Analog Circuits
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Module - 04
Lecture – 08

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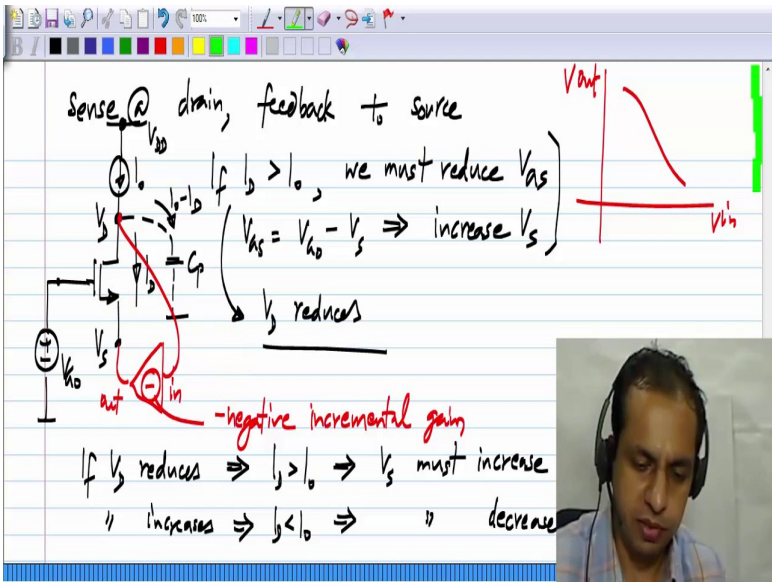

So, far we have discussed two types of biasing a transistor at a desired current. In one case, we sense the difference between desired and actual currents at the drain terminal and feedback to the gate; in the other case, we sense the difference at the source terminal and feedback to the source. There are two more varieties that are possible. One of them is to sense at the drain and feedback to the source terminal. So, let us say we have the transistor, and because we are feeding back to the source terminal, we keep the gate at a fixed voltage V_{G0}. Now, we want to sense the current difference at the drain, so we have I_D, so to be able to sense the current difference, we connect a current source I_0. This gate connected to the supply some voltage.

And now I will come back what happens to the drain node, but this is the source voltage V_s, so if I_D is more than I_0 that is the actual drain current is more than the desired current then we must reduce V_{GS}. If we reduce V_{GS} then the drain current will come down. Now, V_{GS} equals V_{G0} - V_s, so this means that to reduce V_{GS}, we must increase V_s. And similarly, if I_D is too small, if I_D is smaller than I_0 then we must increase the drain current and we do that by reducing the value of V_s. So, this is the action what we want at the source. Now, what really

happens at the drain? The difference between I_0 and I_D flows into this capacitor C_p, which consists of the parasitic capacitance at this node. Now, if I_D is too large that is I_D is larger than I_0 then this current will be negative, current will be drawn out of the top lead of this capacitor. So, if I_D is more than I_0 then the drain voltage V_D reduces. And the opposite happens if I_D is less than I_0 then the drain voltage would increase.

Now, you see that V_D reducing is an indication that the drain current is larger than what is required. And in that case, we must actually increase V_s. So, the sense of change we want at the source is opposite of what is happening at the drain. So, if V_D reduces, we must increase V_s; and if V_D increases, we must reduce V_s. V_D reduces this means that I_D is greater than I_0 and this means that V_s must increase. And similarly, if V_D increases this means that I_D is smaller than I_0 and this must decrease. So, how do we accomplish this? What we really meant is some block which takes its input, which is the drain voltage and gives an output, which is the source voltage. And also it must have this behavior, that is if V_D reduces, V_s must increase and so on.

So, let say these are the input and output terminals of this block whatever that is, then the output versus input that is the voltage at the output versus the voltage at the input should have a characteristic like this, which means if this V_{in} increases, V_{out} what is driven to the source which actually decreases. In other words, it must have a negative incremental gain. So, you must drive the source using an amplifier or some block, which is driven by the drain voltage and this must have a negative incremental gain so that the sense of variation is as shown here. So, this is slightly more complicated than our original case. The very first case we discussed, we sensed at the drain and fed back to the gate; the sense of variation we wanted at the gate was exactly the kind of variation we were getting at the drain.

So, we could connect it with a positive incremental gain in general; and even a direct connection was ok. Whereas, in this case, the direct connection will certainly not work; and you do need a negative incremental gain between the drain and the source. So, because this is slightly more complicated, we normally would not use this for a simple common source amplifier, but these structures do occur in many places in circuits. I will show you one example of how to accomplish this.

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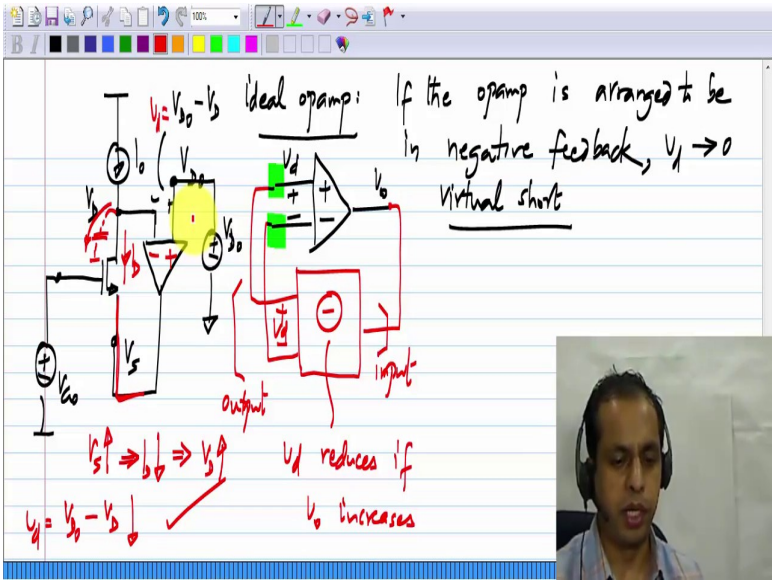

This is at V_{G0}, some bias voltage at the gate; and this is I_0. Like I said I should take this, make it go through a negative incremental gain and drive the source. There are many, many options possible. What I will use one particular option using an op amp and I assume that you are familiar with the concept of an ideal op amp. If not, please go through the relevant lecture material from basic electrical circuits. The ideal op amp, I will describe it very, very briefly here; it has an input V_d between two terminals; it has two input terminals and the difference voltage is called V_d. The input terminals are marked with plus and minus, and this is the difference voltage and the output voltage V_o.

Now, what it means is if the op amp is arranged to be in negative feedback, what does that mean? There is some circuitry around the op amp, you cannot use the op amp just by itself without anything else. So, there is some circuitry around the op amp, V_o gets connected to that, and the input terminals of the op amp also get connected to that. What is the meaning of negative feedback, it means that the action of this circuit whatever is the rest of the circuit is such that V_d reduces if V_o increases. In other words, this stuff has a negative incremental gain, it does not have to be actually a gain. All it has to do is to make sure that V_d, which is the output of this block, as far as this block is concerned, you can think of this as the output and this as the input. And this block should be such that its output reduces if the input increases, that is this V_d must reduce as V_o increase through the feedback circuit.

If that the case, then in case of an ideal op amp, V_d goes to zero that is the difference between these two terminals will be forced to zero by the op amp. And this concept of V_d being forced to zero, this is known as the virtual short. Now, if two nodes are shorted to each other; obviously, there will be at the same voltage. In the case of an op amp, operating in negative feedback, these two terminals are not shorted together, there is no wire connecting them. But this op amp and the negative feedback together will force these two voltages to be exactly the same and that is what the ideal op amp does. In case of real op amp, V_d will become very, very small, but not exactly zero; in case of an ideal op amp, it becomes zero. These things are described in more details in basic electrical circuits or you can use some of the text books that you may have which described the op amp.

So, I am going to use this block to complete the feedback. What I did was I took the drain voltage, fed it to one of the inputs of the op amp, and drive the source with the output of the op amp. And the other input of the op amp, I call it V_{d0}. Basically, it is some fixed bias voltage as far as I am concerned right now, this is V_{d0}. Now, how should the circuit be configured? Obviously, first of all, we already know that the incremental gain from the drain to the source must be negative. So, this appears to be the negative terminal so that is what it should be the terminal on the left side is the negative terminal. You can also examine it from the viewpoint of the op amp and you will reach exactly the same conclusion.

So, what must happen is that if V_d increases, V_s must reduce so that tells you that the sense of the op amp must be like that. Now, going by what I described to you just about the op amp, the difference voltage in this polarity is V_{D0} - V_D. And I will now analyze the rest of the circuit, that is from this point onwards this is the output of the op amp that I call V_s. Now, what happens if V_s increases, this I_D here will actually reduce, because the gate source voltage reduces; and in that case, I_0 minus I_D will flow into this capacitor and raise the drain voltage, the drain voltage increases. And the difference voltage of the op amp, if the signs of the op amp were like that the difference in voltage of the op amp is V_{D0} - V_D and this will fall down. So, it is in the correct sense for negative feedback.

The way you evaluate the op amp signs for the negative feedback is you assume some sort of signs and then you work around and then see if this difference voltage reduces as V_o increases. So, if I choose the signs to be like that then as V_s increases, I_D will fall down which will make the drain voltage increase, which will make the difference voltage V_d, this V_d here, decrease. So, it is in negative feedback. So, the correct signs of the op amp are like that. So,

this is the way of biasing a transistor at constant current I_0 by sensing at the drain and feeding back to the source.