Analog Circuits
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Module - 03
Lecture – 01

We now understand the basic common source amplifier topology. It is the basic amplifier using the two port, but to setup the correct operating point for the transistor, we have some additional components, which also appear in the small signal incremental picture and influence the gain. Now, we go back to the model of the MOS transistor, it turns out that we had omitted the particular detail of the MOS transistor and that further reduces the gain.

If you recall the I D V D S or the output port characteristics of the MOS transistor, this is what we had. We had a family of curves for different values of V G S, and of course, for V G S less than V T current would be zero. And let say V G S of 2 volts, by the way I am still assuming the same transistor that I always been using in the examples, which is a transistor which has a threshold voltage of 1 volt, and a current factor of 100 microampere volt square. And we know that for V G S of 2 volts, the current increases and saturates to 50 microamperes, this is V D S in volts. And also if I plot the I D versus V G S, assuming saturation region in this case, which means that V D S is assumed to be large enough. We would get a parabola, this is in volts, this is in microamperes.

For a V G S of 2 volts, we have 50 microamperes; for 3 volts, we have 200; and for 4 volts, we have 450. And the output characteristics also for V G S of one volt, it saturates to 50 microamperes. For V G S of 3 volts, it saturates to 200 microamperes; and for V G S of four volts, it saturates to 450 microamperes. The key assumption here is that in the saturation region that is to the right side of this curve, there is no variation of current at all with the drain source voltage that is all these curves are perfectly flat as we wanted for our amplifier to maximize the gain. It turns out this is not truly the case, the current does increase with V D S weakly though, in this region as well.

So, current increases weakly with V D S in saturation region. And if you attend a courses on device physics, you will understand why this is the case. The saturation region current equation was mu n C ox by two W by L V G S minus V T square, this was for saturation, which is to say V D S is more than V G S minus V T. Now, it turns out that like I said there is a dependence on V D S, whereas, this equation has no V D S at all and that is introduced by an additional factor one plus lambda V D S. And you can see that as V D S increases this entire thing, the current increases. And the units of lambda are an inverse volts, and this is typically a small number; let say something like this point zero five inverse volts or something like that, so that this correction is still usually small compared to one. Now, it is also depends on the technology itself. We would not go into those details. As far as we are concern, this lambda is an additional model parameter for the MOS transistor.

And this correction factor appears only in the saturation region, because the physical phenomenon by which this current increases is known as channel length modulation and that happens only in saturation region. So, now if I plot this, what happens, the current obtained from this term what I have shown in black is what I have plotted here.

Now, to this, I have to have a multiplying factor of one plus lambda V D S. What happens if I do that, in the saturation region, the current will increase slowly, so that is what we get. This is including the factor one plus lambda V D S. So, this is the true characteristics of the MOS transistor. Now, you can quickly spot a problem here. I told you that this correction factor appears only for the saturation region and not for the triode region. Now, what happens is you can see that the triode region remains as it is, and because at this point, you multiplied by some number more than one, because it is one plus lambda V D S. So, it appears that there is a discontinuity, but do not worry about it, the actual model of the MOS transistor is very sophisticated and complicated and it does not have this discontinuity.

It is because we are using over simplified models that we have this problem, but that is ok, but we need do this over simplified models for any hand calculations. So, do not worry about this discontinuity, it is not going to be there in the real MOS transistor, but we will use these models which do appear like they have a discontinuity without any problems. Because the purpose of hand calculation is to get an idea of what is happening, to get the exact answer, we will use the sophisticated model in a computer simulator and that usually has hundreds of different parameters.

So, the phenomenon by which this additional factor appears is known as channel length modulation. Now, if you do not look at the device physics, this term would not make any sense at all, but that is all we need to know is in saturation region, we have this additional factor. And lambda is the parameter that is given to you. And it turns out that lambda itself depends on the length of the transistor, and this k lambda is some proportionality constant. Again do not worry about exactly why these things come about; usually in this course, lambda itself will be given or if it is given this form, the k lambda will be given. So, as far as we are concern, we have to model in the correct way using this expression and possibly this one if necessary.

So, this has some implications on the amplifier that we will look at by deriving the small signal model corresponding to this new model. So, this is the large signal model of the MOS transistor, including this additional factor due to the channel length modulation. We will derive the small signal model, and see what effect it has on the amplifier.