Analog Circuits
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Module - 01
Lecture – 06

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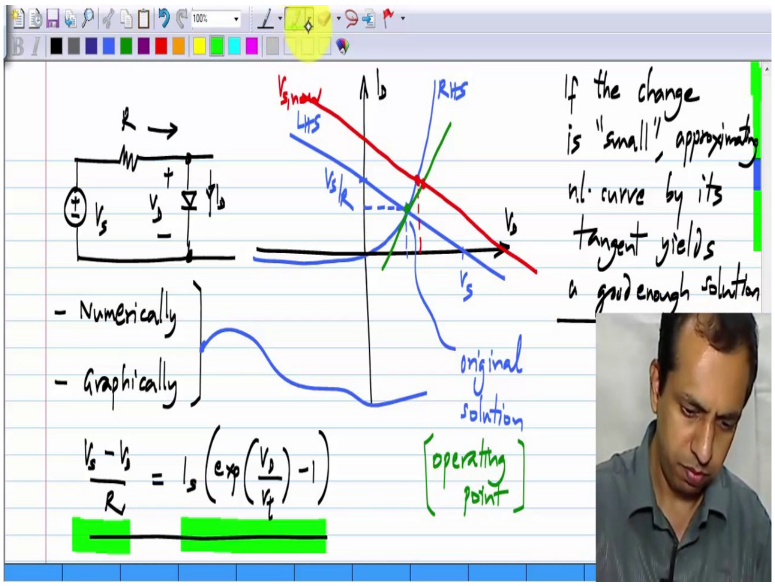

We have seen how cumbersome it is to analyze circuits with nonlinear elements. What we will do now is to look at approximate ways of solving nonlinear circuits. We have previously considered an example with a two terminal nonlinear element. And we can solve this numerically or graphically, but the real difficulty is that for every change in the input, we have to redo this. This by itself is cumbersome and then for every value of input we have to redo this. And of course, when you have time varying signals in our circuit, the input will be changing; so for every point of the time varying signal, you have to redo the numerical or graphical calculation, and this is very difficult. At least to get some insight into the circuit and for hand analysis, we would like to avoid these. So let us see what we can do.

I will repeat the graphical solution which we had got. Essentially, we are solving for this equation, the current in the resistor being equal to the current in the diode. The current in the resistor is $(V_S - V_D)/R$ and that is equal to the current in the diode, which is the $I_S \left(e^{\frac{Vd}{Vt}} - 1\right)$.

So, what we do is we draw a graph for the right side and the left side and see where they meet. So, this is the plot of the right hand side, this is the plot of the left hand side, and they meet here, which is the solution. Now, as V_S changes, we have to repeat this. So, for a larger value of V_S, in this particular case the right hand side does not change, but the left hand side does, and we have a new solution, new point of intersection with the nonlinear curve.

The simplification that we will make is the following. You see that the original solution is here, and the new one is there. We will assume that as V_S changes, it will move to a new point on the nonlinear curve, but it will not move too far away, that is this point is close to this point. Now, we will see later what close means, the point is that if you do not move too far away on the nonlinear curve, then around this point, if you do not move too far away on nonlinear curve, we can approximate the nonlinear curve by straight line that is you take any curve, you zoom into very small part of it, it will look like a straight line, so that is the principle we use. So the idea here is that if we do not move too far away, let me call this as the original solution, this is really just the first solution that you calculate. And this has to be got from nonlinear numerical or graphical solutions, there is no shortcut to this.

What we are trying to do is at least to save some trouble while calculating the solution for subsequent points when V_S changes. So, for one value of V_S, we calculated exactly and the other values we approximate this nonlinearity by a straight line, assuming that we do not go too far on the nonlinear curve. Now, what is the straight line that we can use, so it is the tangent of this curve at the original point, and the original solution is known as the operating point of the circuit. So, I first show this graphically, because it is very easy to understand, it can also be proved formally from the equations. So, we are approximating this curve, which is the blue curve - the nonlinear one by its tangent which is of course this straight line at the operating point. And operating point for now you can consider it as the very first value that you calculate. For some value of V_S, you calculated the exact solution that is the operating point.

So, now, how does this help, because you know this is the straight line. For all other points, we are computing intersection of two straight lines and this is very easy. In fact, we do not even have to calculate the intersection explicitly, I will show the method by which we will do that, because when V_S changes to this corresponding to this red curve the actual solution is that one, but if you consider the intersection with this approximate straight line the approximation solution is there, and they are sort of close to each other. And if you consider a point that is closer to the original operating point, they will be even closer to each other. So for now we will state the criteria vaguely; if the change is small then approximating the nonlinear curve by its tangent yields a good enough solutions. So this is what we will do. Now this is approximate, but it turns out this approximation is quite good and lot of practical context, so we will use this widely.

But of course, you must understand the limitations of this approximation; you must not go too far from the operating point. And how far is too far very much depends on the context that you are working in. And it also depends on how much accuracy you want in the first place. If you want the solution to be very accurate then you cannot go too far from the operating point, but if crude solutions are ok in some cases; many cases you just want to estimates, so in those cases, you could go further from the operating point.