Analog Circuits

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Module - 05
Lecture – 07

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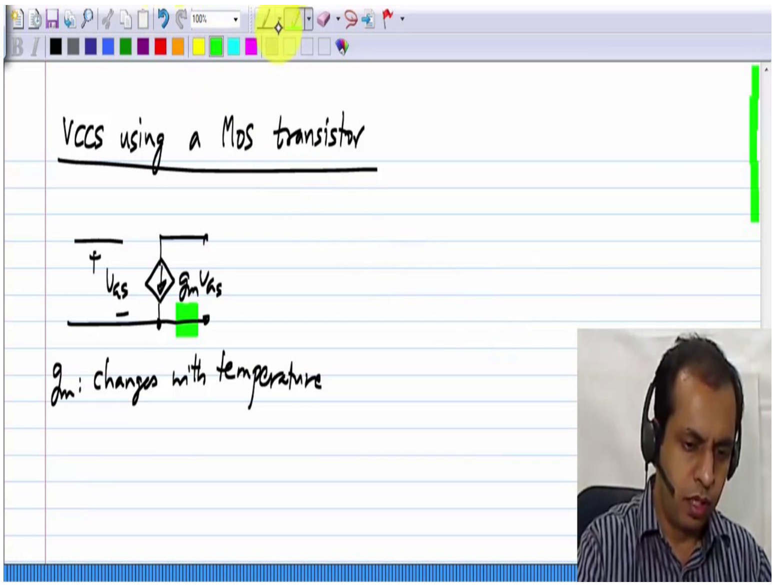

Now, we will try and realize the voltage controlled current source using a MOS transistor. Now this may be a little confusing, because the MOS transistor by itself is a voltage controlled current source. Now, a MOS transistor has this small signal incremental equivalent, v_{gs} and $g_m v_{gs}$; obviously this is a voltage controlled current source. As you know many parameters of a semiconductor device are strongly dependent on temperature and this g_m also changes with temperature. Now, what we would like is to have voltage controlled current source which does not do this, which does not have such a strong depends on temperature and so on. Like voltage controlled voltage source, we would like to realize that using negative feedback, so that it does not depends so much on the MOS transistor parameters, it depends on some other components which can be more stably realized.

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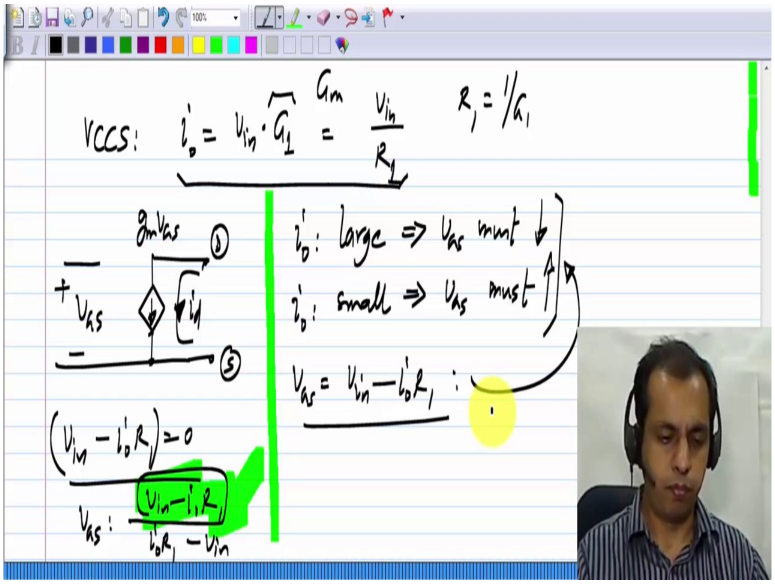

Now, a voltage controlled current source follows the relationship $i_o = v_{in}G_1$. This is usually denoted by G_m, but do not confuse between g_m of the MOS transistor and this G_m, I will use a different term for this trans conductance, this is G_1. Or I could write it as $\frac{v_{¿}}{R_1}$. R_1 is just the reciprocal of G_1. Now, what does this mean, we have to realize this using negative feedback and using a MOS transistor. In a MOS transistor, we have the controlling quantity v_{gs} and the controlled quantity which is the drain current and that is equal to g $g_m v_{gs}$, and i_d flows from drain to source terminal. So, the output current has to come out from either the drain or the source terminal whichever is convenient. And the error between the actual and desired values has to be applied to the gate source voltage, because that is what eventually controls the current in the MOS transistor.

So, we want $i_o = \frac{v_{¿}}{R_1}$; another way to write it is we want $v_{in} - i_o R_1 = 0$. Now this you can think of as the error; $v_{in} - i_o R_1$ as the error, some sort of error between desired and actual values and that is should be zero eventually. So, this means that the error voltage $v_{in} - i_o R_1$ or the negative of that should be v_{gs}, so v_{gs} should be either $v_{in} - i_o R_1$ or $i_o R_1 - v_{in}$. Of course, it can be some other quantity, which is still proportional to this one. And what is the negative feedback action that we want; if i_o is large, it tends to increase then v_{gs} must fall. If i_o is too large, larger than desired, v_{gs} must fall so that the current reduces.

And similarly, if i_o is too small, then v_{gs} must increase so that current increases. Eventually, the drain current of the MOS transistor will be the output current i_o. So, clearly you see that the first form is compatible with this, i_o here appears with the negative sign. So if i_o is too small, v_{gs} will be a larger positive quantity, which tends to increase the drain current. So, v_{gs} has to be equal to v_{in} $-i_oR_1$. The other way around does not work, because if then i_o is very large, then v_{gs} actually will become larger. So, negative feedback action is obtained by having v_{gs} to be equal to v_{in} $-i_oR_1$. So, if $v_{gs} = v_{in} - i_oR_1$, then we basically have this action.

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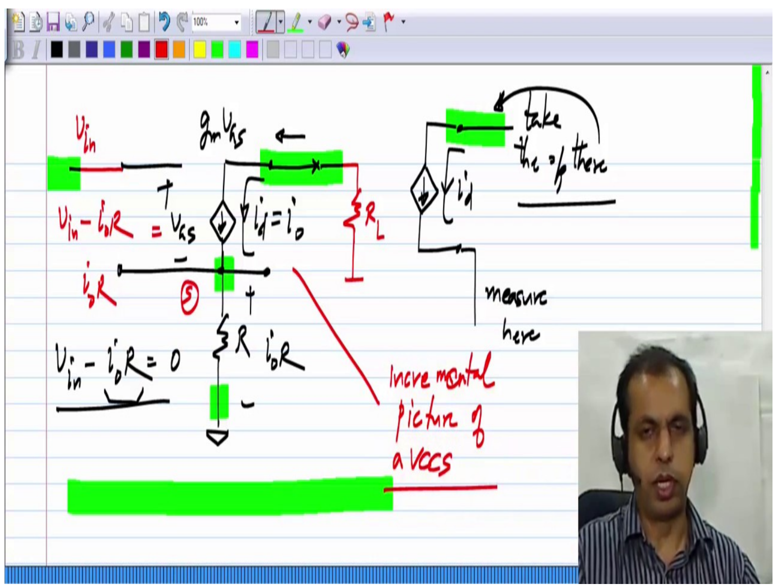

Now, let us try to make a circuit that accomplishes this. This is v_{gs} and this is g_mv_{gs} or basically the incremental drain current i_d. Whenever we have a current output right, we need a terminal at which we take the current; and if you want to monitor the current, we have to use the other terminal through which the current is flowing. What I mean is let say we have a voltage, this node provides the voltage, and if you want to measure the voltage, we just take this node and connect it to something else as well; then we can sense this voltage. To sense the current, we have to place something in series; and one possible way to do that is in this case for instance, the controlled source is like this, and the current it flowing that way. We can take the current output from one of these terminals from that one. And the same current is flowing through this, so we can use the current flowing here to make a measurement of the current.

So, let us try and do that. What is the measure that we want, we want v_{in} -i_oR =0. So, i_o has to be multiplied with some R, so that it can be compared with the voltage. Now obviously, the drain current is the output current that is where we get a current output in the MOS transistor. Let us say that this i_o, it is flowing that way - downwards, so if I pass it through a resistor R, the voltage here will be i_oR. And this one let say I connect it to ground. Now the voltage at the source node of the MOS transistor is i_oR. And what did we want the v_{gs} to be, we want it to be v_{in} -i_oR; so it is very clear that if I connect the gate to the input voltage, I will get v_{gs} to be v_{in} -i_oR. And the load can be connected to the drain, because the same current that is being sensed here, that is being passed through this resistor, flows through the controlled source and into the load. For now, I will represent the load as a resistor, is this fine.

So, what I have now is an arrangement where I connect the resistance between the source terminal and ground that means that whatever drain current is flowing will flow through this resistor and create a source voltage of i_oR. If I connect the gate to the input voltage v_{in}, then the gate source voltage will be v_{in} -i_oR, which is exactly what I wanted. And now you can see what happens, if i_o is very large then this v_{gs} tends to be smaller and the current tends to reduce, that is the negative feedback action that we want. So, this circuit that we want for the voltage controlled current source is basically this, the input applied to the gate; resistance R between source and ground; and the load connected between the drain and ground that is the drain current is made to flow through the load. For now, I will assume that it is a resistance that I can connect in that fashion. So, this is our voltage controlled current source or the incremental small signal picture of a voltage controlled current source.