Basic Electrical Circuits
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Lecture – 120

We will now consider an R C circuit example with a step input which is not zero.

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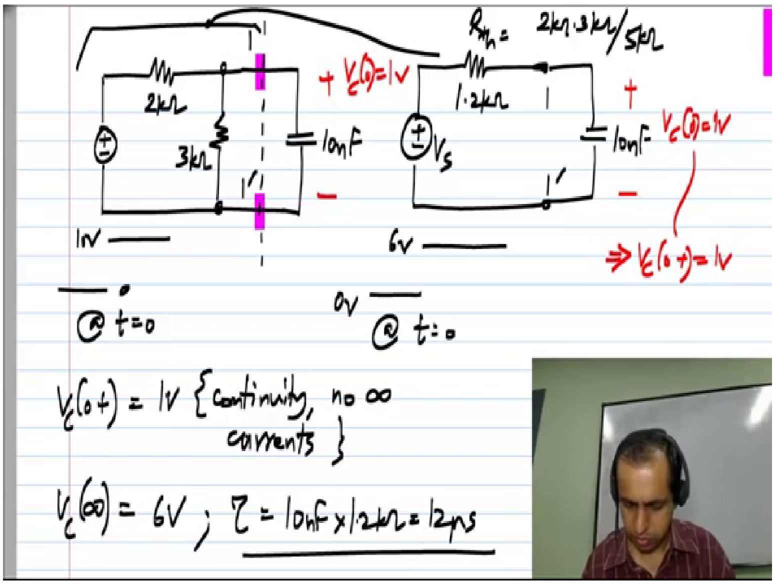

Let me make the circuit slightly more complicated by having two resistors and a capacitor here this is still ((Refer Time: 00:29)) very, very easy. So, let us say this is 2 kilo ohm and this is 3 kilo ohm resistor and this steps from 0 to 10 volts at t equals 0 and we have a capacitance which is let say 10 nanofarads. Now, though we have two resistors this can be effectively reduce to a single voltages sources in series with the single resistors at the terminals of the capacitor using the familiar Thevenin equivalent.

So, these are 1 1 prime and whatever I have on this side I change to the Thevenin equivalent I won't show in steps, but you can this out for yourself I will have some V s and series with a resistance, the resistance happens to be the parallel combination of these two and that will be 2 kilo ohms times 3 kilo ohms divided by 5 kilo ohms, which is basically 1.2 kilo ohms and this V s you can again compute by the usual procedures use for Thevenin equivalent calculations, it will jump from 0 volts to 6 volts at t equal to 0.

So, please do the Thevenin equivalent calculation yourselves and we have I capacitor which is 10 nanofarads. So, this is now the familiar circuit, now whatever initial condition is there on the capacitor will still remain. So, let me say that the initial condition is 1 volt it happens to be their t equal to 0 just before the step is apply this has 1 volt and in this circuit the capacitor and series with in resistor and we cannot have infinite currents through the capacitor which will induces step change. So, the voltage across the capacitor will be continuous and even after this step is applied we will have 1 volt.

So, we have calculated all of these things in general terms. So, this means that we see just after the step V c or 0 plus is also 1 volt. Now, we know the general form of the solution you can do this in many, many ways. So, V c of 0 plus is 1 volt this is because of continuity and no infinite currents then V c of infinite which is final value is computed by assuming that the capacitors and open circuit, this is an open circuit then the resistance here it does not have any voltage drop across it.

So, all of V s appears between terminals 1 and 1 prime and V s the final value 6 volts the 6 volts will appear there and the time constant tau of course, is if you said V s to 0 we will have this R t h across the capacitor, so it is 10 nanofarad times 1.2 kilo ohms is 12 micro seconds.

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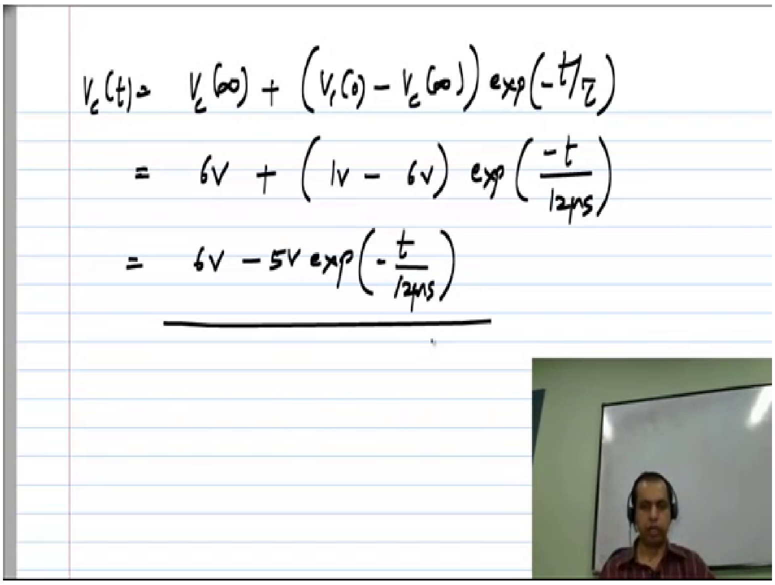

So, we can easily write out the expression we know that V c of t is V c of infinity plus V c of 0 minus V c of infinity exponential minus t by tau which is 6 volts plus the initial value 1 volt minus 6 volts exponential minus t by 12 micro seconds, which is 6 volts minus 5 volts exponential minus t by 12 micro seconds. So, that is the expression for it and you can do this in many, many ways basically the points it to be able to identify the time constant and the initial and final values.

Now, even if you did not reduce in to the Thevenin equivalent you had this circuit and wrote the differential equations for this circuit you would get exactly the same answer and exactly the same differential equations of course, in terms of the capacitor voltage V c and instead of Thevenin equivalent you could have converted to a Norton equivalent. So, again I am not going to show how to convert it to Norton equivalent that you already know from earlier lessons.

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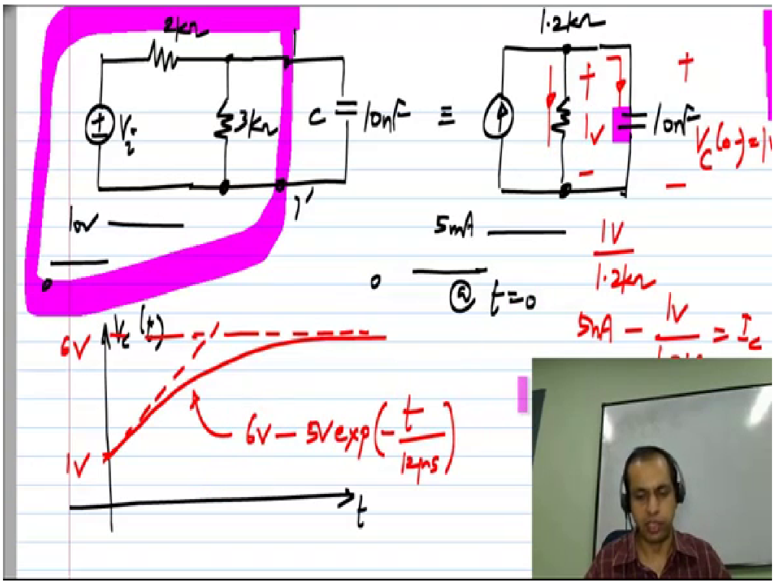

So, the Norton equivalent let me put down the original circuit, this step from 0 to 10 volt. So, now, if there is step change in the voltage source in an independent source in the circuit, then the Thevenin voltage or the Norton current can also show the same step change. So, we had this is let us say V i and it change from 0 to 10 volts and we have 2 kilo ohms and 3 kilo ohms and across these terminals we have the capacitor c which is 10 nanofarad, then the Norton equivalent of this part of the circuit will be a current which is the short circuit current and it will jump from 0 to 5 milli amps at t equal 0 across it we will have Norton's resistance which is the same as Thevenin resistance and equals 1.2 kilo ohms and we have a 10 nanofarad capacitor across it.

So, now, again it is quite easy to solve this gives a slightly different view point, now what happens is that again let us assume that V c of 0 minus is 1 volt and we do not have infinite currents flowing through the capacitor. So, V c of 0 plus will also be 1 volt, so I will show this is the sketch. So, add t equal to 0 minus and 0 plus will have 1 volt, what happens is because we have 1 volt over here and 1.2 kilo ohms.

So, a certain current is taken away by the resistor and that will be equal to 1 volt by 1.2 kilo ohms the remaining current 5 milli amps minus 1 volt by 1.2 kilo ohms. So, that will flow through the capacitor just after t equals 0 and that will make the capacitor voltage become larger and larger as the capacitor voltages increases more current flows in to the resistor, eventually very little current flows in to the capacitor all of it flows in to the resistor most of it.

So, the rate of change of capacitor voltage becomes slower and slower and slower and t equals infinity all of this current 5 milli amps will be flowing through the resistor producing 6 volts across it and no current will be flowing through the capacitor which means that it is voltage will be stable at 6 volts. So, it is start from 1 volt and reaches 6 volts and the equation will be exactly the same as before of course, it will be 6 volts minus 5 volts exponential minus t by tau if you set the independence source to 0 we just have 1.2 kilo ohms across 10 nanofarad which is 12 micro seconds.

In fact, you have to get the exactly the same answer as before; otherwise, you would be in trouble. So, that is the expression for it and this slope again you can calculate from the initial current flowing through the capacitor, because the slope of capacitor voltage is related to it is current or you can find it out by differentiating this expression.