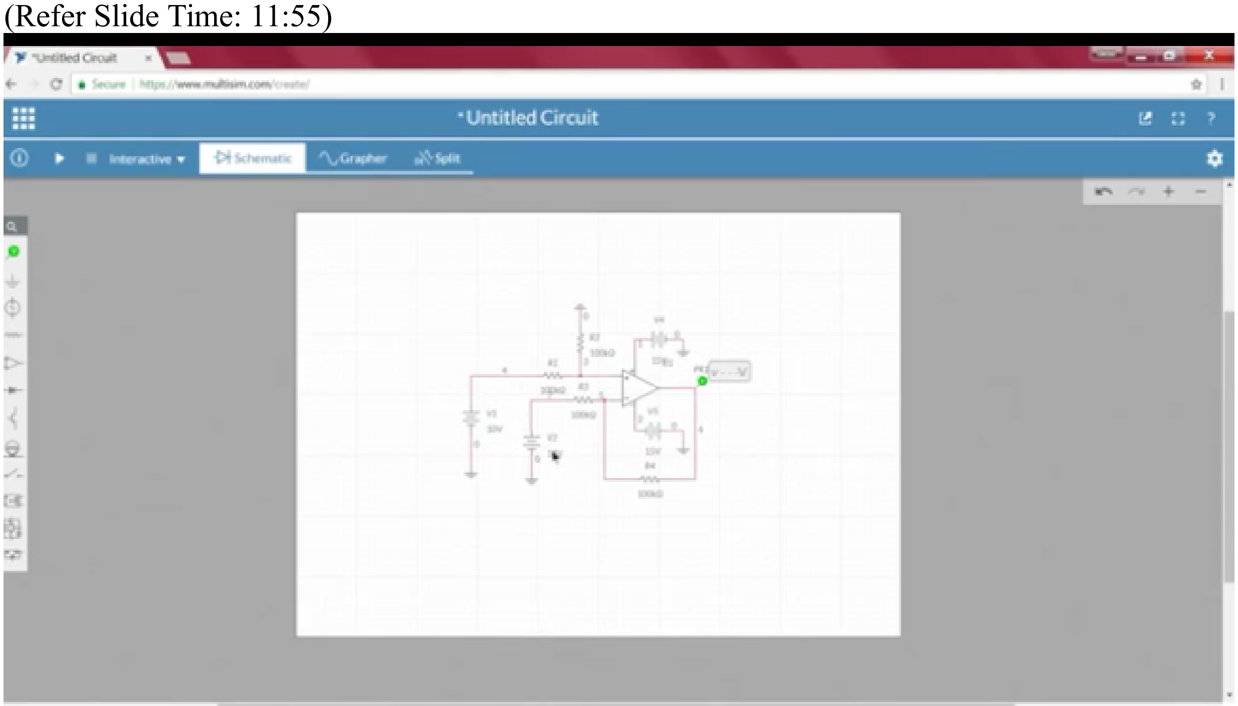
What is other part? The negative feedback and the negative resistance of the negative terminal, so I will take R3 resistor, so this is what R3 that we are considering it, and one more resistor that I have to take which is R4 which should be connected as a negative feedback, so I'm connecting one here, one more to this junction and other terminal to the output voltage, right, so this point I have to connect another voltage source, so just a nomenclature, I'll just slightly change the naming of the system here, so this I'll name it as V5, so whatever I take will be V2, so I will take one more voltage source, this is V2 voltage source and this part should be connected to the ground, connected to ground, okay, this I will start from 2 volts,

(Refer Slide Time: 10:44)



so to understand, to understand what we have done? We have to apply 10 volts, 2 volts, let me see, first we will see the differential gain, then we will do the gain of, I think we have consider the resistance R3, R4 differently and let me do the same experiments once again, so I will take V1, and connected it here and this should be ground, making it as ground, so this would start from 10 volts, so let me take it to 10 volts, then I should take one more voltage source, so I need a DC, so I will take DC connecting it here and this should be ground.

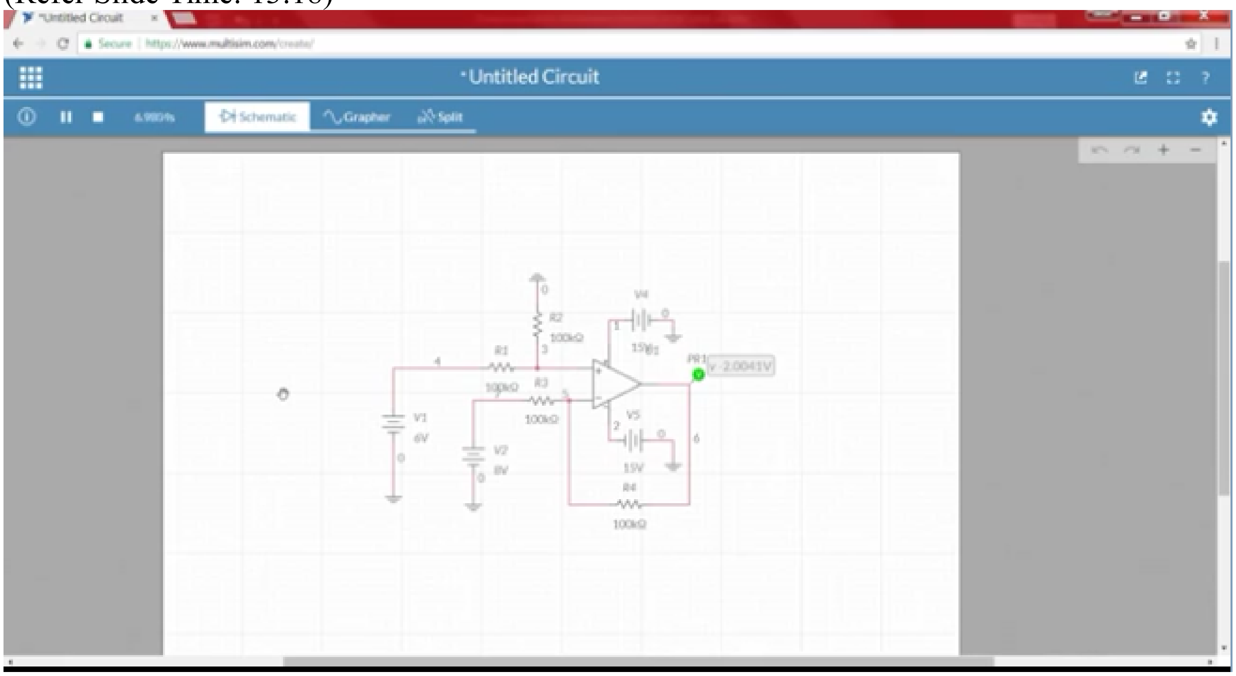
(Refer Slide Time: 11:55)



Now we will start from 10 volts and this value at 2 volts, so what are all values we have considered? One is 10, other one is 2, other thing is 8, so when see what are all that we have considered 10, 2, 8, 4 and 6, 8, 4, 10, so we know that this is 8, 10 and 2 8, 8 and 4 4, -2 -6, so we will see what values we are getting for everything then we will list it out, so let me run, when I run it we are getting output as 7.9958, 7.9958 whereas when the input is 8 volt, I'm making this as 8, and this has 4 volts, so what is the output we are getting 3.995, so approximately are almost close, because we always consider 3.99 as equivalent to 4, so it is also giving 4.

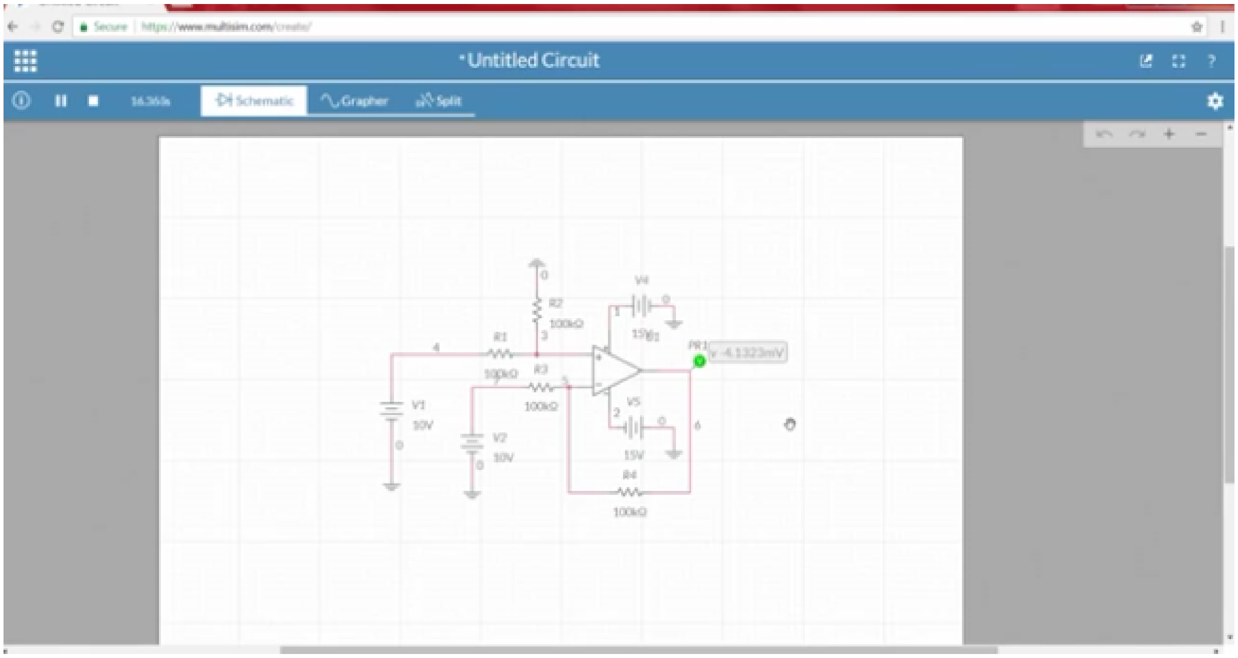
So let me take it as 6, 6, this should be 6 volt and this value should be of 8 volt, 8 volt when I see the values -2.0041

(Refer Slide Time: 13:18)



so almost same 0041, now this will take it as 4 and this I'm taking it as 10, so what is the value we are getting? -6.0040 so we got all the values, we will also take V1 and V2 as same values, and we will see how much we are getting, so we will take V1 as 5 volt, 1 value, and V2 also as a 5 volt other value, so when V1 is 5 volt and V2 as 5 volts actually the actual voltage should be 0, but as I told you it will be always at millivolt, so when we see it is somewhere around -4.0811 millivolt, so what about for other value? So let me take the value somewhere around 10, 10 volt and this also at 10 volt, it should be almost same,

(Refer Slide Time: 14:20)



yeah, see when we see 10 and 10, actually the value should be 0, but we got -4.1323 millivolt, now let me put everything in our slide and let us see how, what we get, what will be the CMRR value, right, and so when we recall what values we got? V1, V2, actual output, so actual output is nothing but V1-V2, so here I will write V1 – V2, no gain because 100k/100k its 0, and consider this is simulation, V naught of simulation, output voltage at simulation what is the value we are getting.

So V1 we are considered 10, this is 2, so what's the value? 8 we got, right, when we do manual calculate this is it, what about the simulation we got? 7.995 volt, then this is 8, this is also 4, this we got 4, whereas this is 3.995, when we apply 6 and 8 as an input voltage we got -2, even here we got -2.004, what about here? 4 and 10, we got -6, when we calculate theoretically and simulation we got 004, -6.004 and we have also done other experiments when both the inputs are same which are nothing but common mode signals, but actually speaking the output should be 0, but we are not getting 0, we are getting some value of 0.811 milli, and even it is almost same even when I'm taking different voltage value of 10 and 10 which is of -4.1323 milli.

Now if I want to calculate CMRR, CMRR first I should know the calculation of differential gain, then I have to calculate common mode gain, but how do we do differential gain? So the differential gain is nothing but output voltage that we are getting, divided by common mode signal, sorry, divided by differential input signal V1 – V2.

Now when we see the theoretical value, so this is 8 for the first one, and 8 this is 1, so we are getting differential gain as 1, right, so even for the second case 4 divided by 8-4, 4, 1,
(Refer Slide Time: 16:59)

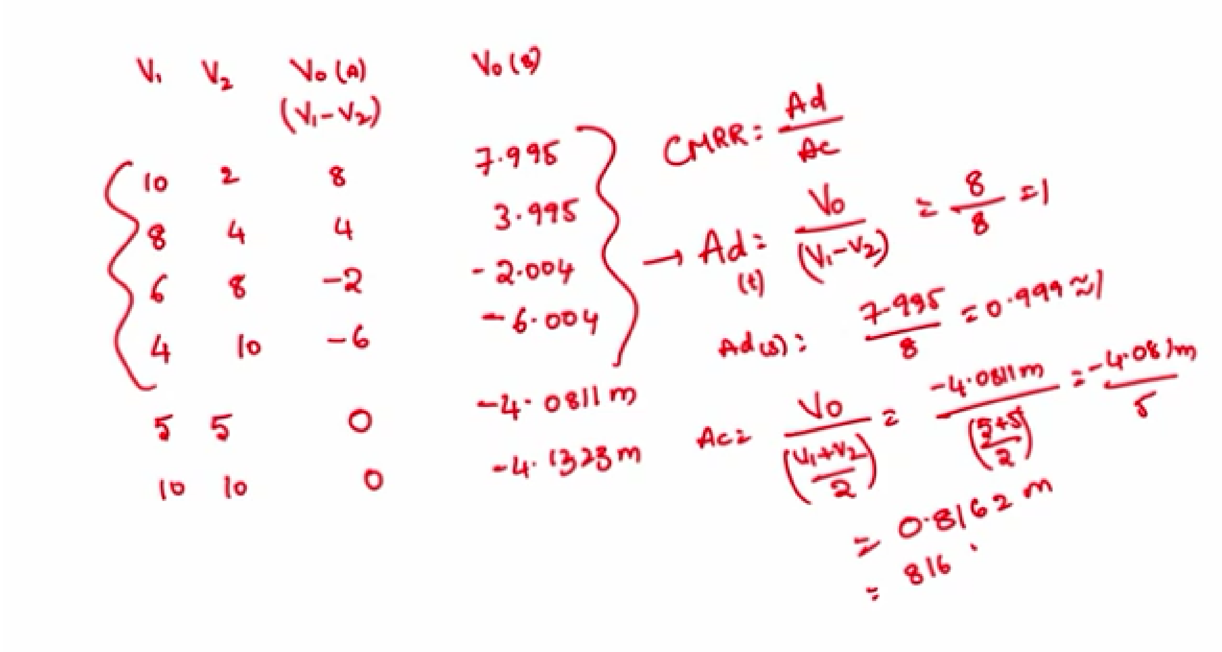
V_1	V_2	V_o (A) $(V_1 - V_2)$	V_o (S)
10	2	8	7.995
8	4	4	3.995
6	8	-2	-2.004
4	10	-6	-6.004
5	5	0	-4.0811 m
10	10	0	-4.1323 m

$$CMRR = \frac{A_d}{A_c}$$

$$A_d = \frac{V_o}{(V_1 - V_2)} = \frac{8}{8} = 1$$

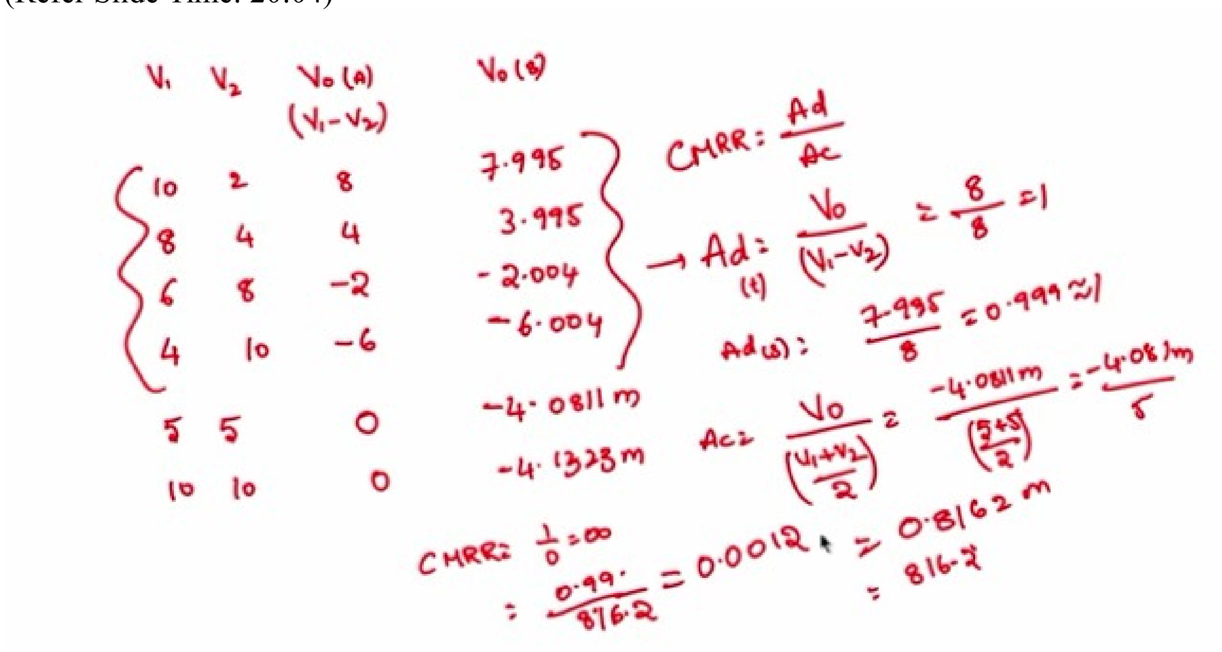
so whatever no matter what for this particular set of values will get the gain as 1 theoretically. What about the practical? This is theoretical, so AD simulation, when we see the values V naught, V naught is 7.995 divided 10-2, 8, so when I calculate I'm taking calci, 7.995 divided by 8, 0.999 which is almost equal to 1, no matter what I'll take the next value to, I will take calci, so 3.995, so 3.995 divided by 8-4, 4, 0.998, so almost equal to 1, right, we are getting almost everything equal to 1.

Now what about AC? Theoretically it should be zero, but practically when I see it simulation when I see, the values -4.0, so how do we calculate? First let me write the formula, output voltage by common mode signal, so V1+V2/2, so what is V naught? -4.0811 milli divided by 5+5/2 which is nothing but 10/2, again this is 5, so -4.081 milli divided by 5, the value is when I take a calci, 4.081 divided by 5, 0.81, how much, 62 milli, 0.8162 milli, so that means the values 816, no volt because volt/volt will be cancelled, right, 0.816 milli or 816.2.
(Refer Slide Time: 19:08)



Now if you want to calculate CMRR, CMRR theoretical when I see it should be AD/AC, 1 divided by 0 which is infinity, but practically is it the same, let me see? Which is differential gain which is of 0.999 or 0.998 or 0.99 divided by 816.2, so the value is let me take a calci, 0.99 divided by 816.2 which is 0.0012, 0.0012,

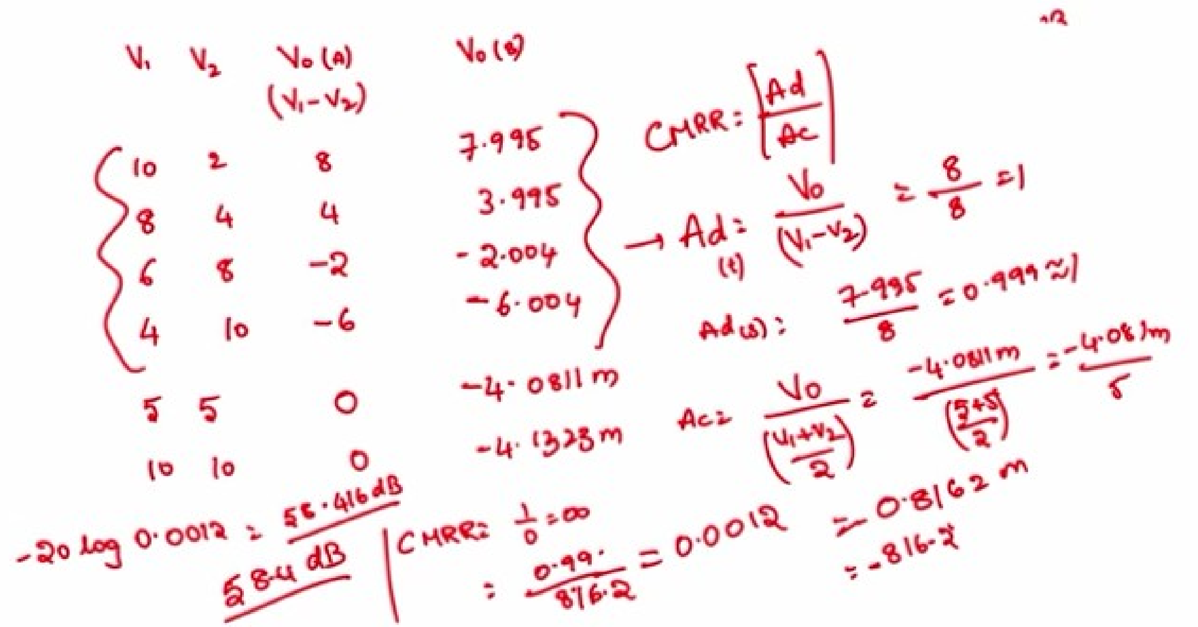
(Refer Slide Time: 20:04)



---

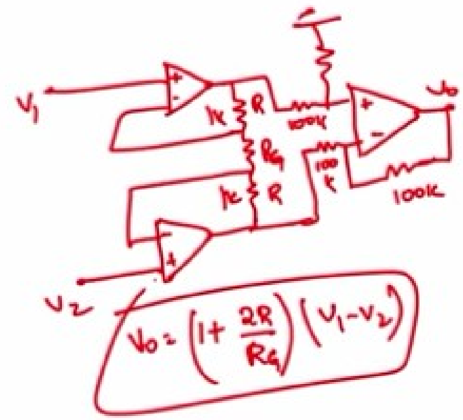
now if I want to calculate DB, 20 log 0.0012, so I will write it down here itself, 20 log 0.0012 which is equal to, so I will take calci once again, 0.0012 log into 20 so which is 58.416, 416 DB, why I'm eliminating minus, because CMRR should be always mod of, or even in this case here we have a negative and when we calculate minus we are getting, minus minus is becoming

positive, but CMRR generally mod of AD/AC so which is 58.4 DB, for this particular type of op-amp, right.
(Refer Slide Time: 21:22)



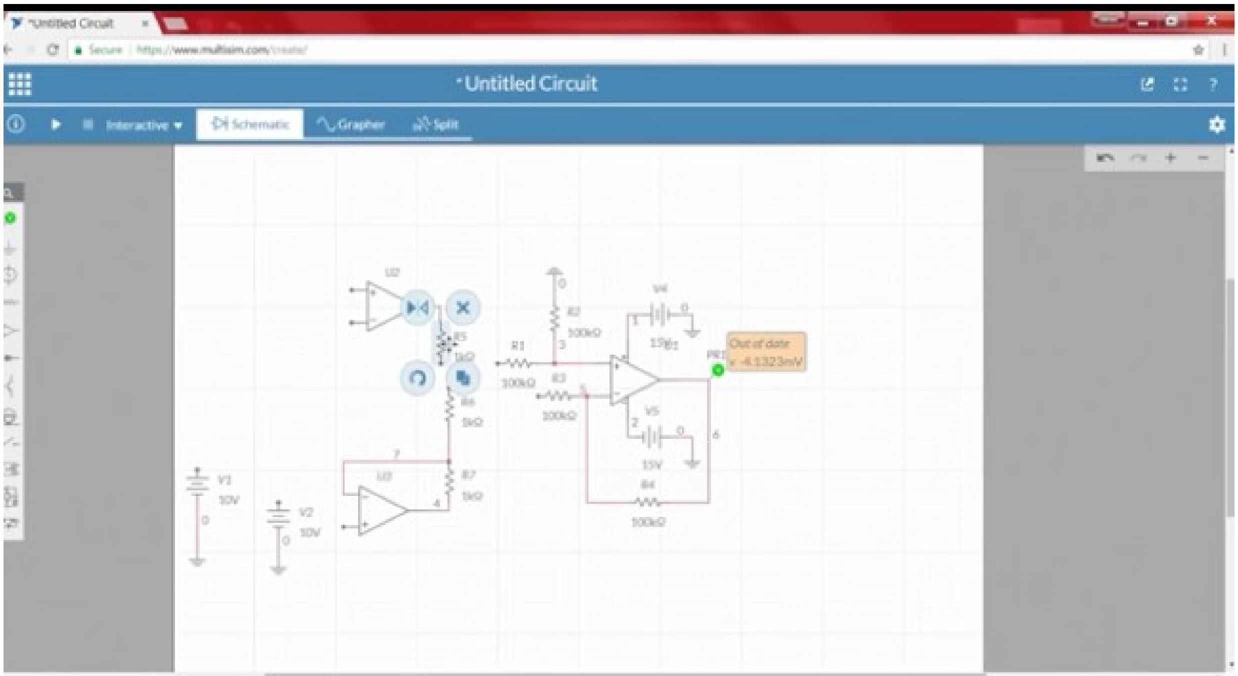
Suppose if you are taking different op-amp I do not know what op-amp that we are considering in the simulation, what make that we have considered, so we have simply used the op-amp that is available there, so this is how we generally calculate the DB of our differential amplifier, but more over since we are not going to apply almost common mode signal, but even if we apply we are getting somewhere in the milli, since it is negligible so we can simply go with a difference amplifier itself.

Now how about for instrumentational amplifier, why don't we look into that? So what I will do is that, I will take one more slide, if you recall the working of an instrumentational amplifier, so it will be somewhere, we will be taking 3 op-amp + - one more op-amp + - right resistor, resistor combination, so this is R, this is R, this is RG if I take, - and + connecting here, this here and this here, and if I say this is V1, this is V2, right, and I should also have to have a differential amplifier here + -, oh sorry this is RG the output should be connected one here, one more here, and one more here, one more here, so 100k, 100k, 100k, 4 resistance here, 1k, 1k if I take the V naught, so when we see V naught is nothing but 1+ generally V naught value is 1+2R/RG into V1-V2 is the equation, just look into the instrumentational amplifier circuit you will understand.
(Refer Slide Time: 23:42)



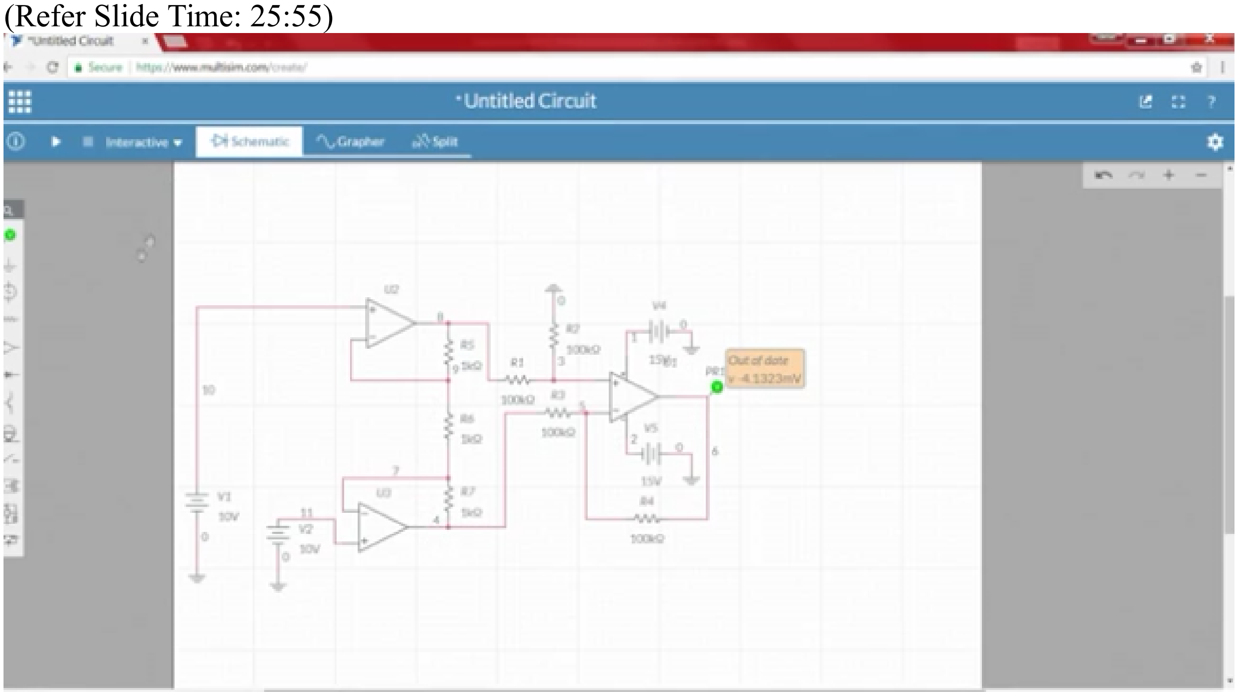
Now in this case what we do is that, we will design the same thing and we will see for different values of V1, V2, now I will say this is VO1, this is VO2, what are the values of VO1 we are getting, what we are getting for VO2, and what about V naught? So I'll take RG as 2k, so if I take RG as 2k the gain will be 1+2 into 1k divided by RG 2k, so this is this one, so the gain is 2, right, the gain of the system is 2, so we will see what is the gain of the system given theoretically, so theoretical we have calculate which is 2, we will see with simulation.

Now so to the same circuit what I will do is that, I will take few more op-amps, so let me keep this, this side, okay, I will take simply 3 terminal op-amps it's more than enough, okay, so I have to choose different resistors, one here, one more here, and one more here, now the output has to be connected at this point and negative terminal should be connected here, this to here, (Refer Slide Time: 25:24)



and this to here, whereas the negative terminal should be connected here, this is my V1, whereas this is my V2, this to be connected, so all the required connections are made,

(Refer Slide Time: 25:55)

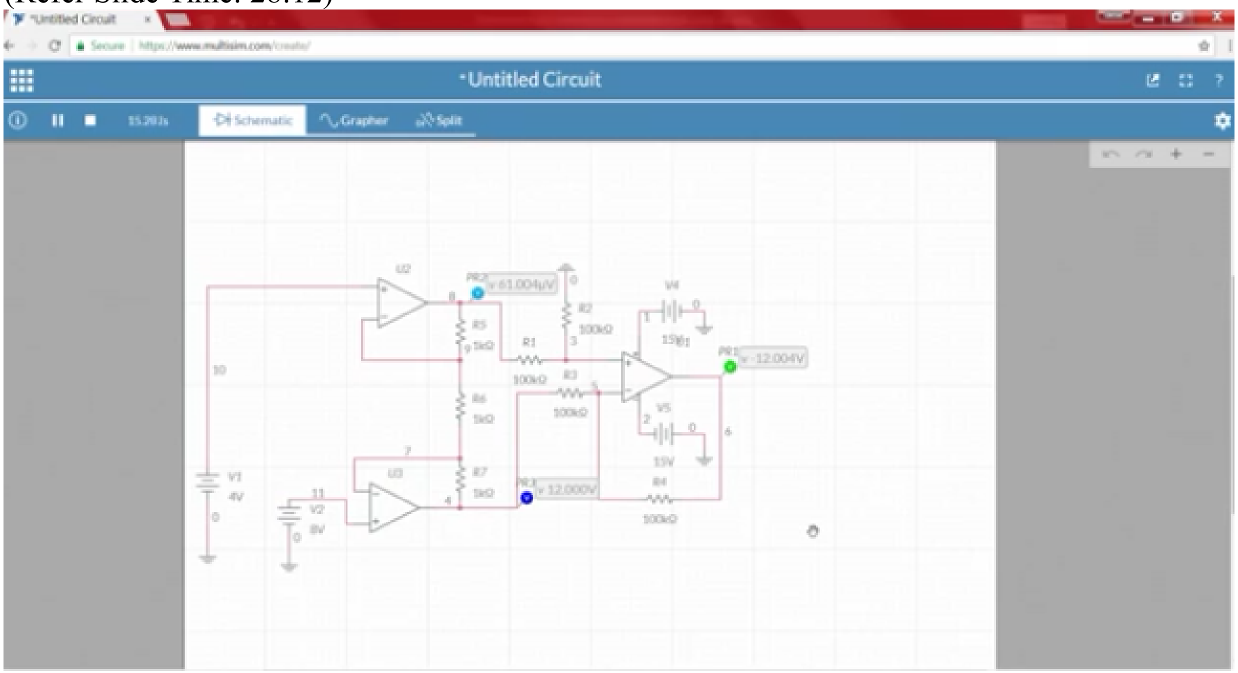


let me run, so this is VO1, this is VO2, this is V naught, so I will take two more probes connected this point, one more probe at this point which gives you VO1 when I run it, yes, so when we see both are at 10, so we are getting -4.1323 milli, so let me change 10 and 2, 10 and 2, so 10 and 2 how much we are getting? At this point we are getting 12, this point we are getting -3.0152.

Now I will see, so V1, V2, VO1, VO2, and V naught, V1 is 10, V2 we are applying to, VO1 we are getting 12, and VO2 is -3, V naught is 15, right, so 10-2 is how much? 8, 8 into gain of 2, 16, approximately 15 we are getting, because why 15? It has gone to the saturation because of the voltage, so what I will do is that I will decrease 2, 4.

Now second input is 10 and 4, 10 – 4 is somewhere around 6, 6 into 2, 12, I should get an output of 12, so we are getting 12.056, right, then so this I will, this I will increase 8, this V2 to 4, let me take this as 8 and 4, so 8 – 4, the theoretical value should be 4, and 4 into 2, so but we are getting 11.996, now what I will do is that, V1 I will make it as 4, V2 as 8, this to 4, this I will make it as 8, how much we should get?

(Refer Slide Time: 28:12)



4 and, sorry, 8 and 4, 4 and 8 we got -12.004, let me apply the same signal which is of 4 and 4, or 5 and 5, because that's a signal that we have used, 5 and 5, so I got somewhere around, when I apply both 5 and 5 I got -4.0811 milli, so this way we can even construct instrumentational amplifier and we can calculate our CMRR value for the instrumentational amplifier too, right, now we will see what is our actual thing, right, so we have calculated and theoretically we got the gain of 1, so theoretical as well as we got, practical we got gain as 1 and the CMRR as 58.4DB, so no problem with this DB for us, so we can go ahead with this differential amplifier.