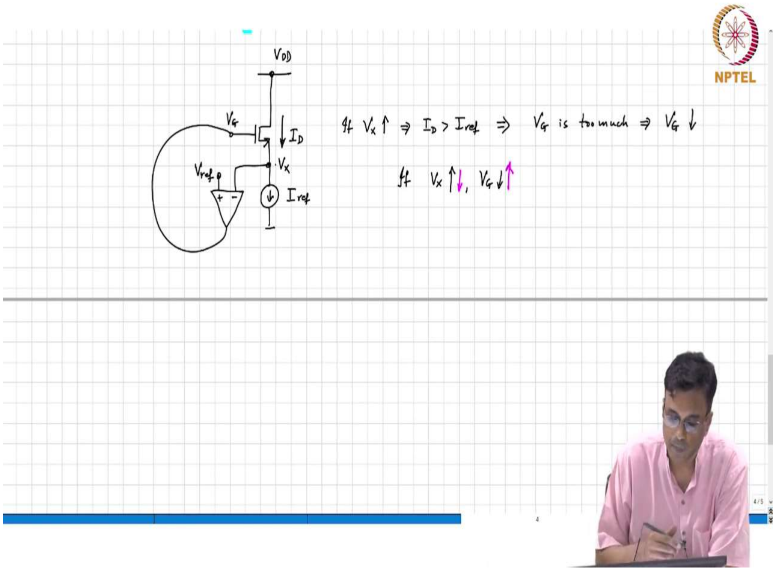
Analog Electronic Circuits
Prof. Shanthi Pavan
Department of Electrical Engineering
Indian Institute of Technology, Madras

Lecture - 24
Robust Biasing with Source Measurement and Gate Feedback

(Refer Slide Time: 00:22)



So, we have the transistor. The gate potential is unknown, right? What are we going to do? We are going to measure the current in the?

Student: Source.

Source, which is I_D again, compare it with?

Now, I am not going to, you know, rewrite all the simple stuff that we have been doing so far. Now, we should be in a position to maybe draw the circuits directly, I_D is fighting. You are comparing I_D with?

Student: I_{ref}.

I_{ref}. So, where is I_{ref} going to happen?

Student: Source.

In the source, we look at monitoring that potential. We compare it with a let us call this V_X, ok. We compare if V_X is going up. What does it mean?

This means that I_D is greater than I_{ref}, which then implies?

It means that V_{Gs} are too large, which means, V_G is too much. Therefore, you must reduce V_G. So if V_X goes up V_G must go down if V_X goes down V_G must go?

Student: Up,

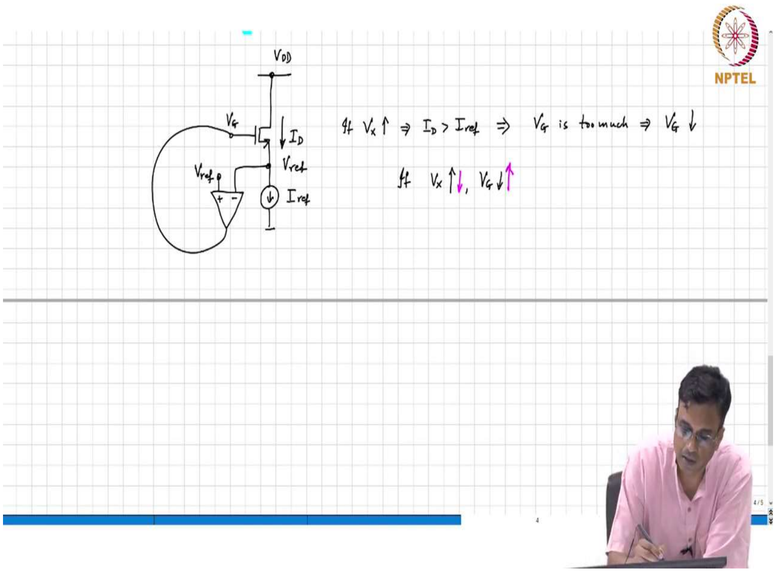
Up. So, what will you do? You therefore, compare V_X to a constant, and if V_X goes up V_G must go down and so on. So, what comment can we make? It is a voltage control voltage source. What must be the gain of this voltage control voltage source?

Student: Infinite.

Infinite and so what must be the science of the op-amp?

Source must be negative, ok. So, in the steady state when obviously, the negative feedback loop is stabilized, what comment can you make about V_X? What is the voltage V_X?

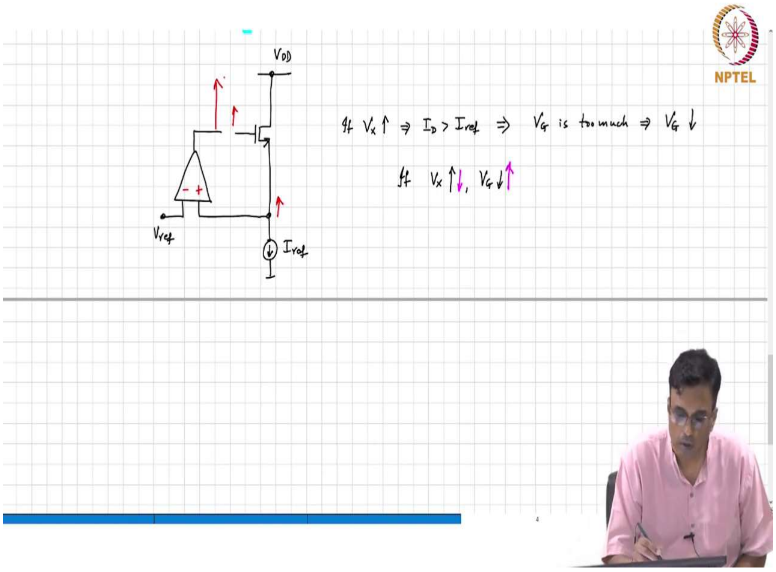
(Refer Slide Time: 03:37)



Yeah, how will you find out? From I_D, how will you find V_G? From I_D we can find V_{Gs}. Once you know V_{Gs}, V_G is nothing but $V_{ref} + V_{Gs}$.

Is this clear folk? And so that basically is yet another way of stabilizing the bias current of the transistor. Let me draw it a little nicer and again if you have not seen this circuit before, there is nothing to get nothing to panic about.

(Refer Slide Time: 04:44)



Alright. So let us go through the exercise. So, let us say we did not know the science of the op-amp, what are we going to do?

We have to assume some arbitrary signs. So, let us assume that this is positive, this is negative, you break the loop somewhere and you yank that voltage up. If I yank the voltage up at the gate what happens to the source?

Student: Increase.

Increase, go up or down?

Student: Up.

Why go up?

Student: I_D is greater than I_{ref}.

So, well I_D is greater than I_{ref} and therefore, this node potential will tend to go?

Student: Up.

Up, if that goes up through the op amp what happens to the output of the op amp?

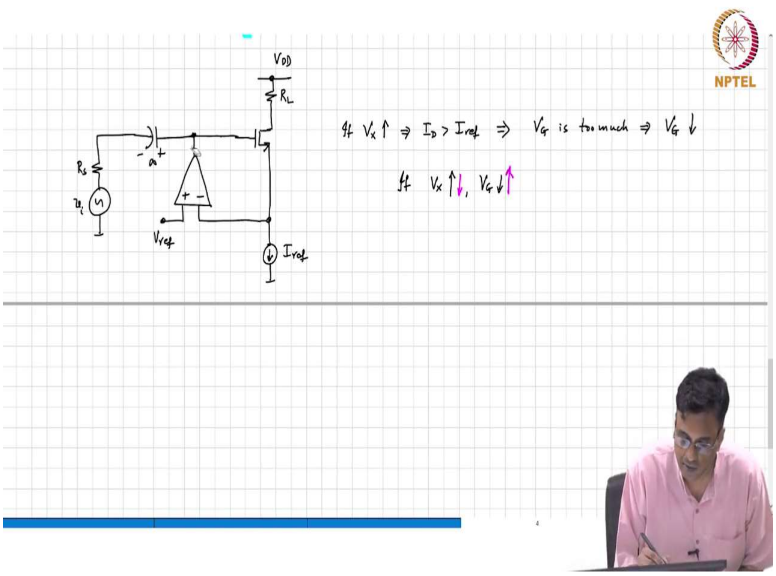
Student: Also goes up.

Also goes up. So, this is it?

Student: Positive feed.

Positive feed, alright. So, therefore, conclude that what the signs we have chosen are wrong and therefore, these correct signs must be this, ok.

(Refer Slide Time: 06:47)

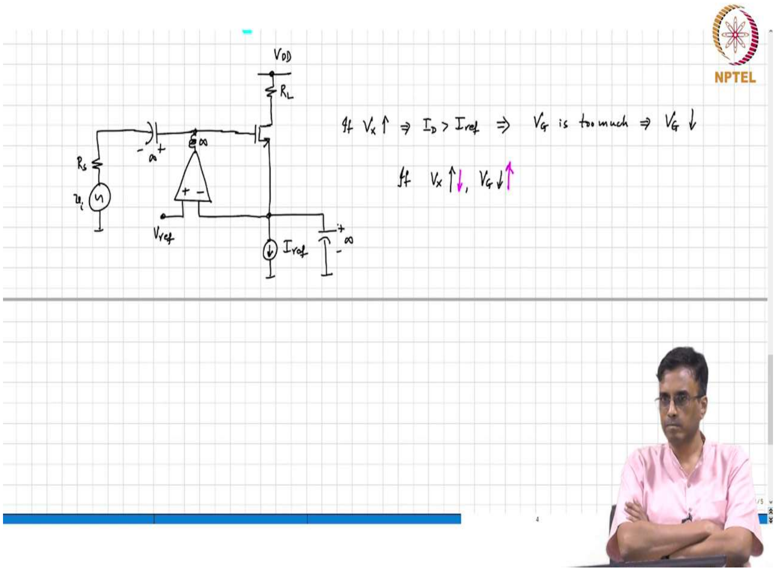


So, this is our bias stabilization loop. Now, what are we going to do? We need to make a common source amplifier yet another one. So, now you should be able to tell me what I should do to make this common?

Student: Source.

Source amplifier, what should I do? So basically we add the infinite capacitor here and so you know again there is multiple ways of doing that you can put an inductor there or you know put the load resistor right there or if you do not like that you can put couple it with the capacitor at the usual thing at the loop, fine. What else we need again we need to break the negative feedback loop. So, how will you break the negative feedback loop?

(Refer Slide Time: 08:24)



Yeah. So, for example, you put an infinite inductor there. And so, that will break, and what comment can we make? Are we done, or do we still need something else to be done?

The infinite capacitor of the source So, the negative feedback loop only exists for DC bias; it is completely out of the picture for incremental signals, and this is our good old common source amplifier all over again. Does it make sense? And for each of these amplifiers, I mean, you can now go and figure out what the swing limits are, etcetera, etcetera, right?

If you find the total potential at the gate, the total potential at the drain, and the total potential at the source, then you know there will be one condition for the transistor entering the edge of the triode region. There will be another condition that will push the transistor into cutoff, and you know, the minimum of those two amplitudes is basically what the maximum input swing you can tolerate will be. Is that clear, folks?

So, this basically covers all four fundamental ways of stabilising the bias current of the transistor, right? Once you stabilize the bias current in the transistor, the transistor is ready for action, right?

And, therefore, we can basically realise that the properties of the transistor, namely the GM, will be very well governed by the bias current in the transistor, which will not vary now in the threshold voltage changes or the supply voltage changes. And, in principle, therefore, I mean that a common source amplifier is a transistor biased in saturation.

In principle, it is simply an incremental voltage control current source with some trans-conductance, and in principle, is there any limit to the amount of trans-conductance we can get? Here, I mean, you have a transistor, right? And the GM, as you know, is the square root of $\sqrt{\mu_n C_{ox} \frac{W}{L}}$. i. So, in principle, is there any limit to the amount of transconductance you can get from a transistor?

No, that is what I said in principle. But, they are not; there are fundamental limitations in principle. See, there is a difference between a limit in principle and a limit in practice, correct? So, in principle, the G-M of the transistor can be anything because you can keep pumping.

More and more current into the transistor. So, there is definitely a limit, and therefore, there is no limit. On the other hand, in practice, there is going to be some limit, as you know and as pointed out before. I mean, you cannot go on. I mean, of course, eventually it will burn the transistor, and so on. So, in reality, there is a limit, but in principle, there is no limit. That is what I want you to be cognizant of.

And the common source amplifier, therefore, is an amplifier that uses the transistor, as in principle you can get a very large gain using a common source amplifier because in principle G M can be very large, and therefore, G M R L, the magnitude of the gain that you can get is very large.

So, this finishes the basic common source amplifier, right? And remember what I mean when I say that when you learned your basic circuit theory, what are all the circuit elements that you saw that you played with, the resistor, the capacitor, the inductor, and the four controlled sources, right, the voltage-controlled voltage source, the voltage-controlled?

Student: Current source.

Current source, the current controlled voltage source and the current controlled.

Student: Current source.

Current source. If you are able to realise these four controlled sources, you can realise an arbitrary transfer function, right? From input to output, it may be current voltage, voltage current, or whatever, and if you have a control source, you can realise transfer functions with complex poles, correct? I mean, if you only want poles on the negative real axis, just R_L or R_C is good enough, and anyway, in practice, using inductors is problematic.

But the moment you have controlled sources, you know, a whole lot of things become possible. So, the next thing that we will take a look at is how to make controlled sources. There are four controlled sources that we have learned in basic circuit theory: the voltage-controlled voltage source, the voltage-controlled current source, the current-controlled voltage source, and the current-controlled current source.

We would like to build them using transistors, and we also would like to make sure that the so-called controlling parameters of these sources match the properties of these sources. Namely, if you say I have a voltage-controlled voltage source, what does that mean? What is the input impedance of an ideal voltage-controlled voltage source?

Student: Infinity.

Infinity. What is the output impedance?

Student: 0.

0 and therefore, if we say I have a voltage-controlled voltage source, the only parameter that you need to justify that you need to specify is the gain between V_O and V_I.

Similarly, if you have a current-controlled voltage source, what is the only parameter that you need to specify?

Student: Trans-resistance.

Because we know that the input impedance of a current-controlled voltage source is what is the input impedance of a current-controlled voltage source?

Student: 0.

0. What is the output impedance? The answers are either 0 or infinity? It is a current-controlled voltage source; what is the output resistance?

Student: 0.

Sure? Why is it 0?

Student: Sir, if we change, I mean if it is a voltage source, then if we change any resistance voltage, we will not get any.

We change what resistance?

Student: Output resistance.

Output?

Student: Load resistance.

load resistance, then the output should not change. So, then the only parameter you need to specify is the trans?

Student: Impedance.

Impedance, and what about a current-controlled voltage? I mean a voltage-controlled current source? What is the input impedance of a voltage-controlled current source?

Student: Input impedance of a current controlled voltage.

of a voltage-controlled current source. Voltage control means what? It is measuring a voltage and creating a current which is proportional to this voltage. So, when you want to measure a voltage, what is the idea you do not want to disturb the voltage that you are?

Student: Measuring.

Measuring, is it not? So, if you do not want to disturb the voltage that you are measuring, what comment can you make about the input resistance of your voltage controlled current source?

Student: Because we are measuring voltage and so, we should not get disturbed by any change in input resistance.

It should not get? Come again.

Student: It should not get affected by any change in input resistance.

What changes in input resistance? Input resistance is not changing. Input resistance is there. What happens if there is input resistance?

Student: Current will flow.

So, basically, if the input resistance of the voltage controlled by whatever source is not infinite, then it will draw some current, which will disturb the voltage that is being monitored. So, if you do, I mean if you do not want that to happen, therefore, the voltage-controlled current source must have an input resistance of?

Student: Infinity.

Infinity, and what about the output resistance of a voltage-controlled current source? Abhishek? It is a current source. So, the output resistance must be?

Student: Infinite.

Infinite. What about the current controlled current source?

Student: It should be 0.

The input impedance must be 0. Why?

All the current that you are trying to sense you again think of it as an ammeter. What is the internal resistance of an ammeter?

Student: We are measuring.

Yeah. So, basically, if the input resistance of an emitter is not 0, then remember that an ammeter is connected in series to measure a current. If it has some finite resistance, a nonzero resistance, then it is going to perturb the current that is flowing, just like the non-infinite resistance of a voltmeter is going to disturb the voltage that it is trying to measure. Does it make sense? Yes? No?

Student: Yes.

So, if you have a controlled current source, therefore, what is the?

Student: Input impedance should be 0.

What about the output resistance? Output resistance of a current source is.

Student: Infinite.

Infinite, alright. So, if you have basically these and only these, if you have a voltage-controlled voltage source, I mean a voltage-controlled current source, what is the only parameter that you need to specify?

Student: Trans conductance.

The transconductance, and similarly, if you have a current-controlled current source, what is the only parameter that you specify?

Student: Gain.

a gain again. So, we will try to use negative feedback again to make either the gain, the trans-conductance, or the trans-impedance robust and independent of the properties of the transistor.

So, in the next class, we will start looking at how to make an incremental voltage-controlled voltage source in such a way that the gain of the voltage-controlled voltage source is robust with respect to parameters with a transistor.

Thank you very much.