Analog Circuits
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Module - 04
Lecture – 05

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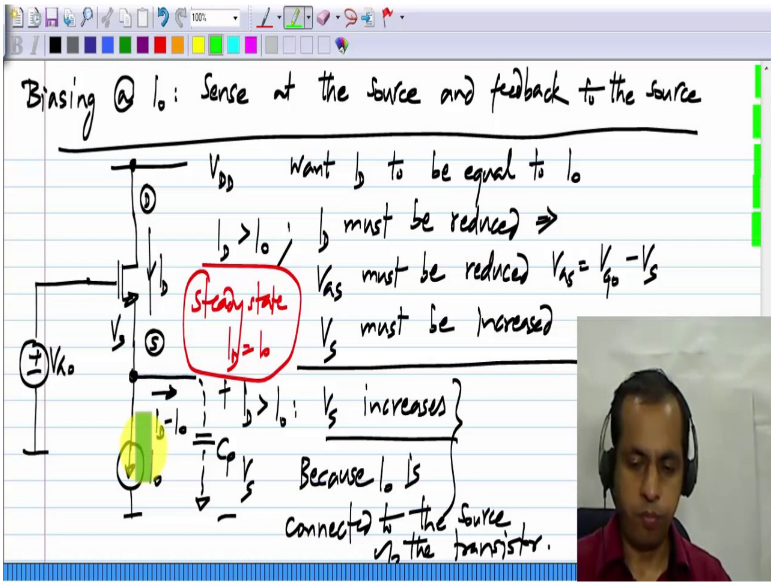

We have studied the scheme of biasing the transistor at constant current, where we sense the current difference at the drain and feed it back to the gate. Now, we will study an alternative where we sense the current difference at the source and feed it back to the source. Then, let us consider the transistor and I will place the current source down here because to sense at the source, I will have to connect it to the source, so that is more convenient. The current I_D in the MOS transistor flows from the drain to source. Sense in this part, we are not using the drain that is we sense at the source and feedback to the source, the drain can be connected to some fixed voltage. I will assume that it is connected to the supply voltage V_{DD}. Later, when we realize circuit using it, it will have to be changed, but for now, I will concern myself with biasing and connect it to the supply voltage V_{DD}. And because we are applying feedback to the source, the gate is connected to a fixed voltage, you can call it V_{G0}.

So, now first let us see what must happen, that is, we want I_D to be equal to I_0. Now, let me call this voltage as the source voltage V_s. Please do not get confused between this and the signal source voltage. In this case, we do not have a signal source, so there should be no confusion, but when you have both do not get confused by that. We have this V_s, and then let say I_D happens to be more than I_0. We wanted to be equal to I_0, so we have to reduce the value of I_D. So, what must happen to be is, please reason it out, now I_D must be reduced which means that V_{GS} must be reduced; obviously, I_D is increasing function of V_{GS}, if I_D has to be reduced, V_{GS} has to be reduced. And V_{GS} itself equals V_{G0}, which is fixed, minus V_s which we can vary in this circuit. So, this clearly means that V_s must be increased.

So, if the drain current of the transistor happens to be more than the desired current, then the source voltage must be increased. When you do this, the gate source voltage reduces and the current reduces, and exactly the opposite must be true when I_D is smaller than I_0; V_s must fall down so that the drain current increases. So, this is the feedback action that we want. Now, we generate the feedback action by comparing I_D to I_0. The current is flowing here from drain to source and the fixed current source is there, and to make the comparison, we tie these two currents to the same node, just like before. Earlier, we had connected the current source to the drain of the transistor, now we connect it to the source of the transistor. So, we connect it up like that.

If we do that a difference I_D minus I_0 tends to flow out that way, and where does it go, it goes into the parasitic capacitor associated with that node. Now, what happens because of this connection, if I_D is more than I_0, so; that means, that a current is being pumped into the capacitor like that. So V_s which is the voltage across the capacitor in that polarity, V_s increases. And similarly, if I_D is smaller than I_0 then the current will be pulled out of the parasitic capacitor and the voltage starts falling down. So, this happens just by virtue of connecting the current source to the source of the transistor. This happens because I_0 - the source, the current source is connected to the source of the transistor.

Now, you see that actually what we wanted for V_s, when I_D is more than I_0, we wanted V_s to increase, and that is already happening. So, we do not even have to do anything. If we simply connected up like that if I_D is more than I_0, then this voltage will go on increasing; as it goes on increasing, V_{GS} will go on decreasing and I_D will go on decreasing. Similarly, if I_D is less than I_0, this voltage will keep on falling, V_{GS} will go on increasing and the current will go on increasing. So, simply connecting the current source to the source also completes the feedback action. And when does it reach steady state? That is when this current going into the parasitic capacitor zero, that is when I_D equals I_0. So, in steady state, I_D equals I_0.

So, to bias the transistor in this way, to sense at the source and the feedback to the source, we do not have to do anything. All we have to do is to connect the current source to the source of the transistor.

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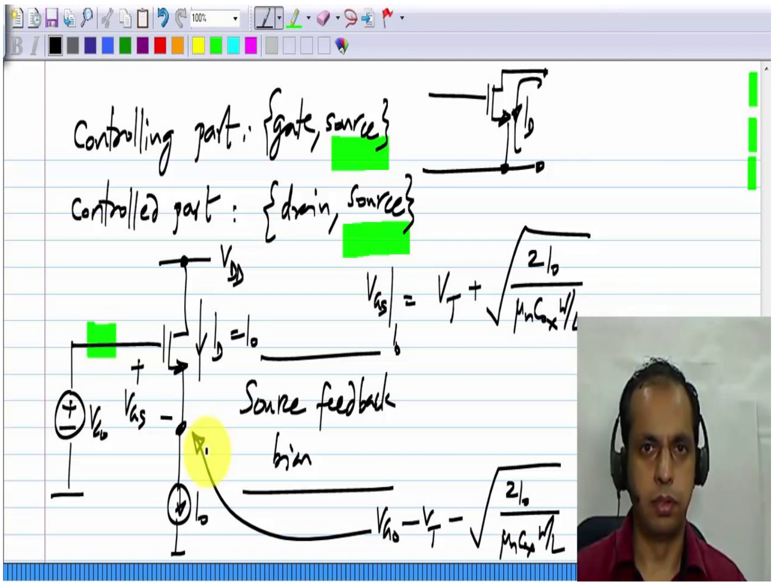

Now, why does this really work? The controlling part of the transistor current, that is, the gate source voltage, so this is between gate and source; when the controlled part, which is the drain current that goes from drain to source. And you can clearly see that the source belongs to the controlled side as well as the controlling side of the transistor. The gate, you can only apply the input, it can only control nothing will come out of the gate, it is not an output. Similarly, the drain, it is only an output, we cannot apply something to the drain. Whereas, source it is common to both the controlling part and the controlled part, so that is why take a transistor bias its gate at a fixed voltage; the drain also at a fixed voltage V_{DD}. And you just apply the current source I_0 to the source, and it reaches steady state, where I_D equals I_0.

But still it is more useful to think of this circuit as having feedback; the feedback is internal to the transistor, that is the source being part of both the controlled side and controlling side introduces feedback. So, it is better if you think of this as a feedback circuit rather than a simply applying the current. That is you connect the current source to the source terminal, and depending on the current difference, the source terminal go up or down, and that action the source voltage going up or down will change the V_{GS}, and consequently, change the current. So, there is feedback in this simple circuit as well. Although, normally for feedback, you assume that there is some circuit and there has to be a wire coming from the output to the input that is our usual notion feedback. Here the feedback is internal to the transistor. The source being part of both the controlling and control side accomplishes the feedback.

And this type of biasing naturally is known as source feedback bias. It is a very popular way of biasing the circuit, it is very simple and used quite a lot. And in the subsequent lessons, we will look at how to realize amplifiers using this type of bias. Like I said many times before, you can have many different kinds of bias circuits, and many different kinds of functions, that is, the incremental picture that we want to realize. Right now, we know only one of them that is the common source amplifier, but typically any function can be realized with any bias circuit, it is possible. Now, of course, some of them are more convenient than others, so they will be preferred, but you can have a variety of function, variety of bias circuit and a combination of biasing and the realization of the functionality. So, this is why there is a huge variety in circuits.

As I explained earlier, in this current source I_0 is connected to the source of the transistor. The source voltage adjusts itself such that in steady state the current flowing in the transistor equals I_0. And this V_{GS} will be adjusted to whatever is required to have a value of I_0. So, V_{GS} to carry a current of I_0 is $V_T + \sqrt{2 I_0 / \mu_n C_{ox} (\frac{W}{L})}$, so the source voltage here is this fixed voltage V_{G0} - V_{GS}, which is $V_{G0} - V_T + \sqrt{2 I_0 / \mu_n C_{ox} (\frac{W}{L})}$. So, eventually the source voltage reaches the correct voltage.