Analog Circuits
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Module - 06
Lecture – 03

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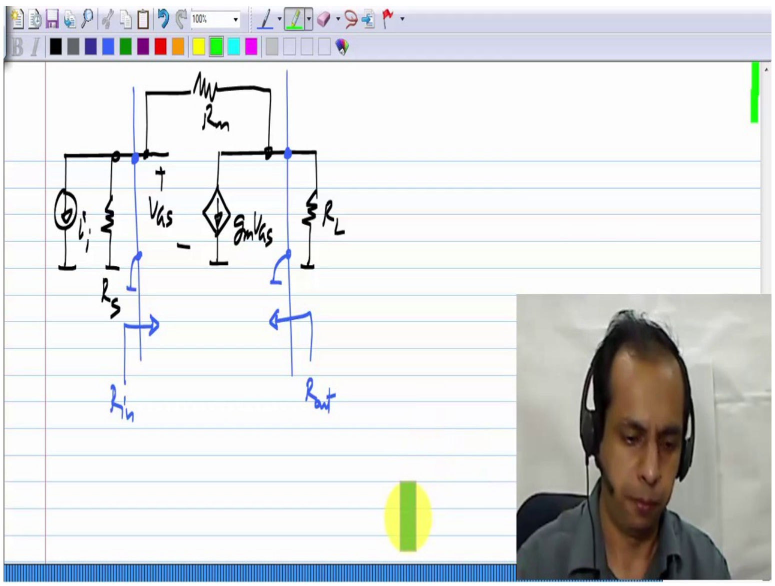

We have examined the current control voltage source and found out the conditions under which it does behave like a current control voltage source with trans resistance or trans impedance of R_m. Other important aspects of a controlled source are the input and output resistances; we will evaluate them now. The input resistance, of course is the resistance looking into this part, that is between the two terminals across which the input source is connected, it is influenced by R_L. And similarly the output resistance is the resistance looking that way between these two terminals, this point and ground across which the load resistance is connected. As usual you can evaluate them by connecting a voltage source and finding the resulting current or connecting a current source and finding the resultant voltage.

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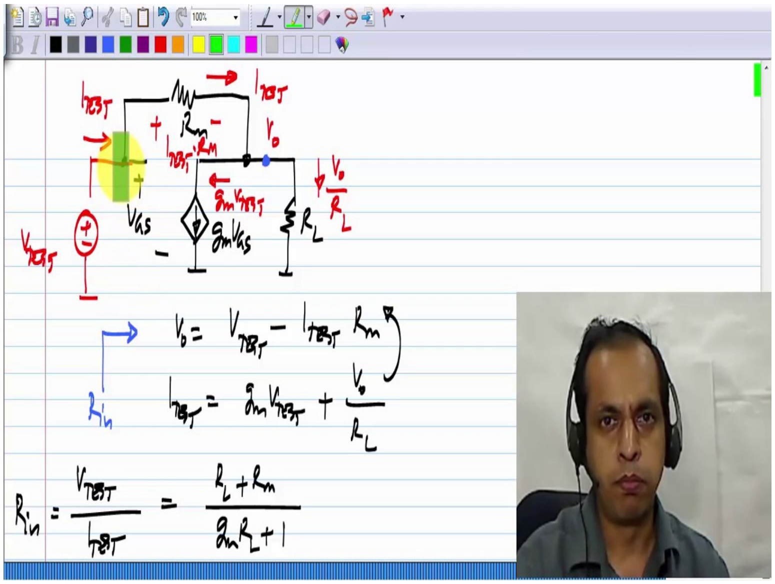

Now to calculate the input resistance, I connect a voltage source V_{TEST} between this point and ground. I evaluate the current I_{TEST} that goes in there. The ratio V_{TEST} by I_{TEST} will give me the resistance looking into it. Now, V_{GS} equals V_{TEST} here right, so this current source here is $g_m V_{TEST}$; and this voltage is of course, something we do not know. Let me call that V_O. The current here is $\frac{V O}{R L}$; and this I_{TEST} simply comes that way. The current I_{TEST} is whatever current is going through R_m. So this voltage here is $I_{TEST} R_m$. So, this voltage V_O is nothing but V_{GS} or V_{TEST} minus I_{TEST} times R_m. $V_O = V_{TEST} - (I_{TEST} R_m)$. And writing Kirchhoff's law here, we get

$$I_{TEST} = (g_m V_{TEST}) + \left(\frac{V_O}{R_L}\right) .$$

So, substituting for V_O from there, we get an expression relating V_{TEST} and I_{TEST}. And it turns out that the input resistance, which is $\left(\frac{V_{TEST}}{I_{TEST}}\right) = \frac{R_L + R_m}{g_m R_L + 1}$. So, this is the resistance looking into the input. Now what happens here, the ideally we would like the input resistance of a voltage control current source to be zero.

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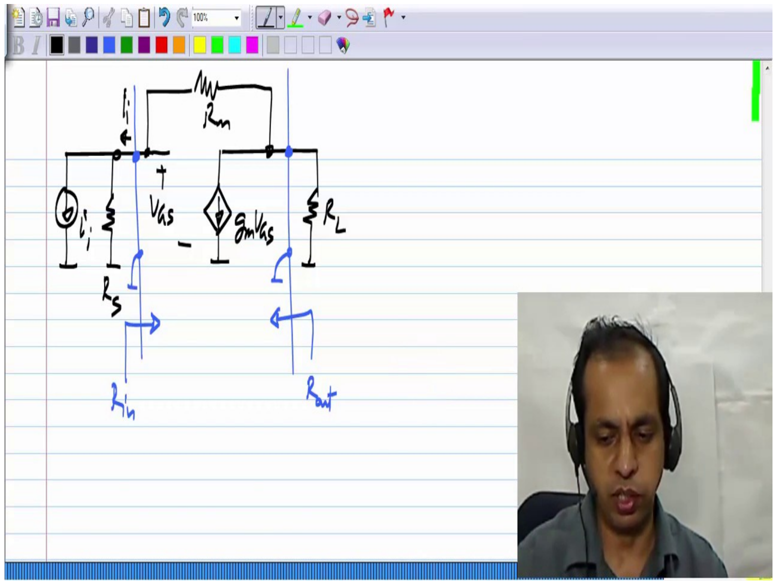

That is because if R_{in} is zero regardless of the value of R_s all of this i_i will flow into the circuit. So, this current here will be equal to i_i if R_{in} is zero, so that is why we want zero input resistance in a current controlled voltage source. Ideally of course, we would not get zero, but we get a small number.

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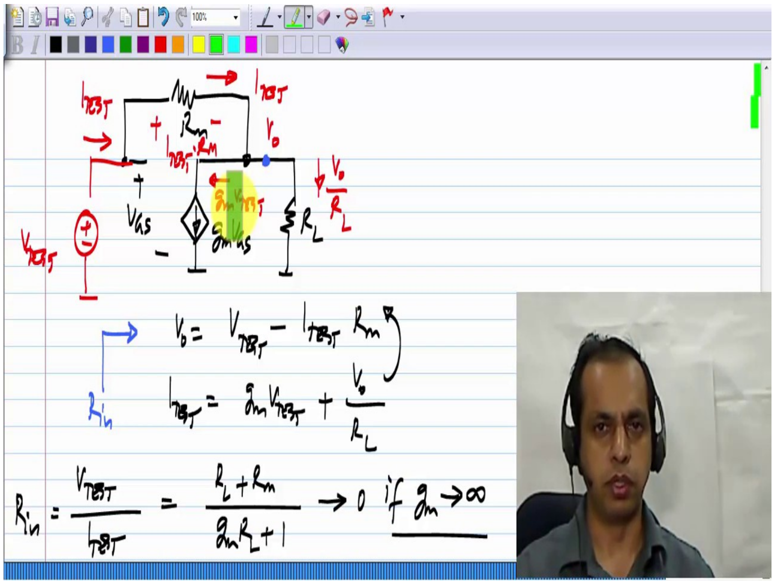

And here you can see that this number turns to zero, if g_m tends to infinity. So, the key to realizing an ideal current controlled voltage source is making g_m infinity. This again you have seen repeatedly for all controlled sources if g_m tends to infinity the control source becomes ideal that is it follows the relationship that is required, and also its output and input resistances will be exactly as we want them. Again we want the product g_mR_L to be very large, if this has to behave like a good current controlled voltage source.

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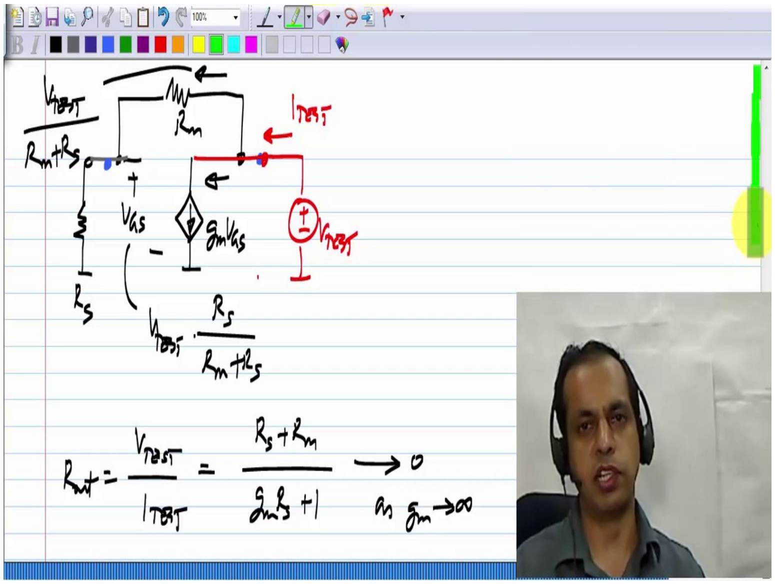

For calculating the output resistance, the input current source is set to zero, so that that means it becomes open circuit, and I connect a test voltage source between these two points, and find the current that flows. You can see that the current that flows here equals this voltage divided by the total resistance, so this current will be $\frac{V_{TEST}}{R_m + R_s}$. $V_{GS} = V_{TEST}\left(\frac{R_s}{R_m + R_s}\right)$. So, this current will be g_m times this number. So, now you can work out that R_{out} which will $\frac{V_{TEST}}{I_{TEST}}$.

In this case, you can find I_{TEST} by summing this current and that current and that will be equal to $\frac{R_s + R_m}{g_m R_s + 1}$. As before as g_m tends to infinity this output resistance becomes zero. It is a current control voltage source, so the output resistance should ideally be zero and it will be zero if g_m becomes infinite. So, we want this $g_m R_s$ product be very large, so that this resistance becomes quite small. You can also observe the symmetry between this expression and what we got for the input resistance, they are quite similar. We have R_s, wherever we have R_s in this case, we have R_L

in the other case. So, our control current controlled voltage source does give you a small input resistance and a small output resistance as desired provided that the value of g_m is very large.