Analog Electronic Circuits
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Lecture - 55
The Two-Stage Opamp contd

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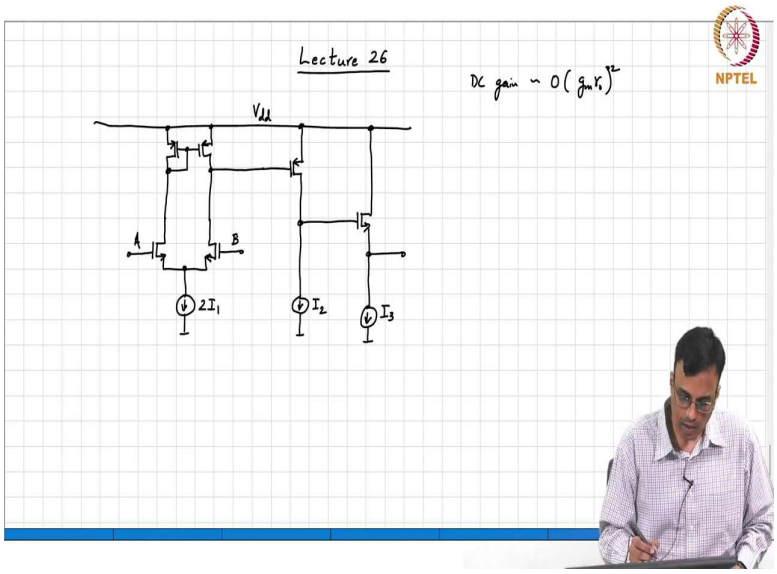

So, a quick recap of what we were doing in the last class. We had a Viable Operational Amplifier, which basically consists of the differential pair. The reason why we have an active load is to be able to get a large DC gain within a limited supply voltage. Then, a common source, second stage and some kind of source follower, so that we get a low output impedance, right.

And the DC gain is approximately of the order of $g_m r_o$, alright because that corresponds to two stages of gain. I mean when I say order of you know there is a factor of 2 and 4 on missing and so on, alright. And more importantly we know why the circuit came about, right. It is not something that we just put on the board and say let sit and analyse, this is an op-amp, let us analyze it, right. There we know why each one of those components is there. And we know why each type of transistors used where it is.

So, the output stage does not really matter whether we use NMOS or PMOS. You know common drain amplifiers, ok. Now, which is the positive terminal of the op-amp? A or B?

Student: B.

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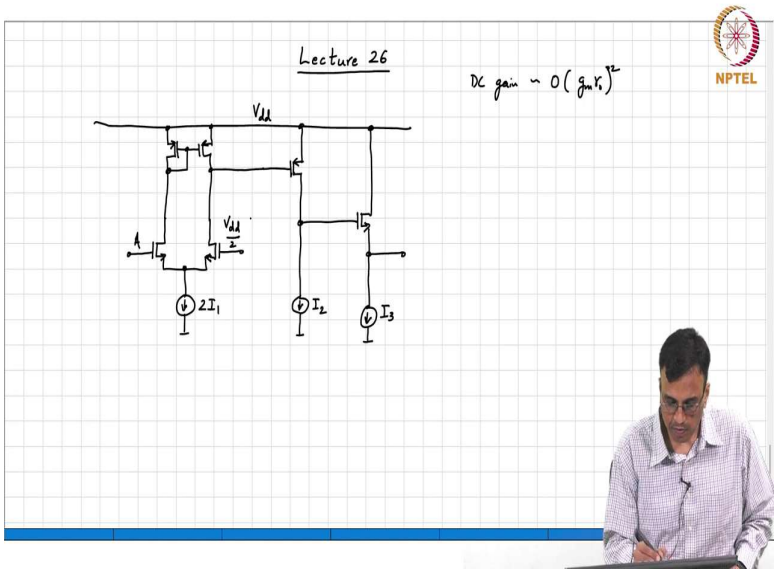

B is the positive terminal. And so, let say we put an input at B which we also discussed yesterday the notion of; and let just take values for argument sake, let say this is 5 volts.

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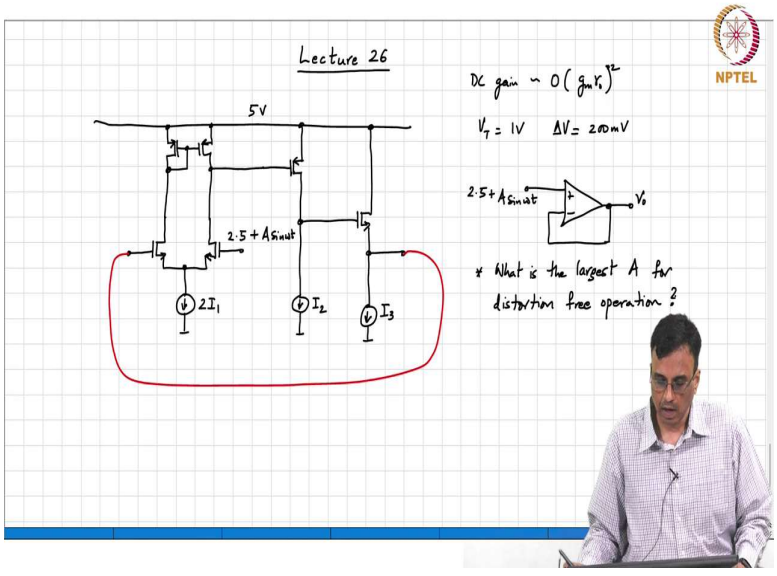

Let say V_T is 1 volt, and ΔV for all transistors is say 200 millivolts and. So, let us by the input must be hovering around $V_{dd}/2$, so this is 2.5 + A sin ωt. That is the input, alright. And let's

say we connect it up as a source follower, so this is the feedback path, alright. And so, what we have in a sense is a unity gain buffer. This is 2.5 + A sin ωt and this is V_o, alright.

And now the question that we are trying to ask is what is the largest A for distortion free operation, alright. I mean so, and to do that we I guess have to replace these; how are we going to implement these current sources? What are we going to do? It must be NMOS current source.

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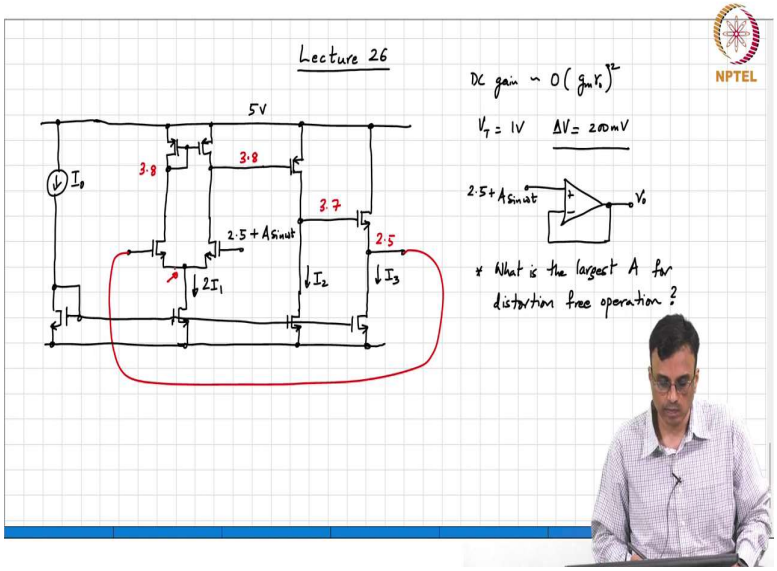

And there is some master bias, I_o and let assume that all the sizes are what you call such as I said, that the overdrive of every transistor is chosen to be 200 millivolts. That can be done by simply playing around with the sizes. Is this right? Is this clear? Alright. Quickly, let us go through the operating point. When A is 0, what is the output voltage assuming g_m r_o is very large? So, this voltage is 2.5. What is this voltage? 3.7, ok. What about this voltage? That is 5 - 1.2 which is 3.8. What is this voltage?

Student: 3.8.

3.8, alright. What is this voltage, which is nothing but the gate voltage minus V_{GS}. And what is V_{GS}?

Student: 1.2.

So, 2.5 minus 1.2 is?

Student: 1.3.

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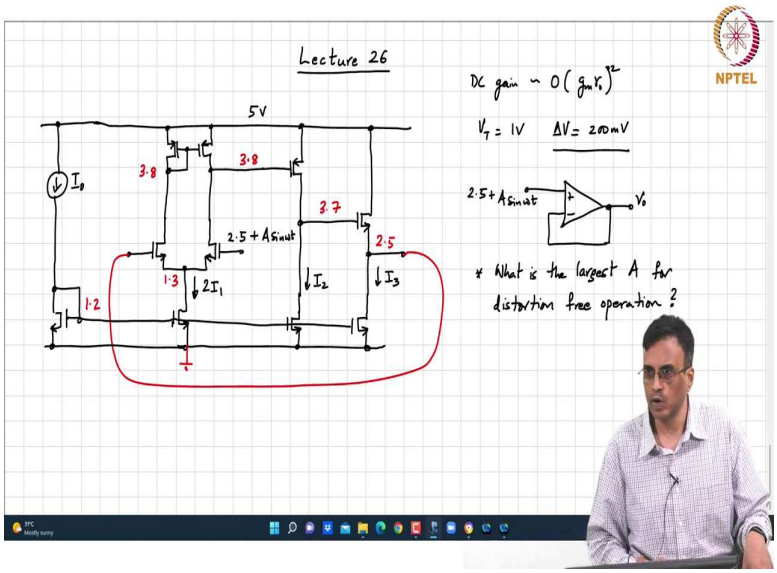

What is this voltage?

Student: 1.2.

So, all the quiescent voltages are known, right. The next thing is to find the swing limits. So, how many transistors are here? 10 transistors, alright. And you know it certainly can look intimidating, but I mean as you know how everything comes about correct, ok. So, how will we figure out what the maximum A is to ensure that the output is not distorted? What should be, what are we looking for?

So, swing limits for individual transistors, and basically, you find the minimum for each transistor and then find the minimum of all the minimums, correct. It sounds like a daunting task, but as you will see going forward, it is not that difficult. So, once we found the quiescent voltage, the next thing is to find the incremental voltages everywhere.

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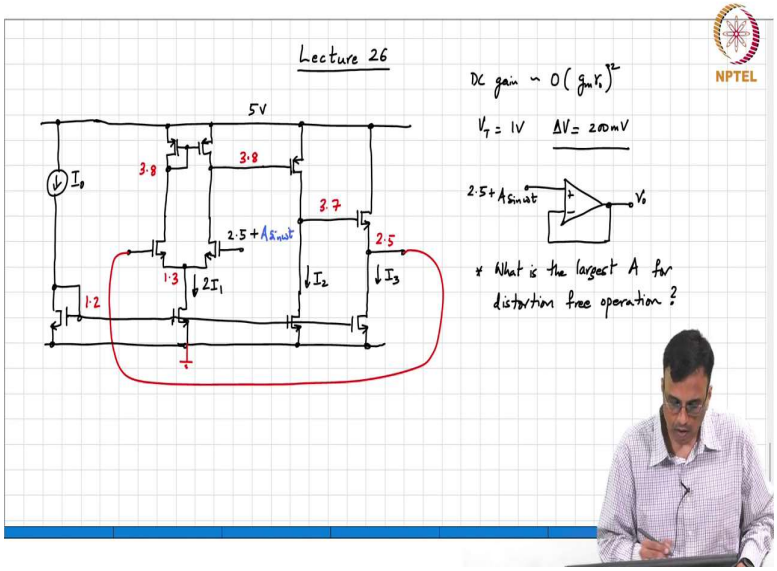

So, if this is A sin ωt; let me write, mark all the incremental stuff in blue.

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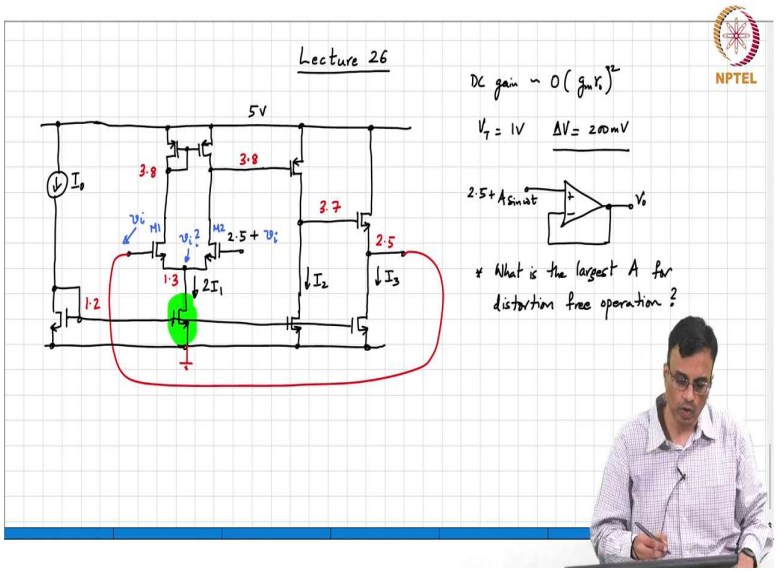

Or let me call this v_i, so that it is easier to track. Now, what comment can you make here? Now, what comment can you make here?

Student: v_i.

If this is v_i and this is v_i, what comment can you make there? Assume I mean for operating point and you know what do you call incremental voltage calculations, let us assume that the

r_o is infinity. What is the voltage on the left side of the differential pair? What is the voltage on the right side? v_i. What is the incremental current flowing in M1 and M2? As I said, let us assume that the output resistance is infinite for all the transistors. Why is it v_i? The claim is that this is v_i. Why is this v_i? So, there is the incremental current flowing through the tail current transistor; what is the incremental current flowing through that transistor colored in green?

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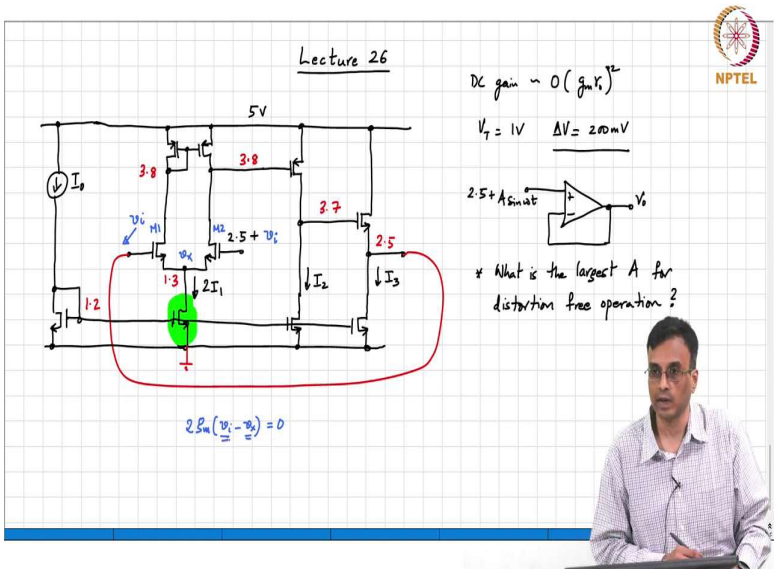

So, if you are still not able to figure it out, let us assume that is v_x. So, the current flowing through incremental current flowing through M1 is nothing but g_m (v_i -v_x), which is the same as the current flowing through incremental current flowing through M2. So, twice that, must be the current flowing through out of the common source node and that must be equal to 0. And therefore, v_i must be equal to v_x, alright.

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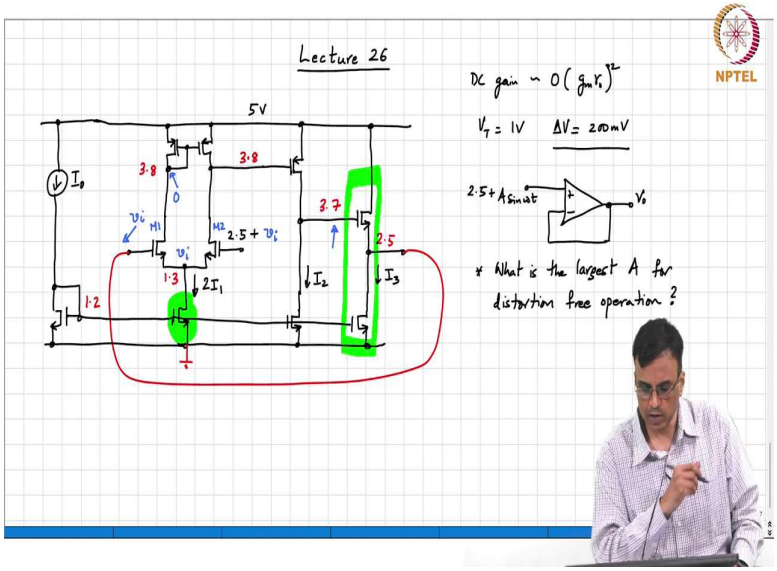

So, this $v_x = v_i$, alright. So, what comment can you make about the incremental voltage there? Incremental v_x is 0, so the current flowing here is 0. So, what comment can you make about the voltage there? Incremental voltage there is.

Student: 0.

Is this clear? Alright. What comment can we make about the incremental voltage here? Where is g_m infinite? g_m is not infinite. g_m and r_o are two different things, you understand that, right. r_o is infinite. So, this character here, what is that?

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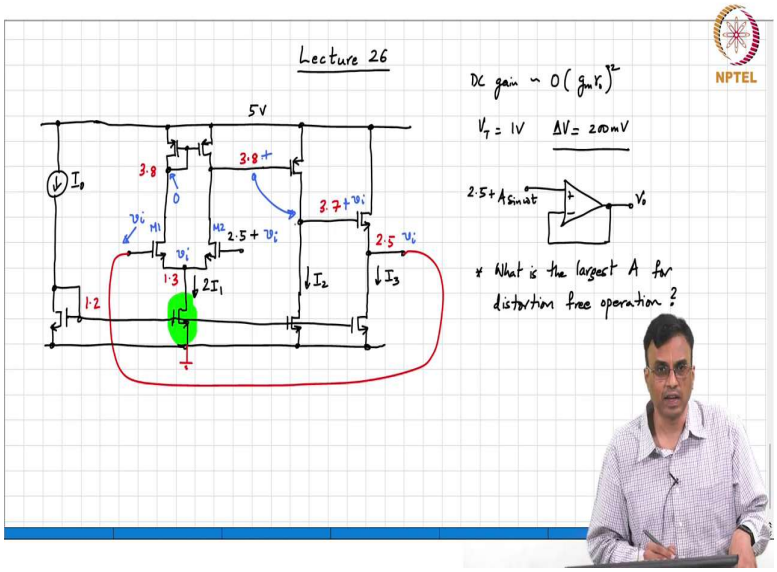

It is an incremental voltage controlled voltage source, ideally its incremental gain is $g_m r_o/(1+g_m r_o)$. r_o is infinite. So, what is the incremental gain?

Student: 1.

So, if the output has an incremental voltage v_i, the input must have an incremental voltage v_i. And if this incremental voltage is v_i, what comment can you make about the incremental voltage here? $-g_i/v_i/r_o$.

Ok. What is r_o? So, what is the incremental voltage here? The incremental voltage there is?

Student: 0.

Is this clear to everybody? That is because the incremental voltage the gain from here to here is $-g_m r_o$. We assume that r_o is infinite. So, therefore, the gain is infinite. If the gain is infinite, it must follow that the incremental voltage at the input must be the output swing divided by output voltage divided by the gain. The gain is infinite. So, this must be 0. So, this does not change, alright, ok. Now, what about the incremental voltage there? So, this is basically, incrementally 0, ok.

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