Analog Circuits
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Module - 02
Lecture – 14

We have now come up with the circuit which can add dc voltage to an ac voltage so that to the transistor we can provide the combination of the operating point and the signal. So, at the gate of the transistor or between the gate source, we need to have 3 volts plus V s. And how do we do that to get 3 volts plus V s, we need to have source corresponding to V s the signal source. For now, I will ignore the source resistance R s later I will put in and see what the effect is. So this has to be coupled through a capacitor C, and the 3 volts source has to be coupled through resistor R. Now this V s is certain frequency omega naught; if it is consist of multiple frequencies, this will be the minimum possible frequency, and the capacitor size such that is omega naught C is much more than 1 by R. There are many ways to express this, this is what it means.

So, at omega naught this is almost a short. So, all of V s comes here and the dc this is an open, so dc just appears there, that is the idea. Now the 3 volts itself is produced from a higher voltage source 23 volts in our case; and R 1, R 2 where the ratio R 1 by R 2 is such that the Thevenin voltage here is 3 volts. We also know that this whole thing is equivalent to a 3 volts source in series with Thevenin resistance whose value is R 1 parallel R 2. So, this entire thing, this three volts plus the series resistance that is the same thing we have here, and the whole thing can be replaced by 23 volts and a resistive divider. So, what do I do now, I will remove this and instead of three volts with the series resistance, I will have 23 volts and the resistive divider R 1, R 2. This is exactly same as the circuit I had before. If you are not convinced, please go through the chain of reasoning once again and convince yourself that this the same as having 3 volts in series with a resistance.

So, what do I have to do to the gate of the transistor, I would have a divider where this is connected to 23 volts. And the signal source is coupled like this and what it be say earlier omega naught C must be much greater than 1 by R, and R is nothing, but R 1 parallel to R 2. So, omega naught C must be greater than 1 by R 1 parallel R 2. Now what do we do with the load, the load also must be ground referenced, that is, the load is like this. Now we know that the drain of the transistor must be connected to the load for signal frequencies. So, how do you do that the arrangement is very similar to what we did here. In this case, we wanted to add an operating point signal, 3 volts to sinusoidal signal V s; in this case, at the drain we will have some operating point which is not zero, which choose the V D S operating point to be three volts, and we will have that plus the signal and only the signal must be applied to R L and this must be ground referenced.

So, in other words, we will have V D S 0 across the drain source. Let us go back to the original configuration of the amplifier, this is what we had and here we had 3 volts plus V s. And we had biased it like this, where this is 23 volts this is 100 kilo ohms and across this, we have an operating point of 3 volts and the incremental signal is nothing but minus g m R L V s that we get from the incremental circuit. So, this is the incremental part. Now the problem is we cannot have R L like this. We want everything else to remain the same; three volts plus V s over here and across the drain and source, we will have three volts minus g m R L times V s; hopefully your convinced of this, if not go back and carry out the incremental analysis of this again.

So, this is the operating point, it does not have to be three volts, it has to be greater than V G S minus V t. In our numerical example we choose this to be 3 volts. And R L, it cannot be connected like this, I would not the show connection here; I will assume that somehow the transistor biased correctly. So, my R L has to be here. And across R L, I need to have the amplified signal that is minus g m R L times V s. Again, I make use of the fact that this part here is dc or zero frequency and this part here is the frequency of omega naught. So, what does it mean, this node here as to be connected to this node for omega naught, but it should not be connected for dc.

So, the answer is pretty obvious, what is an element that I can connect here, which behaves likes a short circuit for omega naught, but an open circuit for dc; if it is open circuit, it is not connected. You see that the capacitor is an open circuit for dc. So, this will go away, if I connect the capacitor here and also, let me call this C 2, and also the impedance of the capacitor drops with frequency. So, if you choose C 2 to be sufficiently large at the frequency omega naught, the impedance of the capacitor will be much smaller than the load resistor, and this appear almost like short circuit. So, we have to make sure that 1 by omega naught C 2 is much less than R L, so that is how we have choose C 2. So, this the way of connecting the transistor; by the way, this is grounded connecting what is across the drain source of the transistor to the load resistor.

So, what I need to do that is this C 2 and to distinguish this capacitor from the other capacitor, let me call this C 1. Now I still need to have some current flowing through this, the operating point current, I D has to be flowing through this, and this V D S the quiescent drain source voltage has to be more than V G S minus V T. So, how do ensure that, I have to use similar arrangement does before that is I need to have some dc voltage let say still take this 23 volts. I have connected back here, I will also connect it to this through a resistor R D. Remember this is not in the original circuit, I have used it to have some path way for this current through the transistor this quiescent current here I D of 200 micro amperes in our example cannot flow through the capacitor, this blocks dc. So, there has to be some path for this current and that is this resistance R D. So, this is my final circuit, we do have some extra components compare to our ideal amplifier that is we have these resistors R 1, R 2 and we have these R D, let see what the effect is.

So, I will redraw the whole circuit; and this time, I will also include resistance in series with the signal source. This is V s and I have a capacitor C 1, R 1, and R 2 and I have a MOS transistor here, and have this resistance R D, which is required to bias the drain. And the load is connected to another capacitor C 2 to R L. Now this is my complete amplifier and I will explain this later. This is the very basic amplifier using a MOS transistor and it is known as a MOS common source amplifier. We spend quite a lot of time getting here many times, you just see the circuit thrown in, but we need to understand why we have every one of these components so that is why I took time deriving this whole thing.

So, let us now start from this and analysis the circuit as though we seeing it for the first time. And also there are different things here. First of all there that is this whole circuit and it behaves some way for dc, because we have these capacitors which will be open circuit for dc. And also for dc which is the total picture we have to consider the non linear nature of this device, let me call this M 1 the MOS transistor. And then we have the increment picture that is over and above the operating point, if we apply some signal what happens. And also in our case, it is assumed that this incremental signal V s is an ac signal some sinusoidal signal of frequency which is at least omega naught and these capacitors behave differently for ac. So, we will have a different equivalent circuit.

What do we have in our amplifier, let me identify these are for biasing the gate that is essentially to establish the quotient V G S. This R D and the 23 volts this is for biasing the drain to establish a quiescent V D S. Remember in the prototype common source amplifier, neither this R d nor R 1, R 2 are there to be able to establish the correct operating point we need these components. So, we will see the effect these they will have some effects on the circuit. And we have our signal source and we have the load and this is of course, heart of the amplifier, this is the amplifier device.

And finally, we have these capacitors C 1 and C 2 in this case we have to add a dc valued the signal and this case we have to couple the voltage across the drain source of the MOS transistor to the load and these are known as ac coupling capacitors this C 1 and C 2 these are ac coupling capacitors so, that means that essentially that behave differentially for ac and dc. So, they let the ac signal through this way, but they are open circuit for dc. And finally, very important think we have the supply voltage. Now notice that we have single supply voltage for the whole thing. So, we have accomplished our goal of using a single battery, and this is usually referred to with the symbol V D D meaning it is there for drain side bias of course, we also bias the gate using the same supply, but conventionally the supply is called V D D. So, what will do in one the next lesson is to take the circuit and analyze it properly, and see how it conforms to our original design or deviates from it.