Analog Circuits

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Module - 06
Lecture – 01

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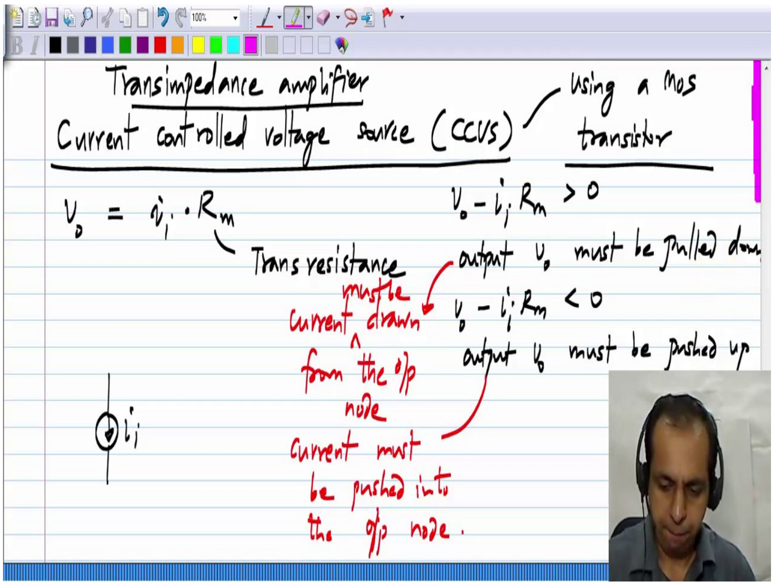

Now, we will see how to realize the large remaining controlled source, which is a current controlled voltage source. And current controlled voltage source, it has an input current i_i and an output voltage v_o, and the output voltage v_o is proportional to the input current i_i and there is some proportionality constant, I will call it R_m. And this can be thought of us the trans resistance, just like trans conductance. It is the ratio of voltage to current, but not between the same two terminals, and because a current controlled voltage source realizes a trans resistance, sometimes it is called the trans resistance or usually trans impedance amplifier. So, how do we go about realizing this. We have an input current i_i and, what is it that we need to do, we have to realize this relationship using negative feedback so; that means, that we can think of v_o-i_iR_m or the negative of this as the error between desired and actual output.

So, if v_o-i_iR_m is greater than zero, then; that means, that the actual output v_o is more than the desired output i_iR_m. The output v_o must be pulled down. And if v_o-i_iR_m is less than zero that is the actual output is smaller the desired output i_iR_m then the output v_o must be pushed up. And we have to realize this using a transistor. Obviously, when I say current controlled voltage source, I mean using a MOS transistor. So, how do I pull or push the output voltage using a

MOS transistor which is really a controlled current source. It means that when v_o must be pull down, current must be drawn from the output node. And similarly, when output v_o must be pushed up, current must be pushed into the output node.

So, putting all these things together and knowing the how the transistor behaves, we can realize our current controlled voltage source. The method we have used is exactly same as what we used for all the previous controlled sources. There is some relationship that we want to implement and we represented as some error, which should go to zero. If the error is positive, we have to do something; if the error is negative, we have to do the opposite. The circuit that we build will correspond to these actions.

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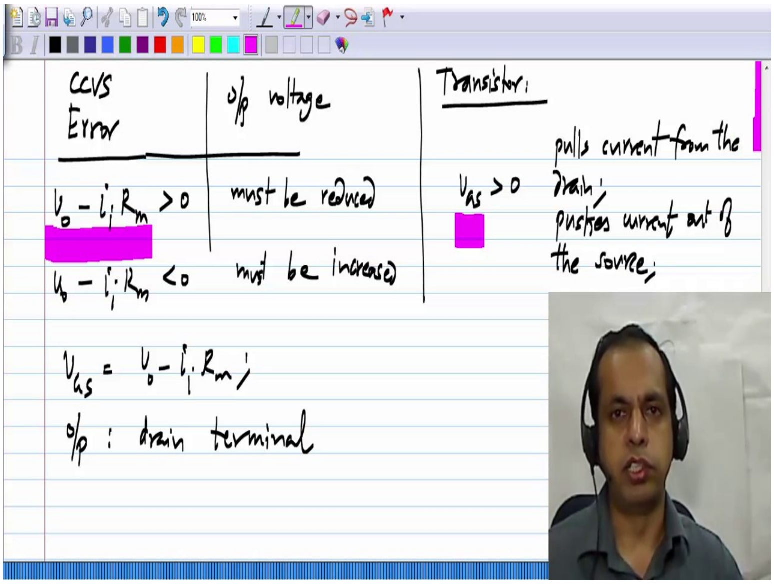

So, again let me write down the relationship. If I denote this v_o-i_iR_m as the error of the current controlled voltage source; if it is greater than zero, then output voltage must be reduced. And if it is less than zero, the output voltage must be increased. And what is the transistor do, the transistor if v_{gs} is more than zero, then it pulls current from the drain; and pushes current out of the source. If the incremental v_{gs} around some operating point is more than zero, then there will be an incremental current flowing from drain to source. It is pulled from the drain terminal, so the drain voltage tends to reduce; and it is pushed into the source terminal, so the source voltage tends to increase. Now, similarly, if v_{gs} is less than zero, the opposite happens.

Now, if you compare these two, v_o-i_iR_m, if this is more than zero, the output voltage must be reduced, so the current must be pulled from the output node. And if v_{gs} is more than zero, current will pulled from the drain node. So, it looks like if you make v_o-i_iR_m equal to the v_{gs} the incremental gate source voltage of the transistor and if you look at what is happening at the drain terminal, what is happening is exactly what you want. So, from this, you can infer that v_{gs} must be equal to v_o-i_iR_m, and the output is the drain terminal. Then it looks like the actions that we want to happen will happen.

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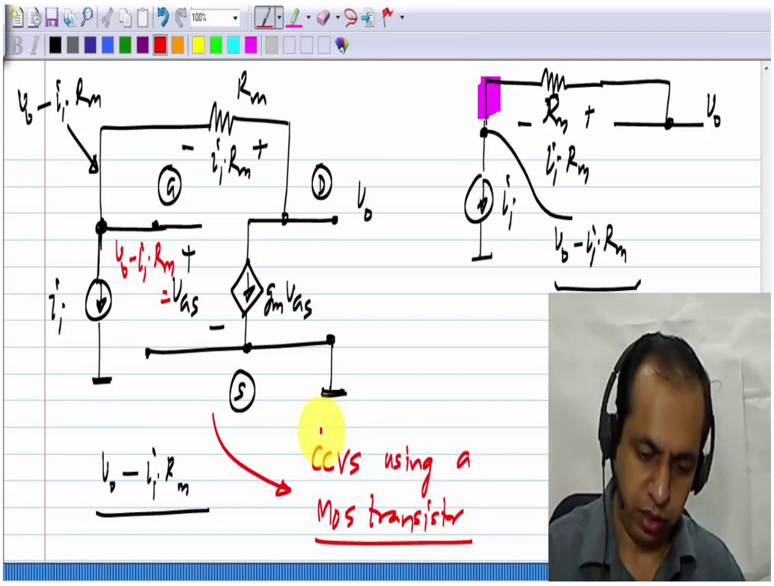

Now, let us complete the circuit. We have an input current i_i and we have the small signal equivalent of the transistor g_mv_{gs}. This is the gate, this is the drain, this is the source, and like I said we have to take the output at the drain or between drain and ground. So, let me connect the source to ground, and consider the drain as the output. If that is the case, then this v_{gs} has to be equal to v_o-i_iR_m, how do I produce this voltage. So, let say there is some node at which there is a voltage v_o, and I have the v_o-i_iR_m current source which gives me I I. So, what is this saying it is. To produce i_iR_m, I have to make i_i flow through a resistor whose value is R_m, then this voltage here in this polarity will be i_iR_m. The circuit is not complete yet, so let say I connect it to this node. You can see that the voltage here is v_o with respect to ground. So, the voltage here will be v_o-i_iR_m. So, this will be v_o-i_iR_m.

So, that is how we can get a voltage, which is v_o-i_iR_m. And we want to make it equal v_{gs}. So, first what I do is, exactly what I described here. I connect a resistor R_m like that, and i_i so this voltage will be i_iR_m, and the voltage at this node with respect to ground will be v_o-i_iR_m, and this voltage must be equal to v_{gs}. The source is grounded, if I connect it like tha,t then v_{gs}

becomes equal to v_o-i_iR_m. So, this is our strategy for building a current controlled voltage source.

So, what happens now, the gate source voltage equals v_o-i_iR_m; if v_o-i_iR_m is more than zero, v_{gs} will be more than zero and the current will be pulled from the drain node. And if you pull current from a node, its voltage tends to reduce, this is exactly what do you want to happen, because if v_o-i_iR_m more than zero, it means that the actual voltage is more than the desired voltage. Similarly, if this quantity is less than zero, then v_{gs} is negative, and this current will be pushed into the drain node increasing the output voltage. So, this is our current controlled voltage source using a MOS transistor.