Basic Electrical Circuits
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Lecture – 110

In this lesson we look at another example circuit, which is to synthesize a negative resistance using an op amp.

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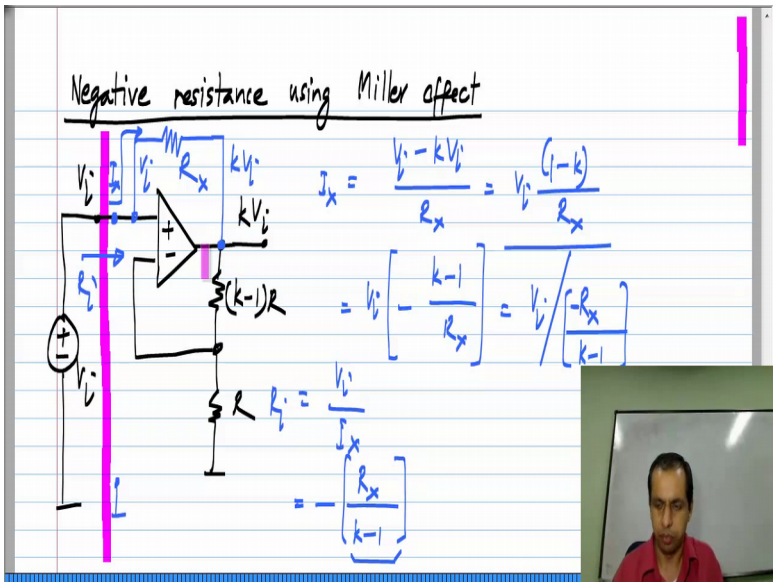

I will say negative resistance using Miller effect; I will explain what that is. Let us consider a non inverting amplifier, if the input is V i the output will be k V i, because of this resistance ratio. It is 1 plus the upper resistance divided by the lower resistance. Now, of course in this condition no current flows into the op amp. So, the input resistance of this circuit is infinity, let me show the voltage source explicitly and let us say, I connect a resistance R x between the input and output.

Then, I will evaluate the resistance of this part of the circuit that is to the right of this line between these terminals here and ground and we know how to evaluate the resistance of any linear circuit. We apply a test voltage, find the current that is flowing in, divide the voltage by the current to obtain the resistance. Now, the only current here is flowing through R x, this node is at V i, this node is at k V i. So, this current I x is V i minus k V i divided by R x, which is V i times 1 minus k divided by R x.

Now, you can see that this I x will actually be negative, because this k will be greater

than 1. We will assume that k is more than 1, because we are making an amplifier of gain k, k is at least 1 and in this case we will choose k to be more than 1, so that this k minus 1 is a positive number. So, this I x in this direction will be actually negative, so the current in this direction I x is V i times minus k minus 1 by R x, which is V i divided by R x by k minus 1 with a negative sign.

So, the resistance looking in here R i which is V i by I x is nothing but, minus R x divided by k minus 1. So, this k minus 1 is a positive number and R x is of course, positive, it is a physical resistor. So, the input resistance of this circuit is negative.

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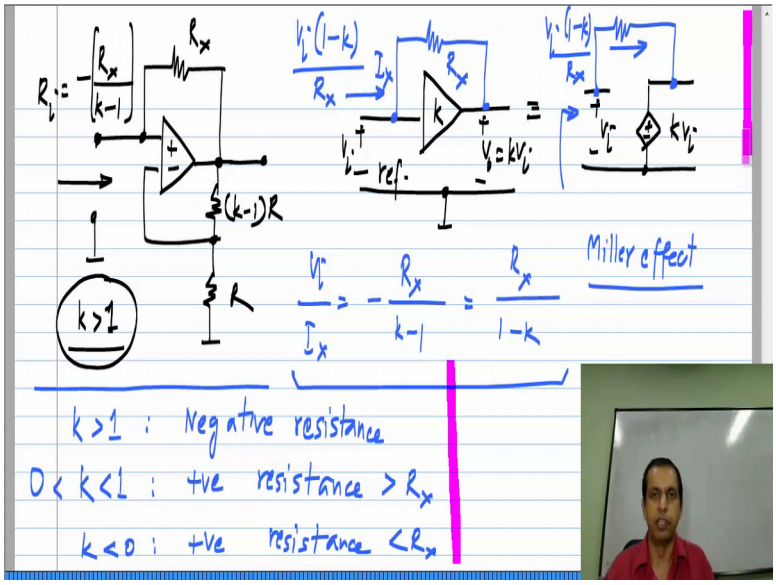

So, if you wanted to synthesize a negative resistance, this is how we do it. This is an amplifier of gain k and I connect some R x, then between this point and ground I see a resistance, which is minus R x divided by k minus 1 and in this circuit of course, k is more than 1. Now, this is quite easy and it turns out, this is a specific case of what is known as Miller Effect. If you have an amplifier of gain k, I use this symbol to mean this circuit. Let say ground is the reference terminal and this is V i, this is v naught equals k V i. This is nothing but, a voltage control voltage source of gain k, so if this is V i, this will be k times V i.

If you connect a resistance between the input and the output of the amplifier R x, let us assume that no current flows in here, like the here it is an open circuit no current flows in there and the amount of current that flows in there would be V i times 1 minus k divided by R x, exactly what I evaluated for the other circuit. If you apply V i here, the amount of

current that flows in there is V i times 1 minus k divided by R x, this comes from simple ohms law.

So, the looking in resistance which is V i divided by I x, let me this I x is the same formula as before. It is minus R x divided by k minus 1 or R x divided by 1 minus k. So, by connecting a resistance between the input and the output of the amplifier, you have an input resistance which depends on the gain of the amplifier and this is in general known as miller effect and also depending on the gain value, there are a few possibilities.

If k is more than 1, we see a negative resistance at the input and if k is between 0 and 1, we see a positive resistance which is more than R x more than the resistor that you have in the circuit. And if k is smaller than 0, that is if k is negative then we have a positive resistance that is smaller than R x. You can make a large resistance look like a small resistance by connecting it across an amplifier, whose gain is negative. So, this is known as miller effect and it manifest itself in some circuits and this is how you calculate the input resistance.

The main point is that, the input resistance is determined by the gain of the amplifier. So, you can think of many possibilities, such as if you have an electronically varying gain you could also have an electrically varying resistance and so on and of course, the additional application is, what I already showed you how to make a negative resistance. It can also be used for realizing a very small resistance and so on.