Analog Electronic Circuits

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Lecture - 44
The Active Load

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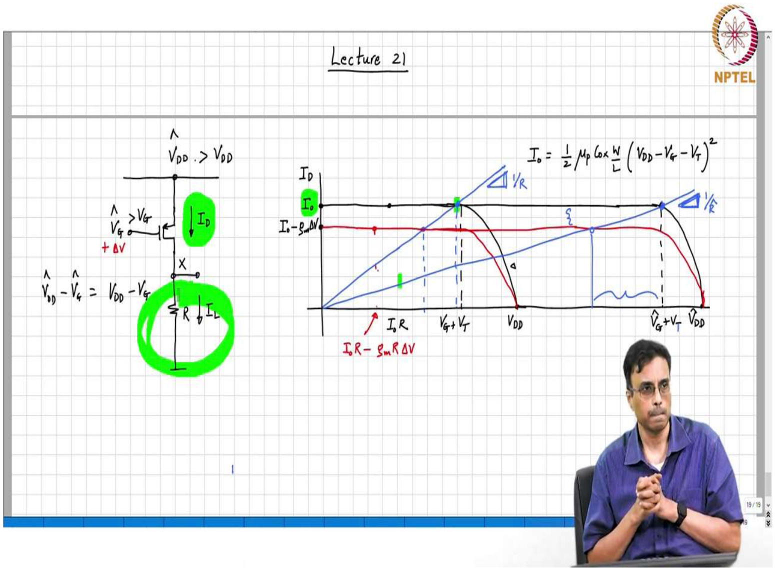

So, the, so, now, the question is can we replace this resistor with something else where we would like to use the small supply voltage V_{DD}, but we still like to get? A higher incremental gain and further the resistor is I mean it is it should be what kind of element? Is the resistor passive or active?

Student: Passive.

It is passive. This is because there is an energy source inside. So, whatever we replace their right must also be must also have? No energy source inside, ok.

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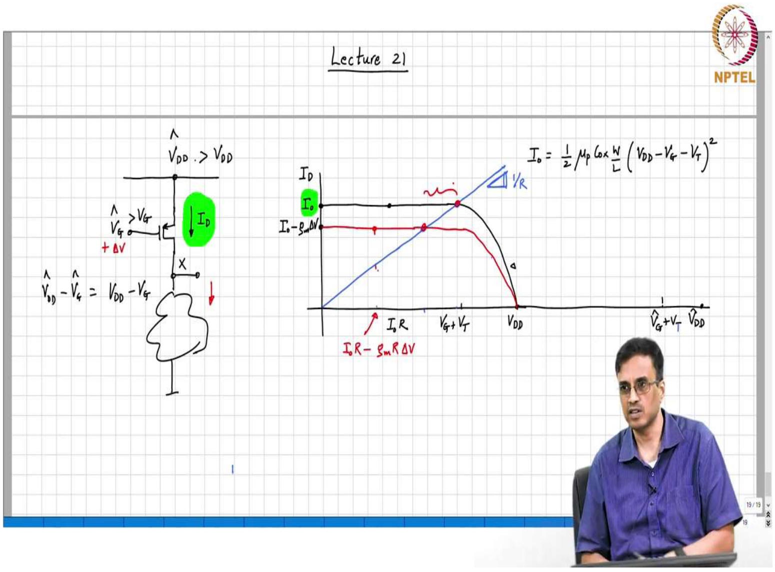

So, we would like to replace it with something else, so that the incremental gain is very large ok even with a small period, is this clear people? So, I am going to rub off all this stuff, alright. So, if you want a lot of incremental gain, alright remember that the incremental gain is basically the difference in the x-coordinates of the point of intersection of the characteristic of the load which is in arc in the case that we have been discussing the load is a resistance. So, it is the difference between the x-coordinates of the points of intersection of the characteristic of the load with that of the transistor, right. The transistor is not changing. So, basically we are back with V_{DD}, alright.

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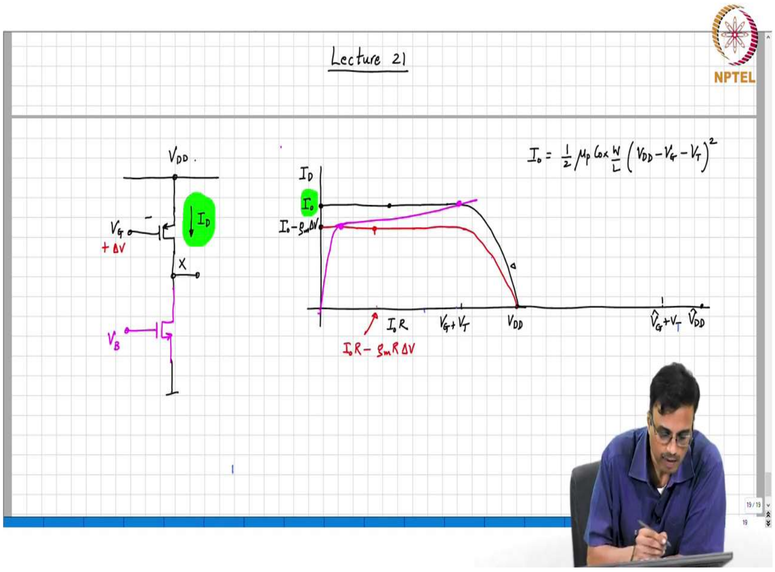

So, if you want a lot of gain basically what you are looking for therefore, is what you are looking for is a characteristic where it intersects this curve with V_G at that point and intersects the red curve where as close to the origin as possible, ok. So, something like that, correct. Now, if this continue to be a straight line what comment can we make? It will no longer be passive because the passive element must have it is characteristics in the first and third quadrant, correct? So, if you want this box to be passive what should the characteristic do?

It must do this and then eventually it must fall to the origin and do something like that right, ok. So, now, can you think of an element you can put here? Whose characteristic looks like that? It is an NMOS transistor, is that clear? And what so, the NMOS transistor has 3 terminals, what terminals will you put?

So, you need to put the drain and what should I connect to the gate?

Student: Constant voltage.

What constant voltage? How should I choose this constant voltage? Let me call this V_B. How will I choose V_B? Remember that this is a very exaggerated picture. In reality the ΔV will be very small.

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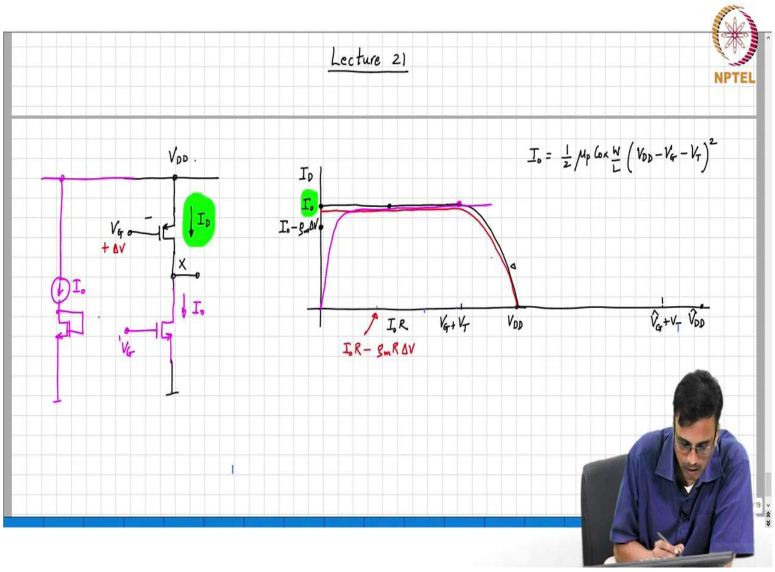

So, the red curve will basically do something like that and therefore, the magenta curve which is the curve corresponding to the load must do something like that, alright. So, now what I mean it is very nice that you guys all figured out that it is an NMOS transistor. Now, the question is what should V_B? How should V_B be chosen?

The current must be the same as in as and what is that same? I_o, right. So, V_B must be chosen such that the current when it operates in saturation is exactly equal to I_o, right. So, one way of doing that is to basically yeah how do you have any suggestions and how we can get that I_o, Siddharth?

Student: V_G.

Yeah. So, basically one way to do that is to say I am going to use an I_o here ok, alright.

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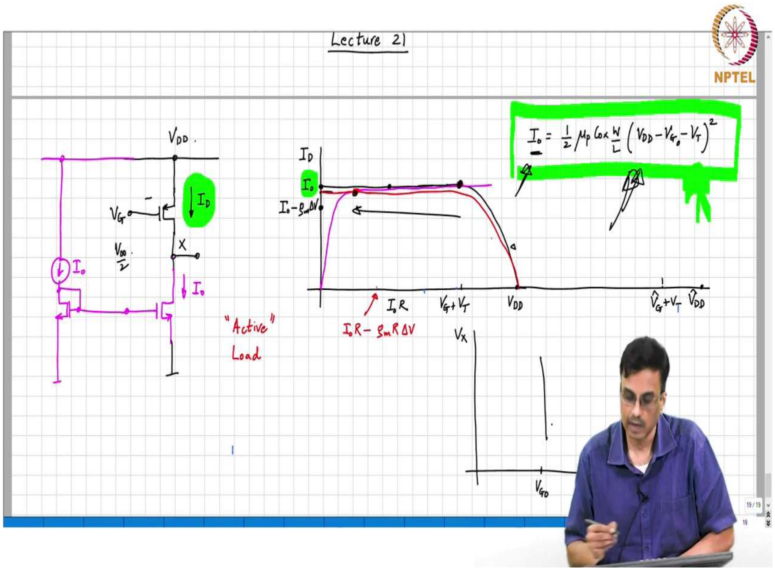

So, when what do you call V_G is the ΔV is 0, you know this is the point of intersection and the output will be close to when ΔV becomes slightly positive what happens the point of intersection will move to the left and because the slope I mean basically what matters is not the slope of this I mean the basically what matters is that the slope of the load characteristic between the red and the black curves must be it must have as small a slope as possible, correct. Only then will the distance between these 2 points of intersection be very very large. Is that clear? So, this basically is called I mean even though the load is actually passive it is called the active load, alright and you know as you can imagine the this is an extremely useful technique because it allows you to get a very large incremental gain you would have to increase the V_{DD} by a large factor right whereas, here by using a transistor you are able to get a large incremental gain with only a small supply voltage, alright and remember on an IC it is always you know it is cheaper to have a transistor rather than a resistor. So, it basically allows you to get a large incremental gain from a small supply and that is basically why this technique is very very useful, ok.

So, now for example, if I plot if I now plot say V_G let me call this V_{Go} which results in I_o. So, if I plot V_G versus V_X how does this characteristic look like? V_{Go} results in I_o, ok. So, for what V_G will I get a large incremental gain? I mean by the way when you get a large incremental gain, what comment can you make about the region of operation of all the transistors? They all operate in saturation and the current in the NMOS transistor is the same as the current in the PMOS transistor, correct? That is the only circumstance under which you get a large incremental gain, is that clear? Alright, now based on this can you tell me for what V_G will you get a large incremental gain?

When I_o flows I mean the current flowing in both the transistors is exactly the same no matter what the region of operation is, correct? If the NMOS transistor is in saturation the current that flows through its drain is I_o, alright. If the PMOS has to be I mean the PMOS current has to be therefore I_o. If the PMOS has to be in saturation what must be it is gate voltage V_{Go}. When the magic voltage is V_{Go} what comment can you make about the both the transistors are operating in? What comment can you make about the incremental gain therefore? The incremental gain is very high, is that clear or not? Right, ok. So, if I mean the incremental gain is simply the slope of the in this picture how will you get the incremental gain? If I draw the V_X versus V_G characteristic how will we get the incremental gain at a given operating point V_G?

Student: Slope.

Slope of the characteristic. So, when $V_G = V_{Go}$ the slope is? What comment can we make about the slope? Very high and what about the sign of the gain is it negative or positive?

Student: Negative.

Why is it negative?

Why is it negative? Looking at the picture, why is it negative? In this picture what corresponds to the sign of the incremental gain? I mean what corresponds to the incremental gain? Originally the operating point was here when I increased the input voltage from V_G to $V_G + \Delta V$ where the point of intersection moved towards the left. So, it is actually reduced and therefore, the incremental gain is?

Student: Negative.

Negative. So, what comment can you make about the slope?

Student: Steep negative.

Steep negative slope. So, you will see something like this.