Analog Circuits
Prof. Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology, Madras

Module - 02
Lecture – 10

We are now familiar with the large signal and small signal characteristics of practical amplifier device namely the MOS transistor. We will now try to make a two port amplifier using the MOS transistor. The signal source as we have seen earlier is modelled by a voltage source in series with a resistance. This is the generic model that holds for any source as you know from Thevenin's theorem. And we have a two port, this is how we consider it, we will soon replace it with the MOS transistor; this is the common port, and the load is connected to the other side. Now what is this two port, this is the small signal incremental equivalent of the nonlinear two port. We have seen that we need nonlinearity to get gain and we will get gain only in the incremental sense. So, what we need to do is to replace this with the incremental equivalent of the nonlinear two port and eventually come up with the complete circuit including the nonlinear device, which is the MOS transistor.

So if I replace the incremental equivalent of the MOS transistor here; we will have V S, R S and the incremental equivalent of the MOS transistor is just this, y 1 1, y 1 2 and y 2 2 are all zero. We will have V G S here. Let me show the correspondence, this corresponds to the gate terminal, the common one is the source terminal and this terminal two, port two is the drain terminal. So, we will have gate, source and drain; and of course, I have assumed that the transistor is operating in saturation region. So, what I have done is to replace this with the small signal incremental equivalent of MOS in saturation region, because in saturation region we have the characteristics which are desirable to make a good high gain amplifier. So, this source will be g m V G S.

Remember, we have to make the circuit with the real MOSFET and its incremental equivalent should turn out to be this. So, just to be clear about what we are doing here this is the incremental equivalent of the amplifier. We have not shown the complete circuit yet, the complete circuit will contain a MOS transistor, and if we replace the MOS transistor with its incremental equivalent at the correct operating point, we should get this circuit. So, we will see how to do that. We have to

go through a several steps and we may or may not be able to do it exactly. So, what does this do, it is very simple between gate and source, we have an open circuit, so the current flowing in this branch is zero. So, the voltage V G S simply equals the input source V S. This we saw earlier when we evaluated the desirable y parameters, we saw that y 1 1 being zero, and y 1 2 being zero; eliminate any voltage division from V S to the first port of the circuit. So, we will get all of the input voltage as V G S, and this causes a control current g m V G S all of which flows into R L.

So, the voltage here the output voltage will be simply, because the current is flowing upwards through R L, this will be equal to minus g m R L times V S. So, the output voltage of this amplifier is minus g m R L times V S, and this minus g m R L is the gain. And we can set this to whatever value we want; the input source and the load will be given to us that is V S, R S and R L are given. So, to have a desired gain, we have to set the value of g m, and to set the desired value of g m, we have to set the correct operating point for the MOS transistor. Now, this gain has a negative sign; for now just ignore it; it is just a matter of fact of this type of amplifier. Later you will see many other topologies some of which will give you a positive sign, some of which will give you negative signs. So, this is what the small signal model of the amplifier using the MOS transistor should look like. I am not done much here, earlier had this idea to connect source to one port of a two port network, load to the other port and between the source and load, we will have some gain and all I have done is to replace the this two port with the small signal linear model of the MOS transistor.