Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture – 21
Applications of Operational Amplifier: Differential Amplifier

Welcome to this module. And here today we will see what exactly is a differential amplifier. So, we have seen the opamp as an inverting, we have seen opamp as a non-inverting, and we have seen opamp as a summing amplifier. So, let us see how the operation amplifier can be used as a differential amplifier all right.

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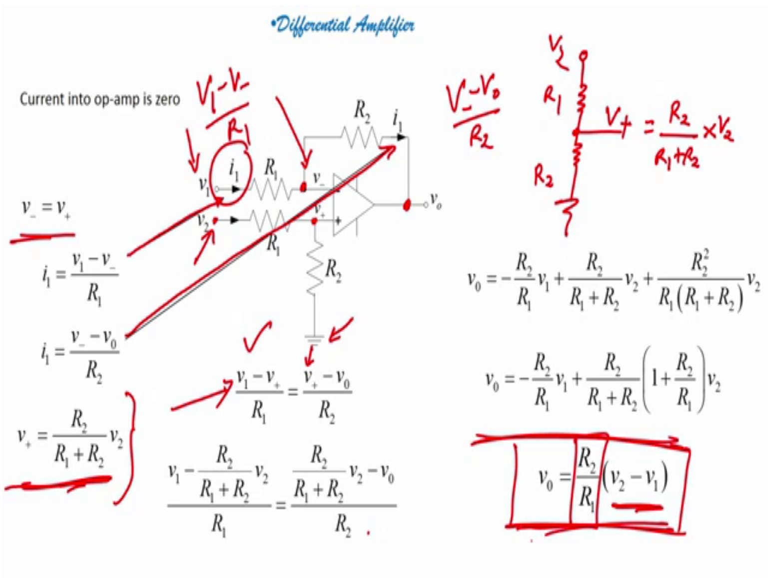

So, if you come back to the screen, so if I have a opamp in the following configuration, in the following schematic or following circuit, then what I see is I am applying input to the inverting as well as non-inverting amplifier correct applying input to the inverting as well as non-inverting terminal of the amplifier. I have values R 1 R 2 right. In this particular configuration, how can I find my output voltage v o. First case is how first I have to find the output voltage v o, the relation between the R 2, R 1, v 1, v 2 with respect to v o.

So, you see these points one is v minus, another one is v plus; one is v minus, another one is v plus. Now what can I see v minus equals to v plus, how, because current into the opamp is 0 or because of the virtual ground concept, v 1 equal to v 2 or v minus equals to v minus v plus. So, i would be so this one first we are considering this value which is i 1 then we will consider the value which is right over here i 1. So, this value is nothing but what will be v 1 minus v minus, so v 1 minus v minus divided by R 1 correct.

And if I consider this value then it will be nothing but v minus right because here you can see here and you have to see here, so it will be v minus minus v o by R 2 minus v o by R 2. So, what is my v plus, my v plus here, now if I want to measure this value v plus right. What is v plus v plus will be so you see here v plus you have to consider this ground, you have voltage here. So, this is like a potential divider. So, v plus will be R 2 divided by R 1 plus R 2 into v 2 correct, because you see here v 2 and here is a ground. So, it looks like we are measuring we have v 2, we have R 1, we have R 2, and we are measuring the v plus correct. So, v plus would be nothing but R 2 by R 1 plus R 2, v plus would be nothing but R 2 divided by R 1 plus R 2 into v 2 right.

Now, I know that v plus right because v minus equals to v plus. So, I will also put my value i 1 equals to these both values. So, v 1 minus v minus by R 1 equals to v plus minus v o by R 2 correct, this is the value. Now, if I substitute the value of v plus, if I substitute the value of v plus in this equation, what will I write v 1 minus this value divided by R 1 equals to R 2 divided by this whole value again we are substituting here in this place right.

So, if I solve further what will I have, when I solve the complete equation, I will find that my v o equals to minus R 2 by R 1 v 1 plus R 2 by R 1 plus R 2 into 1 plus R 2 by R 1 into v 2. Or further I solve it then my output voltage will be nothing but R 2 by R 1 into v 2 minus v 1 correct. When you solve it, further you will get nothing but R 2 by R 1 into v 2 minus v 1. So, what is it doing, it is the differential amplifier, it is amplifying, it is amplifying the difference of voltage at the output. And what is the amplification factor, amplification is done by values of R 1 and R 2. Amplification is done by substituting the values of or selecting the values of R 1 and R 2. What is R 1 and R 2, R 1 and R 2 are my feedback registers, R 1 and R 2 are nothing but my feedback registers. You got it?

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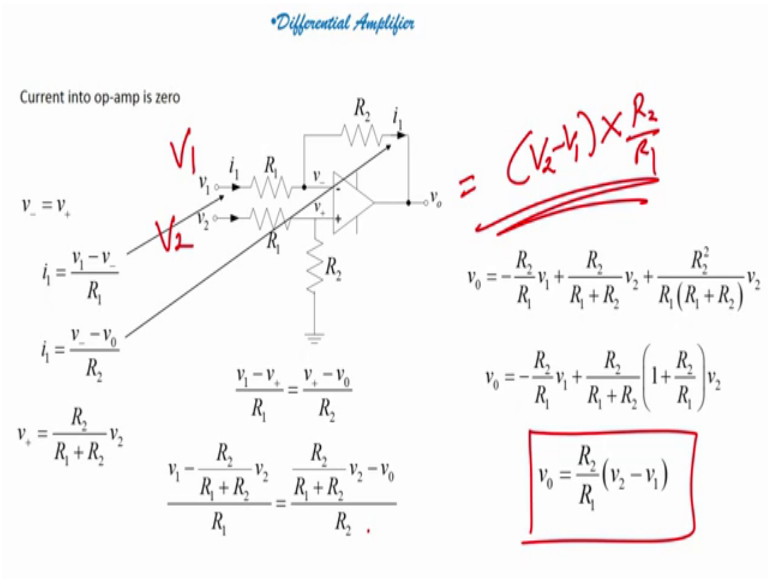

So, this is how my differential amplifier will work that whenever I apply a voltage at both the terminals voltage v 1 and here, v 2 at the another terminal, my output voltage would be nothing but difference of the voltage into R 2 by R 1. This is the formula that I have to remember. And this will be my differential amplifier, this will be my differential amplifier.

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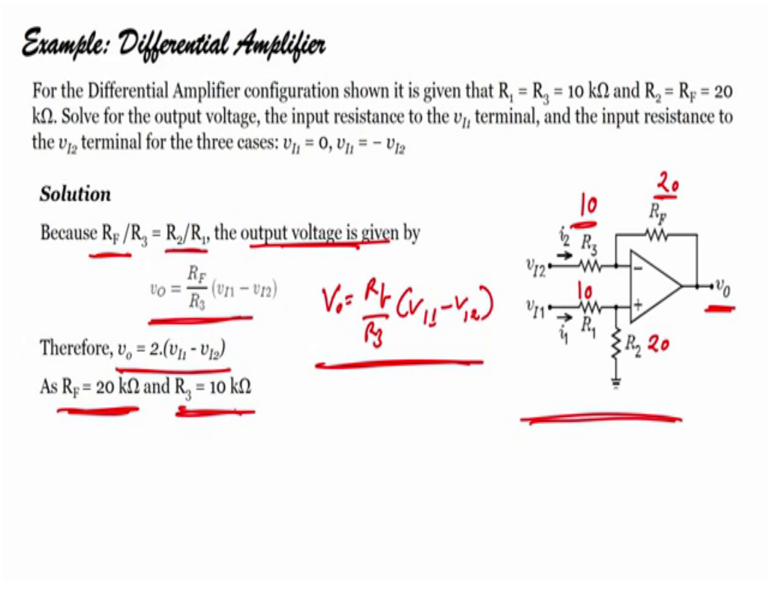

So, let us solve an example, let us solve an example. So, for the differential amplifier configuration shown here; it is given that R 1 equals to R 3 equals to 10 kilo ohms. So, this is 10, this is 10. R 2 equals to R f equals to 20; this is 20; this is 20. Solve for the output voltage we have to find v o right the input voltage v 1 terminal and input resistance to v 1 terminal for three cases v 1 equals to 0 and v 1 equals to minus V I 2 right. So, let us see one by one. Now, because R f by R 3 equals to R 2 by R 1, the output voltage is given by it is very easy right v o equals to R f by R 3 into this one V I 1 minus V I 2 right. If I substitute the value 20 divided by 10 equals to 2, so 2 times V I 1 minus V I 2. So, as R f equals to 20 kilo ohm and R 3 equals to 10 kilo ohm, input resistance to terminals V I 1 and V I 2 varies as shown here, you can show this here right.

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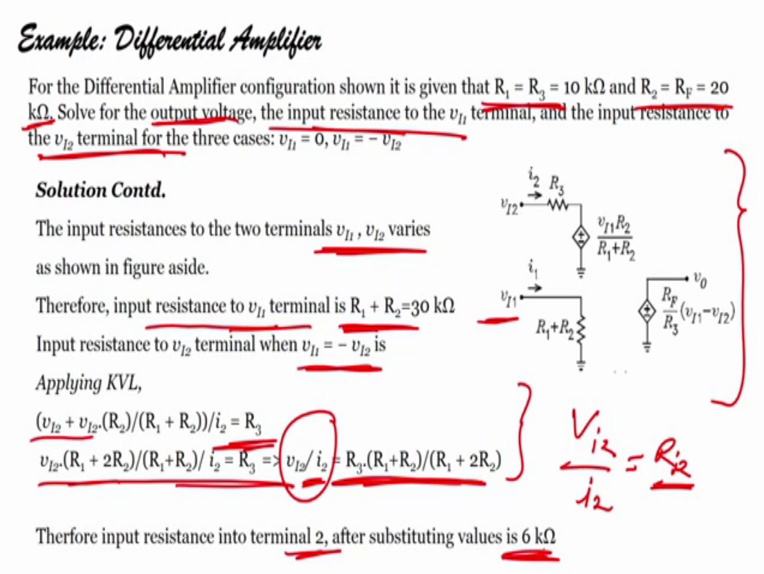

So, what will happen therefore, input resistance to V i terminal one is nothing but R 1 plus R 2 right. If you see this circuit, what we will find that the input resistance to terminal V i 1 will be nothing but R 1 plus R 2 right. What is R 1, R 1 is 10, R 2 is 20, so it is 30 kilo ohm. Input resistance to V i 2, when V i 1 equals to minus V i 2 will be if we apply the Kirchhoff's voltage law then you will find that V i 1 V i 2 plus V i 2 into R 2 divided by R 1 plus R 2 divided by R 2 equals to R 3. If we see this circuit, you have to see this circuit, we will find this, how we are solving. Also V i 2, so when you further solve it what do you get V i 2 by i 2 equals to this particular value.

So, therefore, the input resistance into terminal two after substituting the value, so if I this is nothing but my input resistance of the terminal two right V i 2 by i 2 is nothing but input resistance to the terminal two right whatever the input resistance is. So, substituted if we substitute the values what will I have 6 kilo ohm, I have value of 6 kilo ohm right. So, this is how we can solve the problem for the differential amplifier. Now, understand that I am little bit getting faster in solving the things, I am little bit speeding up my lectures, the reason is that you have to also try to understand how to go in a frequency with the teacher all right. This is another skill that as a student, as a listener, we should develop that if the speed is increased our capability of understanding the problem should also increase and that can increase only when we are clear with the earlier lectures all right.

So, when I talk suddenly about virtual ground, you do not have to go back and see what is virtual ground right, because you have already seen and you have already know what exactly virtual ground is. Similarly, when I talk about inverting, non-inverting amplifier, immediately you should be able to say there was the case there is a equation; a differential amplifier v o is nothing but minus R f by R 1 into V 2 minus V 1 or R f by R 1 into V 2 minus V 1. Now, if I talk about solving the in differential amplifier this is how you can solve the differential amplifier. So, we have taken two problems in which we have solved the differential amplifier right.

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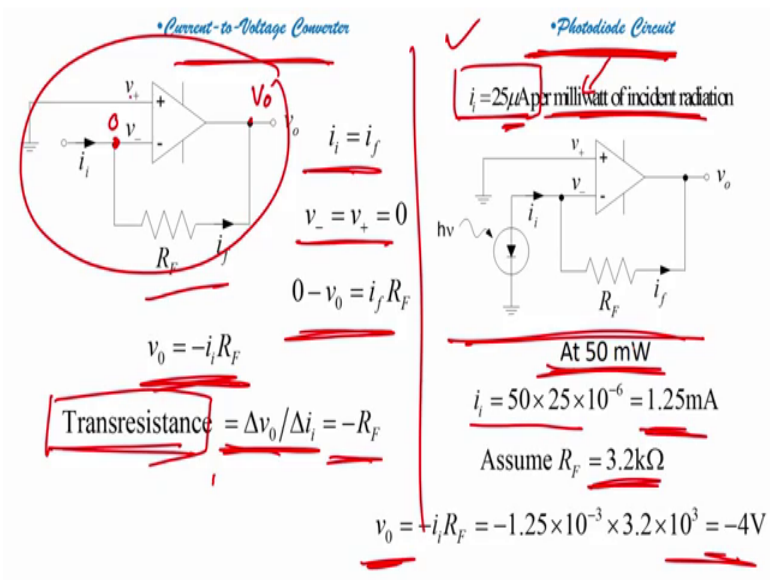

Now, if I want to show you problem where there is a current to voltage converter. So, if you come in the screen, there is a current to voltage converter. What do you see here is the first circuit right. And here if I want to understand then what is it if would be equals to i 1 right. So, another way is v and v plus equals to v minus equals to 0 that is also true right. So, if I substitute the value and 0 minus v 0, 0 minus v 0 is nothing but minus i f by R f because v i 1 is what – 0, and here is v 0. So, 0 minus v 0 is nothing but i f R f. So, v o equals to minus i f R f. The trans resistance is nothing but delta v o by delta v delta i i is minus R f.

So, now let us see this particular circuit. Let us see this particular circuit. Now, I am not going to teach you what is transconductance trans resistance that you have to understand how trans resistance can what is how it is defined, and how we have written delta v o by delta i i right. So, understand what is trans resistance, ok guys, understand something, try to learn by yourself as well.

Now, v o equals to minus i 1 R f correct. So, this is value of output voltage given a circuit to you. Now, let us consider this particular circuit, which is our photodiode circuit. So, if you are given a photodiode, how can you measure the output, how can you measure the output. So, this is a photodiode as you can see. And what is that i 1 is 25 microampere per milliwatt of incident radiation, this much is the current that we can generate. So, at 50 milliwatt, at 50 millivolts, what is the power, what is the current. 50 milliwatt, it will be 50 into 25 into 10 raise to minus 6, because this is microampere 1.25 milliampere.

Now, if I assume that R f equals to 3.2 kilo ohm, then my output voltage v o would be minus 4 volts, then my output voltage v o would be minus 4 volts all right. So, again if I am given a photodiode circuit as shown in figure, and if I am told that i 1 equals to 25 microampere that is the amount of current that the photodiode generates per milliwatt of incident radiation. And at 50 milliwatt, what should be the final voltage a 50 milliwatt, what should be the final voltage, then I had to use this formula that i 1 equals to 50 into 25 10 raise to minus 6 will be 1.25 milliampere. And then I have to assume the value of R f, assuming the value of R f to be close to 3.2, I will have output voltage equals to minus 4 volts. So, this is how your current to voltage converter works, and photodiode circuit is an example of current to voltage converter. And we have also seen how the differential amplifier works right. So, this is all about this particular module.

In the next module, let us see the application of an integrator. And then in another module, we will see application of an differentiator. Again you see I am breaking this module into small modules or breaking the lecture into small modules, so that you can understand the concept, read it, solve the problems get more problems and solve by yourself all right. And also see how what is the application of this amplifiers all right. So, that is why the time I am squeezing down in 20, 25, 30, half an hour whatever the lectures I can bring it to whatever modules I can bring it to so that you have enough time to understand, and then digest and then solve more. And if you have an query you can ask, if you have an query feel free to ask.

So, in the next module, we will see the integrator, till then you learn about this thing; understand what I have taught right, understand how the current to voltage converter works and at solve few more examples by yourself all right.

Till then you take care, I will see you in the next module, bye.