Basic Electrical Circuits
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Lecture – 109

We have already discussed how to determine the signs of an op amp in a circuit, so that it is a negative feedback. Now, the circuits we considered had only one op amp, let us now see how to do it when we have multiple op amps in a circuit and we do not know the signs of any of them, we have to determine the signs such that all of them are in negative feedback.

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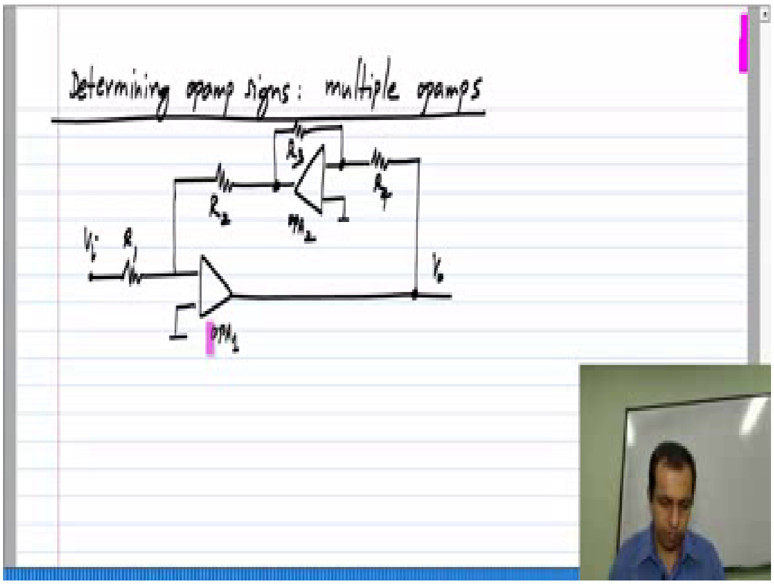

Let me take some circuit I won't worry about what the circuit is and that you can determine for yourself from circuit analysis. But, let me have a circuit of this type may be the circuit has an input voltage here and then output voltage there, but these are not relevant to determining the signs, we know that we will deactivate the inputs while determining the signs. And let me call this OPA 1 and OAP 2, now I will show the systematic procedure after you have a little experience you will be able to mostly simply by looking at the circuit, but initially you have to proceed systematically.

Now, the procedure is still exactly the same as before, we remove an op amp we substituted the output of the op amp with the test voltage and see what comes back to the input side of the op amp. Now, you may run into a slight complication because of multiple op amps and you do not know the signs of any of them, we will see how to resolve those issues.

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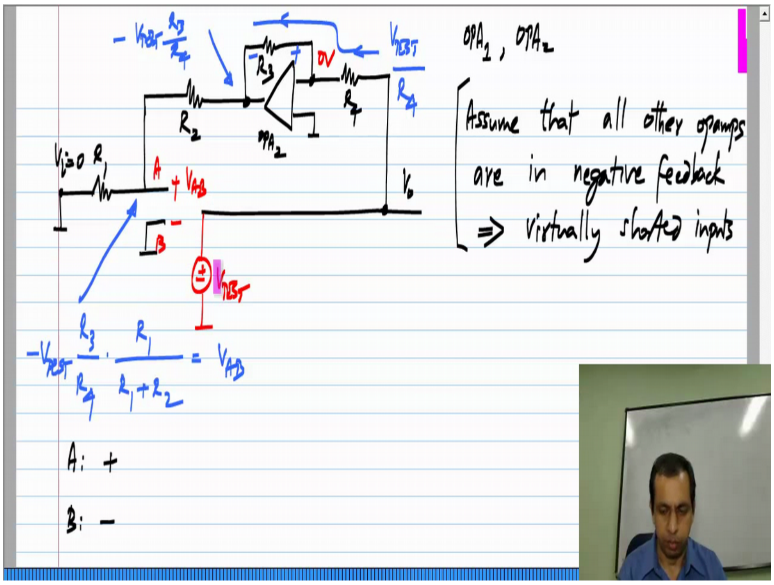

So, let me first determine the sign OPA 1 and then OPA 2 the ordering has some influence as we will see later and V i set to 0 which means that this is connected to ground we are determining the signs of OPA 1; that means, that this is removed and I apply V test here let me call these A and B and I will determine V A B over there. Now, the rest of it is regular circuit analysis, the only thing is this what to do about of the other op amp.

So, we have this other op amp also, so how do we deal with that the easiest thing is to assume that it is in negative feedback already, we do not know what the signs are, but it is operating as those it is in negative feedback. So, that means that it is inputs are virtually shorted. So, in general you assume that all other op amps are in negative feedback which means, they have virtually shorted inputs. Now, this is the easiest thing, if you can do this it turns out that you cannot always make this assumption.

But, if you can make this assumption it makes your life easy, because you do not have to worry about what signs the other op amps had in the first places. Because, whatever signs they had the inputs are virtually shorted, because it will be in negative feedback eventually, so this is also at 0 volts. Now, I later discuss what happens if you cannot make this assumption, but for now in this case it turns out that we can make this assumption.

Now, in those cases where we cannot make this assumption if you proceed with making this assumption you will run into a contradiction. So, that is one way of kind of after the fact checking, whether you can make this assumption or not. So, let say what happens here, if we do make the assumptions we have applied V test here this point is at 0. So, a current V test by R 4 flows that way and of course, nothing flows into the input of the op amp and the same thing will flow into R 3 as well.

So, the voltage drop across R 3 in this direction is this current times R 3. So, the voltage at this point is minus V test R 3 by R 4. And now between this point and V A B we just have a voltage divider consisting of R 2 and R 1. So, the voltage here will be whatever the voltages here, which is minus V test R 3 by R 4 times the divider ratio which is R 1 by R 1 plus R 2.

Now, after you get some experience you do not have to evaluate this explicitly, because you know that the sign is negative already, the ratio the value of ratio does not quite matter in many circuits, but now we have determined that. So, this voltage is V A B and according to the algorithm I described earlier, if V A B turns out to be a negative number times V test like this, then A is the positive terminal of the op amp and B is the negative terminal of the op amp that will ensure that this op amp is in negative feedback. Now, once the signs for this op amp have been determined.

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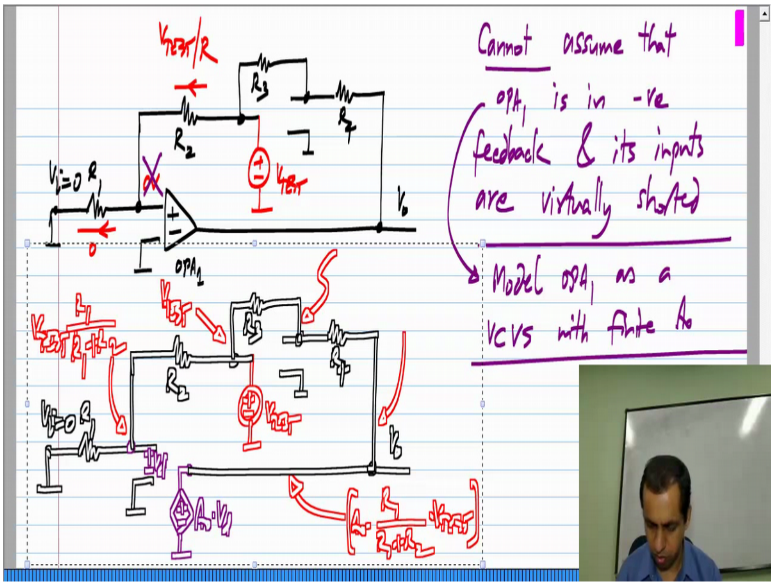

We have to determine the signs for OPA 2. So, the signs for this op amp have been determined as plus and minus and V i is 0 which means this is grounded. Now, I will remove the second op amp and apply a test voltage like that. Now, what to do with OAP 1, we can try the same assumption that is that OPA 1 would be in negative feedback. So, it is inputs are virtually shorted, but now we will run into a contradiction, because let us assume that the inputs of OPA 1 are virtually shorted.

So; that means, the non inverting input is at 0 volts, but if that is the case the current here is 0 and the current over there we have V test on this side 0 volt on the other side it is V test by R nothing flows into the op amp. So, you can see that Kirchhoff's current law is violated at this node. So, in this case cannot assume that OAP 1 is in negative feedback and it is inputs are virtually shorted, so we have to try a different approach.

Now, when the circuit is complete with this op amp it will be negative feedback and it is inputs will be virtually shorted. But, when OPA 2 has been removed and you replace that with V test you cannot make this assumption any more. So, in that case you have to model OPA 1 as a voltage controlled voltage sources with finite A. So, let us do that instead I said we cannot do this, we cannot assume that OPA once inputs are virtually shorted.

So, instead what we have to do is we know that this is the positive and negative terminal of the op amp. So, this will be A node times V d, now this is just a model for OPA 1, OPA 1 is in the circuit, OPA 2 has been removed and I will apply V test over there and this time I won't make the assumption that the input terminals of OPA 1 are virtually shorted I just calculate whatever is there by the way V i as usual is set to 0. So, now, I have apply V test here and I have a voltage divider R 2 and R 1.

So, the voltage of this point is V test times R 1 by R 1 plus R 2, so the voltage is here is whatever this V d is times A naught. So, it is A naught R 1 by R 1 plus by R 2 times V test. Now, at this point we have V test at that point we have this voltage and this can be calculated by say linear combination of this voltage and that voltage.

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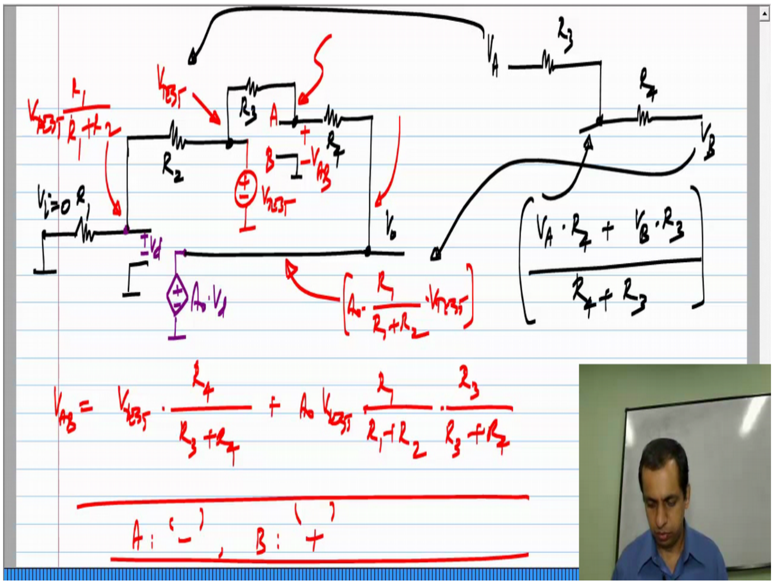

So, in general if you have a circuit like this with two resistors and no current is flowing out of this, remember nothing is flowing out of this one and if I have V A here R 3 R 4 and V B you can prove this for yourself I will just write down the results, this voltage will be V A time times R 4 plus V b times R 3 divided by R 4 plus R 3, you already found a result like this in some activity question or assignment question and that is what we will use here. So, now, what is the voltage here in my case V A is this V test, V B is that whole thing.

So, the voltage at this point let me label this A and B these are the inputs of the op amp OPA 2. So, V A B would be V test times R 4 by R 3 plus R 4 plus A naught V test R 1 by R 1 plus R 2 times R 3 by R 3 plus R 4. So, like I said after getting some experiences you will not time and have to write done this expression, the important thing to see that coefficient of V test here is positive. So, once you recognized that it is positive you know that A has to be the inverting terminal and B is the non inverting terminal.

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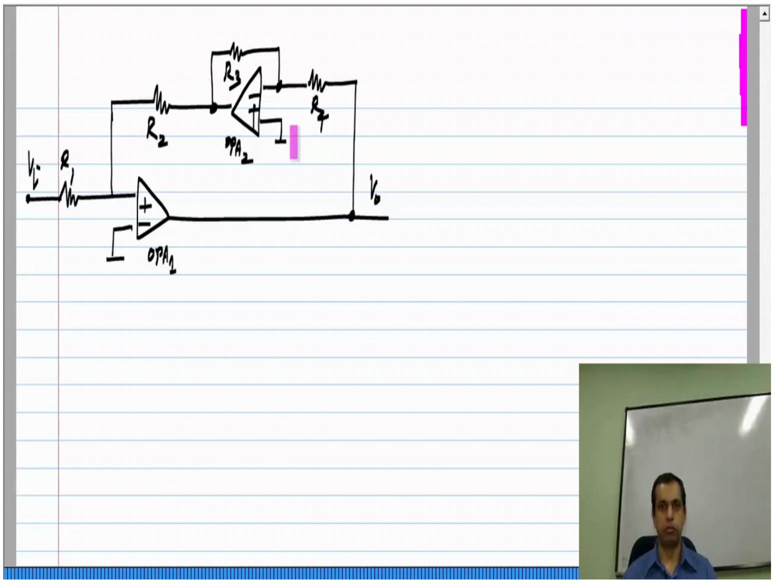

So, now, OPA 1 has signs like that OPA 2 has signs like that, so a couple of points about this you can find the signs of all op amps systematically by going through them one by one. Now, after a while what happen is that if you design a negative feedback circuit with a number of op amps or any other stages, you will assign the signs. So, that negative feedback is valid once you learn this properly. But, the most important thing here is to remember that all the nice properties of the op amps such has virtually shorted inputs are valid only if each of the op amp is in negative feedback and you need to be able to make sure that this is indeed the case.

Now, the second thing is sometimes it is said that a feedback comes to some terminal that should be negative for it to be negative feedback. But, clearly that is not the case for OPA 1 you can see that it is going through this stage and coming back to the positive terminal. And now with the feedback coming back to positive terminal OPA 1 is in negative feedback, whereas OPA 2 is the signal is going out and coming back to it is negative terminal and it is in negative feedback.

So, either way is possible finally, both of this op amps are in negative feedback and just as an exercise you can apply V i here and then determine the value of V naught. Now, for ideal op amps you can make the assumptions that the inputs are virtually shorted, because we have already determined that the op amps are in negative feedback. So, the general algorithms is as follows. So, one by one you remove the op amp and you replace the op amps output with a voltage sources and see the polarity of the return voltage to the inputs of that op amp.

Now, in doing that calculation you have to do something with the rest of the op amps in the circuit, the easiest would be to assume that all other op amps are in negative feedback, so their inputs are virtually shorted. Now, sometimes you cannot make that assumption, because that will lead to a contradiction that is some Kirchhoff's law will be violated or some circuit law will be violated. In those cases those op amps which are given you trouble have to be modeled instead as a voltage controlled voltage source which is the modal for the op amp with the finite gain and then you proceed with the analysis.

Finally, sometimes you may have to resort to trial and error, because the op amp which you are replacing with the voltage controlled voltage source you may not have determined it signs already. So, you have to consider both signs and then proceed, but eventually there will be unique solution you cannot have a different possibilities for this circuit for instance, this is the only possibility. So, if you reverse the signs of both op amps you will find that one of the op amps will be in positive feedback. So, that is the algorithm in short and you can use this for any circuit with multiple op amps.