Circuit Analysis for Analog Designers
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Lecture - 16
Properties of circuits with multiple ideal opamps

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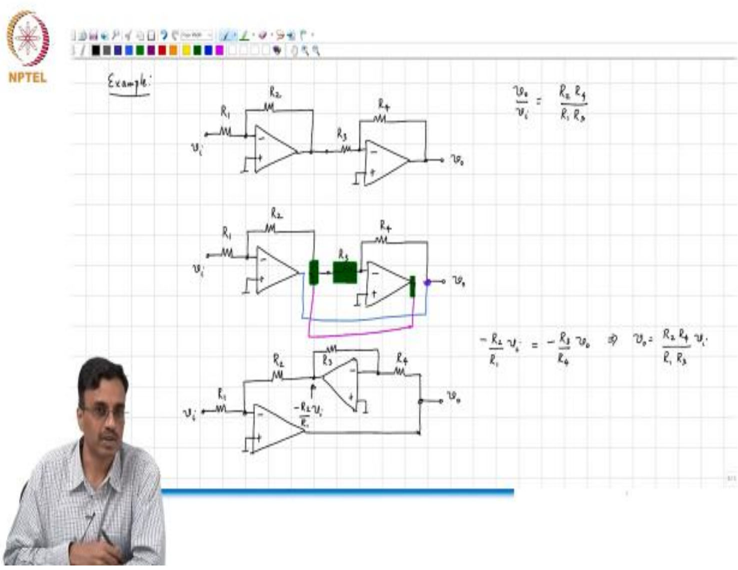

Exactly a pretty nifty trick. So, let us say this is v_i, this is v_o, this is R_1, this is R_2, this is R_3 and this is R_4. What is the gain from the input to the output? Well, the voltage here is basically R 2 R 4 by R 1 R 3, correct?

$$\frac{v_o}{v_i} = \frac{R_2 R_4}{R_1 R_3}$$

Now, what I am going to do? What did we discuss? So, what did we discussed just before this? What did we say? If the op-amps are ideal? And there is negative feedback around the Op-amps 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 op-amp. Now all I am going to do is drive it with the output of the second op-amp.

And I am going to and this node which was earlier being driven by the output of the second op-amp I am going to? Drive it with the first op-amp alright and our claim is?

What is the claim, now what should happen or what should not happen? Nothing should change right, as far as the node voltages are concerned correct ok. So, in other words this voltage must remain what it was and this voltage must remain what it was ok. Is that true? How would you do this? Well, 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 op-amp. So, it looks like I am just taking that op-amp and drawing it this way right and I and R 3 goes between R 3 goes between the output of this R 3 goes between the output of the second op-amp and the inverting terminal. So, this is R 3 alright and R 4 goes between this is R 4 and what happens? The output of the first op-amp and this is v output. Does make sense people? Yeah. Now, you tell me what the output is.

What is it?Yeah. So, well this is v i, this is virtual ground. So, what must this be? Minus, Minus R 2 by R 1 times v i. And that must be equal to minus R 2 by R 1 times v i must be equal to? Must be equal to minus R 3 by R 4 times v o and therefore, v o must be R 2 R 4 by R 1 R 3 times v i. That make sense people right.

$$-\frac{R_2}{R_1}\,v_i = -\frac{R_3}{R_4}\,v_o$$

$$\Rightarrow v_o = \frac{R_2 R_4}{R_1 R_3}\,v_i$$

So, if you have, we have 3 op-amps in a circuit right that basically means that you can? You can generate multiple looking circuits you know 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 one in the middle right, I mean now the circuit on top looks. What comment can you make about the circuit on top and the circuit below?

They look the same or they look different or you know it you do not care or what I mean what is it? They look? They look very different right, but its same it turns out I mean amazingly it turns out that you know you get the same transfer not merely the same output, but also remember the junction here, the junction here what was the voltage there?

Minus R 2 by R 1 that corresponds to this junction here now right, that is also minus R 2 by R 1 times. Yeah. Does make sense or you might wonder yeah so what right ok, alright ok. I mean I have to go to watch a movie in half an hour, I mean how is this any more interesting than that ok. And of course, with ideal op-amps these two are exactly identical.

Now, if the op-amps become non ideal alright, then what comment can you make? Let us say the op-amps you know do not have infinite bandwidth or infinite gain or whatever, now what comment can we make about the behavior of these two circuits.

I mean generally the only thing you can expect is that they will be different, correct? Because it is not after all the same network anymore correct ok. Now, if you have you know multiple networks, I mean this in this case you have two networks which claim to do the same job when the op-amp is ideal right, when the op-amp is not ideal they will do the same job with different levels of effectiveness, correct? Because your op-amp is not ideal.

So, one circuit must be better than the other right. I mean you have two things one must be greater or less than the other ok. So, it might turn out that you know one this circuit may be better than that circuit when the op-amp is non-ideal, right.

So, you know it turns out that in some applications it turns out that you know a circuit derived by doing this right, when the op-amp is non ideal it actually turns out to be much better than the straighter forward-looking circuit ok. We will see that you know when we learn about filters you know I will download. Is this clear?

Right. So, that is one application of the MNA stamp of an ideal op-amp. When you are doing this, I mean you must be careful to ensure that there is DC I mean of course, the op-amp is ideal and that there is DC negative feedback around the op-amp which is what is needed to ensure that the two input terminals of the op-amp are at? Are a virtual short ok, otherwise it is you know it is not valid and if you have you know 5 op-amps in the circuit ideal op-amps in the circuit, then I mean you I mean it is now field day right.

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

You understand right. Of course, before people discovered this you know this actually happened because somebody you know discovered you know here is a way of hooking up these two op-amps should give you us you know when the op-amp is non-ideal gives you know much better performance than you know when than the other one, than the more straight forward looking one correct. And you know then of course, after people started looking at it, then they figure out that you know you know these are all the if the op-amp is ideal all these are nothing, but the same circuit right, but when the op-amp is non-ideal they all start behaving differently. So, now it is like you know treasure hunt right. I mean basically if you have 4 op-amps in your circuit you know you I mean the guy who goes and quickly creates all the 4, I mean all the million possible combinations and you know analyze all of them you know with finite you know op-amp gain bandwidth right.

And you will find obviously if you have you know 10 people you know it is always easy to find one which is better than the others right or maybe you know you find all of them are equally bad and then you say oh you write a paper about that too right ok.

But this is a pretty it certainly came across as quite a quite surprising to me right. I mean if somebody told me showed me these two circuits and told me that these two are exactly identical right, I would not believe them correct, but actually when you write the MNA matrices for both these circuits it is exactly the same MNA matrix. Does it make sense?

Yes. Pardon? Actually yeah, sorry that is a good point right. So, you know again with network theory right I mean they just assume that there is negative feedback around the op-amp. It is the, 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 you know we just carried over the signs without bothering right.

Now what should we do with the signs of this op-amp? I mean this op–amp, of course, there is negative feedback around it, there is no issue. If you want negative feedback around this op-amp, what should we do?

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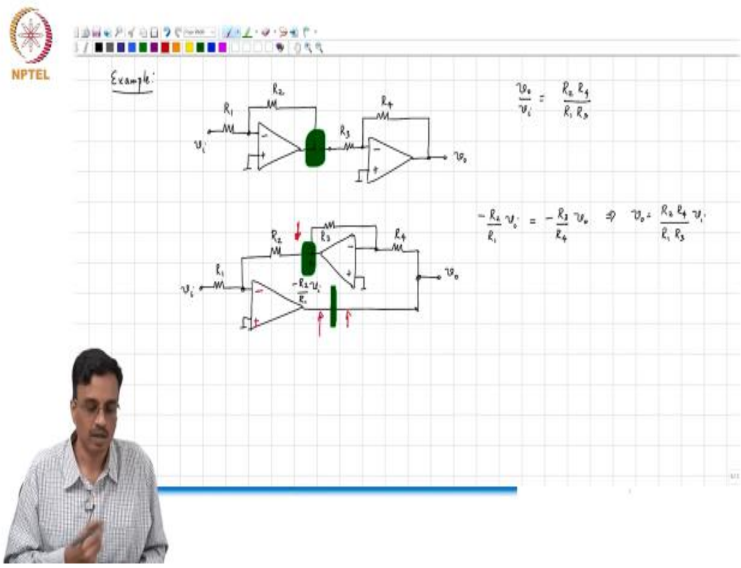

You break the loop ok and then you know let us say you yank this voltage up, what happens to this voltage? This goes down right or rather this goes down. If this goes down and let us say we assume the original signs like this, what happens if this goes down? This goes up. So, is that negative feedback or positive feedback? Positive feedback. So, what should we do?

We go invert these signs ok, so ok. So, whenever you do this, you know you have to make sure that there is negative feedback ok. So, it is not necessary that the earlier signs that you used will work for the modified circuit right.

Of course, if you are a network theorist then you know none of this stuff bothers you because you just assume that some fellow has gone and done all that work and then you know the op-amp is an ideal element where you know v 1 equal to v 2 i 1 equal to i 2 equal to 0 and v 3 I mean i 3 can be arbitrary.

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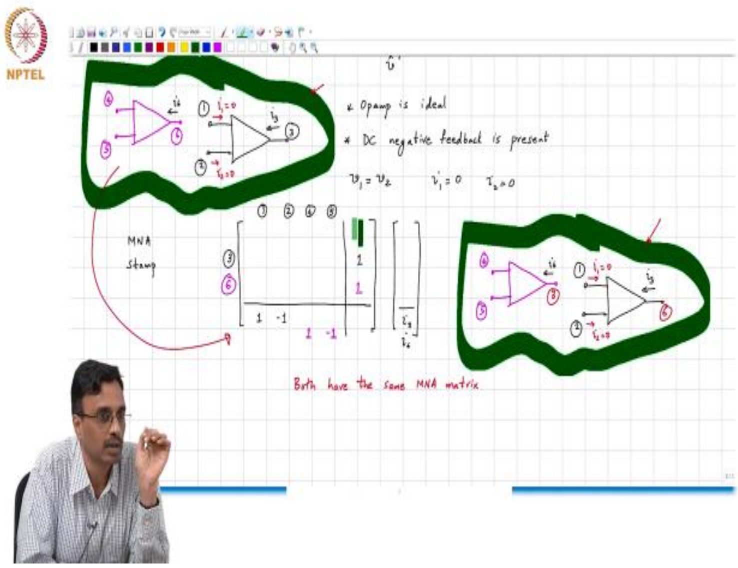

This is question for the benefit of all of you. So, he says well with an op-amp you know this confusion is probably arising because we have access to only one terminal, right. If we had access to both the terminals of the output port would things have changed right. If we had access to both terminals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

Yeah you have you know you get another 1 and another minus 1 there, but it is still possible to associate. There are two ways of choosing plus 1 and minus 1, no?

Right. So, the problem is not solved ok. So, it is got nothing to do with it is got nothing to do with one port not be accessible, one terminal of the output port not be accessible ok. Is that clear? Alright. So, I think this is a good place to stop.