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

Module - 03
Lecture – 09

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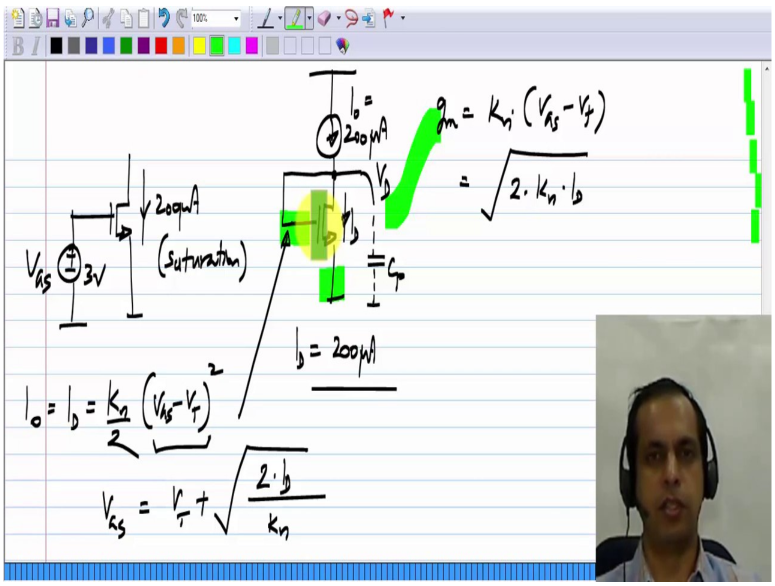

We now have come up with a biasing scheme that promises to reduce the sensitivity of transistor's small signal parameters, the transistor transconductance with respective to the parameters of the transistor such as the threshold voltage and current factor. So, what we did was the following, instead of saying that the transistor should be provided with a V_{GS} of 3 V. So we know that if it is in saturation, it would draw a current of 200 μA. So, instead of this, what we do is we have a 200 μA current source and we compare that to the actual drain current of the transistor, whatever that is. So, now this drain voltage here V_D will increase or decrease depending on the difference between this 200 μA and I_D. So if I_D is too small, it increases.

What we realize is if I_D is too small, we have to increase the gate voltage. So, if you simply connect the drain to the gate, the gate voltage will be adjusted in the correct direction. So, if I_D is too small, this voltage will rise, because 200 μA is more than I_D, and the difference will flow into parasitic capacitance at this node, raising its voltage, which raises the gate voltage, so I_D increases and so on. So, finally, the circuits settles down when this 200 μA and I_D are exactly equal to each other so that no current flows into the parasitic capacitor. So circuits settle down to I_D being 200 μA . Now, why does this help? We have already worked out the expression for g_m, k_n – the current factor times (V_{GS} - V_t) or $\sqrt{2k_n I_D}$. The first expression is useful when V_{GS} is constant, so then you can see that V_t will directly influence g_m and also k_n will directly influence g_m.

Whereas here in the second case, which is useful when I_D is kept constant. You see that g_m is dependent on the square root of the current factor. So, if current factor changes by ten percent, g_m changes only by five percent. We can also understand that by examining this voltage. What should this voltage be? I suggest that you calculate it by yourself and then compare it to what I have. The way you calculate is by recognizing that in steady state I_D has to be equal to 200 μA or I_0 in general. So, we also know that if it is in saturation, I_D will be $\frac{k_n}{2}(V_{GS}-V_t)^2$. k_n , by the way, is $\mu C_{ox}\frac{W}{L}$.

Now I_D has to be equal to I_0, so we can solve for V_{GS} here, and we will find that it is ($V_t+\sqrt{2k_n I_D}$). So, this is just some algebraic manipulation, but what is it tell us? It says that if the transistor had larger V_t than you expected what would happen in this case? If the threshold voltage is larger than you expected? The current would be smaller. But in this case, you can see from this expression; if V_t is larger than you expected V_{GS} also would increase correspondingly. So, a transistor with a larger V_t will automatically get biased with a larger V_{GS}. Similarly, if the current factor is smaller than you expected, so in this case, you will get a smaller current.

On the other hand, here what happens, you can see that k_n is in the denominator here. The current factor is smaller than expected, V_{GS} increases. So, a transistor with a smaller current factor automatically gets biased with a higher gate to source voltage. This is exactly the kind of feedback that you want. It is basically saying that given this current the gate source voltage will get set automatically and that V_{GS} value will be larger if the threshold voltage is larger. It will also be larger if current factor is smaller. That gives you an understanding of why the variation of g_m will be smaller. For instance, in this case, if the threshold voltage is larger, V_{GS} would be correspondingly larger; so the difference remains constant.

Similarly, if k_n is smaller, V_{GS} will be larger, so that compensates this to some extent, so that also comes out here, because in this particular circuit, in the second circuit V_{GS} is not fixed. This expression is always correct. You just have to apply the correct value of V_{GS}. So, essentially this negative feedback is a way of adjusting the V_{GS} in response to changes in transistor parameters. A transistor with a higher threshold voltage or a smaller current factor will automatically get biased with a higher V_{GS} compensating for the effect of the higher threshold or lower current factor.