Circuit Theory
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Lecture - 10
Network Functions (Contd)

And the topic for today is network functions. Before we start the topic, I would like to recall what we did in the last lecture.

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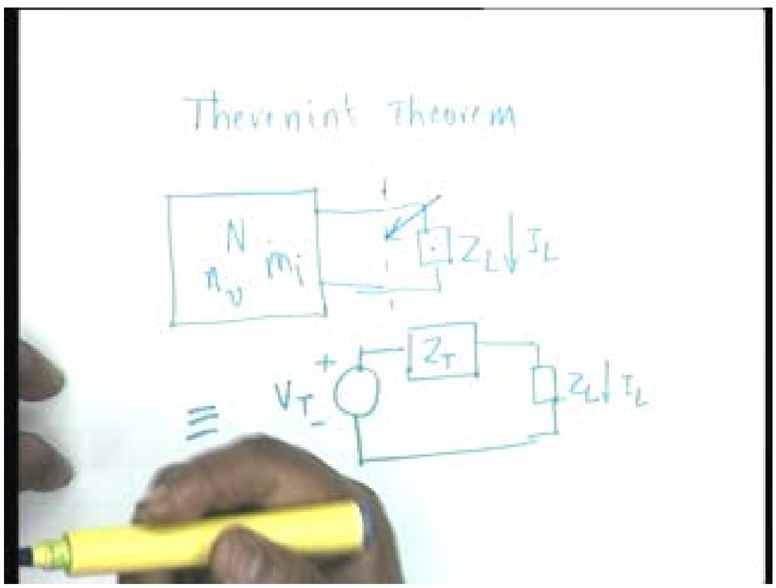

We first proved Thevenin's theorem and to recall what Thevenin's theorem is, it is that, if a network N which contains sources; current sources as well as voltage sources, and elements network elements but no magnetic coupling between N, there are voltage sources n v. There are current sources m i and if this is connected to load a Z L then the current I L in the load, as far as the load is concerned, the network behaves like a voltage source V T, which is equal to the open circuit voltage, in series with an impedance Z T. Then a Z L and this current is I L.

These 2 networks are perfectly equivalent to each other, provided Z L and N have no magnetic coupling. V T is the open circuit voltage and Z T is the impedance looking into the network N with current sources and voltage sources replaced by their internal impedances but control sources being untouched, control sources should be left as they are. This is Thevenin's theorem and starting from Thevenin's theorem we can very easily derive Norton's theorem and we did it a bit hurriedly, in the last class.

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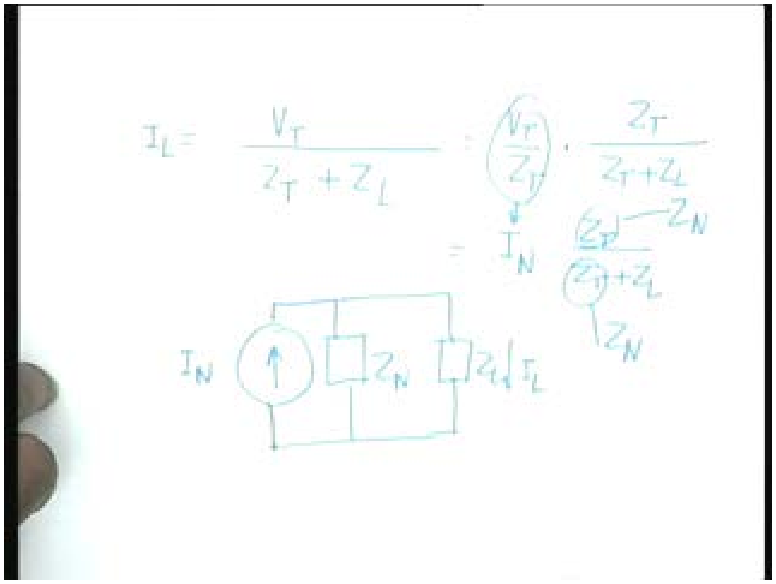

Now let us look at this derivation of Thevenin's theorem, I am sorry, Norton's theorem. By Thevenin's you get I L equal to V T divided by Z T plus Z L and we wrote this as V T by Z T, multiplied by Z T by Z T plus Z L. This can be written as I N. If you call this as I N, I N Z T by Z T plus Z L and you call Z T as Z N. Then, the equivalent circuit becomes a source I N, then a parallel combination of Z N and Z L which indeed is, Norton's theorem. Norton's theorem says that, as far as the load current is concerned, the network can be replaced by a current generator whose current IN is equal to V T by Z T and if you look at this, if you look at this equivalent circuit, VT by Z T is the current obtained here when Z L is equal to 0, that is the short circuit current.

So, the current I N is the current flowing through a short circuit at the terminals of the network and the parallel impedance, parallel impedance Z N is the same as Thevenin impedance. Thevenin equivalent impedance: that is the impedance looking into the network, after replacing the current sources and voltage sources independent ones by their internal impedances. I repeat this because people make mistakes. Independent sources have to be replaced by their internal impedances but dependent sources should be left in peace; no disturbance to dependent sources. We want to take an example from the text to illustrate the application of Norton's theorem.

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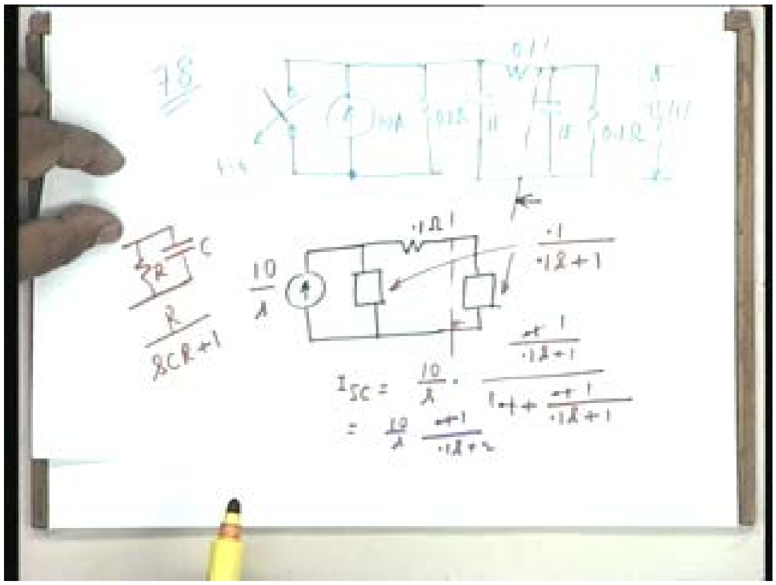

In this example that I have chosen, is 7 point 8. The example says that there is a 10 ampere current source. The problem is to be solved by Norton's theorem. While solving such problems, I continue giving you tips on several peripheral things which I would like you to pay attention to. For example, here I shall tell you something which is a trick of the trade, which if you remember then you shall be able to analyze networks much quicker than others who do not remember.

There is a current source which is switched off here at t equal to 0. So if the switch is on, all the current will pass like this. If the switch is off, the current will pass in the other direction and in the other direction, you have a point 1 ohm in parallel with a 1 Farad capacitor. Then you have a point 1 ohm resistor and a parallel combination of 1 Farad capacitor and point 1 ohm resister. The voltage that is needed, the response that is needed, is the voltage across this parallel combination and we have to solve this network by Norton's theorem, by application of Norton's theorem. So this is the load as far as Norton's theorem is concerned. This is the load and this is the network but first let us draw the equivalent circuit in the transform domain. It is given that energy sources that the capacitors are initially energy free; that means they are relaxed.

In case they had initial conditions, then all you do is, you place them by their equivalent circuits either in the time domain or in the transform domain. Well, we shall work in the transform domain and initial conditions if these capacitors are initial condition free. Then the transform equivalent circuit is 10 by S. This current source is 10 U T, so it becomes 10 by S. Then these combination point 1 ohm and 1 Farad can be combined into a single impedance. Then you have a point 1 ohm and again 1 Farad and point 1 ohm, they can be converted into a single impedance and both of these impedances are,

Now, this you should remember that, wherever there is a resistance and a capacitor in parallel, R and C, the equivalent impedance is R multiplied by 1 by S C divided R plus 1 by S C and you should remember that on simplification that simply becomes R by S C R plus 1. This you should remember always. Then you do not have to write this again and again. So both of these impedances are point 1 divided by S C R, so point 1 S plus 1. Both of these impedances are equal to point 1 divided by point 1 S plus 1. This is something which you should remember throughout your life.

Therefore, if I apply Norton's theorem, the current source I S C, you can easily see that this should be 10 by S multiplied by this current will split into two parts. One is through this and the other through point 1 o and this will be short circuited. So this would be point 1 divided by point 1 S plus 1 the other impedance divided by the s of the 2 impedances, that is, point 1 plus point 1 divided by point 1 S plus 1 which you can now simplify. This is I S C.

Now to find out the Z T or Z N, is this okay? You can simplify this. You cross out point 1 S plus 1. Then you get 10 by S point 1 divided by, I can also cancel out point 1, why not make it 1. Then I shall write 1 divided by point 1 S plus 2. This will be the simple.

Student: (…)

Sir: Which is very small.

Student: (…)

Sir: Oh, the writing is small. I thought the impedance was small.

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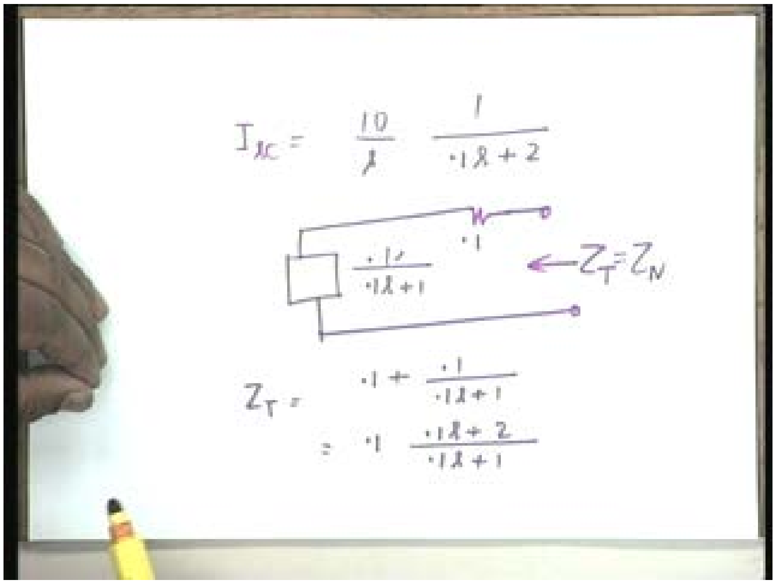

I S C would be equal to 10 by S, one divided by point 1 S plus 2. This is the current source and the equivalent admittance, equivalent impedance is the same as Thevenin impedance and that would be that would be point 1 divided by point 1 S plus 1, this the impedance. Then in series with point 1 ohm. Do you agree that this would be my Z T or Z N, because in parallel with this, there is a current source which is open circuited and therefore, Z T is equal to point 1 plus point 1 divided by point 1 S plus 1, which you can see is, point 1 S plus 1 point 1 S plus 2 multiplied by point 1. So we know I S C and we know Z T. Therefore the voltage response V, if you go back to the circuit; my circuit is now this.

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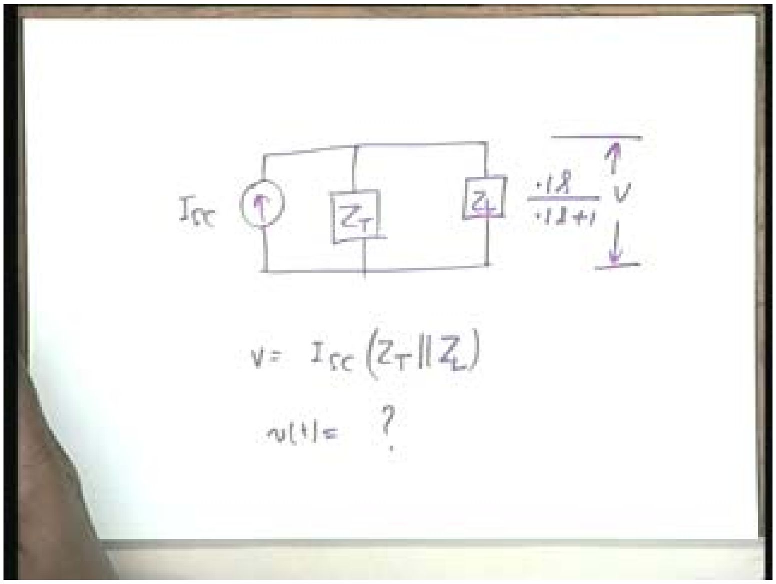

I S C in parallel of Z T in parallel of Z L which again is point 1 S divided by point 1 S plus 1 and it is this voltage that I want to find. So capital V is simply I S C Z T parallel Z L, agreed? Z T parallel Z L. Then you can now find out this expression and find by inversion v of T that is the time domain response. I would not do the algebra. I leave that to you. Agreed? So we have shown an example. We shall work out other examples in the problem session for Norton's theorem, some very interesting examples.

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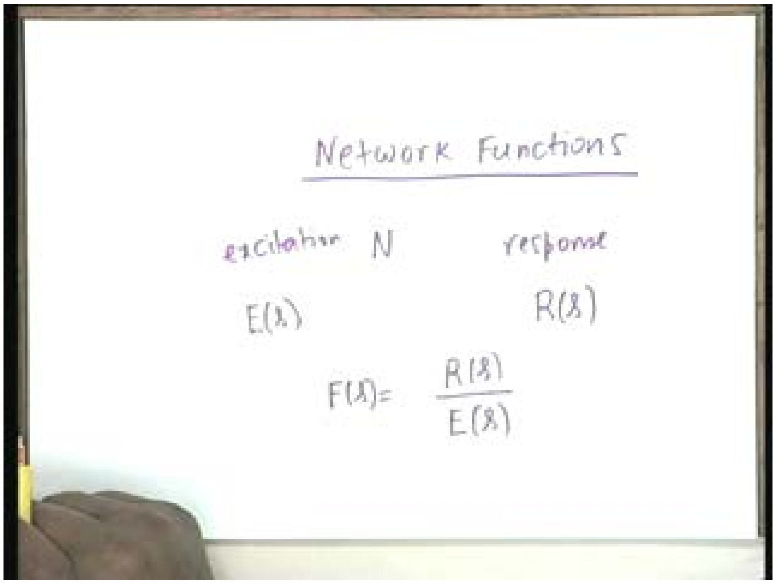

We now turn to the main problem, main topic of today, namely network functions. As I have said earlier, a network in order to be useful, must have an excitation and must have a response. These are the three essential components of circuit analysis or circuit synthesis. If I call the excitation as small e of t and its transform as small e of s and the response is capital R of S the transform of the response, then you know the network function F of S is the ratio of the response transform to the excitation transform. This is the network function, definition of network function, under the condition that the network is initially relaxed that must be remembered. A network function is defined only under that condition. The network is initially relaxed. This must not be lost sight of.

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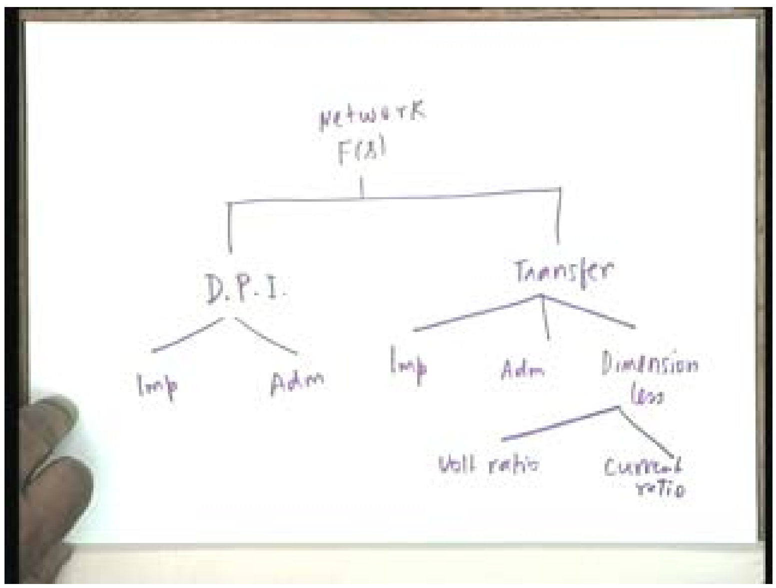

Now, the network function F of S as you know could be, I have already told you, this could be a driving point function D P driving point function. That is, if the excitation of the response is at the same port or same pair of terminals, that is, excitation is either a voltage or current and the response is either a current or voltage. That is the only thing that you can do.

So the function F of S, network function F of S can be either driving point, and if it is driving point, it could be either impedance or admittance and the both of them are combined into a single term called immittance and you call this D P I driving point immittance function or it could be a transfer function. That is, if the excitation and the response are at different ports then it could be a transfer function and the transfer function could be either an impedance or an admittance or dimensionless. It is a transfer impedance, if the response is a voltage and the excitation is a current, then it will be a transfer impedance. It will be a transfer admittance if the response is a current and the excitation is a voltage. It is dimensionless, if the response and excitation are both voltages, are both currents and therefore dimensionless transfer function can again be split into two classes, that is voltage ratio or current ratio. These are matters of terminology. I have already explained earlier I recall this. I recall this various kinds of network functions and then I take a simple example to illustrate what this means.

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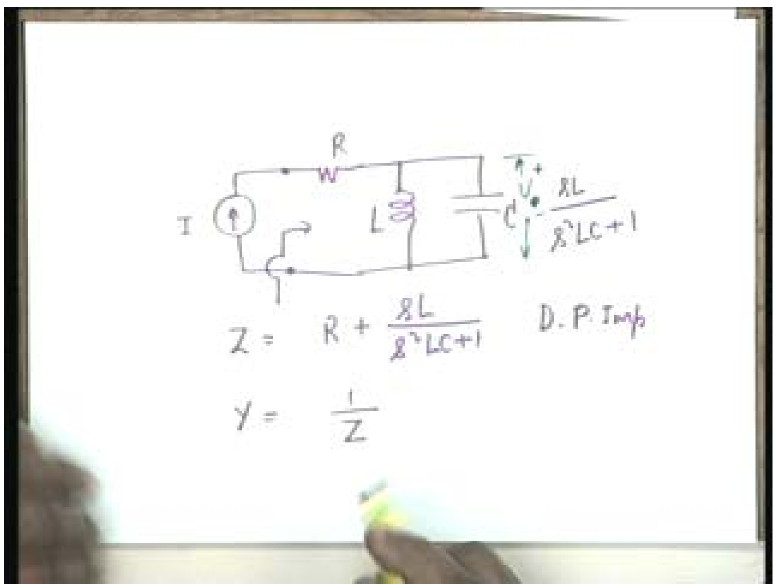

Let us take this example. I have a current generator I. Now I am drawing the I N terms of the transforms and since I am talking of network functions and therefore, I am talking of initially relaxed elements. Let us say, I have R L and C. Now obviously, the driving point function, you are driving only at this port. So the driving point function can be either an impedance or admittance instead of a current generator. If you had a voltage generator, then you would measure the current. So I by V would have been the driving point function.

In any casem the impedance Zm the driving point impedance Z, driving point impedance, why do you call driving point? Because there are other kinds of impedances. There can be transfer impedance also. So the driving point impedance, obviously, is given by R plus. Now this also, you should remember, that whenever L and C are in parallel, then you get S L multiplied by 1 over S C divided by S L plus 1 over S C, and this is simply S squared L C plus 1.

So I get S L divided by S square L C plus 1. This is the driving point impedance. The driving point admittance, Y, is simply the reciprocal of Z, the driving point admittance is simply the reciprocal of Z. Now if I want to find out, let us say, this voltage, if this voltage is your response, capital V, I beg your pardon, plus minus, then the transfer function would be a transfer impedance V by I and the transfer impedance V by I, obviously. If you look at the network, it shall be equal to parallel combination of L and C which is S L by S squared L C plus 1 multiplied by I divided by I.

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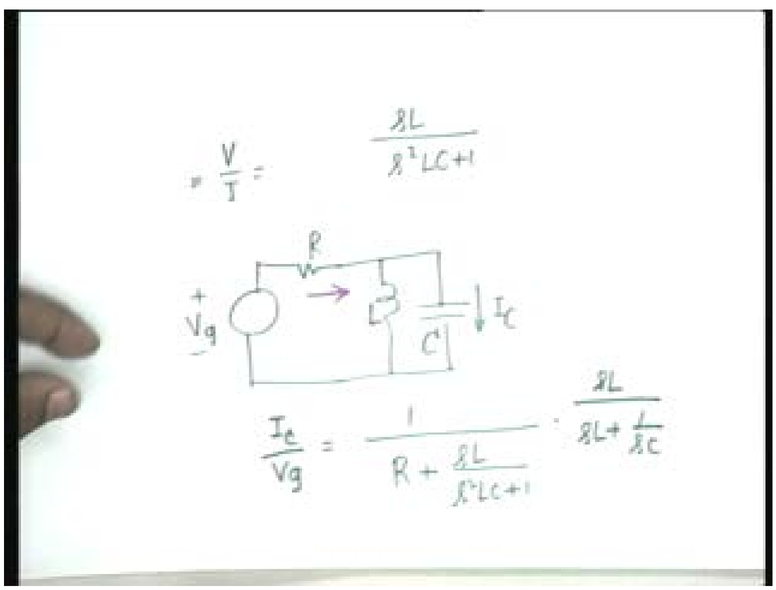

Therefore this is the transfer impedance. Is that okay? V by I, capital I is a current generator. So R does not affect the current. This current flows through a parallel combination of L and C to produce a voltage capital V and therefore, V by I the transfer impedance is simply S L by S squared L C plus 1. What would be the transfer admittance? Suppose it is a voltage generator, suppose we had a voltage generator here, VG, let us say, and we have the same network R L and C and this current, let us say, this current was the response. Then you see, transfer admittance is I

C divided by V G would be equal to S 1 by R plus S L divided by S squared L C plus 1. This gives the total current. Then multiplied by S L divided by S L plus 1 over S C, is that okay? I have find out, what I have found out is the total current first that is this current. This current is V G divided by the total impedance. Then this current split into 2 parts S L divided by S L plus 1 over SC. I can write this down by inspection this is the transfer admittance.

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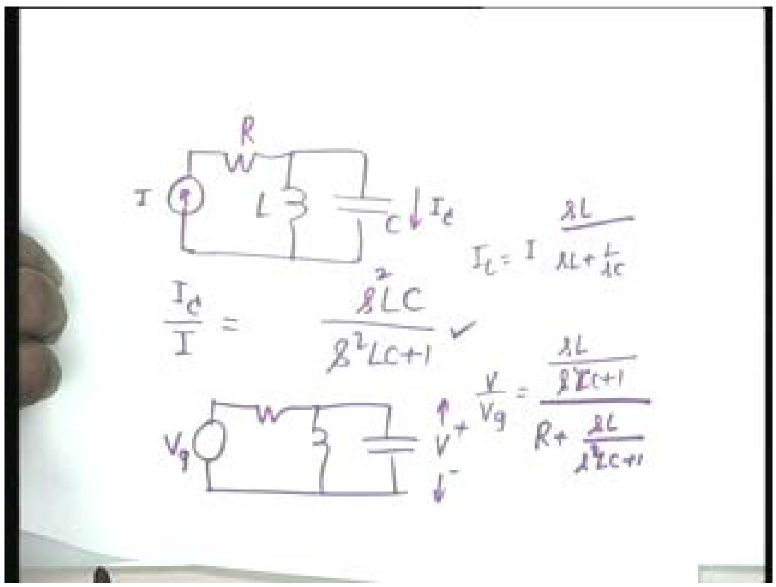

Now let us look, let us go back to the circuit and see if we can define two transfer, dimensionless transfer function. First, let this be the current I L C and, suppose, this current is my response. Then the current transfer ratio I sub C by I, which is a dimensionless transfer function, would have been simply S L divided by S squared LC plus 1. No, that is not correct. Is that okay, now? You see, the current flows and then splits into 2 parts. So it would be this current I sub C would be equal to I S L divided by S L plus 1 over S C. Is that okay, now? It is the dimensionless current transfer function.

Suppose I replace this by a voltage source now, let us say, V G and I want to find out, this is my V, the dimensionless voltage transfer ratio. Then obviously, V by V G would be equal to S L divided by S squared L C plus 1 divided by R plus S L divided by S squared L C plus 1. These, findings such quantities in simple networks like this should be done by inspection, no loop equation, no node equation, no Thevenin's theorem, no Norton's theorem; it should be done simply by inspection, as long as we can do, that is the best thing to do. Observation, there is no replacement for a keen power of observation and that is the strongest tool. Common sense and power of observation, these are the two strong tools for an engineer.

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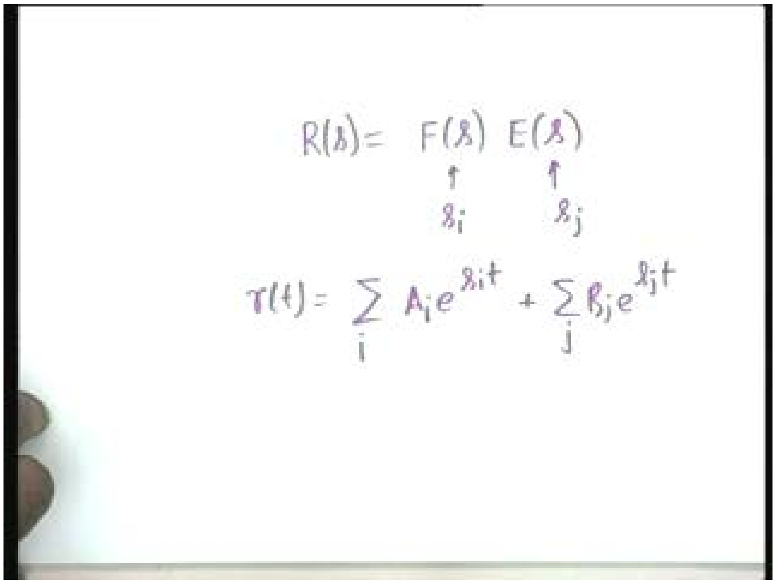

Now let us go back to our response transform. R of S is equal to network function multiplied by excitation transform. This is the equation. Definition of network function is; transform of the response divided by the transform of the excitation, with the network initially relaxed. Now, you see that if I take the inverse transform of this, then there would be two types of terms. One would be the terms, the poles of F of S and the other will be due to the poles of E of S. Is that clear?

There will the 2 types of terms. For example, if S sub i are the natural frequencies of the network, then they will belong to F of S, the properties of the network, and suppose the frequencies, forced frequencies, let say S sub j. Then obviously, r of t would be summation of s A i e to the S I t over i plus summation B j e to the S j t over j.

Sir: Now let us take an example.

Student: (…)

Sir: Correct. That is what I am coming to. Let us take an example.

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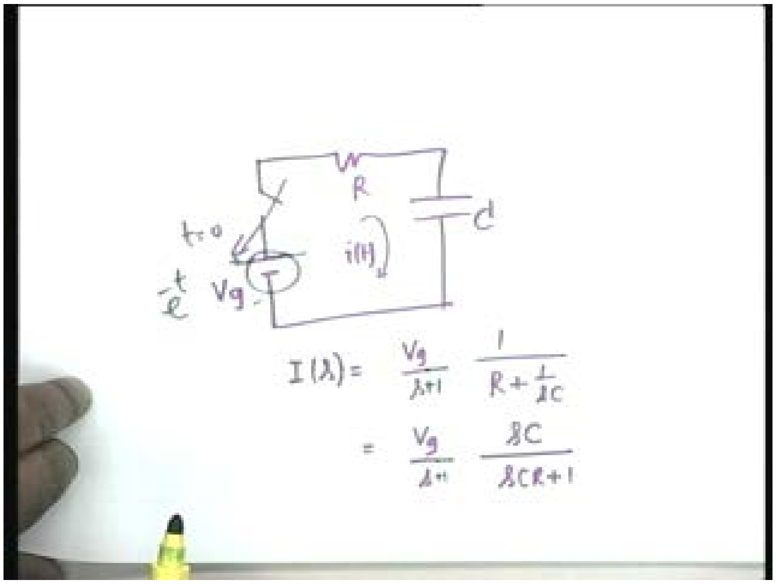

Suppose I switch on a battery, to an R C network. This is my battery, let us say V sub g battery and my response is the current i of t. So I know I of S would be equal to V g by S. See the voltage transform divided by impedance, that is, 1 over R plus 1 over S C, agreed? We are assuming, of course, that the initial conditions are 0. Now this I can write as V sub g by S multiplied by S C divided by S C R plus 1. This is not a very good example but let me make a modification, let me make a modification.

Instead of battery, this is V g that is e to the minus t. Instead of a battery, it is an exponential source, V b g e to the minus t switched on at t equal to 0. This will bring out the point more clearly. What I have is then, V g by S plus 1, agreed. The transform will be Vg by S plus 1.

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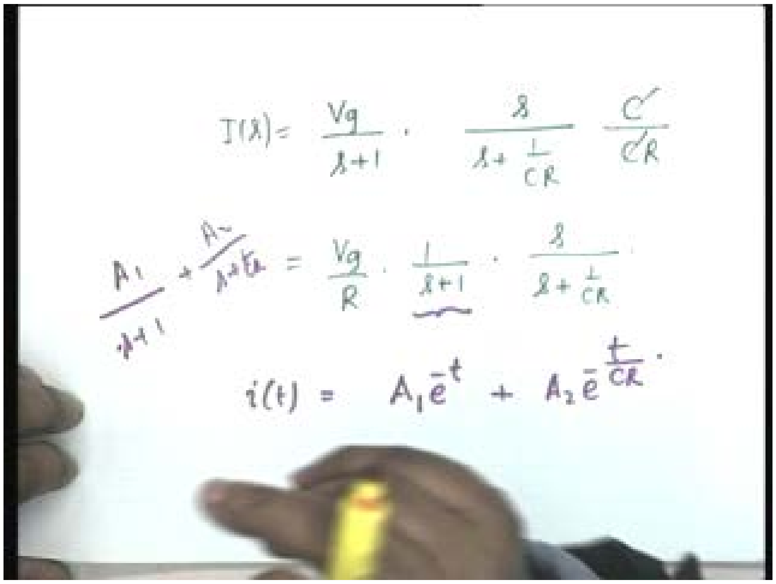

Therefore, the response transform I of S, now consists of, let me write this down again, Vg by S plus 1. Then I write this as S, S plus 1 over C R, C divided by C R. So C and C cancel. Therefore, this is Vg by R, which is a constant, multiplied by 1 over S plus 1 multiplied by S divided by S plus 1 over C R. Now you notice that the response transform has two kinds of term. Besides, this constant is simply a constant multiplied, so you can retain it as it is. It is two types of terms. There is a pole of the transform due to the excitation function. This pole is at S equal to minus 1. There is a pole. The response goes up when S is equal to minus 1.

So it is a pole. The other term S by S plus 1 by C R has a pole, which is characteristic of the network. It does not arise because of the excitation. It arises because of the network and you know S equal to minus 1 by C R is a natural frequency of the network and therefore, without making a partial fraction expansion, I can write I of t equal to, in terms of constants, I can write this as A 1 e to the minus t because of this term plus A 2 e to the minus t divided by C R.

So there is a term due to the forcing function which are, which was e to the minus t and there is a term due to the natural response of the system. Again it collaborates with the fact that the total solution shall be the sum of 2 functions. One is the complimentary function and the other is the particular integral. The particular integral, represents the forcing function natural frequencies. If this was a sine omega t, we would have got a sine omega t terminal, whereas, the complimentary function is the solution to the homogeneous equation and represents the natural frequencies. We take another example. Suppose we had.

Student: Excuse me sir? Sir, (…)

Student: Sir, there is, 1 S is the numerator of I S

Sir: That does not matter. If I make a partial fraction expansion I will get A 1 by S plus 1 plus A 2 divided by S plus 1 over CR.

Student: S square

Sir: In case we had S squared, then you shall have to write this. That is a good question.

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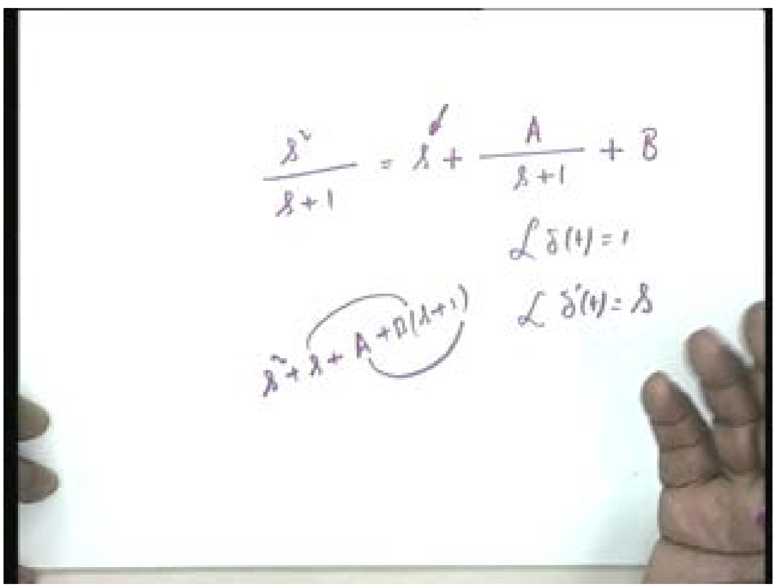

Suppose we have an S squared, suppose my network function is S squared by S plus 1, then what is the partial fraction expansion of this? We have to write as S plus, S plus 1 divided by A. So you will have to divide numerator by denominator and take account of such terms. Now what is the inverse transform of this? Delta prime t. The term transform of delta t is 1, inverse, the transform of delta prime t is equal to S.

Student: (…)

Sir: So this is not a correct solution, this is not a correct, I was waiting for this. This is not a correct partial fraction expansion. What should we do?

Sir: We must have

Student: Another A plus B

Sir: A constant. Then, everything is taken care of. You see, we will have S square plus S plus A plus B S plus 1. Now you can cancel S and B S. S squared can be A and A and B, A plus B has to be equal to 1.

Student: Sir, does that imply that if in partial fraction then in numerator if S comes, that will not be taken.

Sir: That will not be taken, why not?

Student: That means, sir, suppose there is any

Sir: No, there is no problem. I will tell you. Let me illustrate one by one.

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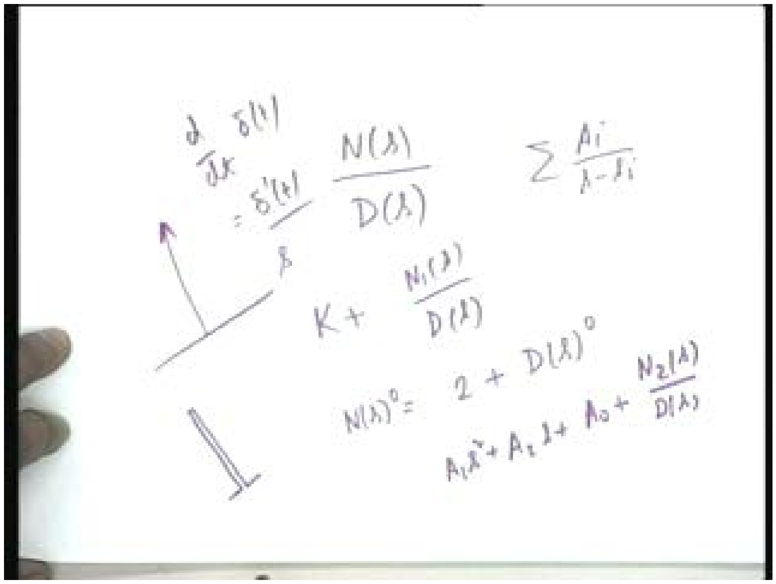

One is that, a network function shall always be a rational function. That is, it will be a ratio of a polynomial N of S divided by D of S, it will be a rational function. If the numerator degree is less than the denominator degree, then there is no problem. You can always write this as summation A i divided by S minus S i. If the numerator degree is equal to the denominator degree, then you have to take out a constant. That is, you will have to write this as some K plus N 1 S divided by D of S. Where N 1 is at least 1 degree lower than D. Has not this been taught in signals and systems in partial fraction expansion? It must have. Does not matter, we will recall.

If N of S degree was higher than the degree of D of S, suppose N of S degree is 2 plus degree of D of S, then you have to take out a term like A 1 S squared plus A 2 S plus A 0 plus N 2 S divided by D of S. Where N 2 is at least 2 degrees lower than D, at least 2, it could be more because not only the second degree term, but another term may also, can say. So we come we will come to this applications. We are not going to discuss why it is so. We will come to the applications when we come to specific problems.

Student: Sir, what is the representation of differential of delta T, in the time domain?

Sir: In the time domain?

Student: Yes Sir.

Sir: It is doubly, infinitely large. You are differentiating a discontinuous function, which is 0 at t equal to 0 minus, 0 at t equal to 0 plus, exists a t equal to 0 the amplitude is infinite. So you are differentiating an infinite function and it is only a conceptual quantity. However, its Laplace transform exists. Laplace transform is simply equal to S. In the time domain, you cannot even you imagine a delta function, an impulse function, it is conceptual. You cannot generate it in the laboratory. In the laboratory, what you can generate is this and if you differentiate this, then you will get 2 delta functions one here and one here negative.

Student: (..)

Sir: What should be 0?

Student: delta S t.

Sir: delta S t is 0 for t equal to 0 plus, it is 0 at t equal to 0 minus, but at t equal to 0 it is not 0. It is infinitely large. That conceptual, you cannot generate this in the laboratory.

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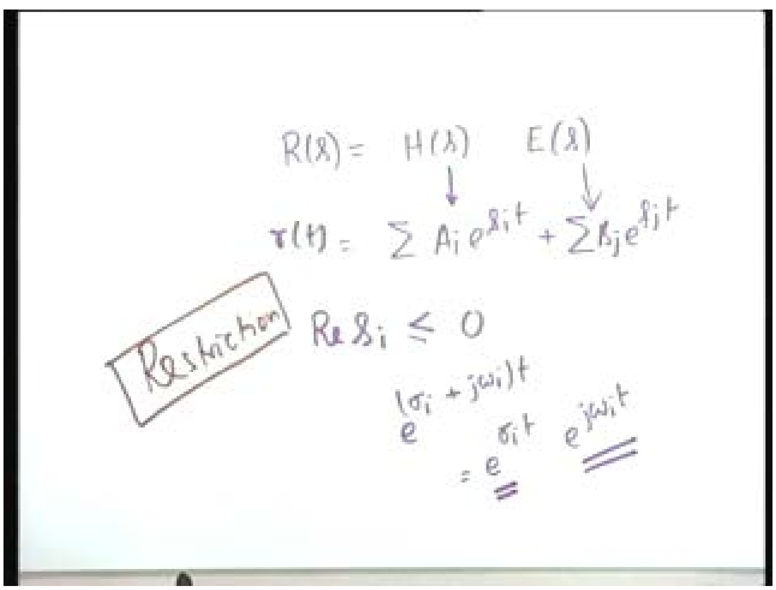

Let me go back to the original ((penny's)) (33:49). That is, I have shown that R of s is the product of network function and the excitation transform. So in r of T, there will be 2 kinds of terms. One would be summation of terms like this where S i's are the natural frequencies and the other would be summation of terms like this, which are the reflections of forced frequencies, S j's are the forced frequencies. They are poles of E of S. The qualification or the restriction on the sub i's, there is a restriction on S sub i's and this restriction is that, real part of S sub I, restriction, let me put it in red.

There is a restriction on the natural frequencies. It says that real part of S sub i's must be less than or equal to 0. The real part of S sub i must be less than or equal to 0. Now this can be supported by physical concepts like this that S sub i's represent natural frequencies and therefore, the natural response or the complementary function shall be, shall contain terms like e to the sigma i plus j omega i multiplied by t. That is, sigma i plus j omega i is Si. It is a real part and an imaginary part. That is, e to the sigma it e to the j omega it. Now this is oscillatory, as you know, it contains sine and cosine. Cosine omega i t plus j sine omega i t. This is an exponential function and if sigma i is allowed to be positive, then naturally, natural response shall grow, in time, indefinitely or in other words, the circuit will be unstable.

Now a passive circuit cannot become unstable. That is, it cannot generate a current of voltage which grows indefinitely without limit and therefore, the real part of S sub I, the natural frequencies, must be less than or equal to 0.

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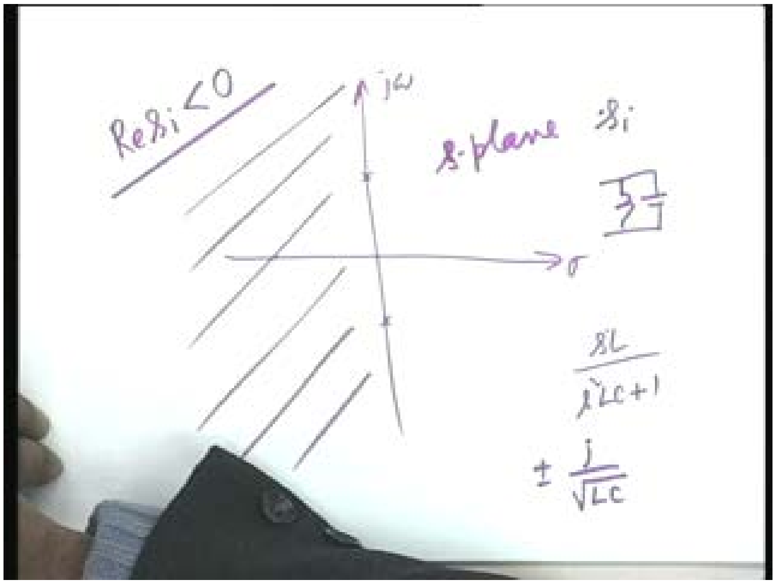

If I consider the complex plane, that is the S plane, in which this is real part and this is imaginary part, then S sub i locations should be such that the real part is always non negative. It could be 0. For example, if you have, let us say, a parallel combination of L and C. The natural frequencies are on the j omega axis plus minus j 1 by root L C. What is the product, what is the impedance? SL divided by S squared LC plus 1? So where are the poles? Poles are at plus minus j by square root L C. So you can have poles here, on the j omega axis and it can be, the real part of this is 0, the real part has to be either 0 or negative. In other words, the real part is not, I am sorry, the location is not allowed. The poles should not cross the j omega axis to the right.

So the possible locations of natural frequencies are the left half of the S plane. Now the j omega axis, the imaginary axis can be equally demanded or claimed by the right half and the left half. So how do you indicate that left half of the S plane including the j omega axis, you have to say the location of natural frequencies are left half of the S plane including the omega axis. In mathematics, there is a term for this. If the left half of the plane is to include the j omega axis, we call it a closed left half plane. That is, the boundary on this side is closed. j omega axis is not available to the right half plane. On the other hand, if you had strictly real part of S i, if it is was strictly less than 0, then you would have said S i lie in the open left half plane. Is that clear? Open and closed.

A closed left half plane is left of S plane plus the j omega axis and open one is left half of the S plane excluding the j omega axis. These terms, we shall use later, very frequently, open left half plane and closed left half plane. Now we will conclude this class with an example. I have fifteen minutes more and this example is 7 point 21.

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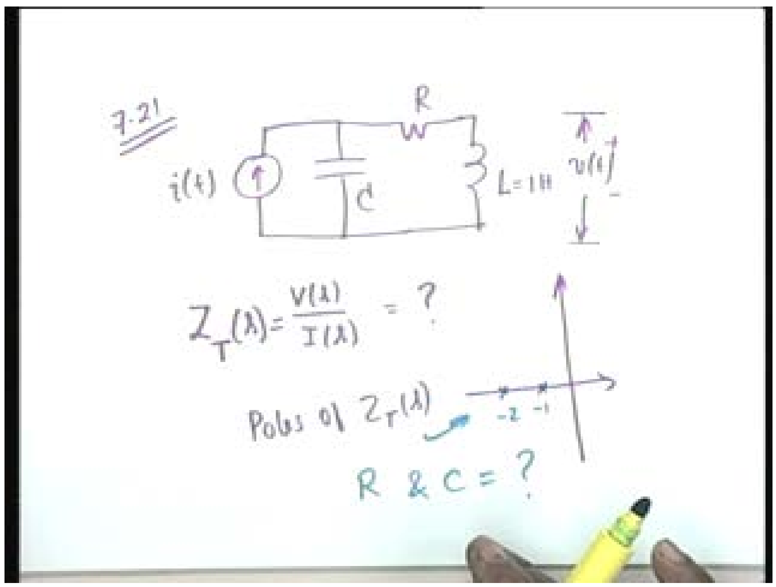

Please try to follow what I have been doing. This is a simple example, can be solved by inspection. That is, what we will do, we will not write in the loop node or even Thevenin's Norton's. We will not do that. This example is that, there is a current source i of t, there is a capacitance C, there is a resistance R and there is an inductance L. L is 1 Henry that is given. This is the response that is to be found out, V of t. The circuit is initially relaxed. The question is to find out the network function, v of S by I of S. What kind of a function is this? This is a transfer.

Student: Impedance.

Sir: Impedance voltage by current. So this is a transfer. You can write this is as Z T of S, where this T, not Thevenin, this T stands for transfer. We have to find out this and number 2 if Z T of S has poles, poles of the transfer impedance r at the 2 locations shown. Here and here, this is minus 1 and this is minus 2. Poles of Z T S are given. One is at minus 1 and one is at minus 2. We have to find out R and C, that is the second part of the question. First part is, find this, that is, the poles are located like this what are the values of R and C and the third part of the question is, if i of t has this wave form.

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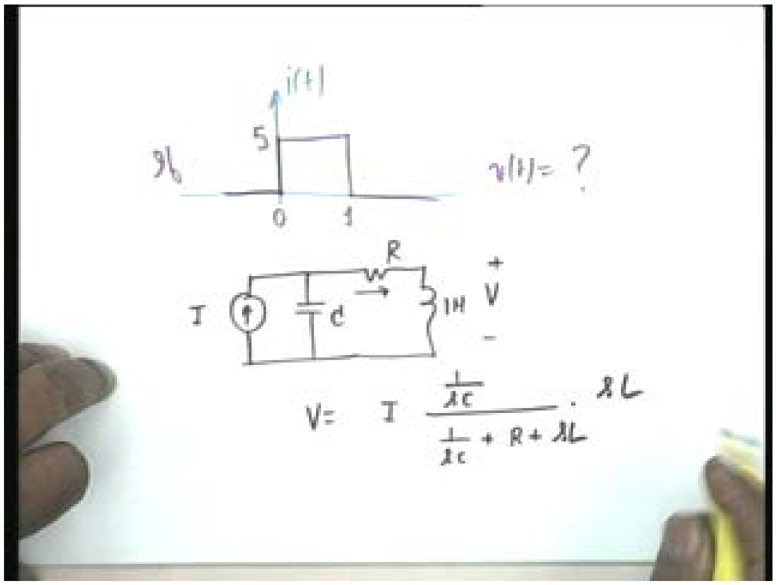

This is 0 and this is 1. This is 5. If i of t has this wave form, that is, it is a window, it is a pulse or it is a gate. Then if i of t is this, then what is V of t? These are the three part of the question. Now to solve it, first thing first, we look at the we look at the circuit. I have capital I C R, L is given as 1 Henry and therefore, capital V would be equal to I. Now, I do by inspection. I first find the current in this and then the voltage. The current would be 1 over S C divided by 1 over S C plus R plus S. L is 1 Henry. This is the current, through this branch this would be multiplied by S to get the voltage, so is that point clear?

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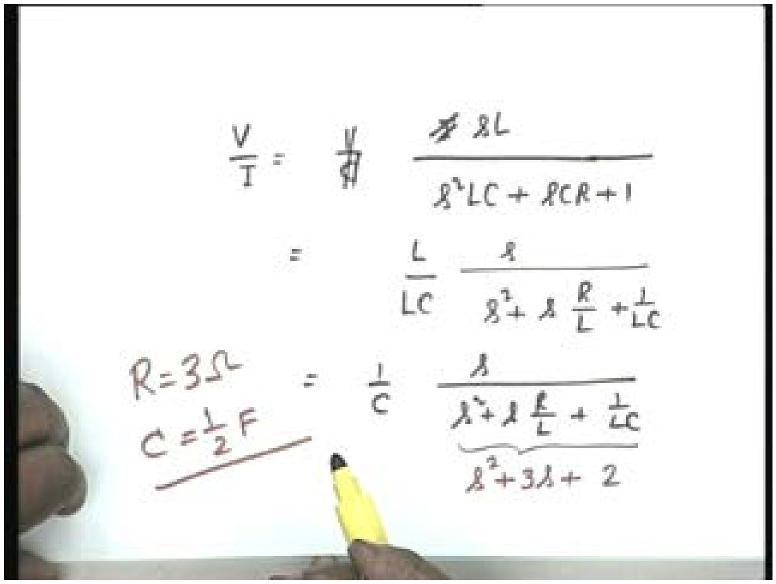

So the transfer function v by I would be equal to 1 over C, no. Let us look at it like this, yes?

Student: C parallel to series of R and L.

Sir: That is okay, but I have a current generator. So what I am trying to find out is this current. It is not this voltage that we are required to find out. If that was so, if this was the voltage, that is a driving point function. We would have simply found out the impedance of C in parallel with R and L. That is not what we want to find out. I want to find out this current then multiply this by S L to get the voltage. The simplification, is the question answered? The simplification would be, let us include L first and see what this is. Sorry, So my V by I would be, I first multiply by S C. So I get I S L divided by S squared L C plus S C R plus 1.

Student: I will not be there.

Sir: I won't be there. Fine? Then I write S, I want to write this S as S squared plus because I want to find the poles. So, the highest power term is made unity. Similarly in the numerator highest power term is made unity. So L by L C, S squared plus S R by L plus 1 over L C. That is equal to 1 over C S divided by S squared plus SR by L plus 1 over L C. It is given that the poles of the network function are at minus 1 and minus 2. So this denominator polynomial must be S plus 1 multiplied by S plus 2. So it must be S squared plus three S plus 2, which means that capital R equal to

Student: 3 ohms

Sir: 3 ohms and capital C would be how much?

Student: Half Farad.

Sir: Half Farad. So we have found this out.

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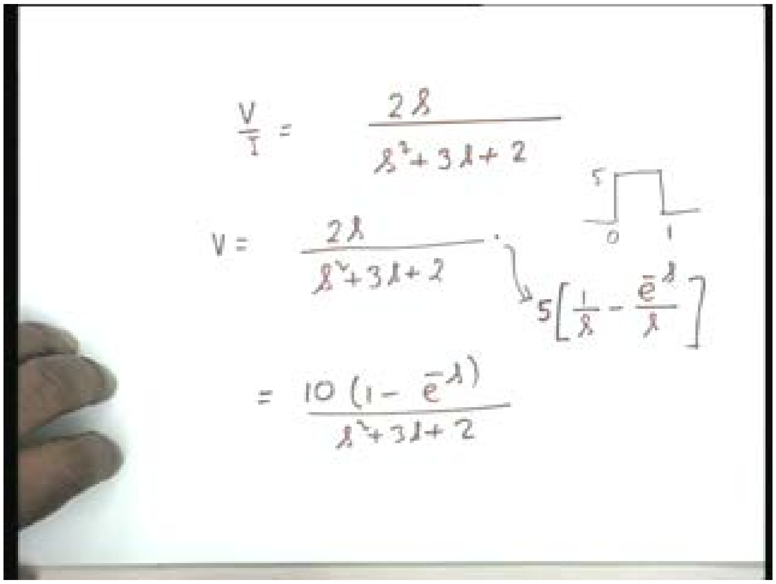

And therefore, my network function, v by I, becomes equal to 1 by C is 2. So 2 S divided by S squared plus three S plus 2, this is my network function. And therefore, capital V would be equal to the network function multiplied by multiplied by capital I of S. Now, if you have looked at capital I, capital I is simply this pulse, amplitude 5 and the times at 0 and 1. So what is capital I then? 5, in the time domain it will be 5 u t minus 1. So in the frequency domain, it is 1 by S minus e to the minus S divided by S. That is because of u t minus 1. Therefore, my capital V simply becomes equal to this which is equal to 10 times 1 minus e to the minus S, if i simplify S squared plus three S plus 2. Agreed?

Student: Yes sir

Sir: And inverse transform, with a little practice, you should be able to write it down by inspection because I know S squared plus three S plus 2. I do not need to write and find the coefficients. I can write this directly as S plus 1 minus 1 by S plus 2. Therefore, my V of t would be equal to 10 u t minus u t minus 2. I beg your pardon, this is not correct. Therefore, my V of t would be 10 e to the minus.

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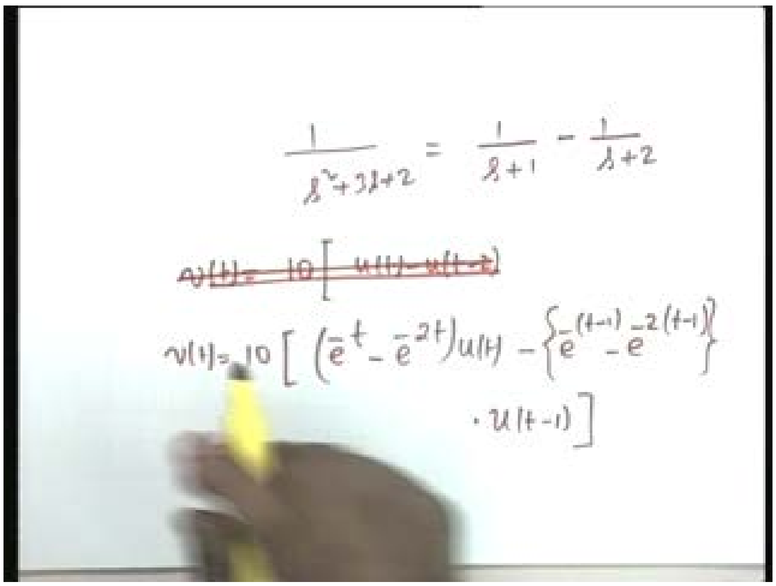

Student: (…)

Sir: t minus e to the minus 2 t multiplied by u t. Then minus, if it is multiplied by u to the minus S, that means t should be replaced by

Student: t minus 1

Sir: t minus 1. So it would be e to the minus t minus 1 minus e to the minus 2 t minus 1, whole multiplied by u t minus 1, and this is written down by inspection. With a little bit of practice, an electrical engineer should be able to solve a circuit like he is throwing dirt out of his fingers, just like that, it should be as easy as that. On the next occasion, that is, on Thursday, I still have 2 minutes, this watch seems to be fast, on the next occasion let me introduce the topic.

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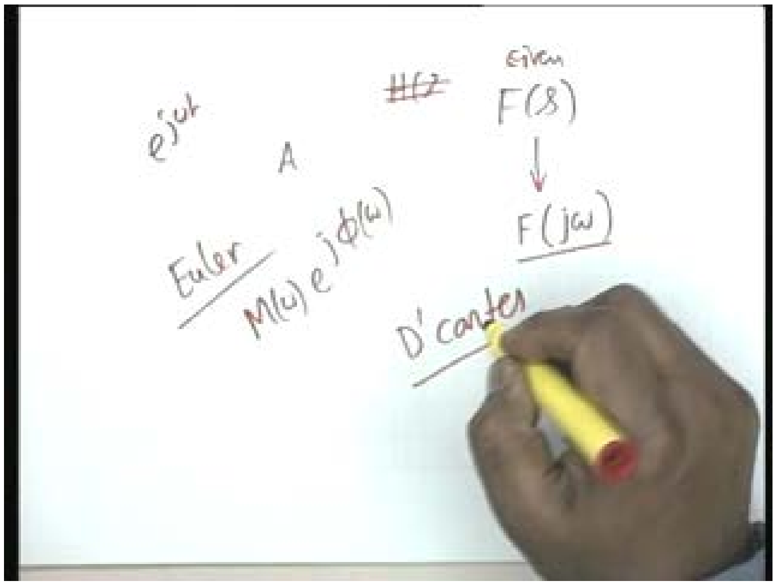

We shall consider sinusoidal network functions. That is, what we have considered here is F of S, a function of the complex variable S. How does this function behave on the j omega axis? Now what does the j omega axis correspond to? It corresponds to sinusoidal excitation. As you know, e to the j omega t is cosine plus j sine omega t. So it is real part as well as the imaginary part is sinusoidal.

Now given F of S we can of course find how it behaves on the j omega axis. We simply put S equal to j omega and we shall see that this function, which in general is a complex quantity, can be described by its amplitude and phase in 1 manner or by its real part and imaginary part. The amplitude phase description is the Eulerian description, Euler, E u l e r, that is, a polar description, amplitude and phase. That is, you write some M omega, multiplied by e to the j phi omega. On the other hand, the real part and the imaginary part description is due to, what kind of description can you call it?

Student: Cartesian

Sir: Cartesian, who is a, whose name is associated with Cartesian coordinate? D'cartes not Cartes there is a D, D, c a r t e s. We shall have occasion to look at this gentleman, Euler D'carte Laplace, in this class in some, on some near future day. We will do a little bit of about them. It will be very fair if you know writing into the j theta or cosine theta j plus sine theta. It is a, it is a very simple thing for you but it is not a simple thing for Euler. So we will do this sometime in future. Thank you.