Analog Circuits
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Module - 01
Lecture – 14

So what we do is the following when encounter a nonlinear two port in a circuit, first we obtain the operating point by the usual painful way of solving any nonlinear equation. Once we have the operating point, things are easy; all we do is substitute the nonlinear two port with a linear two port. And what are the parameters of the two port, they are nothing but partial derivatives of the large signal characteristic at the operating point. And what is the circuit equivalent; in case of a one port network, the equivalent was the resistor; in case of a two port network, the equivalent is the linear two ports.

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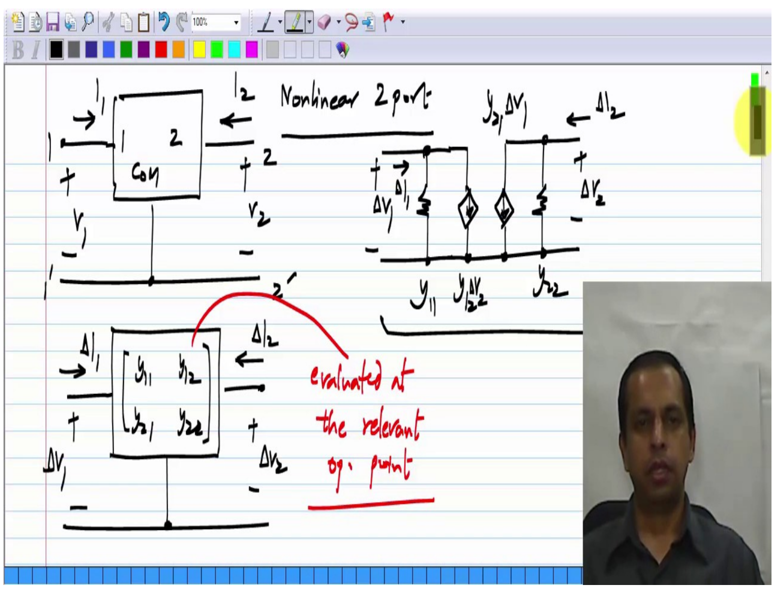

And what is that we have our nonlinear two port. The equivalent of this is a linear two port, sometimes here just given the matrix inside the box, you know exactly what it means. If this is V_1 , I_1, V_2, I_2; this will be ΔV_1, ΔI_1, ΔV_2 and ΔI_2 and the most important thing is first of all this is valid only for small increments and this is evaluated at the relevant operating point. Just like you calculate the small signal resistance diode at the desired operating point, you have to calculate all these parameters, these partial derivatives at the relevant operating point. Now, you can use this in equations usually we find it more comfortable to work with circuit equivalence, so the circuit equivalence of this also you know, it will be on port 1, you will have a conductance y_{11} or a resistance 1 over y_{11}.

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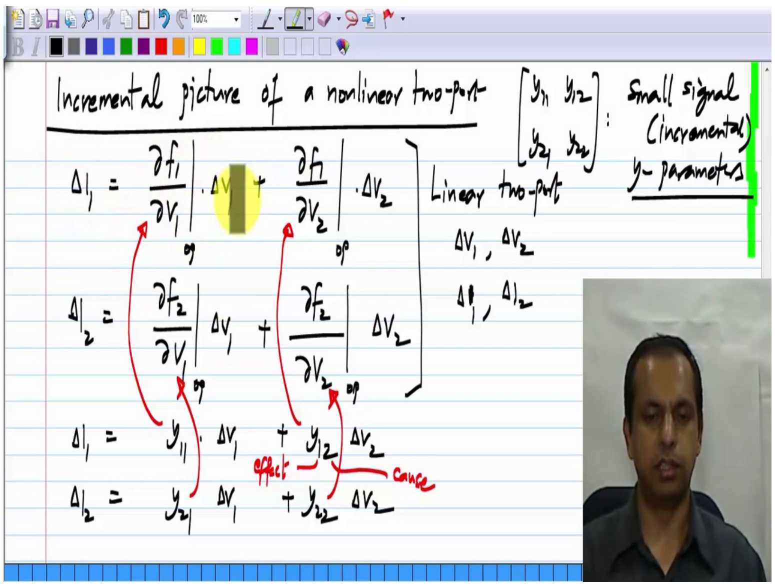

By the way it must be pretty obvious that the dimensions of all these are conductance that is clear from here. You have currents here, and voltage is there, you have to multiply the voltage by something to get a current, so this has to be a conductance, so do all four. And you will have a control source which will be $y_{12}\, \Delta V_2$, and the other side, you have a control source which is $y_{21}\, \Delta V_1$ and a conductance y_{22} or a resistance one over y_{22}. This is ΔV_2, this would be ΔI_2, and this would be ΔI_1. Just like you replace the diode or a two terminal nonlinearity with resistor, you will replace the two port with a linear two port, so that is all, that is there to it…

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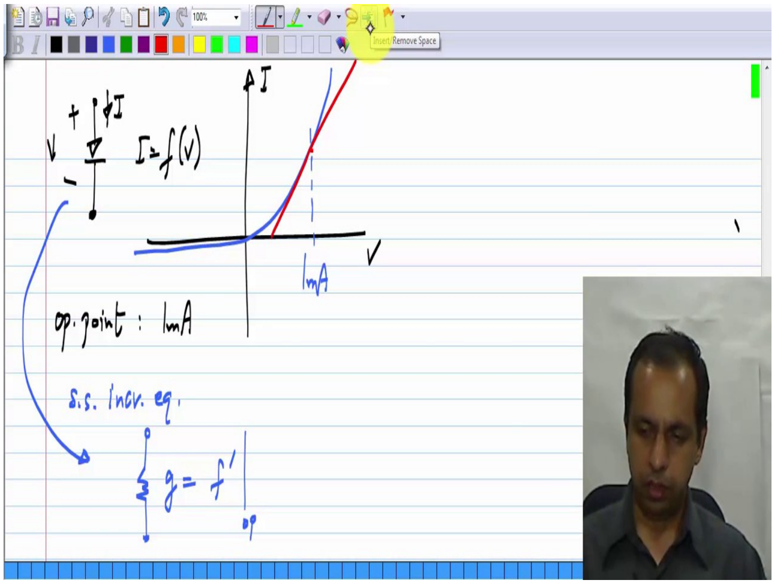

Now one more thing is we know that let me again take a example of diode or you could consider any other one port element or a two terminal element, we have the plot of current versus voltage. And we know that for a diode, it is something like that. And let say it is biased at a current or the operating point current is 1mA. We also know that the small signal incremental equivalent; what is it, it is a resistor. We know how to find the value of this resistor; this r will be basically if the nonlinearity is f, r will be f' the conductance g will be f' at the operating point, so that is you have 1mA. And it's the slope of this graph.

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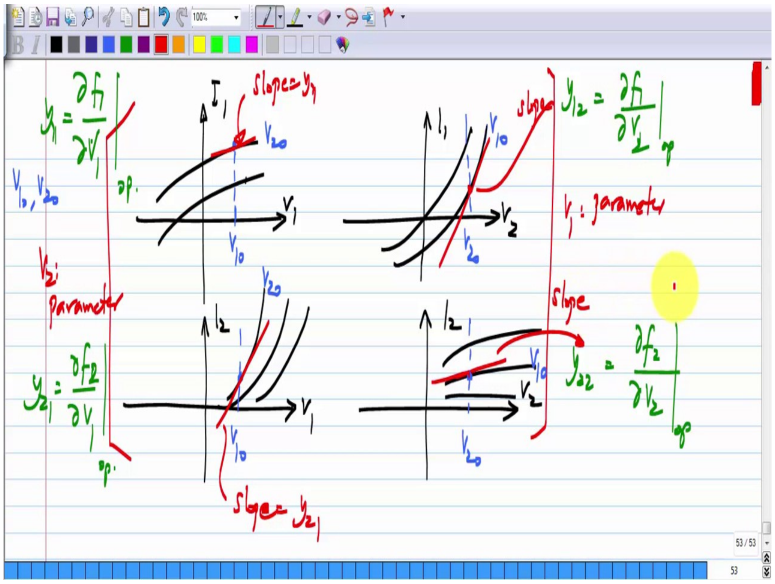

What is it for a nonlinear element, as we saw earlier a graphical depiction of a nonlinear characteristic requires four plots; I_1 versus V_1 with V_2 as parameter. So for these two plots, V_2 is the parameter; and for these two plots, V_1 is the parameter. Now we know that the incremental parameter y_{11} is nothing but $\partial f1/\partial V_1$ at the operating point. We need the slope of the curve I_1 versus V_1, which is in this graph at the operating point. And let say the operating point is something, we will what it is, let me call it V_{10}, V_{20}. So what do you do, you look at where V_{10} is on this graph, and you select the curve that corresponds to V_1, and the slope of that at that point that is equal to y_{11}. Similarly on this curve, we know that y_{21} is $\partial f2 / \partial V_1$ at the operating point. You look at where V_{10} is, you pick the curve corresponding to V_{20}, and the slope at that point equals y_{21}.

Similarly, these two graphs give you y_{12} which is the derivative of f1 with respect to V_2 at the operating point. So, here you look at where V_{20} is, you pick the curve corresponding to V_{10}, let say it is this one, then the slope there equals y_{12}. And finally y_{22} is the partial derivative of f2 with respect to V_2 at the operating point. So again you look at where V_{20} is, you pick the curve corresponding to V_{10}, so let say it is that one then the slope there, slope of that curve at the operating point that is equal to y_{22}. So in general all small signal parameters are basically derivatives of the large signal curves. This I_1 versus V_1, these curves are known as large signal curves, it is large signal, because it is not small signal; the small signal refers to small increments around the operating point, large signal refers to the total characteristic. And the small signal characteristics are derived from the large signal characteristics, the small signal linear parameters are basically slope of the large signal characteristics at the operating point. This is true for one port two port or any number of ports, any kind of nonlinearity.