Analog Circuits
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Module - 03
Lecture – 06

We now have determined that biasing the transistor at a constant drain current is better than biasing a transistor at a constant V G S that is the sensitivity of the trans conductance g m to variation in transistor parameters such as the current factor and threshold voltage will be much smaller if you maintain the same current through a transistor as opposed to maintaining the same gate source voltage that is the context of the following. There is some nominal threshold voltage and nominal current factor, let say one volt and 100 microamperes per volt square, but these quantities vary with temperature for a given transistor and also they are vary from transistor to transistor. So, every piece that you make with a different transistor will have a different gain and also it will have different gain at different temperature.

We would like to keep this specification as tightly controlled as possible, so this means that the our original idea was to make a common source amplifier where every common source amplifier you make which is basically copies of the same design should have a V G S of 3 volts. Now, we know that is not a good idea. What is the better idea is to somehow make sure that in every amplifier that you make the transistor carries a current of 200 microamperes. Now, how do we go about doing this; it is not as easy as the sounds, as we will just see.

This is correct, but how do we do this. The point is that the transistor is unilateral device, this by the way is true of all the controlled sources and so on. What does it really mean, for now let us ignore the slight dependence of drain current on the drain source voltage. So, we can safely say that I D depends only on the gate source voltage, that means that, if you apply some gate source voltage, and of course, we will assume that V D S is more than V G S minus V T, so that this approximation is correct. If you apply certain V G S, you will get a certain current. But you cannot apply a certain current and expect that V G S will be magically found. Now, every control source is of the same type.

So, let us take a voltage controlled voltage source. This is also a unilateral device, this means that so let say this is k times V i, if you apply one volts here, here you will get k volts, but you cannot apply k volts to this side. This circuit has no meaning, you cannot apply k volts and expect one volt on the other side, so that is the meaning of a unilateral device. So, if you have a two port network, if let say y 1,2 is zero that becomes a unilateral device, that is you applies something to port one you will get something at port two, but you cannot apply something to port two, and expect something at port one.

So, this is the unilateral devices as opposed to, let us say resistor, this is an important difference. So, resistor follows V equals I R, and I could always write this as I equals V by R. Now, this is just mathematical relationship, but it also works this way, that is if you apply a current you can force it through a resistor, and the voltage that will be found will be equal to I times R. Alternatively, you could also apply a voltage and the current that flows will be equal to V by R. Now, a MOS transistor is not like that. So, I D is current factor K n times V G S minus V T square. I can of course, invert this mathematical relationship, I could say V G S is V T plus square root of two I D by K n. This is possible, but whereas, I can do this, I can apply a V G S, and this I D will flow. This will work and this is just to make sure that the transistor remains in saturation, you need some bias.

Other hand, you can do the other way around, though you can calculate it you can calculate V G S from the current or current from V G S. You cannot apply some I D here, and expect that this V G S will appear there, it would not work at all. If you do, in fact make this circuit, what happens is the drain source voltage will reach some very high values and the device will go out of its limits where this model is valid, something else will happen. Either the device could be damaged or the current will be flowing into some other junctions in the device and so on, so this does not work at all. Exactly, like a controlled source, where the control flows only in one direction. So, this is very, very important thing to remember; although you can invert the mathematical relationship, you cannot arrange the circuit in the converse direction. V G S is the controlling quantity, and I D is the controlled quantity, the other way around does not work.

So, how do we setup a transistor so that a fixed amount of current is flowing, there is only one way, there is only one quantity that changes the current in a MOS transistor and that is the gate source voltage. So, what you have to do is the following. Let say you are doing this manually you have an ammeter here, and you apply some bias V D S which is more than V G S minus V T, and this is not difficult to arrange. If you choose a sufficiently high value here, it will remain in saturation. Then, I need to connect a voltage source to this V G S, I have to keep on varying this, so I vary it, I look at the ammeter reading then let say it is fifty micro amperes then I know that I want to have a current of 200 microamperes. So, what do I need to do, if it is 50 microamperes, I know that I have to increase V G S to increase the current, so I increase the V G S little further may be it becomes 100 then I increase it further, it becomes 150 and so on. And I increase it finally, until it reaches 200, and then I stop there so that will work.

It could be that I started off with that very large value of V G S, I do not know what to apply, and the current is already 400 microamperes. I know that the current is more than what I want, which is 200 microamperes, so I have to go on reducing V G S until this current becomes equal to the current that I want. So, in other words, I have to observe the actual drain current, I have to compare it to the desired drain current. And in this example, this is 200 microamperes. And based on whether the actual drain current is less than or more than the desired drain current, I have to increase or decrease V G S as required. So, in other words, I have to look at the output, which is the drain current and control the input, and I have to do it in such a way that the error between the actual drain current or the actual value and the desired value becomes smaller and smaller.

In other words, this whole process is known as negative feedback and this is what I need to use. So, the way to set a fixed drain current is through a negative feedback, because it is only by changing V G S that you can control the drain current. You cannot apply the current directly to the drain of a transistor and expect that current to flow. The transistor will not be operating in the correct region of operation. The way to do is to compare the actual drain current to the desired drain current and continuously adjust the V G S such that the error between the desired and actual value goes to zero. In other words, we have to use negative feedback. And there are number of schemes with which you can do this, and you will quickly see that the number of biasing arrangements are really, there are lots of them. What is more important is to understand the principles behind them and not learn individual topology by heart. So, you need to know the simple topology, but the principles are more important. So, we will discuss all these arrangements in the forthcoming lessons.