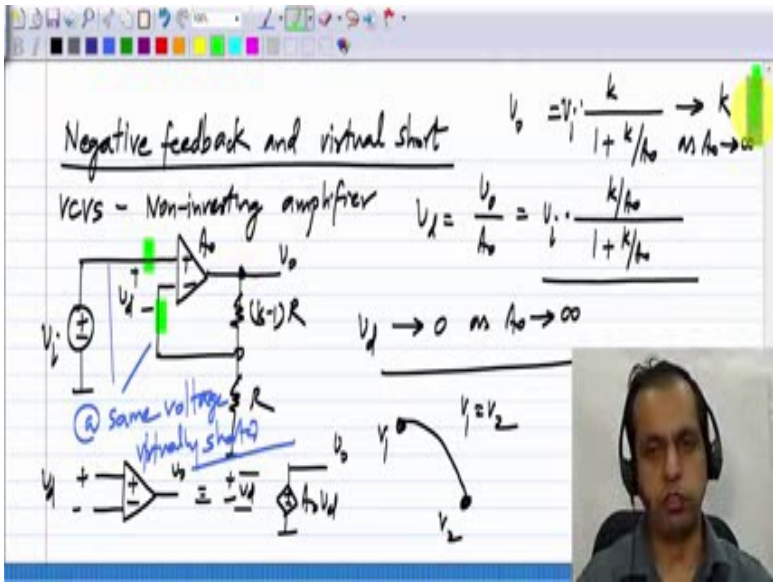
Analog Circuits
Prof. Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology, Madras

Module – 06
Lecture – 07

So far we have learn how to implement all the four control sources using MOS transistor. We have also discussed how to implement the voltage controlled voltage source, and the current controlled voltage source using an op amp. All these circuits are based on negative feedback, and sometimes there is a great deal of confusion when talking about negative feedback and related concept which is known as virtual short. What will do in this lesson is to discuss this business of virtual short and how it is needs negative feedback with the very large gain in the loop.

(Refer Slide Time: 00:32)



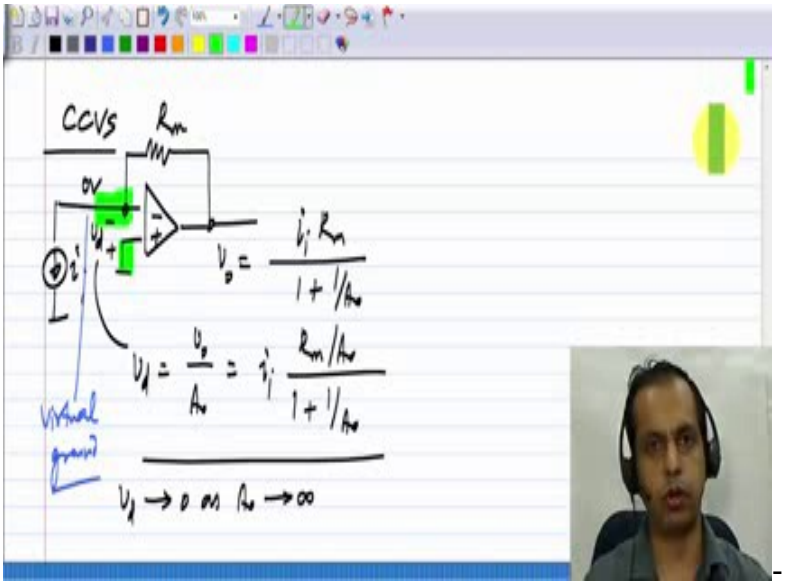
Now let me first take the op amp example which are easier to discuss. And specifically I will consider the voltage controlled voltage source using the op amp. You also know that this is what is voltage known as the non-inverting amplifier. We have an input signal V_i and we have a voltage divider from the output, and this is V_d. And let us say the gain of the op amp A_o; that means, that the op amp is equivalent to voltage controlled voltage source of gain A_o. This is V_o and this is V_d. Now we have already analyzed and found that $V_o / V_i = (k / (1 + (k / A_o)))$ or V_o equals V_i times this number. And difference voltage V_d is V_o/A_o which can also

be written as $V_i * (k / A_o) / (1 + (k / A_o))$.

Now what happens as A_o -- > ∞, this number of course, becomes equal to k as A_o -- > ∞ and this V_d -- > 0 as A_o -- > ∞ so that means, that the voltage difference between these two terminals return to zero as A_o -- > ∞. If A_o -- > ∞, this will be at the same voltage and this is what is known as the virtual short. Now if you have some two points let say two nodes then you short circuit them the wire then clearly the voltage at this node, and this node will have to be exactly equal to each other. they may have been different before you connected to the wire before you sorted them, but after you short them with the wire the voltages has to be the same.

Now in this circuit, we have a situation where the voltage at this node and this node will have to be the same. If A_o is infinity and they are not shorted by the wire. So, it is there not really shorted each other they are not connected at all. In fact, if you use this model it looks like that it is an open circuit between them, but the negative feedback action with a very large A_o that is an infinity large A_o makes these two voltages equal to each other. So, then in such a case we say that these two nodes are virtually shorted clearly there not really shorted there is no wire connecting them. So, these nodes are virtually shorted. And this is true for any op amp circuit which is operating in negative feedback and the op amps gain goes to and when the op amp gain goes to infinity.

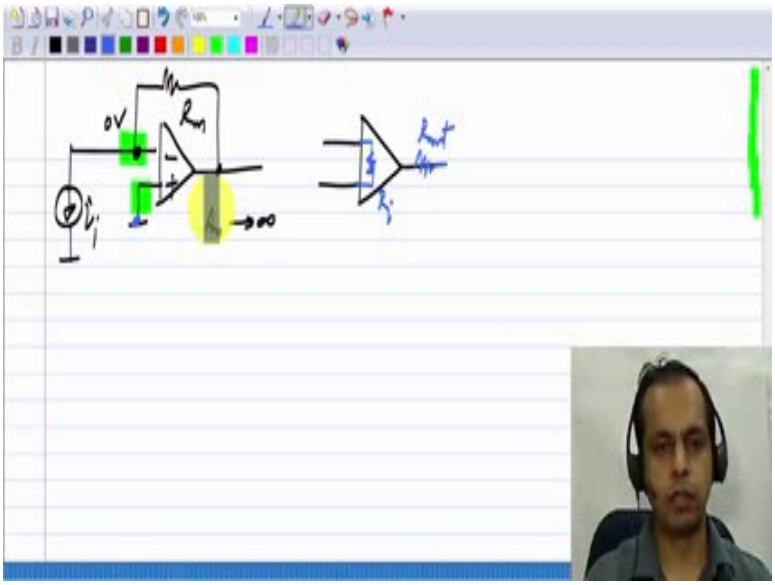
(Refer Slide Time: 04:49)



We can also take current controlled voltage source example, we know that the output voltage

is (i_i * R_m) / (1 + 1 / A_o) , and this difference voltage V_d of the op amp is in this case V_o / A_o which is i_i * (R_m / A_o) /(1+ (1/ A_o)). So, again V_d -- > 0 as A_o goes to infinity that is the input terminals of the op amp are virtually shorted again this happens because $A_o = \infty$. Now in this particular case because the positive terminal of the op amp connected to the ground when then become virtually shorted because of gain becoming an infinity this node here also is at zero volts. So, sometimes it is also called a virtual ground that is its voltage is guaranteed to be at zero volts, but it is not shorted to ground through a wire, so that is the virtual ground.

(Refer Slide Time: 06:32)

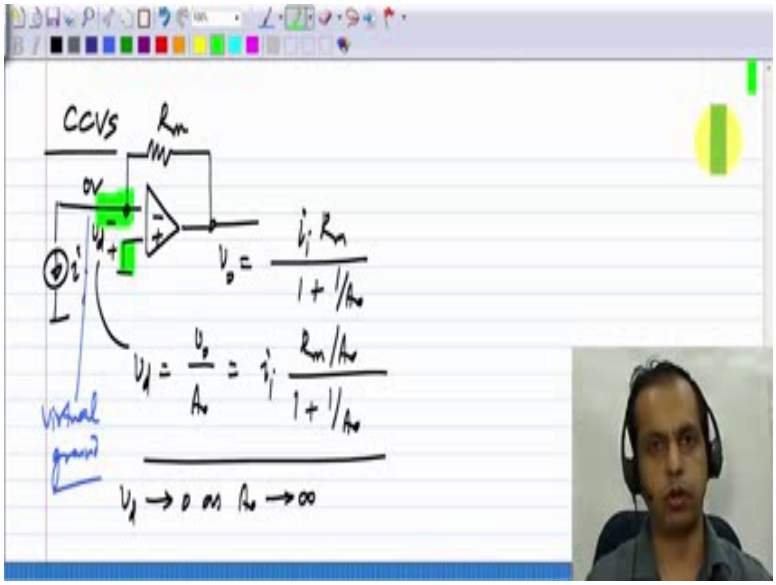


Many times there it is a great deal of confusion about why this virtual short comes about. its not that if it is just a op amp and do nothing with that there be virtual short between its terminals. You have to configure the circuit in negative feedback and the gain of the op amp has to be very large. Of course, if you buy on op amp its gain will be very large because op amp circuit are useful only when and the gain of the op amp is very large. And the designer source of the op amp do take cared make sure the gain is very large, but it is up to you to put the op amp in negative feedback then these two terminal will be virtually shorted and lots of very useful functions can be realized with this property. And also this virtual short business make it very easy to analyzed ideal op amp circuits and even when the op amp is real that is the gain is not quite in infinity, you can go still ahead and virtual shorts and analyze the circuit what you get will be the approximate transfer function or approximate gain of the op amp circuits.

So, many times you just look at an op amp circuit and you can tell what it is going . after that you can put in the finite gain of the op amp and analyze the exact transfer function. So, sometimes there is some confusion about why the virtual short comes about like I just mentioned and there is some confusion about whether it comes because the input resistance of the op amp is infinite or zero or something else. It is very easy to see that the resistance of the op amp that is let us say that there was some internal resistance between the two terminals to the op amp it is very easy to see that it place absolutely no role as per virtual short is concerned. In fact, further that easy to first consider an op amp in which there is no resistance and we have A_o tending to infinity lets gain became infinite we know that this is at zero volts and these two are virtually shorted because of finite gain.

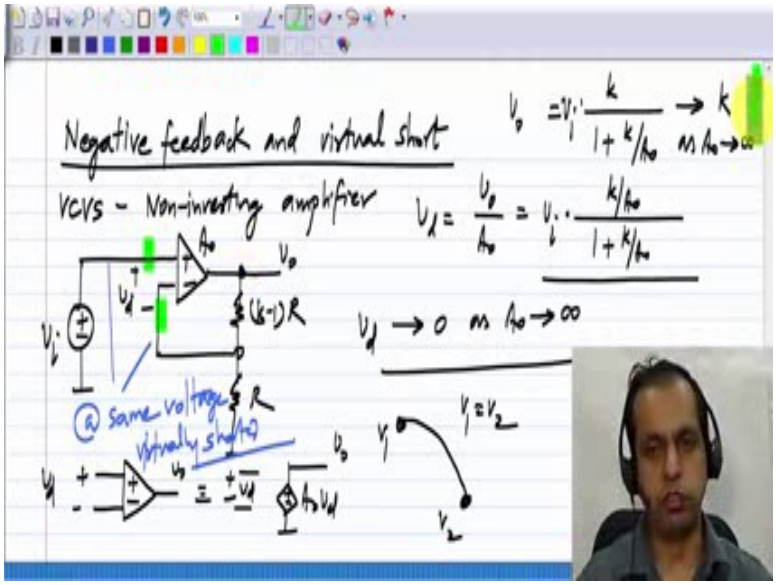
Now, you can connect whatever resistance you want between this. so that corresponds to the resistance that may be there inside the op amp I am drawing it outside, but it may be inside the op amp what is the voltage across these resistance at zero volts. So, it is carries no current. So, it is make no difference to the Kirchhoff's current equations here. So, it makes no difference whatsoever to the circuit. So, if the gain is infinite the input resistance of the op amps make absolutely no difference and the virtual short is not because of the input resistance its because of gain infinite and similarly the same goes for the output resistance the output could have some series resistance and you can do similar analysis and find that it has absolutely no effect whatsoever.

(Refer Slide Time: 09:42)



So, now another way to think about this virtual short business in an op amp is that because the gain is infinite and the output is finite that is something assumed, and the output will be finite only if there is negative feedback; if it is positive feedback it could be diverging off to infinity. If the output is finite then the input which is output divided by the gain has to be equal to zero. So, the input voltage is zero for any finite value of output.

(Refer Slide Time: 10:10)



And similarly, here for any finite value of output the input has to be zero think that to be guaranteed is that output will not diverge of the infinity and that is guaranteed by negative feedback if you do have positive feedback you will find that the steady state output will go to infinity. So, this is what virtual short all about it also happens circuits using a transistor as long as there is negative feedback around the transistor.