Introduction to Time – Varying Electric Fields
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Lecture 16
Properties of Circuits with Multiple Ideal Opamps

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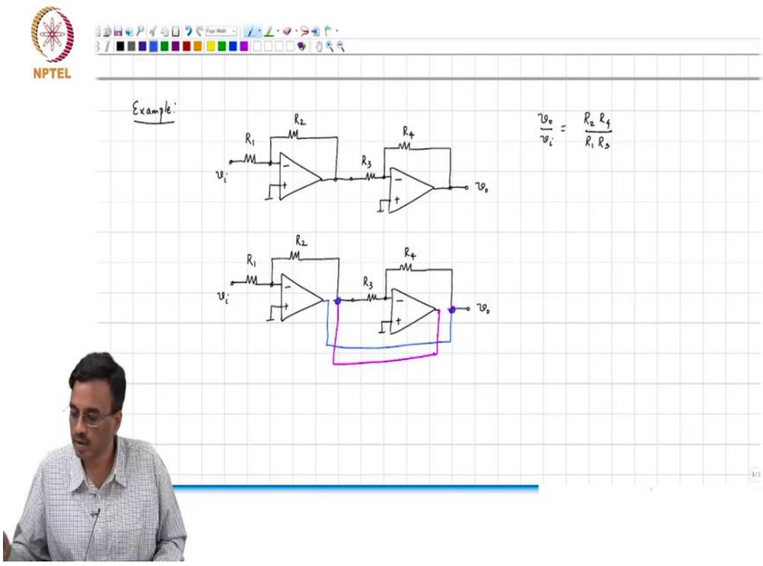

That is a pretty nifty trick. So, let us say this is V I, this is V O. This is R1, this is R2, this is R3 and this is R4. What is the gain from the input to the output?

Student: (())(1:00)

Professor: Well, the voltage here is basically R2 R4 by R1 R2. Now, what I am going to do, what did we discuss? What did we discuss just before this? What do we say if the opamps ideal and there is negative feedback around the opamps? Evidently there is.

So, what can you do? So, you can cut this off here, you can cut this off there and do what? Earlier this node was connected to the output of, was being driven by the output of the first stop. Now, all I am going to do is drive it with the output of the second opamp. And I am going to and this node which was earlier being driven by the output of the second opamp, I am going to drive it with the first opamp. And our claim is, what is the claim? What should happen or what should not happen?

Student: (())(2:44)

Professor: Nothing should change as far as the node voltages are concerned. So, in other words, this voltage must remain what it was, and this voltage must remain what it was. Is that true? How would you do this?

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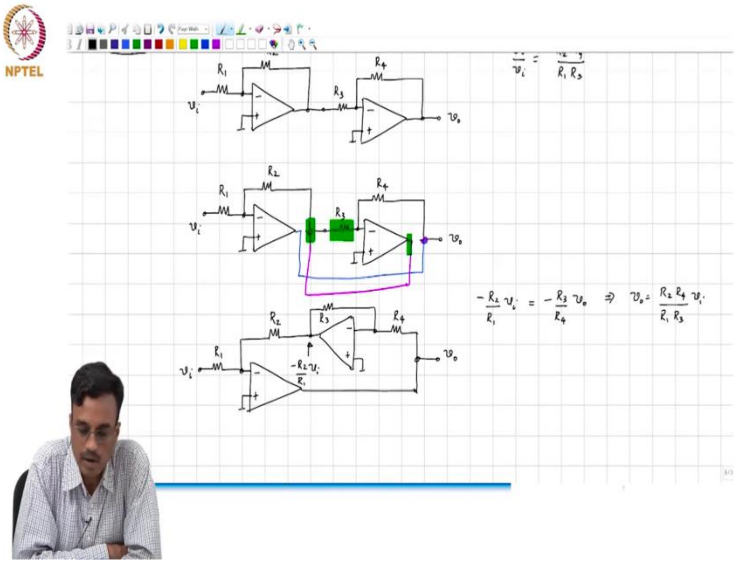

First thing to do is redraw this confusing diagram into something less confusing. So, remember, see look at this, this node is being driven by the output of this opamp. So, it looks like, I am just taking that op amp and drawing it this way and I and R3 goes between, R3 goes between the output of this R3 goes between the output of the second opamp and the inverting terminal. So, this is R3 and R4 goes between R4 and what happens, the output of the first opamp and this is, it makes sense people. Yes. Now you tell me what the output is? What is it?

Student: (())(4:58)

Professor: Yes, so well, this is V I, this virtual ground. So, what must this be? Minus R2 by R1 times V I and that must be equal to minus R2 by R1 times V I must be equal to must be equal to…

Student: (())(5:26)

Professor: Must be equal to minus R3 by R4 times V O and therefore, V O must be R2, R4 R1 R3 times. That makes sense people, right?

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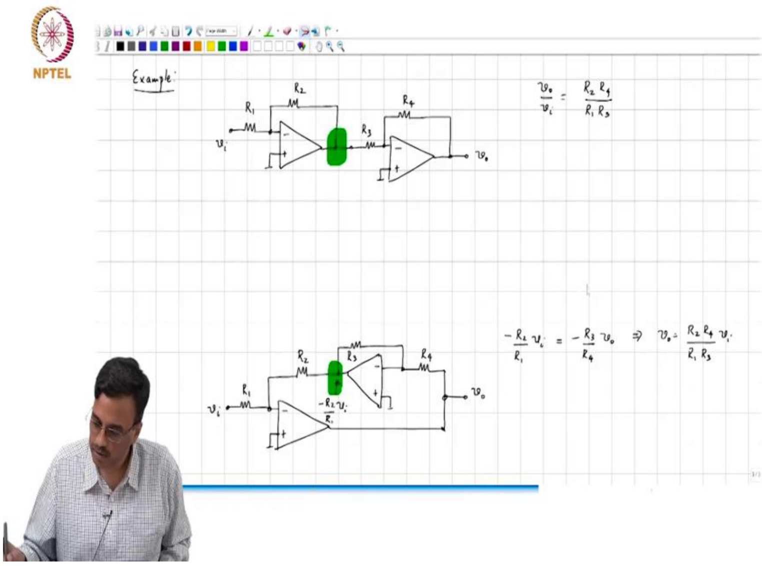

So, if you have if you have three opamps in a circuit that basically means that you can you can generate multiple looking circuits, I mean, they all look I mean, this circuit I do not I mean, I do not know about you, but if I saw this for the first time, if I did not show you this, if I did not show you the, the one in the middle, I mean, the circuit on top looks what comment can you make about the circuit on top and the second below?

Student: (())(6:47)

Professor: They look the same or they look different or, it does not you do not care

Student: (())(6:54)

Professor: or what I mean, what does it they look? They look very, very different. But same it turns out, I mean, amazingly, it turns out that, I get the same transpose not merely the same output, but also remember the junction here, oops, the junction here, what is the voltage there? Minus R2 by R1 that corresponds to this junction here now.

That is also minus R2 by R1 times. Does it makes sense? Or you might wonder, so what? And I have had watch a movie in half an hour I mean, how is this any more interesting than that? And of course, with ideal opamps, these two are exactly identical. Now, if the opamps becomes non-ideal then what comment can you make? Let us say the opamps say, do not have infinite bandwidth or infinite gain or whatever, what comment can we make about the behaviour of these two circuits?

In general, the only thing you can expect is that they will be different because not after all the same network anymore. Now, if you have, multiple networks in this case, you have two networks, which claim to do the same job when the opamp is ideal, when the opamp is not ideal, they will do the same job with different levels of effectiveness because the opamp is not ideal. So, one circuit must be better than the other you have two things one must be greater or less than the other. So, it might turn out that, one of this circuit may be better than that circuit when the opamp is…

Student: non-ideal.

Professor: Non – ideal. So, it turns out that in some applications, it turns out that, a circuit derived by doing this when the opamp is non-ideal; it actually turns out to be much better than the and the more straightforward looking circuit. We will see that, when we learn about filters, down the road. Is this clear?

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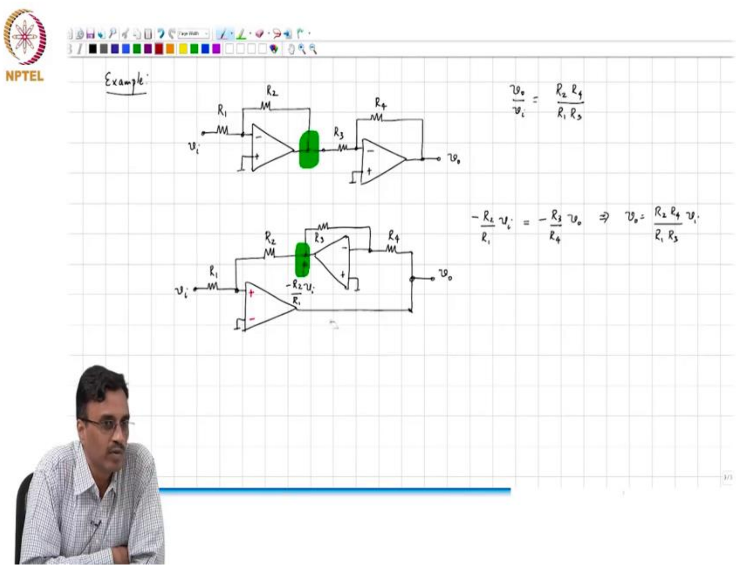

So, that is one application of MNA stamp of an ideal opamp. When you are doing this, you must be careful to ensure that there is DC, of course the opamp is ideal and that there is DC negative feedback around the opamp, which is what is needed to ensure that the two input terminals or the opamp are read. I know what is your shot. Otherwise it is not and if you have to, five opamps in the circuit, ideal opamps in the circuit, then when it is now a field day.

You can now numerate all possible circuits with that and they will all look very different, which means you can write 5 factorial papers because nobody will be able to figure out that this circuit looks very different. There is a while here is a new circuit, but actually, it is the same thing drawn differently.

You understand, of course, before people discovered this, this actually happened because somebody, discovered, hey here is a way of hooking up these two opamps to give you a say, when the opamp is not ideal gives you, much better performance, then, when then the other one, then the more straightforward looking one, correct?

And then of course, after people started looking at it, then they figured out that, oops these are all the, if the opamp is ideal, all these are nothing but the same circuit, but when the opamp is not ideal, they all start behaving differently. So, now it is like, treasure hunt. Then basically, if you have four opamps in your circuit, the guy who goes in, quickly creates all the for all the million possible combinations and analyse all of them, with the finite, opamp gain bandwidth and you will find, obviously if you have, 10 people, it is always easy to find one which is, which is better than the others.

Or maybe, you find all of them are equally bad and then you say. Oh, you write a paper about that too. But this is a pretty; it certainly came across as quite surprising to me. If somebody told me, he showed me these two circuits and told me that these two are exactly identical I would not believe them but actually, when you write MNA matrices for both these circuits, it is exactly the same MNA matrix. That makes sense? Yes.

Student: Positive feedback seems like…

Professor: Actually, so that is a good point. So, again with network theory they just assume that there is negative feedback around the opamp, it is the job of the circuit designer to go and make sure that there is indeed negative feedback. So as he points out, we just carried over the signs without bothering.

Now, what should we do with the signs of this opamp? This opamp there is negative feedback around it, there is no issue. If you want negative feedback around this op amp, what should we do? You break the loop and then, let us say you yank this this voltage up, what happens to this voltage? This goes down or rather this goes down. If this goes down and let us say we assume the original signs like this. What happens if this goes down?

Student: This goes up.

Professor: This goes up. So, is that negative feedback or positive feedback?

Student: Positive feedback.

Professor: Positive feedback, so what should we do? Go invert these signs. So, whenever you do this, you have to make sure that there is negative feedback. So, it is not necessary that the earliest signs that you used will work for the, for the modified set. Of course, if you are in network theorists, then, none of this stuff bothers you, because you just assume that some fellows gone and done all that work and then, the opamp is an ideal element where V1 equal V2, I1 equal to I2 equal to zero and V3, I mean, I3 can be arbitrary.

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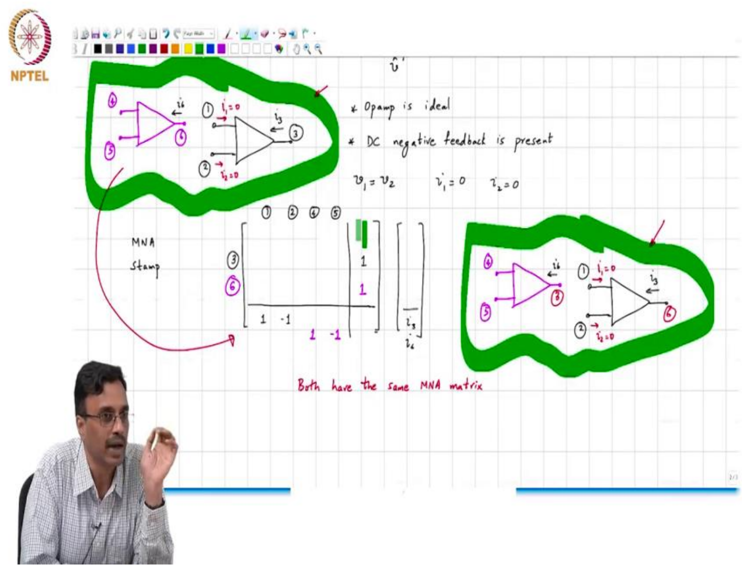

See, this question for the for the benefit of all of you. So, he says, well with an opamp, this confusion is probably arising because we have access to only one terminal. If we had access to both the terminals of the output port, would things have changed? If we had access to both terminals of the port, what would happen? You would get?

Student: (())(14:23)

Professor: Yes, you have, you get another one and another minus one there but it is still possible to associate? There are two ways of choosing plus 1 and minus 1. So, the problem is not solved. So, it is got nothing to do with it is got nothing to do with one port not be access one terminal of the output not the axis. Is that clear? So, I think this is good place to stop.