Network Analysis

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Lecture – 81
Examples of Ideal Op – Amp Circuits - II

So, we have been discussing about analysing circuits, where ideal Op Amp's will be present with negative feedbacks and so and we have seen that if you have signals, then you can add them using an Op Amp, output signals will be some of these 2 signals as well as amplification similarly, you can subtract to signals that we have discussed in the previous circuit.

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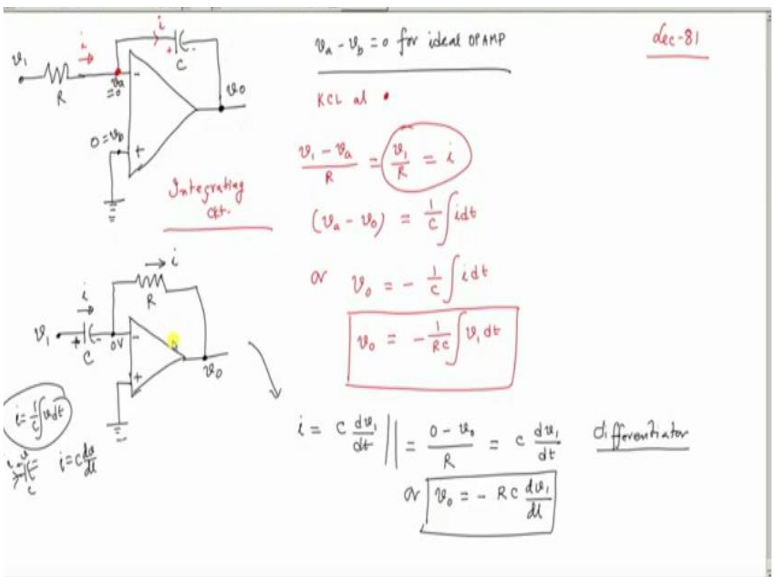

Another interesting circuit is this one is that suppose, you have an Op Amp; ideal Op Amp and these are the 2 things where you connect a resistance R here, connect; this is your input signal V1, this mind you is negative, this is plus and here what you do; you connect a capacitor, this will be your output signals and this is grounded, mind you this is your Va and this is your Vb. Looking at the circuit, I will say Vb is equal to 0, potential of Vb, this is equal to 0.

And if this is 0, Va cannot but V0, it has to be also 0, why; because voltage drop between these 2 points Va - Vb is equal to 0 for ideal Op Amp, there is a negative feedback through a passive element C, so output voltage will be finite and we want to find out the relationship between output and input voltage. So, what you have to do? Same procedure, you have to write down KCL at this point, will be how much?

KCL will be the current going in here, this is V0, is it not, so how much is the current here going; this current is V1 – Va by R which is same as V1 by R because Va is 0 and what is the current going there; same current has to go, is it not, same current has to go, so current in this branch is, if I say this current is i; is i because ideal Op Amp does not take any current practically, so this current goes there, so this is i, this is also i.

If this current is i, then voltage across the capacitor you know with this is plus, this is minus, what is the voltage across the capacitor; here you should be careful, voltage across the capacitor is Va – V0 and that should be equal to; we have learned so much about capacitor, so this must be equal to idt, this is how it will go and I must be consistent, this is plus minus, so i going into the plus that is to be integrated.

If you integrate, you get the potential of this point with respect to this but Vi is 0, therefore V0 is equal to -1 over C into idt but i is V1 by R, so this will become - 1 over RC into this one, i is V1 by R, I am putting there, so it will be V1 dt, therefore output voltage is what; 1 by RC is constant, so it will whatever input signal it gets here, it will simply integrate that and will return you at the output, so it is called integrating circuit, very popular circuit using Op Amp.

It will of course invert the input signal after integrating, it will scale it up or down depending upon 1 by RC, so there will be an amplification factor as well as inversion of this input signal, we can easily see. Similarly, you see another circuit just similar to this suppose, somebody connects a capacitor here minus plus this point is grounded and it connects a resistance there that is a reverses these 2 elements, this is output voltage.

Is there exists a negative feedback here? Yes, this is a passive element and this is C, this is V1 and henceforth I am not going to write down Va here because I know this is Vb which is 0, Va should be equal to Vb, therefore Vb is 0 means this potential is also 0 volt, I will straight away write down this equation, so this current i has to be same as this current because no current is drawn by the ideal Op Amp.

So i; what is the value of this current, it will be potential of this point with respect to this that is V1 by C, i is equal to 1 by C Vdt, is it not, this is the rule for the capacitor. If you this is i, this is the voltage, this V, so that is the rule, so 1 by C, what is the voltage of this point with respect to this V1, is it not, so or you can say okay, let me write 1 by C V1 dt, you integrate it, this will be the current and this current is same as this current.

So, this current is how much; this current is potential of this point minus potential of this point divided by R that is 0 – V0 by R, is it not, or I will say you get this output voltage as V0 is equal to minus; some mistake is there? C, oh this should be C; 1 by C idt, I am so sorry, this equation q by C know, see you should be careful, q by C is the; let me write like this, let me write much more simpler way.

So, just one second, I delete it, this one was correct know. Now, here what I will do, this current relationship you see this i in this case, this problem, i is equal to also C dV dt, so I will write C dV1 dt, in one stroke I will do. This current is voltage across the capacitor i is equal to CdV dt, that information I use and I am consistent this is the direction of the current, this is the potential of this point with respect to this, so C dV dt, this is the value of the i.

And once you get that this i, this the same i flows here, therefore I will say in this branch, this current is 0 – V0 divided by R has to be also this current that is C dV1 dt or I will say V0 is equal to – RC dV1 dt, is it not, this will be this, so this circuit will behave like a differentiator that is you give an input signal V1, at the output the voltage will be proportional to the differentiation of the signal.

So, this can be turned away differentiator, so you are differentiating your signal without doing mathematics, realising a circuit like this you can always say output voltage will be the differentiation of the input signal.Like that there are several problems you can do it, one very quickly I will do one small problem, in fact I will solve 2 more problems, so that you understood.

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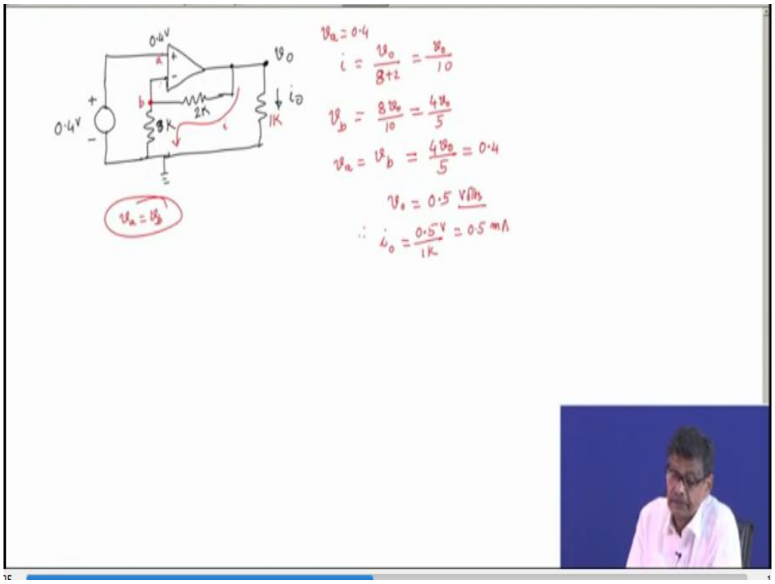

I have taken it from a book exercise problem to be done by the students; I will name the books in the next class. Suppose, you have a voltage here, 0.4 volt, let us see how quickly we can do it, here is the circuit given, this is drawn like this plus minus and here is a resistance here, which is say 3k and there is a resistance there, it is 2k and at the output, you have another resistance say, some value is there at the output, we will see this value of output.

Now, in the circuit I have been asked to calculate what is V0, I have to calculate okay, now how to calculate V0 in the circuit and this is suppose some i0 will be flowing in the resistance connected. Now, if this is the output signal is there any negative feedback; yes, see this time it has been drawn like this but you should not be under the impression that it is a positive feedback, it is a negative feedback to the negative inverting terminal a portion of the output signal is fed.

So, under this condition you know this current; current drawn by the Op Amp will be 0, so this potential is 0.4 volt, this is the ground with respect to this I am measuring 0.4 volt, there will be no current here, therefore this current, that is current in this path will be simply 2 and 3k in series, is it not, 2 and 3k ohm in 8k, let us call this is given to be 8k actually, so this current will be i, this current will be V0 divided by 8 + 2k is equal to V0 by 10.

Then, what will be the potential of this point, potential this is the point V; Vb will be voltage drop across 8k, so 8 into V0 by 10 which is equal to 4V0 by 5, so much volts. Now, it is an Op Amp; ideal Op Amp with negative feedback, therefore potential of this point and this point must be same, now what is the potential of this point that is point a? It has been conditioned by this external source 0.4 volt.

So, I will say that Va has to be equal to Vb and Va as you can see it is 0.4 volt, so I will say Vb which is equal to 4V0 by 5 into this one Vb and that is equal to 0.4 volt, so V0 will be equal to 0.5 volt, is it not 0.5 volt. So, at the output you will get 0.5 volt and if you have terminated this output by some resistance say, 1k here this value, then I will say this i0 will be 0.5 divided by 1k, this is volt, so this will be 0.5 milli ampere.

How, first you can solve it you must understand that is ideal Op Amp in any circuit with a negative feedback, this is the crucial thing; Va and Vb should be equal under this condition and you can solve the circuit. Let us take another circuit which is slightly bigger than this but let us see with 2 Op Amps.

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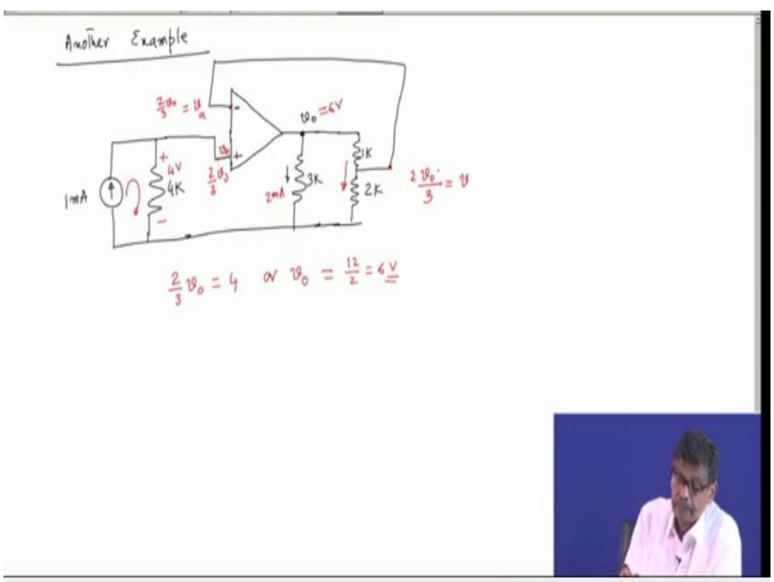

Another example; this circuit goes like this, here is a 1 milli ampere current source okay, across which there is a 4k connected and this one is fed to an Op Amp which is drawn like this with this is plus, I think I should; this one is connected here, the plus terminal like this 4k and at this output let me first draw the circuit, there is a 3k connected and this is their plus and here is a minus, there must be negative feedback.

Let us see where from the negative feedback is taken now, at the output of this first Op Amp 3k, now this one; only one Op Amp here, this one is connected across 1k and 3k, 2k in series and this potential is fed back here, let this; this is the circuit, what you have to calculate is the output voltage V0, you have to calculate for example to begin with, they have asked you to calculate some other things also, calculate the current here, this that.

Now, first thing we should check that okay, there is a negative feedback because a portion of the output is drawn here, it is an ideal Op Amp circuit, things like that now, how to solve this circuit. So, this is V0 okay, can there be any current here; yes, I do not know because this is not this input terminals but what I know is this, this output voltage whatever it is this current, here it is 0, no current will be inputted.

Therefore there will be no branch of current at this point, therefore the current in this branch will be just series thing that is this current will be V0 by 3, if V is in ohms, this is kilo ohms, so much milli ampere is flowing here and the potential of this point, then will be this current into 2 and this is the potential that is equal to Va, so Va I have been able to calculate, Va is known, is it not that will be Va.

Now, what I am telling if this is Va, the Vb has to be same as Va and this voltage here, so Va I have got is equal to 2/3rd into V0, so this potential is also 2/3rd into V0 that is the thing, got the point, this is the voltage which will exist here. What will be the current in this branch? Op Amp does not draw any current, so this current is 0, therefore this 1 milli ampere will circulate here and what will be the voltage between these 2 points?

Potential between these 2 points will be then 4 volt; 4k into 1 milli ampere, so this voltage is known, so 2/3rd of V0 must be equal to 4 volt or V0 will be then equal to 12 by 2 is equal to 6 volt, so this output voltage the answer will be 6 volt, then what ever things you have been asked to calculate you can calculate, what will be the current in this branch; current in this branch will be 6 by 3; 2 milli ampere as will flow here and so on.

Therefore, you see no matter how complex this circuit look like, you can always look for whether negative feedback exist and the Op Amp is ideal, then this is the crucial thing, Va and Vb, they should be then equal and this current drawn by the Op Amp is to be 0 that is the (()) (23:46), it is much simpler than what we have solved earlier, let us solve another problem, another example.

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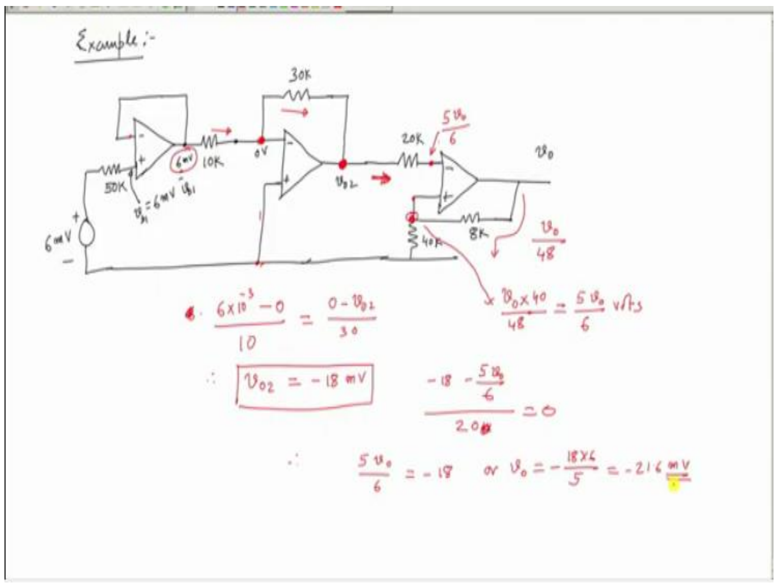

Example; this circuit is having more than 1 Op Amps, suppose you have a circuit like this, let me draw quickly, so this is some 10k, this is some 50 k, here is a voltage source plus minus 6 millivolt and here is a connection which goes like this, this connection is very popular and this is minus, this is plus. Now, this Op Amp is output of this straight to another of Op Amp whose inverting and non-inverting terminals are connected in this way, okay.

And here is this negative feedback exist; yes, therefore this also 30k, some values are given and then you have a third Op Amp, 20 k has been connected and these Op Amp looks like this, minus plus and this is 40k resistance and this output; output voltage is there for this whole thing, this is the input signal output voltage and this one is connected here by 8k impedance, hopefully I have drawn the circuit correctly now, for this problem to do how to proceed.

First of all this current here will be; here is a negative feedback for this Op Amp, so this current is 0, if this current is 0, there is no voltage drop here, so for this transformer the non-inverting terminal voltage that is V1 is equal to 6 millivolt, it will be like this. If it is 6 millivolt, ideal Op Amp negative feedback this will be also 6 millivolt, so here this voltage is 6 millivolt has to be, no resistance here, same voltage, 6 millivolt.

Now, for this Op Amp, let this voltage we called V02, second Op Amp, this is V01 of the output of the first Op Amp, now this potential is 0, there is a negative feedback, so 0, so this voltage must be 0 volt that is Va; Va2 has to be 0 volt here because this is 0, the Op Amp does not carry any current, it will be 0 volt and then this voltage we have to calculate. So, what do I do is this; for this Op Amp, I will write down the KCL equation at this point okay.

So, KCL if you write here how I am going to write it; it will be this current 6 millivolt mind you, so take care of that; see, the potential of this is 6 millivolt, so 6 into 10 to the power – 3, if the voltage in volt minus 0 volt divided by 10 is a current coming in here, this current is 0, so this must be same as this current which has to be equal to 0 – V02 by 30k, is it not, this will be the thing.

Therefore, I can calculate V02 to be; this can be 30k, so k we forget, current we are measuring in milli ampere and so on, so if you calculate V02, it will be - 3 into V01, that is -18 volt; -18 millivolt; millivolt suppose voltages are, so it will be V02 is known, what is V02, potential of this point is known. Then, if I know the potential of this point and if this is an ideal Op Amp, so the current in this; the potential if this Op Amp does not take any current, this V02 will appear here, minus 18 volt.

And there will be no current here, so current in this path will be V0 by 48 and potential of this point will be V0; potential of this point will be this one will be V0 by 48 into 40, is it not and that is 5V by 6, so much volts. So, I have been able to calculate this potential, so this potential there will be no drop here because of that this potential and this potential are same and this current is 0.

With that condition, what will be the potential of this point; it is already calculated to be V02 is this potential but from this I know the potential of this point has to be 5V0 by 6 volt, is it not, therefore I can proceed to calculate the output voltage as; how do I calculate the output voltage; this current is 0 and this potential V02 is - 18 volt, so this current or deal with the expression of this current -18 millivolt minus potential of this point, this current I am calculating, divided by 20k.

And that must be equal to 0, therefore I can say 5V0 by 6, this 20 does not matter is equal to – 18 and your V0 will be equal to -18 into 6 by 5 that is -21.6 volt; millivolt, anyway roughly this will be close to 18 volt, slightly less than, 18 into 6 by 5, so this is the answer, so we started with this and applied the same rule for all the Op Amps, here it is no feedback, so 6 millivolt, it should not draw any current.

Therefore, there will be no drop in this 50k, so same voltage appears here and there will be; if this is 6 millivolt, this point potential is also 6 millivolt, it comes here, then 6 millivolt and look at this Op Amp, this is at ground potential and so it has to be at 0 potential, so many things are known. So, the current in this one; 6 – 0 by 10k, it does not draw any current that current will be same as this current which will be 0 – V02 by 30, it will be this current we have calculated that.

So, from that I got the value of V02 output and once I get V02 here, look at this third Op Amp, it is V0, this is, there will be no current, so V0 by 48 into 40 that will decide this potential that potential you bring it here but this Op Amp should not draw any current. If that be the case, then you know, I can easily calculate the output voltage, therefore these are some of the examples. So, we have discussed some ideal; using ideal Op Amps circuit, what can be done.

My next class will be the last lecture class where one more circuit I will discuss about Op Amp and it will be a concluding lecture class where these whatever I have tried to cover I will discuss briefly about that and you please prepare well for the examinations covering the courses but do not just remember formulas, try to concentrate on the basics and I hope all of you will do very best in the exams, so next class will be the concluding lectures, thank you so much.