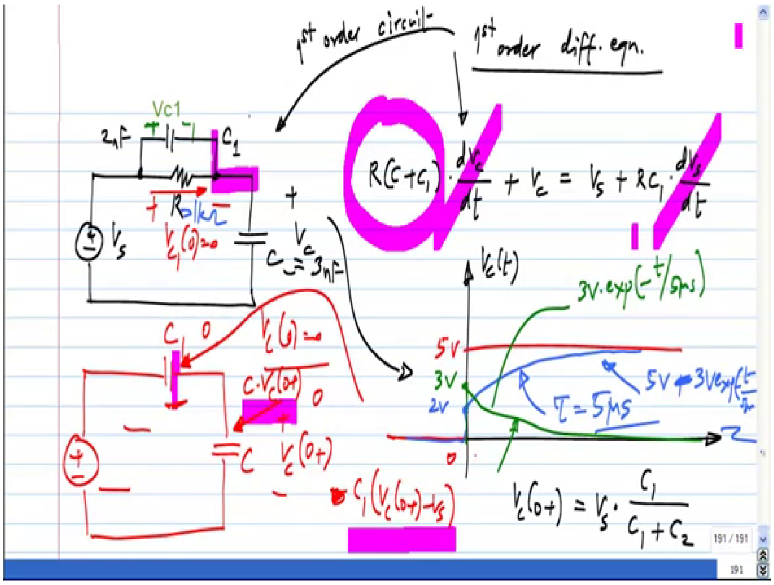
Basic Electrical Circuits
Dr Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology Madras

Lecture - 127

(Refer Slide Time: 00:00)



So, let us say V s to the step goes from any way 0 to 5 volts. What is V c look like? So, V s goes from 0 to 5 volts. What will V c look like? V c is 0 0, this capacitor has 0 initial condition. Now, we have done it without the capacitor C 1. What is the voltage on the capacitor C? What is the value of V c just after applying the step? So, V c of… Again that is before I do anything it has 0 volts across it. Now, my question is, just after applying the step, what is the value of V c. Now, previously we said the capacitor voltages cannot jump in the previous circuit and then, we said that it is 0.

So, first of all we have voltage across this capacitor also. So, before you apply the step, V c 1 of 0 is 0 and V c of 0 is also 0. Now, if you say that this voltage does not jump at all, then other voltage will jump. The same reasoning does not seem to apply. So, what is the solution? You understand the issue here, the V c cannot stay at 0 just after the step. So, what should it be? How would you find out the value?

Initially, let us add some of these two plates 0 and any current coming through R will be finite and it cannot change these things instantaneously. So, any instantaneous change can only come from the charge on this plate going in to the charge on that plate. See, first I said that, if you assume that V c is still 0 after the jump; that means, that only a finite current was going through it. But, then this V c 1, which was 0 initially will have changed to 5 volts, the voltage across this capacitor.

So; that means, that there was infinite current there, so those two cannot be balanced. I mean if you imagine the KCL equation here, the current through the resistor is finite, the current through this capacitor is finite and the current through that is infinite, that will simply not balanced. So, the only solution is where this V c changes by some amount, but not the same as V s. So, there is an instantaneous change in both V c and V c 1.

So, the infinite current that is actually going there, which is really a charge packet that is going in to C 1 is exactly equals that of C that is the only way KCL will be satisfied at that point. Another way to think about it is that, this d v s by d t that is definitely infinite here. So, that can only be balanced by having an infinite value for this also; that means, that V c has to jump. Is this clear?

Now, how much will it jump by? So, we already concluded that both the voltage across C 1 and C will jump. So; that means, that the current through C 1 and C are both infinite at that instant, not before not after, but just at that instant, but the current through R will be finite. So, as far as KCL here is concerned, we have some finite contribution and two infinite ones, so we can completely neglect the resistor.

So, essentially you can solve for a step apply to just taken this network with the resistor removed, may be your solved problems of this type, where initially the charge on this is 0 and the charge on this is 0. And clearly if just after the step, let us say this becomes V c of as you know the notation for this is 0 plus, so just after the instant of the step. So, the charge on this will be C times V c of 0 plus and the charge on this will be C 1 times V c of 0 plus minus V s; that is the charge on this plate and those two have to be equivalent and opposite.

The sum of those two charges, I mean the charge cannot go anywhere else from these plates, so the sum of the those two has to be still equal to 0. So, if you equate the sum of this and this to 0, what you get, V c of 0 plus V s C 1 by C 1 plus C 2, some capacity divider times the input step. Now, this is good only for calculating the step itself, after that of course, the current through R will change the picture and so on.

So, let us say C is 3 nanofarad and C 1 is 2 nanofarad, so what is the step, towards. So, this will jump to 2 volts; after that what happens. What you think will happen? What is the final value on C when steady state is reached, when no currents are flowing to the capacitors any more, what you think is the final value, 5 volts. So, that you can imagine by no current of y means, you can open circuit the capacitors. So, you have V s all of V s appearing here, another way to think about it is from the equation all the derivative terms will go off and V c will be equal to V s.

So, it will creep up to 5 volts with an exponential and what will be the time constant, let say R is 1 kilo ohm. What is the time constant is going to be 5 micro seconds, 5 nanofarad times 1 kilo ohms, which is 5 micro seconds. So, it is possible to have discontinuities in capacitor waveforms, if you apply steps and this will happen only if you have a voltage source across a capacitor or across a series combination of capacitors.

In other words, if you have a loop containing only capacitors and voltage sources, it is possible to have jumps. Because, with any finite current we cannot produce a jump in the voltage across a capacitor, it is only with an infinite current can you do that. If you take a capacitor and apply a voltage across it, clearly that will draw infinite current and then, the capacitor voltage will change to whatever the voltage sources. Similarly, if you have a loop of voltage source and capacitor, the same thing will happen.

Student: We can also evaluate V c 1, the voltage across the capacitor C 1.

So, it will jump to 3 volts and what is the final value, 0. So, what I happens to the waveform? It will do that and it will also have the time constant, which is 5 micro seconds. So, just looking at this, I can write that this equation is 3 volts exponential minus t by 5 micro seconds and the equation for the blue stuff would be, what 5 volts minus 3 volts exponential. It is not 5 volts, because if it is 5 volts; it means, it starts from 0, it starts from 2 volts. So, it is 5 volts minus 3 volts exponential minus t by 5 micro seconds.