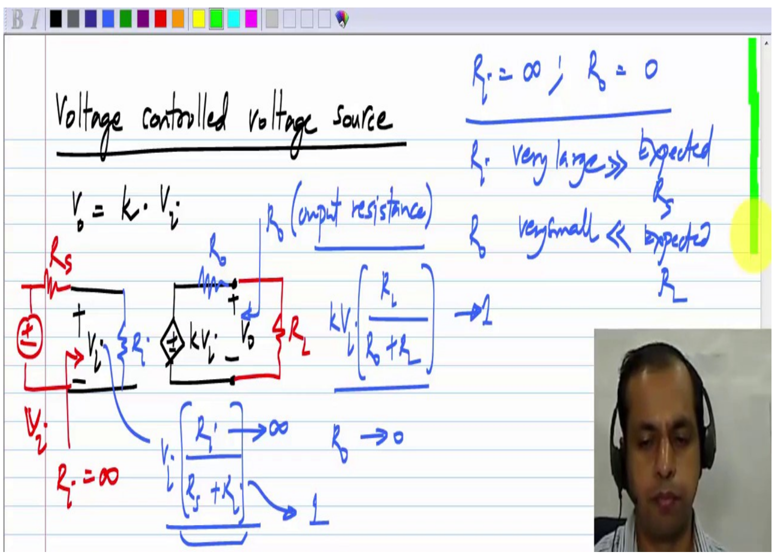
Analog Circuits
Prof. Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology, Madras

Module - 05
Lecture – 02

(Refer Slide Time: 00:06)



Let us first try to realize a voltage controlled voltage source. Now a voltage controlled voltage source has an output voltage which is some fixed constant times the input voltage, that is let say the input is applied between two nodes, there will be a voltage kv_i which is the output voltage. Now, you may think that any linear circuit is like this right, if you apply a some input somewhere then you will get an output which is some number times the input that is the characteristic of a linear circuit. Any linear circuit will give you some k times the input, but there are other characteristic that are important for a voltage controlled voltage source, that is, you can connect an input voltage with any internal resistance, now you can see that there is an open circuit between these two terminals which are the controlling terminal of a voltage controlled voltage source.

So, this v_i appears here entirely. This is characterized by saying that the input resistance of a voltage controlled voltage source is infinity. If the input resistance is infinite then you can use an imperfect source v_i with whatever value of R_S, but all of these input voltage appears across the controlling terminals of the voltage controlled voltage source, that is a very important thing. For instance, if you had a resistance here R_i then this voltage would not be v_i, but it would be

$v_i\left(\frac{R_i}{R_s+R_i}\right)$. And if R_i is very small, the fraction of v_i that appears there could be very small

also; R_i should ideally be infinity, in reality it should be very, very large so that for a range of values of R_s, the fraction of the input voltage that appears here is very close to one.

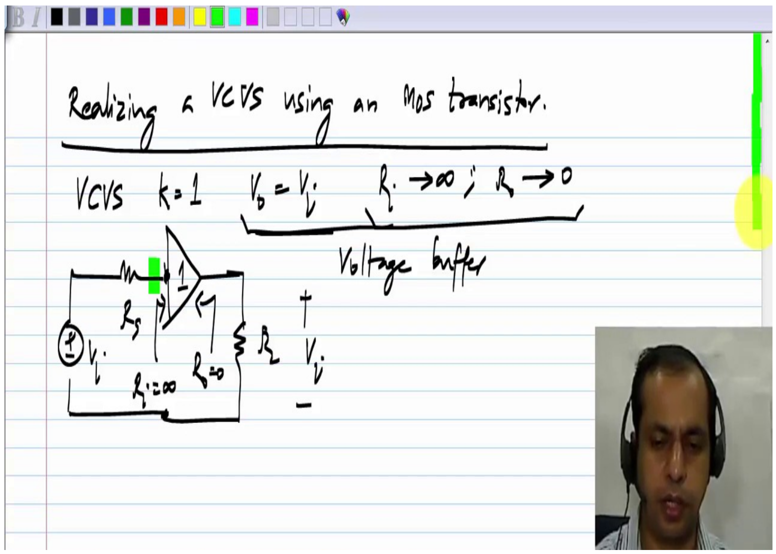
Similarly, you should be able to connect whatever load you want here, that should not change the output voltage. What could possibly change the output voltage, its output resistance. So let me call this R_o that is the resistance looking back that way, the output resistance then you can see that let us first imagine that R_i is infinity, so all of V_i appears here and this voltage source gives

you kv_i, but the actual output voltage that appear here is $kv_i\left(\frac{R_L}{R_o+R_L}\right)$. So if R_o is comparable

to R_L or higher, then the voltage that you get across the load is very different from kv_i, it is much smaller than that. So in reality, you can clearly see that R_o must be zero; so in this case, this fraction becomes one. And similarly, R_i becoming infinity takes this fraction to one, so that is the ideal characteristic of a voltage controlled voltage source.

So, characteristic of a voltage controlled voltage source is that the input resistance R_i is infinity and the output resistance R_o is zero. In practice, we cannot get an infinitely large input resistance, so R_i has to be very large. And when you have a quantity with dimensions like R_i we have to say it is very large compared to what; and in this case, it should be much larger than the expected range of values of R_s. In that case, regardless of the value of R_s, this fraction here will be close to one. Similarly, R_o, we cannot get it to be exactly zero, we want it to be very small, and what does very small mean it should be much smaller than the expected range of values of R_L. So, again if this condition is satisfied this fraction here will be close to one. And we will have a ratio of output voltage to input voltage, which is k, which is also independent of R_s and R_L that is quite important. In a controlled source, the output quantity should also be independent of load resistance and source resistance.

(Refer Slide Time: 04:58)



How do we realize this using a MOS transistor? First of all, because of certain restrictions that is because the source is common to the controlling and controlled side of the MOSFET, it turns out that we can only realize V C V S with k equals one that is $v_o = v_i$. We will come to this later, this is using a single MOS transistor. Now you can ask what good is this, I already have the input voltage why should I generated again, the point is this one. We will generate a control source which will maintain k equal to one, regardless of temperature and other process parameters that govern the transistor. And also we will maintain a very large input resistance and a very small output resistance.

So, such a circuit, which does not provide gain, it provides unity gain, but still has input resistance tending to infinity and output resistance tending to zero. This is known as voltage buffer. It still has it uses because if you have V_i and some R_s and you have some R_L, if you connect it directly, what do you get here will not be V_i; it could be much smaller than V_i. Instead of that if you connect it through a buffer, it has a gain of one, but its input resistance is infinity and the output resistance is zero, that case the output voltage you can see it is exactly equal to V_i, because at this point we will get V_i, and its output will get the same as the input, so here we will get V_i. And it is not affected by the value of R_L. So, what we will be realizing is actually a voltage buffer, it is still quite a useful thing; it is also very useful building block using a single transistor.