Analog Circuits
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Module - 02
Lecture – 18

Let me copy over this circuit. Again, now you evaluate V o by V G S, you can think of this circuit as producing some V G S because of V s and this V G S produces some V o. The current that flows here is of course, g m V G S and what we want is the voltage across R L. Then you have this current division between this resistor and this branch. So, that current is given by R D divided by R D plus the impedance of R L and C 2 in series plus, so that is the current that is flowing in this in the upward direction. So, the actual voltage across R L, V naught is negative of this, times R L, which can be written as minus g m V G S times j omega C 2 times R D times R L divided by one plus j omega C 2 R D plus R L.

Again, now assuming that C 2 must behave like a short meaning, what do we mean by that we have evaluated V naught. When we say C 2 must behave like a short, what we mean is this value of V naught must be the same whether we have this capacitance C 2 here or we have a short circuit. And you see that if this number here, omega C 2 times R D plus R L is much greater than one then you can neglect this one here, because this imaginary part has much greater magnitude. And then this j omega C 2 will cancel off, what will we get R D R L by R D plus R L, that is R D and R L appear in parallel across this controlled current source. So, this is the condition that we need. This is as far as the output voltage is concerned.

Now, you can also relate these two, the other thing I said earlier how to evaluate this is to identify the capacitor and the resistance across it. You null the source, you set V s equal to zero, this V G S also becomes zero, because there is no V s driving this, this V G S becomes zero. And this g m V G S also becomes so that means this becomes an open circuit. So, what do we have, all we have is a capacitor C 2 and R D and R L. So, across the capacitor C 2, you see the series combination of R D and R L and that is what this is saying. If I rewrite it differently in terms of the reactance, one by omega C 2, the reactance of the capacitor must be much smaller than the resistance across it, which is R D plus R L, so that is how we can choose C 2.

And as before, you calculate the constraint on C 2, C 2 must be much larger than a certain capacitance C naught. And if you, in the practical circuit use about ten times C naught that is usually good enough. Now, this is perfectly all right as far as V naught is concerned, but there could be a slight problem with this particular choice of C 2 that I will show. Let us evaluate this V D, which appears between the drain and source of the transistor that is the incremental V D. Everything here is incremental, this is the incremental equivalent circuit. If I do that, what is that, this V D is nothing but, this current flowing into the parallel combination of R D and this series branch.

So, V D by V G S equals minus g m times R D times R L plus 1 over j omega C 2 divided by the sum of everything R D plus R L plus 1 by j omega C 2. Now, previously we had only R L in the numerator for V o, if you look at this expression. So, the bottom line is, the drain voltage magnitude will be greater than the output voltage magnitude. And this is especially so if R D is very large. So, let me rewrite this as minus g m one plus j omega C 2 R L 1 plus j omega C 2 R D plus R L. So, now you see that you have this extra factor one here, if R D is very large the drain voltage can become much larger than the output voltage. As far as the incremental equivalent circuit is concern, there is no problem at all. If you satisfy the earlier condition, you will get the value of V naught, which is minus g m times R D parallel R L times V G S.

But, in practice, you also do not want the voltage across the transistor to become very large, because it is after all the non-linear device and that will cause nonlinearities. So, in this case, you have to satisfy both conditions that is you want the voltage here to be equal to V o, not much larger than V o. In this case, you have to satisfy both conditions, you want this number to be much more than one, and this number to be much more than one, that is omega C 2 R L to be much more than one, and omega C 2 times R D plus R L to be much more than one. And you clearly see that this is the stronger condition as far as C 2 is concerned. And if R D and R L are about the same magnitude, these two are about the same. If R D equal to R L, this is two times that, so it is not a big problem, but if R D is ten times larger than R L, what can happen is it could satisfy this condition and not that one.

So, typically on the output side, you try to satisfy this condition that is omega C 2 times R L being much more than one. The reason I went through all of these calculations is make sure that this is not for the output voltage, the output voltage will come out just fine, even if you satisfy this one. This is just to make sure that the drain source signal voltage equals the output voltage. So, I hope you understand exactly how these criteria are arrived at. Essentially, it is like evaluating time constants, which you would have done in basic electrical circuits course. As I said please revisit that you need to know sinusoidal steady state analysis or phasor analysis in order to do these things fluently.

And once you do that, once you understand these things for first order circuits, which is what we most often encounter, the criterion is really easy. You identify the capacitor, you identify the resistor across it and make sure that the capacitive reactance is much more than the resistive, the capacitive reactance is much smaller than the resistive reactance.

Now, one last thing when we have multiple capacitors, what do you do, the easiest thing is, I mean you could calculate the entire transfer function with multiple capacitors all together, it can lead to very messy expressions. So, what do you do is the following, you take one capacitor at a time, and for calculating the value of that capacitor while doing that assume all other capacitors are shorts. This way you will only have to consider first order circuits. And each of this is each of this is only going to give an inequality, it says that capacitor has to be much larger than something, so you make it ten or twenty times larger than that and everything will be fine.