Basic Electrical Circuits
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Lecture – 106

In this lesson we will look at the inverting amplifier, which is one of the standard amplifiers using an op amp.

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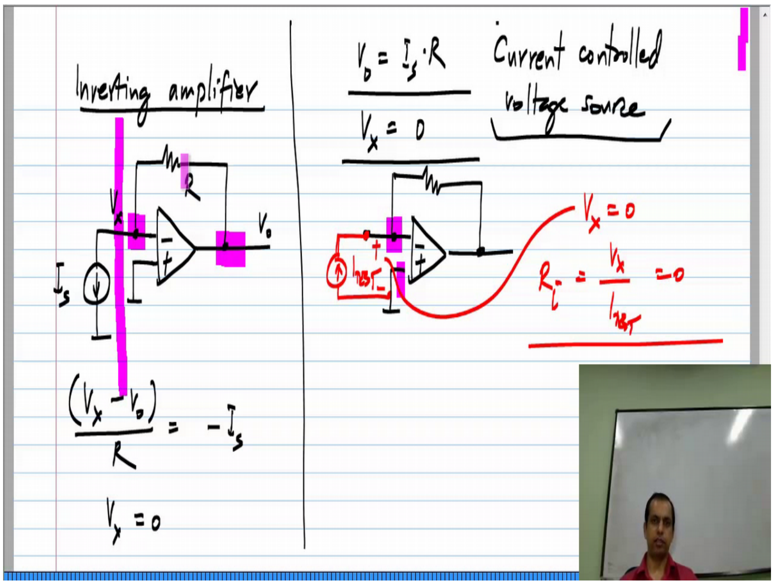

Now, the basis for the inverting amplifier is this particular circuit through the current input and feedback around the op amp with the resistor R. Now, this circuit can be derived using the principles of negative feedback, but in this case I am not going to do that I have just put on the circuit. So, let say this current is I s and this voltage is V naught, then the analysis of the circuit is very easy, really there are only two nodes.

So, at this node if I write Kirchhoff's current law equation I will see that, let me call this node voltage V x. V x minus V o divided by R, which is the current leaving this node through resistors equals the current being injected into this node, which is minus I s and we have the other node which is the output of the op amp. As I mentioned, we cannot write Kirchhoff's current law equation here, instead we write the virtual short equation at the op amp input and that turns out to be just V x equals 0.

Because, the non inverting terminal of the op amp is connected to ground, that has 0 volts and the other terminal has to have the same voltage as this one and if you solve for these two, you will easily see that V naught is I s times R. So, this is a very nice circuit which is used quite frequently also, other standard circuit is the non inverting op amp amplifier, which we have discussed earlier.

Now, this has a current input and a voltage output and this truly is a current controlled voltage source. So, the solution to this is V naught equals I s R and of course, V x equals 0, the inverting terminal of the op amp is at 0 volts. So, now, as I said it is a current control voltage source. What does it mean? First of all let us evaluate the input and output resistance of this circuit, to calculate the input resistance I have to apply a test voltage or a test current between these two terminals.

I will use a test current, because that result is already available to me and in fact, if you try to use the test voltage you will find that you will end up with the contradiction, so you can only use the test current. So, you can apply I test and see what the voltages between these two nodes and I already have the solution to that, this circuit is exactly the same as that one. The direction of I test is opposite to that of I s, but that is irrelevant, because whatever the value of I s this V x is 0, thus because of the virtual short between this point time, that point between the inputs of the op amp. So; that means, that basically that voltage V x is 0, so the input resistance R i is V x by I test which is 0.

So, the input of this circuit presents a short circuit to the source, whatever source is connected. So, it is truly a current control source. What I mean by that is, if the input resistance is 0, even if the current source is imperfect the circuit will behave in exactly the same way.

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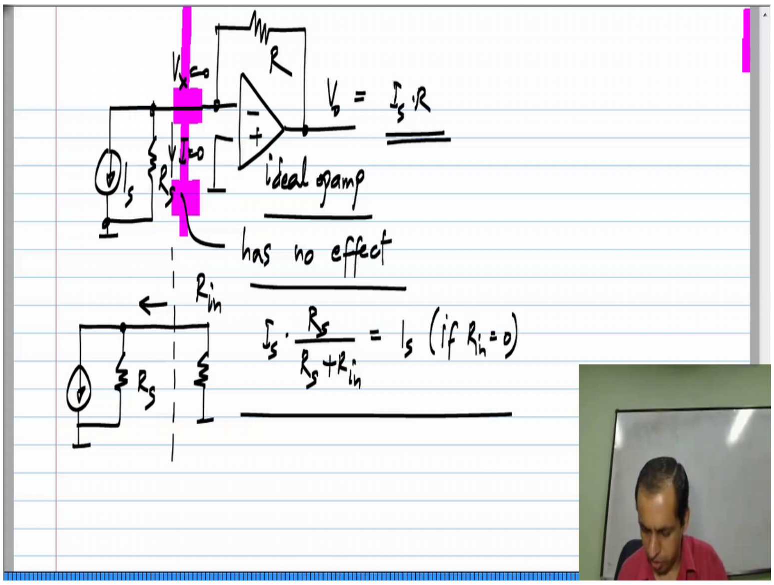

Let us say the current source had some resistance across it; that is, it is not an ideal current source, but it is the Norton equivalent of some circuit which has I s and some R s across it. Again I am considering an ideal op amp here, this is in negative feedback as you can verify for yourselves. Now, this V x here is 0 which means that this R s no current flows through it and if no current flows through it, I could remove it and it makes no difference to my circuit.

So, all of this I s still flows through R, the equation I wrote earlier are still true. So, the solution to this again you can calculate this for yourselves systematically, if you are not convinced, this V naught is still equal to I s times R. So, this R s has no effect, this is always be the case if the input resistance of the circuit is 0. So, this is now the model for the input of the circuit, it has some input resistance R m, basically that is the resistance between this terminal and ground, which is the input of this circuit.

Now, you can see that the current that actually flows into the circuit is I s times R s by R s plus R n and if R n equals 0, it is equal to I s. So, if the input resistance is 0, even if the current source is imperfect, all of the current flows into the circuit and that is exactly what happens over here.

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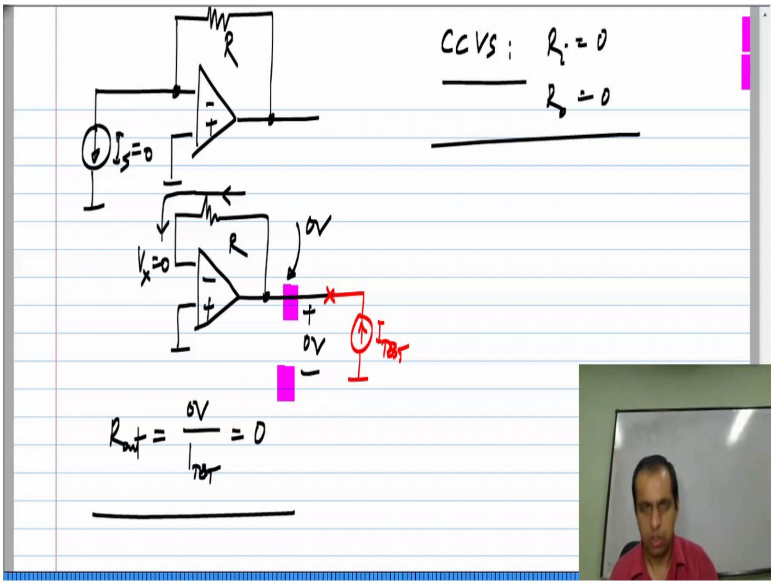

Similarly, let me take this circuit and evaluate it is output resistance and to evaluate the output resistance, I set I s to 0. So, this becomes an open circuit and I have this resistance R. Now, to evaluate the output resistance I connect a test current, now is V x here is 0 and no current flows through the resistor, because no current can flow into the input of the op amp, so this voltage here is also 0.

So, again the voltage across this is 0 which means that the output resistance which is the resistance between these two terminals is 0 volt by I test which is equal to 0. So, this is the current control voltage source, this is truly a current control voltage source with 0 input resistance and 0 output resistance, sometimes this circuit is used in slightly modified way.

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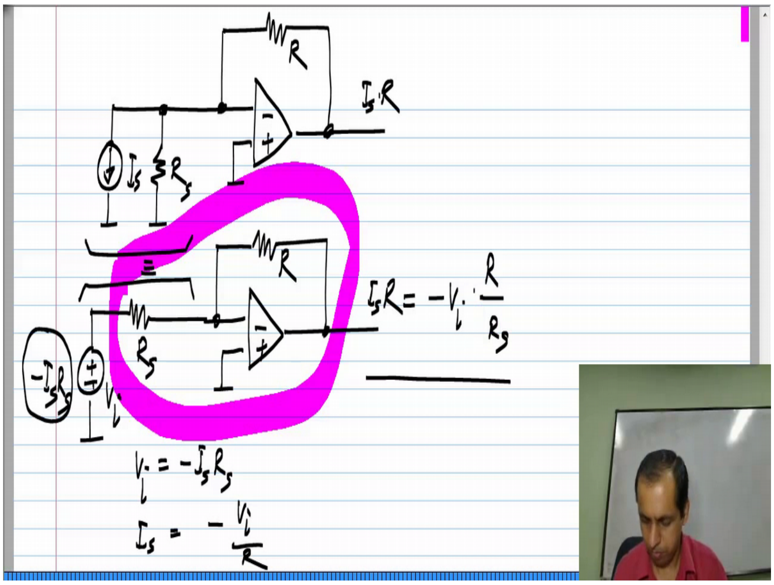

So, let me again consider my circuit, we know that even if there is an R s in parallel with I s the output voltages is I s times R this comes from straight forward circuit analysis. Now, this combination here you can see is a parallel combination of a current source and resistor, we can think of it as Norton equivalent of something and the Thevenin equivalent of it would be a voltage source in series with resistance and we also know from earlier discussions on Thevenin and Norton's equivalents that this resistance is same as R s and this voltage source given the direction of current is minus is R s, so these two are exactly equivalent.

Now the output voltage is still exactly the same I s times R and if I replace this minus is R s by V i I think of this circuit with a voltage input V i and some resistance R s which is connected to it is then V i will be minus I s R s and I s will be minus V i by R subsiding that in here I will get the output voltage to be minus V i times R by R s.

So, this circuits is known as the inverting amplifier I originally started from this idea of a current source with a resistance in parallel, but in general this resistance can be anything, it does not matter whether it belongs to the voltage source or whether you put it the total resistance being R s, the output voltage will be minus V i the voltage source value times R by R s.

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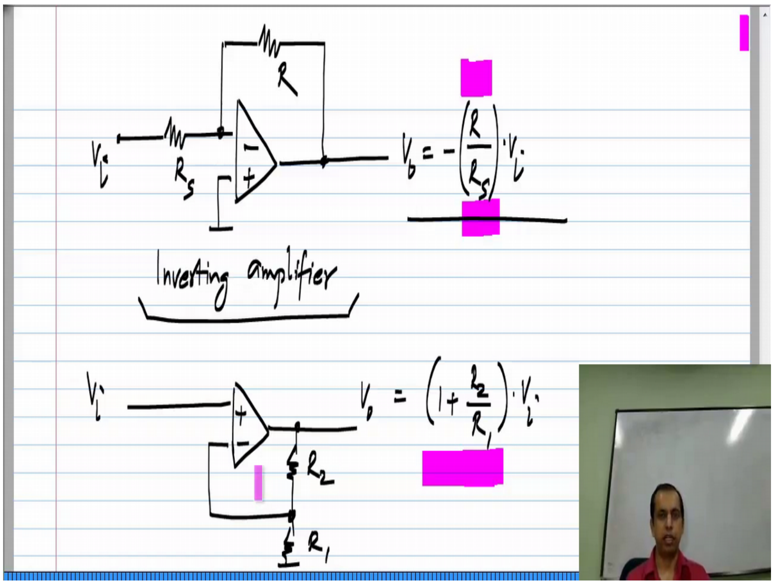

So, this circuit is known as the inverting amplifier if this is V i the output voltage will be minus R by R s times V i and it is called inverting; obviously, because the gain is negative and you can contrast this to the non inverting amplifier, if I called these R 1 and R 2 and V i and V naught, V naught will be 1 plus R 2 by R 1 times V i. In both cases the again depends on ratio of resistor does not really depend on the op amp, the op amp is ideal the gain will be exactly this much 1 plus R 2 by R 1 for the non inverting amplifier and minus R by R s for the inverting amplifier.

If the gain of the op amp is finite we have analyzed it for the non inverting amplifier you can repeat that for the inverting amplifier, the gain will be slightly difference from that and if the gain of the op amp is very large the difference will be very small.