Analog Circuits
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Module - 04
Lecture – 04

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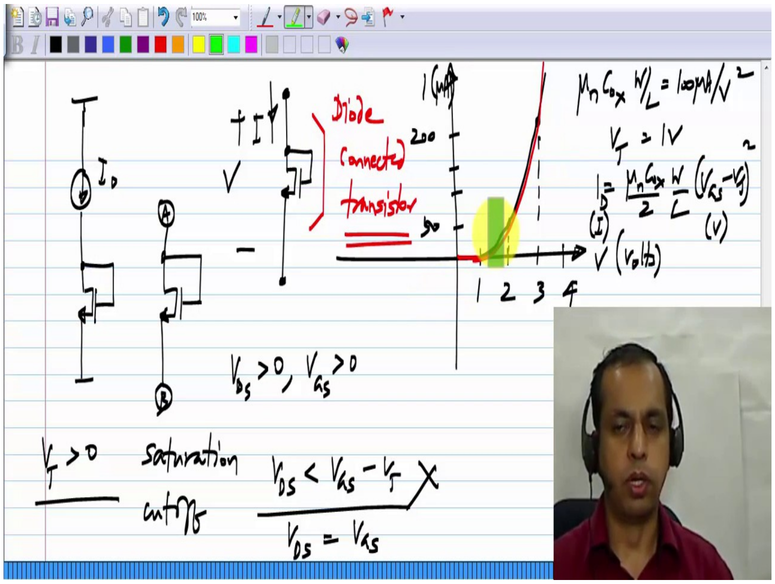

While realizing the current mirror, we have encountered the structure, the basic drain feedback structure where the drain voltage is fed back to the gate. Now, this structure occurs quite often, so let us spend some time studying this. Now, the MOS transistor has three terminals, and with this connection, you can think of that as a two terminal element. So, I could put this MOS transistor in a box and bring out only two terminals, and one of the terminals is connected to both the drain and the gate. Now, if we think of this as a two terminal element, and let us also make our usual assumptions that the threshold voltage is positive. So, this structure will be either in saturation or cut off completely; it cannot be in triode region, because if it has to be triode or linear region, V_{DS} has to be less than V_{GS} - V_T, but we have V_{DS} = V_{GS}. So, this is not possible for positive threshold voltages V_T.

Now let us just plot the I-V characteristics of this element; thinking of it as a two terminal element. We have the voltage V, and the current I. What happens is that if I do plot the I-V characteristics and I will plot it only for V > 0 because our model of the MOS transistor is valid only when the voltages are greater than zero. So, let us say 1, 2, 3, 4 V. Now, I will consider the same transistor as before where $\mu_n C_{ox} (\frac{W}{L})$ is 100 μA/ V^2 and V_T is 1 V. So, it is pretty obvious that if this voltage V is less than 1 V, no current can flow because V_{GS} is smaller than 1 volt, and the transistor is cut off. And beyond that because it is in saturation, it follows the square law equation, which says that I = $\mu_n C_{ox} \left(\frac{W}{L}\right) (V_{GS} - V_T)^2$, in this case is this current I, the I_D is basically this current I and V_{GS} is this V. So, it follows the square law behavior. So, it V_{GS} of 2 V, it will be 50 μA, so let say this is graduated in μA; at 3 V, it will be 200 μA; at 4 V, 450 μA and so on.

So, these are the I-V characteristics of the transistor. And this you recall is reminiscent of the diode. In the diode also had some characteristics where there was very small current here up to some point and after that the current increases. Now in case of the real diode, it increases exponentially whereas here it increases only a square law, but this can be in a way thought of us, a two terminal element which is the diode, so this connection is known as a diode connection or this transistor whose drain and gate are connected together is known as a diode connected transistor. So you encounter this in many places, you have this characteristic, it can be used to obtain a certain voltage drop or it can be used to obtain certain bias voltages and so on.

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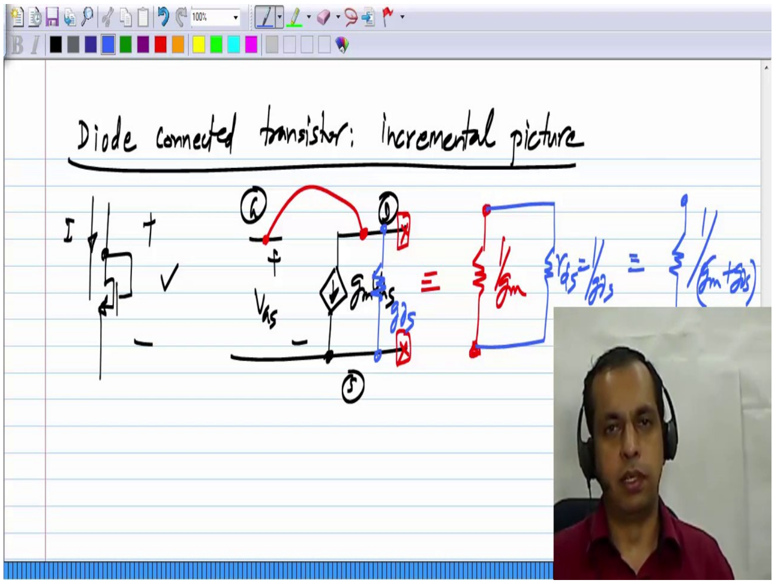

Now, the incremental picture of this we are already familiar with we calculated it while analyzing the common source amplifier with current mirror bias. So, it will have certain operating point I and V. And around that operating point, what will we have? If you write it in terms of the small signal model of the MOS transistor, this is the gate, drain and source; this is V_{GS}, and this is g_mV_{GS}. And the gate is connected to the drain, so now between these two terminals either gate source or the drain source it is the same, this is equivalent to a resistor of value $1/ g_m$, this we already know. We have analyzed it. If not you apply a test voltage here and see what can it flows, take the ratio, you will find this.

So, diode connected transistor has an incremental equivalent which is the resistor of value one by g_m; and g_m has to be evaluated at the operating point. And you can also include the output conductance of the transistor in saturation region, if you do include that what happens is that that appears in parallel with this one. This will have a resistance r_{ds}, which is the reciprocal of the conductance g_{ds}. And the whole thing will be equivalent to a single resistor of value $\frac{1}{g_m+g_{ds}}$, the conductances add because they are in parallel. And this is the useful result remember you do encounter the diode connected transistor in a lot of situations in electronic circuits, and it is useful to know it is large signal and small signal behavior.