Analog Circuits
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Module - 03
Lecture – 04

Now, we understand the common source amplifier, and also the limitation caused by the transistor output conductance and so on. Now, in this lesson we will look at some practical aspects of a common source amplifier and in general any amplifier. The point is that the parameters of a transistor, or in general any active device semiconductor device vary quite a lot, that is if you realize a lot of transistors and you nominally intend to have the same current factor and same threshold voltage and so on. In reality they will come out to be different from each other, and also it different from one manufacturing batch to another. And also like many semiconductor characteristics, these things are a strong function of temperature. Now, these will have some effect on the amplifier performance, we will first see what that is and try to come up with techniques that fixed these things to the extent possible.

So, let say the transistor is operating at some operating point; it has some V G S, some V D S, and a certain I D. Now the small signal parameters of this g m, we know it is mu n C ox W by L V G S minus V T. Again I am ignoring the one plus lambda V D S term. And also the output conductance g d s is lambda times I D. So, these are the parameters of the small signal equivalent circuit. In the small signal circuit, we will have the g m V G S, where this is the incremental V G S; and we have the conductance g d s. Now, how did we setup the operating point in our common source amplifier. Basically, we wanted a certain g m, and from that we found the V G S, and the way we fixed the operating point was to fix V G S to the desired value. So, if you recall our circuit looked like this, I am not drawing the complete circuit, but only the part that fix is V G S. And in our particular example, we had a 23 volts supply and an appropriate ratio of resistors such that the operating point V G S was equal to 3 volts. We fixed V G S to 3 volts.

So, now let see what happens with this type of setting up of the operating point. So, g m is mu n C ox W by L V G S minus V T; and as usual I will consider the threshold voltage to be 1 volt, and mu n C ox W by L to be 100 microampere per volt square. Now in our circuit, this is fixed at three volts. So clearly, if you calculate this, this will come out to be 200 micro Siemens, which is what we wanted. Now, it turns out the threshold voltage of a transistor can vary considerably. So, let say it varies from 0.8 volts to 1.2 volts; it can vary by even more than that.

So, if V T happens to be 0.8 volts, and let say the current factor does not change at all. What happens, this V G S minus V T will be three volts minus 0.8, which is two point two volts. So, this g m will turn out to be two twenty micro Siemens. So, I hope it is clear what I am doing here. In our circuit, V G S is fixed; and we thought that V T was one volt for our transistor, but who knows when you buy many transistors, it could be 0.8 volts or even smaller. So, if you do apply the same formula with V T being point eight volt, you will get 220 micro Siemens.

And similarly, if V T is 1.2 volts, V G S minus V T is smaller than what is required, it is one point eight volts, and g m will be 180 micro Siemens. So, you can see that instead of two hundred, we are getting either 220 or 180 or some value in between. Now, we have not even taken into account the variations in mu n C ox. So if mu n C ox varies by let us say plus ten percent, if it is higher by ten percent then g m will also be higher by 10 percent. And similarly if this value is lower by 10 percent, the g m will also be lower by 10 percent and so on.

Basically, g m is proportional to mu n C ox W by L, and any variations in mu n C ox, by the way like I said mu n is mobility of the semiconductor and that varies quite a bit with temperature. So, there are couple of things here, one is that the value of V T may not be known exactly; one possible way though tedious is to when you buy transistor you somehow measure V T and then you design your amplifier. Even that does not solve your problem, because over temperature things will vary. So, let us say you measure it at room temperature, let us take this particular case; V T is only 0.8 volt, so to get 200 micro Siemens, you calculate whatever V G S is required, and then apply that V G S, and that does not help, because if V T changes with temperature, this g m will shift, change with temperature and so on. And similarly as current factor changes with temperature, g m will change with temperature. So, we need to have a more robust way of setting up the operating point, so that the g m does not vary as much as it does now.