Analog Circuits
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Module – 06
Lecture – 08

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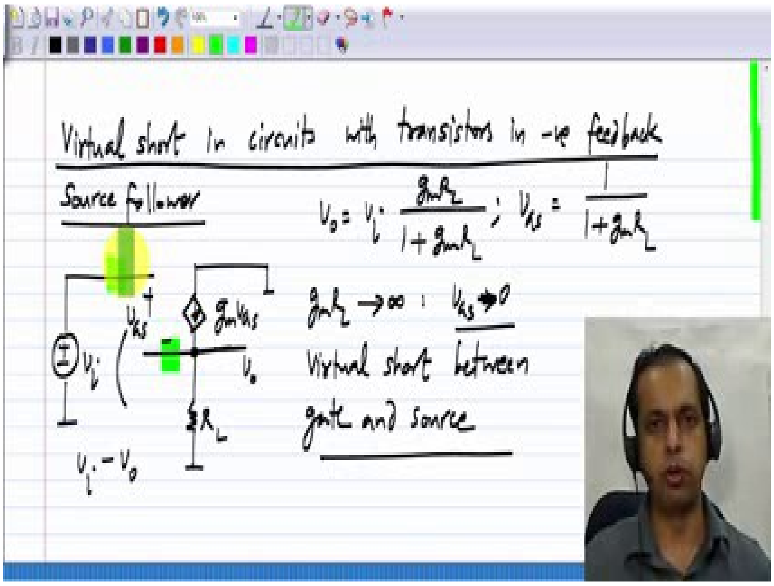

We have discussed the concept of virtual shorts in circuits switch in op amp in negative feedback loops. Now we can do the same for transistors in negative feedback. I will take one particular example which is the voltage controlled voltage source as source follower and the same principle applies to all other circuits as well. the incremental picture of the source follower is like this just for simplicity I will omit the resistance of the input source, this is the load resistance we have V_{GS} and g_m*V_{GS}. Now we know that the output voltage which appears at the source terminal is given by V_i *(g_m*R_L) / (1 + g_m R_L) this V_{GS} is nothing but V_i - V_o and V_{GS} will be 1 / (1 + g_m R_L) .

While the discussing the voltage controlled voltage, source of the source follower, we said that , as g_m*R_L becomes very large , as it tends to infinity. We get an ideal voltage controlled voltage source gives $V_o = V_i$, that is ideally gain equals one and similarly for other feedback circuits, other controlled sources. We evaluated that another feedback circuits other control sources we evaluated that g_m of the transistor becomes very large. When it tends to infinity the circuit behaviour tends to the ideal. Now we can discuss it in terms of V_{GS} what happens to the incremental V_{GS} when g_m*R_L becomes infinity, as g_m R_L --> ∞ , V_{GS} becomes zero ,

V_{GS} --> zero that is there is the virtual short between gate and source terminals it is normally not thought of like this. You talked about Virtual short only in op amp.

Now that is because the value of A_o that you can get in op amps very large it is in the many thousands at least whereas the values of g_m*R_L you may get with transistor circuits is not So high , it may be modest more like twenty or thirty or something like that, but it is still true that if g_m R_L does tends to infinity these two nodes will have the same voltage and gate becomes virtually short to the source. So, if the transistor is in negative feedback then there will be a virtual short between gate and source now this is also useful way of quick analysis of circuits. In this case, for instance, if you did not know the circuit before, if did not know that it was source follower, but you did recognise that there is feedback for the transistor how to recognise it is another question, I am not going to deal with that here. So, if you do that then you can assume a virtual short between the gate and source then clearly $V_o = V_i$ and the same thing for all other controlled source.

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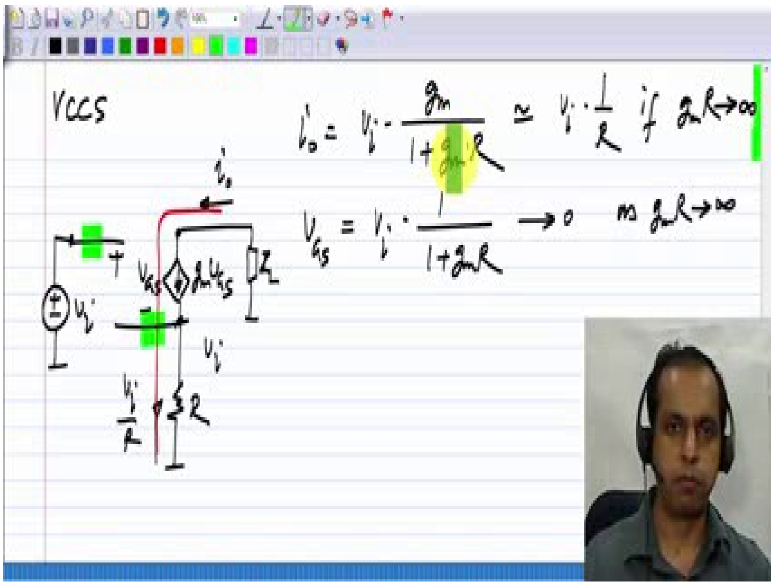

Just as another example, I will show the voltage controlled current source whose incremental picture looks like this we have the load over this is g_m*V_{GS} , this is V_{GS} . now we have already evaluated that this current $I_o = V_i *(g_m / (1+ g_m*R))$ and its approximately V_i / R if g_m R --> ∞ and you can also evaluate it in terms of the V_{GS} . now if you assume that there is virtual short between gate and source what happens the source is virtually shorted to the gate. So, the voltage at the source V_i the current through this resistor V_i by R and exactly the same current flows to the output there is nowhere else for it go. So, if you assume a virtual short here you will immediately see that current here should be V_i / R and of course, in a real transistor there won't be a virtual short because g_m is finite . so this current will be close to V_i / R exactly how close is it to V_i / R that depends on the actual value of g_m*R.

Just for completeness let me put on the expression for V_{GS} the expression for V_{GS} in this case you can work out it terms out to be V_i * (1 / (1+ g_m * R)) which goes to zero as g_m R -- > 0 and exactly the same happens in a current controlled current sources as well as a current controlled voltage source. So, if you want to evaluate all these negative feedback enable control sources with g_m trending to infinity. It is very easy you just assume a virtual short between gate and source. It also gives you the approximate value of transfer function as well as the input and output resistance. Now you have to put down entire circuit and analyse to get the exact values reason, this is used more often with op amp is that gain of the op amp as such is very high whereas these numbers like g_m that you get in single transistor circuits is not very high.

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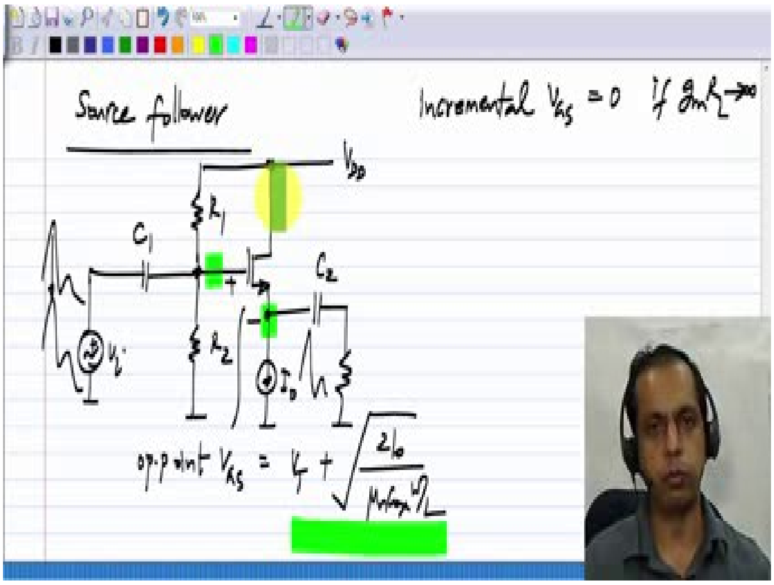

But the same principle applies now what does it means for the complete circuit, let me put down again the complete circuit of the source follower including biasing. This is connected to supply voltage V_{dd}. First of all the bias point get established and there is negative feedback for biasing itself that is if the actual drain current more than this current the source voltage will increase, the V_{GS} will reduce. And eventually this operating point gate source voltage will settle to the ($V_T + \sqrt[2]{(2*Io/(\mu n*Cox*W/L))}$). Let me call this C_1 now what happens when you apply a signal V_i we evaluated that in the incremental picture $V_{GS} = 0$. I did not show R_L here; R_L will be the asusual capacitors are shorts g_m*R_L -- > ∞ . So, the incremental V_{GS} is zero what it means is that the value of V_{GS} will remain the same and it will be the same as operating point value even when you apply the signal.

So, for instance let say the difference between these two or three volts in this number was three volts and even when you apply the single this remains at three volts. So, that is the virtual short incremental it is virtually shorted in the total picture V_{GS} will remain constant there is no incremental V_{GS}. So, this V_i whatever waveform you apply here will appear here as well with some level shift that is it will be lower it will be shifted down, but the shape will be exactly the same. There is the other reason why people called it the source follower, the source follows the gate voltage is not the same; there is a difference of one V_{GS} between them, but it does follow the variation of the gate voltage.