Introduction to Electronic Circuits
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Lecture no 19
Module no 01
Complete Response of Electrical Circuits

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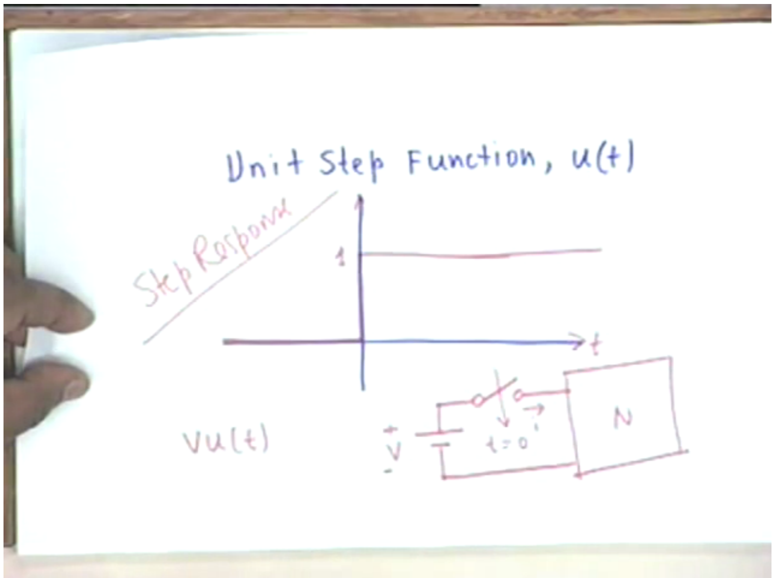

19th lecture being delivered on 21st and the topic is Complete Response of electrical circuits. Before I take up examples, have you seen most of these theories I am doing through examples and before I take this take specific examples, I want to introduce a function called a step function, had I done so earlier? No. And 1st I would say I would introduce the unit step function, A unit step function is usually denoted by u of t; u for unit, t for time, it is a function of time and a unit step function is 0 for t test than or equal to less than 0 and at t = 0 it suddenly rises to magnitude value of 1 and then stays constant for all times to come, this is the plot of u of t versus t it is a unit step function.

Well as you see if you switch ON a battery V to a circuit some circuit capital N at t = 0 then what you have applied here is a step function of magnitude of V, is that clear and this is why the step function terminology is to be introduced at this point that is when you when you switch ON a battery to a 2 terminal circuit what we are precisely applying is a step function of magnitude V, in other words what we are applying is V times u of t alright what we are applying to this is v times u of t.

Now and the corresponding response suppose I want the current i is called the step response of the circuit. If V was unity 1 volt then you say it is the unit step response of the circuit, so this term step response is sometimes used to indicate what we have essentially finding out when we switch ON a battery to an electrical circuit alright. This term shall now be used repeatedly so I thought I must introduce it at this point. Last time under complete Response we had considered a 1st order circuit to which a battery was introduced switched ON or switch off, we also saw a sinusoidal source being switched ON to oppose order circuit okay, today we consider 2nd order circuits.

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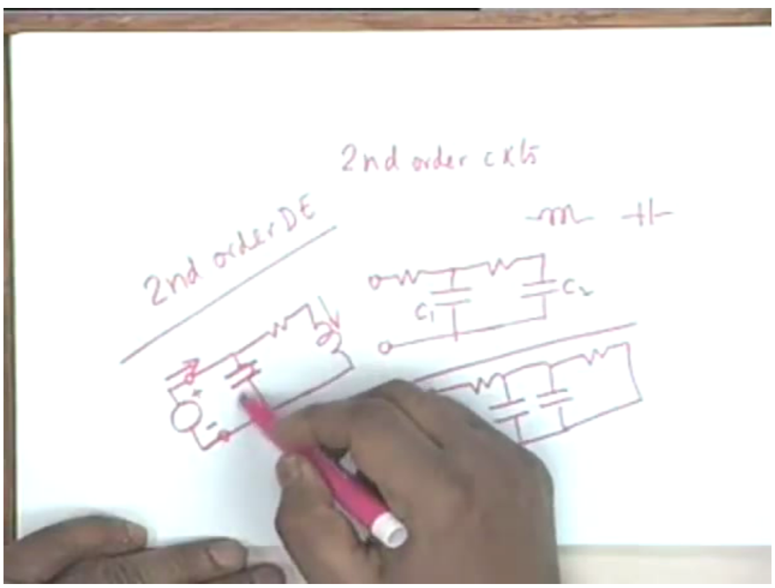

As we know 2nd order circuits must have 2 energy storage elements, it can be either 2 capacitors or it can be 2 inductors or a combination of the 2 that is one inductor and one capacitor. If it is more than one element of the same kind that is 2 inductors for example, they should be nontrivial connected, if they are trivially connected then it becomes a 1st order circuit so this must be remember, if there are 2 different kinds of elements one inductor and one capacitor then there is no problem, you connect them trivially or non-trivially they are elements they are storage of energy of different kinds, one stores what is similar to Kinetic energy and the other stores what is similar to potential energy, who stores potential energy? The capacitor, and the inductor stores

Kinetic energy or you say one stores in the electric field, the other stores in the magnetic field alright.

So in a 2nd order circuit as you know 1st thing is there must be 2 energy storage elements, which if of the same kind must be non-trivially connected for example, this circuit here the 2 capacitors C 1 and C 2 are nontrivial connected, you cannot combine them into one so this is a truly 2nd order circuit and on the other hand if you have something like this well this is a 1st order circuit alright this is a 1st order circuit, 2 energy storage elements are needed if the same type they must be nontrivial connected. 2nd order circuit is described by 2nd order differential equation and a 2nd order circuit shall have 2 roots of the characteristic equation alright.

For example, you can have a 2nd order circuit like this, this is a 2nd order circuit but when you are determining the current response to an excitation from here alright, it becomes a 1st order circuit is that clear? If there is a voltage source here alright and you want to find out the current here okay in this circuit then the response that you get essentially is that of a 1st order circuit, why? Because for a voltage source whatever you connect here it does not matter alright, so you must also see how the source is connected, a truly 2nd order circuit is one in which the natural response is determined by 2 distinct frequencies and therefore, the characteristic equation of the circuit must have 2 roots which may be distinct and not be distinct, which may also be coincident but 2 roots.

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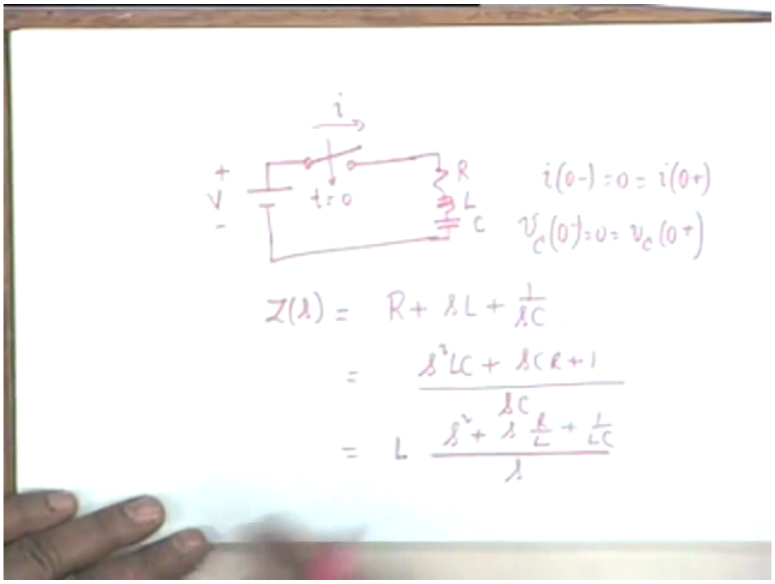

Well, the simplest example is if a step voltage V u t is applied to a series RLC circuit, let us say this switch is closed at t = 0 and we have a resistance, inductance and a capacitance R, L and C and the problems to find the current I alright. Obviously what we are applying to the circuit is a step of magnitude capital V and if we assume that initially this circuit is de-energised or relaxed then obviously i of 0 – the current through the inductor that is equal to 0 = i of 0 + this is one of the initial conditions and the other initial condition is that V c of 0 – = 0 = V c of 0 + these are the 2 initial conditions.

And the natural response of the circuit because it is a current shall be determined by the Zeros of the impedance function that is R + L + 1 over s C and as you know we can write this as s square L C + s C R, I am repeating this again and again so that it gets imprinted in your mind. And the style of writing is that we take the coefficient the numerator and denominator both to be unity highest power coefficient and therefore we shall get L times, have I made a mistake? This is okay, s square + s R by L +1 over L C and here we shall get simply s so the Pole-zero diagram is that there are 2 zeros which are the solution of this quadratic equation and the Pole at the original that is at s equal to 0.

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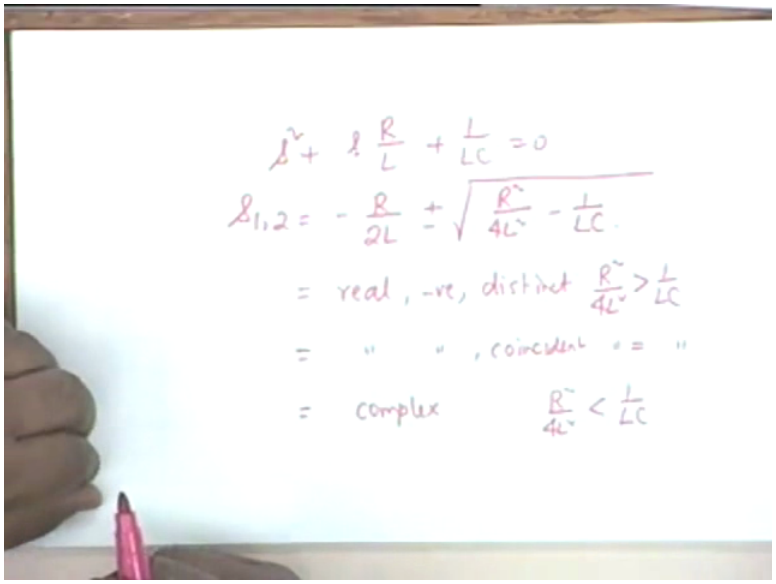

So the natural response of a circuit that is i n t would have 2 exponentials components and these components shall have the frequencies given by s square + R by L + 1 over L C = 0, which means that s 1 2 shall be equal to – R by 2 L + – square root of R square by 4 L square – 1 over L C. And depending on the sign of this, s 1 2 can be real, negative, distinct If R square by 4 L square is greater than 1 by L C they would be real, negative, coincident if these 2 are equal and they would be complex if R square by 4 L square is less than 1 by L C alright so there are 3 distinct cases 3 distinct cases and depending on what the cases are, the solution for the natural response shall also be different.

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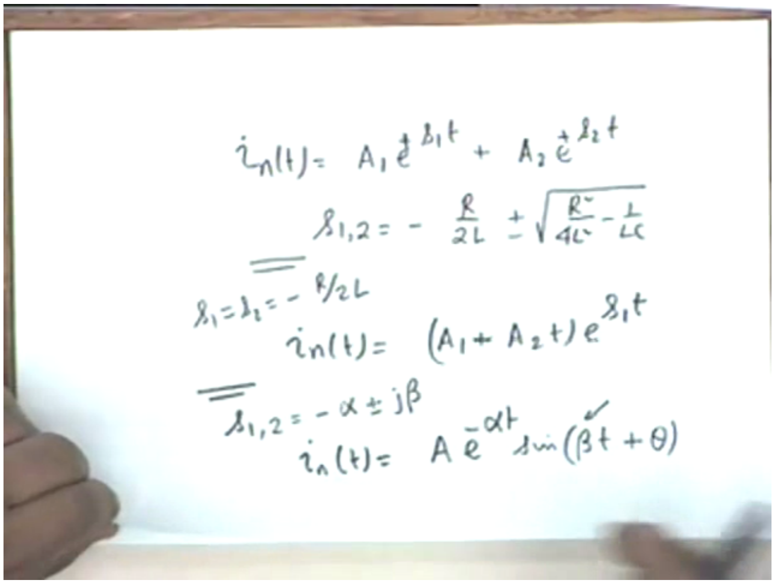

For example, for the 1st case in which the roots are real, negative and distinct, the natural response shall be A 1 e to the – s 1 t + A 2 e to the – s 2 t where s 1 and s 2 are yes okay, is it – s 1? Recall we wrote s 1 2 = – R by 2 L + – square root of R square by 4 L square – 1 over L C, it should be + s 1 alright do not allow me to make mistakes, s 1 and s 2 themselves are negative so it would be A 1 e to the s 1 t, A 2 e to the s 2 t on the other hand if the roots are coincident that is if s 1 equal to s 2 equal to – R by 2 L, the discriminant is equal to 0 then my current response natural response shall be A 1 + A 2 t e to the power s 1 t.

3rd case if s 1 and s 2 are complex, s 1 2 equal to let us say – Alpha + – j beta that is if the discriminant is negative then my natural response would be of the form A e to the – Alpha t damping coefficient multiplied by Sin of Beta t + Theta where beta is called the damped frequency of oscillation, this term we have introduced an Alpha is called the damping coefficient alright. Now if you go back to the circuit, what was the circuit? Have taken it too fast, is it okay? Alright. What was the circuit?

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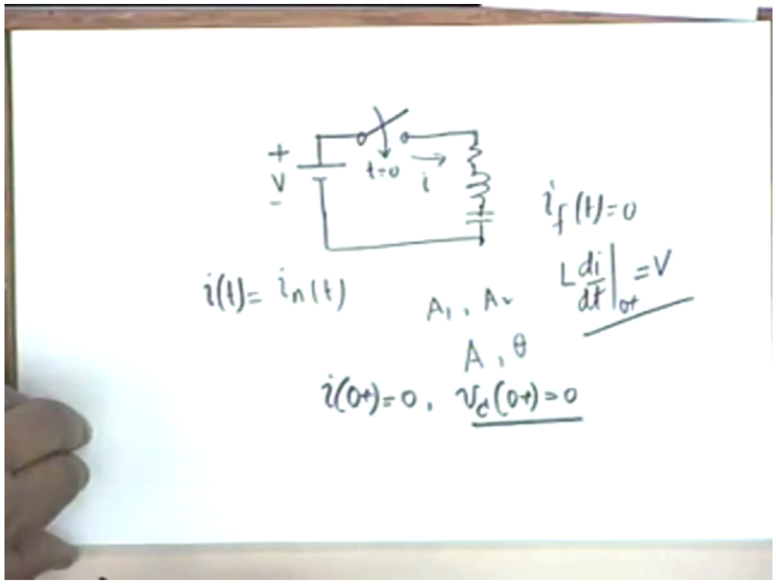

The circuit was that I had a battery of voltage V switched on at t equal to 0 in this circuit R, L and C and we said we have found out the natural response i n t, what about the forced response? The forced response for the current obviously is equal to 0 because at infinite amount of time the capacitor when the battery to the battery the capacitor acts as open, I does not allow any current and therefore i of t = 0 and therefore the total solution is equal to i n of t and the 2 constants A 1, A 2 or A and Theta, A 1, A 2 in the 1st 2 cases, A and Theta in the 3rd case when the roots are complex shall be determined from initial conditions that i of 0 + = 0 and V sub c 0 + is also equal to 0, the 2 initial conditions shall determine this.

Let us take a variation of this example and try to solve it okay, there is one small point that v sub c 0 + = 0, this is not enter into the solution or evaluation of the constants directly, what it does is that this is 0, i 0 + = 0 to the drop across resistance is 0 and therefore L di dt at t = 0 + becomes equal to V this is how this initial condition comes into the picture, this also I have discussed earlier, so in a sense so far it has been a repetition.

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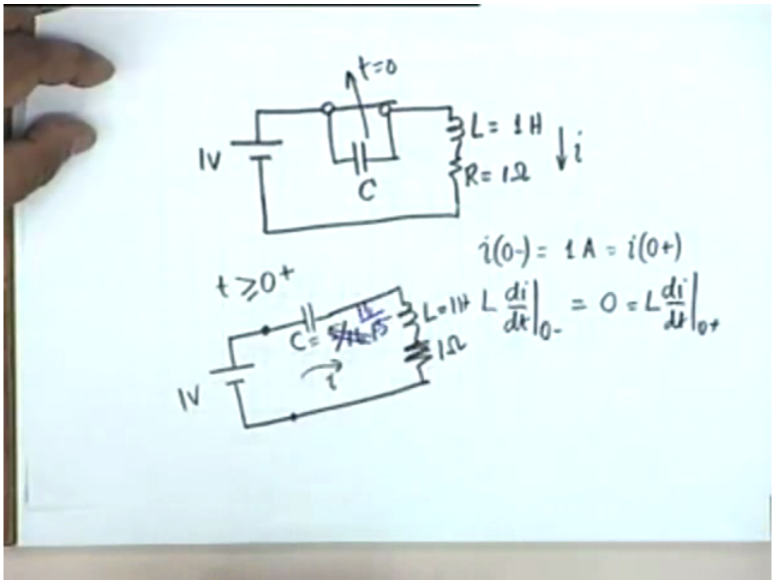

Now let us look at a slightly tricky situation that we have a 1 vote battery and there is a switch here which is open at t = 0, this switch is shunted by a capacitor C alright then you have an inductance L and a resistance R, L = 1 Henry and R = 1 ohms, it is this current that we are interested in, current i for t greater than equal to 0 +. You see for t less than 0 when the switch is there, obviously the current shall be established at i of 0 – shall be equal to 1 Ampere alright, i of 0 – shall be established at 1 Ampere and what is L di dt at 0 – , it is 0 alright. When now the inductor the current through the inductor cannot change suddenly and therefore when this switch is open and the capacitor is put in the circuit, the current must remain at 1 ampere.

And what about this voltage the voltage across the inductor? It will change, let us see if it changes. The capacitor cannot change its voltage suddenly alright so the capacitor remains at 0 volts, the resistance the current through the resistance is 1 ampere and therefore this is 1 volt so what is the drop across the inductance, it must be 0. So depending on the condition of the circuit the initial condition may be different in other words, this is also true for L di dt 0 +. Not only here the current cannot change, the voltage also cannot change because we have made it a constraint situation that is a capacitor has been suddenly switched in and the current since the current cannot change, the total drop occurs across resistance alright so you must look at the problem to be able to determine the initial conditions.

Now at t greater than 0 at t greater than 0 + alright our circuit if this, 1 volt then you have to capacitor C, the capacitor is given as 5 by 16 Farad alright, I have chosen it for reasons that you will see in a moment, we have a 1 ohm and 1 Henry inductor, this becomes the circuit. And therefore to determine the current i in the circuit we should determine the impedance looking into the alright Z of s then you shall be able to find out the steady-state response and the natural response alright.

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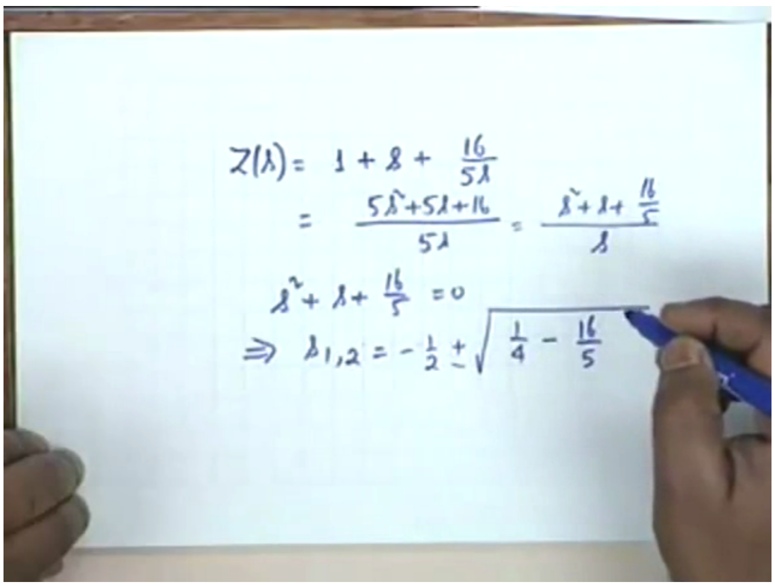

So we look at the circuit and we see that Z of s the impedance is given by 1 ohms resistance + s L, L is 1, 1 + s + 1 over s C that is 16 by 5 s and therefore this is 5 s, 5 s square + 5 s + 16, which I can write as s square + s + 16 by 5 divided by s alright and I do mean the zeros of this s square + s + 16 by 5 = 0 gives us the roots as s 1 2 = – half + – square root of one quarter – 16 by 5 no, have I made a mistake? 5 by 16, I want it the other way round, I want this to be 5 by 16 so what should I change? Pardon me... I will change the capacitor okay. I want to keep life simple so I make this 16 by 5 okay, we will make this change 16 by 5 Farad. Then my coefficient here becomes 5 by 16 s so does the whole thing change? Oh dear alright my choice is bad. But anyways, the roots still can real?

Student: No sir.

Professor: Oh they do not come real okay I made a I goofed up. Pardon me... Let us not cook the example now, the point that I am making is, we will leave it in (())(20:41) we will take some other fortunate example.

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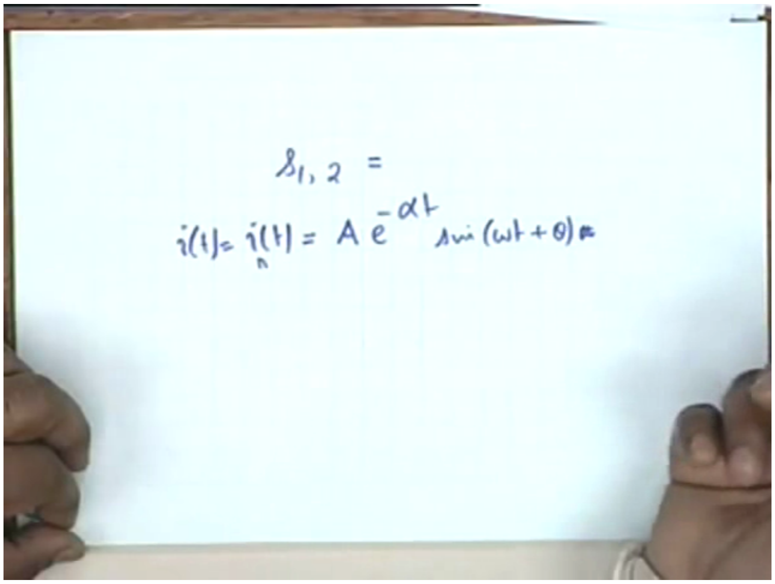

Well the point, the point that I was making is if s 1 2 is obtained, it does not matter whether they are complex or real it does not matter, supposed they are complex as it happens in this case alright then my equation would be A e to the power – Alpha t sin of mega t + Theta this is the i of t this is the i n t of t natural response. And in common with the previous example this must also be the total response of the circuit because the forced response it is after all a DC battery, forced response is 0 and from this you can find out A and Theta by equating the initial and 0 A sin Theta = 0 and initial di dt also equal to 0 alright, the 2 equations will now determine the constants alright.

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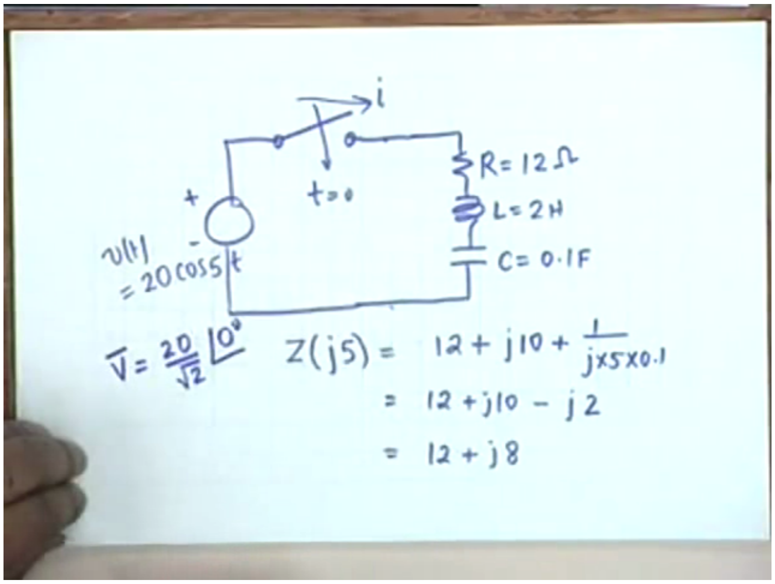

We take a slightly different example now where a sinusoidal generator voltage generator sinusoidal is switched to a series RLC circuit, let us see what happens. A series R L C circuit and I hope I have taken the values now not to end up in a mess, R = 12 ohms, L = 2 Henry and C = 0.1 Farad alright and the switch is put ON and t = 0, now no longer we apply the voltage because v of t now is sinusoidal 20 cosine 5 times t, this is the voltage okay. In other words here we shall have to solve for both i n of t and i f of t alright. As far as i f is concerned, i f is concerned all that I have to do is to find out Z of the impedance between what I want to find is the current and therefore I find the impedance between these 2 points Z of j, what is mega, 5 is not that right?

Cosine of 5 t so mega is 5, Z of j 5 this would be 12 + j mega L to j, mega is 5 and L is 2 so j 10 then + 1 over j mega that is 5, C is 0.1 and therefore this is 12 + j 10 – j 2 that means 12 + j 8 alright this is my impedance and therefore and what is my voltage phaser? Voltage phaser is 20 divided by root 2 this must be remembered angle 0.

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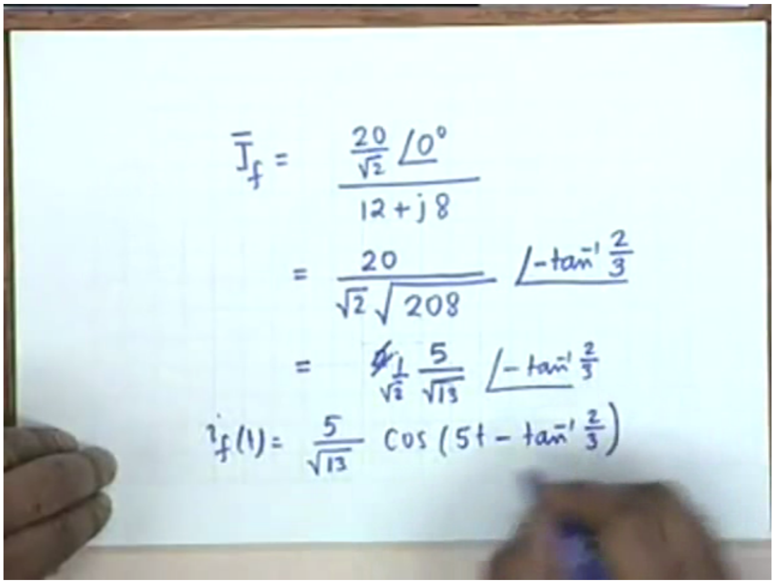

And therefore the forced current phaser I f shall be equal to the voltage which is 20 divided by root 0 degree divided by 12 + j 8 alright, which I can write as 20 divided by root 2 square root of 144 + 64 how much is that? 208 and the angle would be – Tan inverse yes 2 by 3 agreed, – Tan inverse 2 by 3 because this is the angle of the denominator when it goes to the numerator it becomes negative alright. So this I can write as 20 well you see that this is 16 multiplied by 13 I hope I am right yeah okay 16 and square root of 16 is 4 so I can write this as 5 by root 13, 1 over root 2 – Tan inverse 2 by 3, can you write i f of t now? Yes it would be 5 by root 13 you must multiply this by root 2 okay, that is why I did not absorb root 2 in the in this quantity then cosine of 5 t – Tan inverse 2 by 3 this is the forced response.

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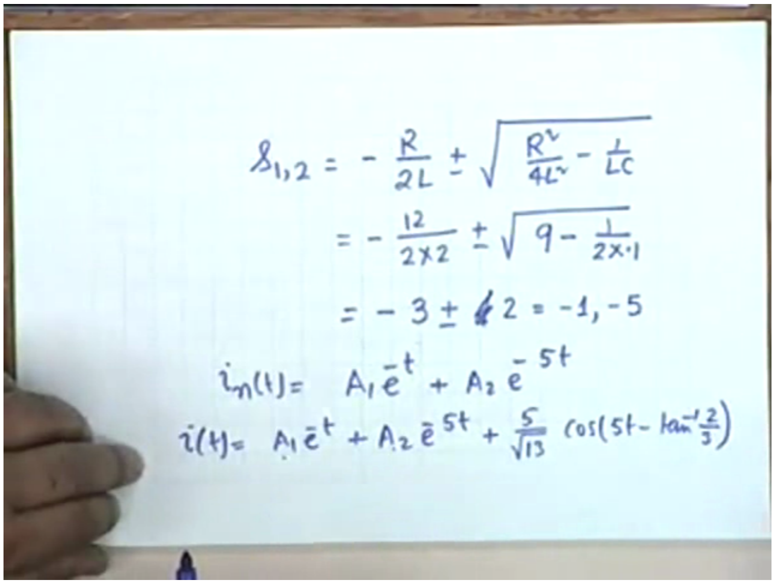

Now to determine the natural response to determine the natural response I must find Z of s and its zeros okay. Without writing Z of s I know that the natural response shall be determined by s 1 2 where s 1 2 is – R by 2 L + – square root of R square by 4 L square, this result I already know I do not have write this again and again and in this particular case if we take the values of r and L, R is 12 ohms and L is 2 Henry so 2 times 2 which means that this is equal to 3, 12 by 4 is 3 so + – square root of 9 – 1 over L C that is 1 over 2 times 0.1 and that would be 5 and therefore this is – 3 + – square root of 4 which is equal to 2 and therefore the roots are – 1 and – 5, which means that i n of t shall be equal to A 1 e to the – t + A 2 e to the – 5 t, is it okay? Right.

Therefore my total current response i of t shall be A 1 e to the – t + A 2 e to the – 5 t then + 5 by root 13 cosine of 5 t – Tan inverse 2 by 3, the problem that remains is to find out A 1 and A 2. Now what are the initial conditions, i of 0 shall be equal to 0 because what is why?

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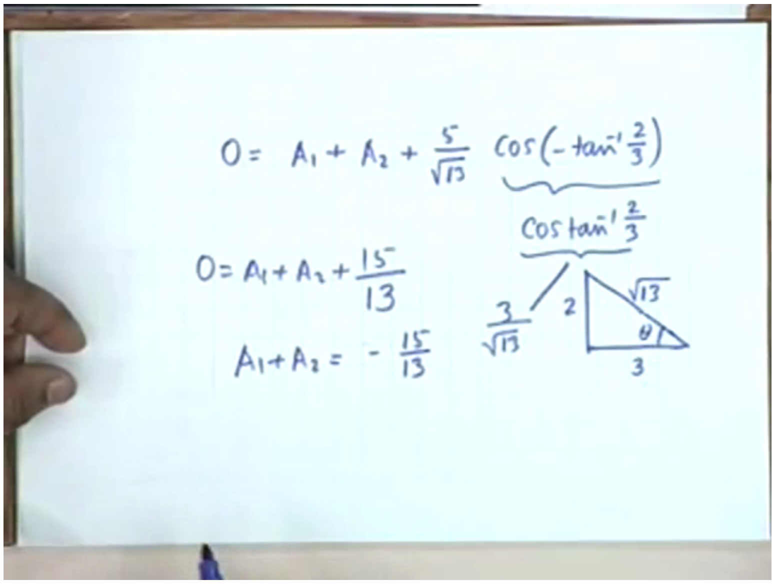

Because the inductor current cannot change instantaneously and therefore 0 shall be equal to A 1 + A 2 + 5 by root 13 cosine of – Tan inverse 2 by 3, now cosine of negative angle is the same as cosine of positive angle so it is cosine of Tan inverse 2 by 3 and without consulting the table you know how to how to find out cosine of Tan inverse, Tan inverse means this is 2 and this is 3 write and therefore cosine of this angle this will be therefore this would be equal to 3 by under root 13, which means that 0 shall be equal to A 1 + A 2 + 15 by 13 and therefore A1 + A 2 shall be equal to – 15 by 13, without consulting the table it is possible to write it in this form alright. And what is the other condition? Other condition is L di dt at t = 0 + should be equal to... Why is that? Let us look at our circuit.

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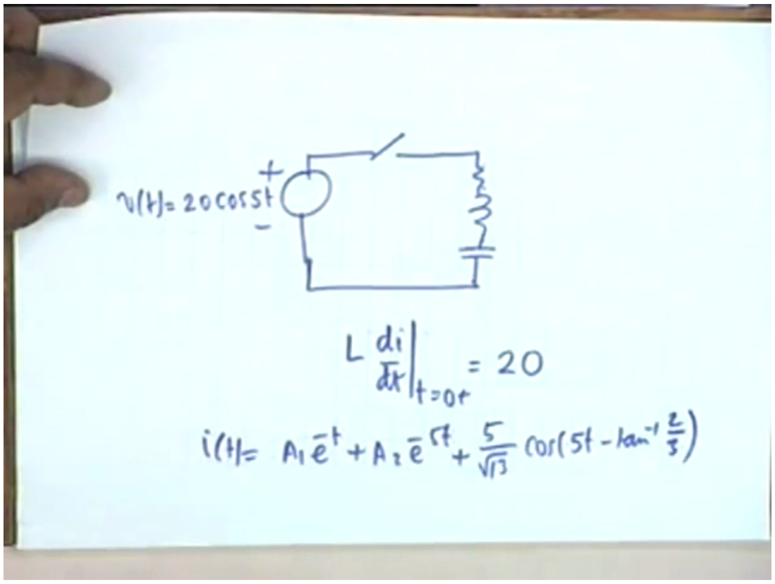

This is the point that this is the point that I used to emphasise that every circuit has its special initial condition okay, this is the circuit okay, V c 0 – is 0 so V c 0 + must be 0. Now the current at 0 – is also 0 so the drop in R and the drop in C both are 0 therefore, L di dt at t = 0 + must be equal to the voltage of the source which is equal to, it is no longer zero you have to look at the condition of the circuit to determine the initial conditions. And therefore my expression for if of t which was A 1 e to the – t + A 2 e to the – 5 t + 5 by 13 cosine of 5 t – Tan inverse 2 by 3, 2 by 3 not root 3, 5 by root 13.

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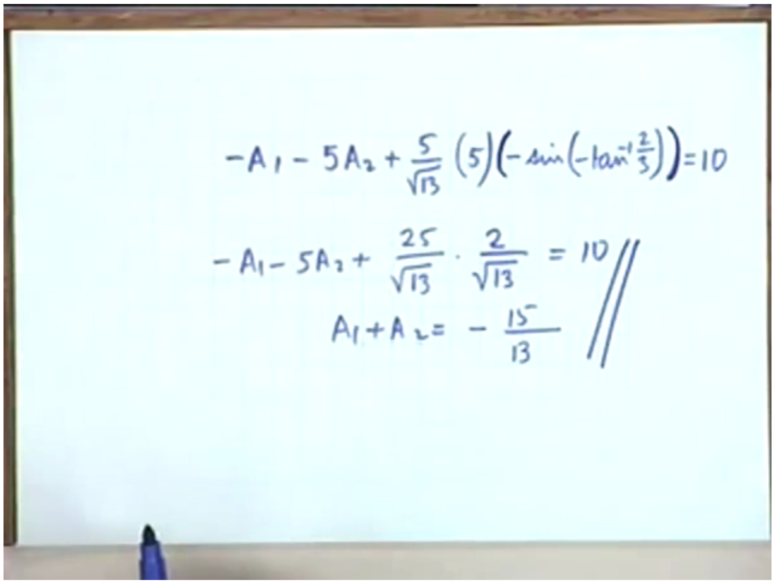

So if I differentiate this and put t equal to 0, the 2nd condition becomes – A 1 – 5 A 2 alright + 5 by square root 13 if I differentiate cosine it becomes a – sin and therefore 5 that comes from cosine 5 t then – Sin 5 t = 0 shall be 0 – Tan inverse 2 by 3, I must distinguish this is the bracket alright. Now see how this simplifies, this should be equal to how much? 20 by L and what was L? 2 and therefore 10 alright, the initial conditions must be identified properly and must be utilised properly and therefore what I get is – A 1 – 5 A 2 + 25 divided by square root 13, now what is – minus so that will make +, Sin of 2 by root 13 alright Sin of this would be 2 root 13 and this would be equal to 10.

The other condition as you know was found as A 1 + A 2 was equal to how much? – 15 by 13 I have a doubt no, 15 by 13. So these are the 2 equations that we have to solve now to find out A 1 and A 2 alright. So the style of working for finding the complete response is you must find both the natural response and also the forced response. For the forced response, forced response would be similar to the forcing function if it is DC then the forced response will also be a DC if it is an exponential function, forced response will also be the same exponential function, if it is a sinusoidal function then it would be sinusoidal. And if it is sinusoidal then we do not have to work in terms of time domain, we can work in terms of the phasor and that is a great simplification.

On the other hand, the natural response the natural response if you have to find the current then you find Z of s Z of s and take its zeros, if you have to find the voltage then you take Z of s but take the polls alright so the natural response will be determined by either the polls or the zeros depending on what you want alright. In this context a term which is sometimes used for determining the characteristics of electrical circuits is the so called pulse response. We have already said what is a step response, a step response is when a battery unit step response would be one in which a battery of 1 volt is switched on at t = 1.

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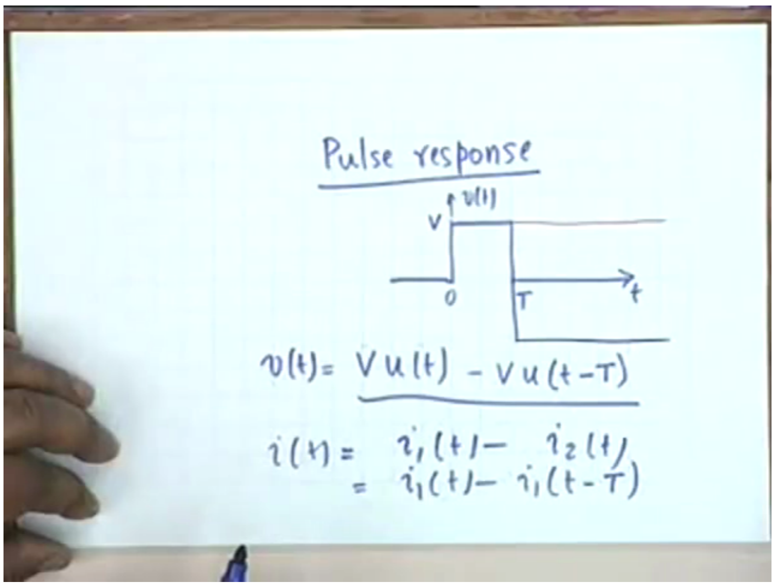

A pulse is 1 which is non-zero for a duration for a certain duration and then it becomes again 0 for example, if this is a voltage pulse then this voltage is typically let us say is at capital V between 0 and capital t that is its duration is capital t alright, this is called a pulse. And the laboratory you shall get so-called pulse generators, where you get not just one pulse, you will get repetitive pulse. Why do you require repetitive pulse? Because if you wish to see the response of an electrical circuit to such an excitation and you want to see it in the oscilloscope then you have to repeat this so you get repetitive pulse generator.

But if you look at it, this voltage pulse can be written in terms of 2 step functions, one is capital V u of t which is a step which goes on indefinitely – – another step occurring at capital T alright so – V u it does not occur at t = 0, it occurs at t = capital T so t – T is that okay? This voltage pulse can be represented by the difference between 2 steps each of amplitude V but the 2nd one occurring at a later instant that is capital T. You see if we add the red curve with the pink curve is what you get precisely alright.

Now we also do superposition and therefore if a voltage can be broken up into 2 voltages obviously the response suppose you apply this to an electrical circuit and you want to find the current i t then the response would be i 1 t – i 2 t, where i 1 t is the response to V u t and i 2 t is the response to V u t – capital T alright. You see the only difference between these 2 is that one is delayed that is small t is replaced by t – T and therefore i 2 t must be equal to i 1 t – T right and this is the way to determine the response of electrical circuit to a pulse voltage like this, let us take an example.

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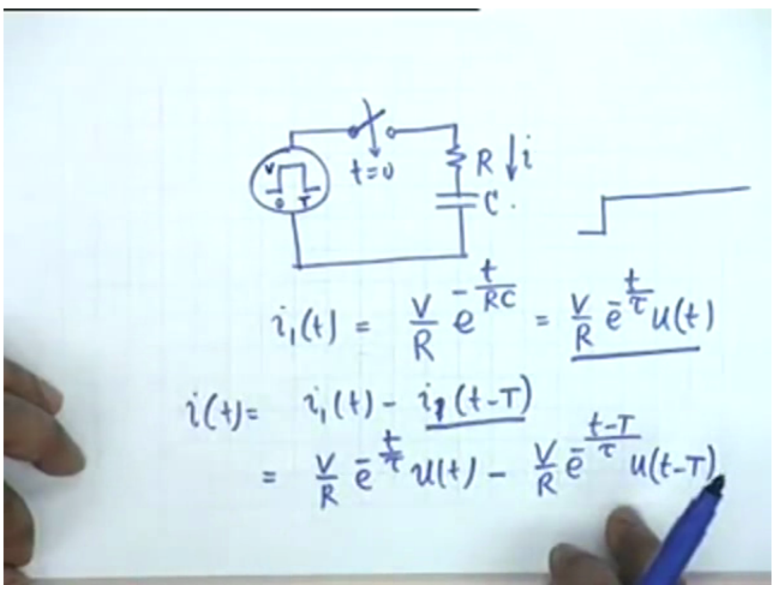

Let us say a pulse voltage of this nomenclature that is the height is capital V and the duration is 0 to capital T, let us say such a voltage is applied to at t = 0 to a series RC circuit a 1st order circuit to keep things simple and we used to find the current i. So what we do is we 1st find the current i 1 t, we 1st find the current to a step of magnitude capital V and we know what this current shall be, we know that this would be V by R and then then what? This current if I simply a voltage like this then the initial current would be V by R because initially voltage across C is 0 alright and therefore it is V by R then it would decay with time according to e to the – t by R C alright, let us call it as V by R, let us call this time constant because I have used capital T here let us call it as Tau t by Tau.

And this response obviously is valid for the time interval between 0 and capital T because at capital T something else comes into the picture so the total response therefore shall be i 1 t – i 1 of t – capital T. Now here, a certain discipline has to be imposed on ourselves namely that his i 1 of t is true only for t greater than equal to 0 and therefore I multiply this by u of t, what is u of t? Unit step function it is 1 for t greater than equal to 0 and it is 0 for t less than 0 therefore this is the correct solution, we did not include the u of t because it was implied in the context but now we have to discipline ourselves because i 1 of t – t starts functioning only at small t = capital T so I cannot combine the 2 unless I use this function therefore what I get is V by R e to the – t by Tau u of t – V by R e to the – instead of t we shall have t – T divided by Tau Mu of t – T, is this clear is this point clear?

I have found the 2 responses independently I could not write without u of t because then the 2nd term would have affected the response even for small t less than capital T is not it right? And this is where I have to write t – T, this function is unity only when small t is greater than or equal to capital T otherwise it is 0.

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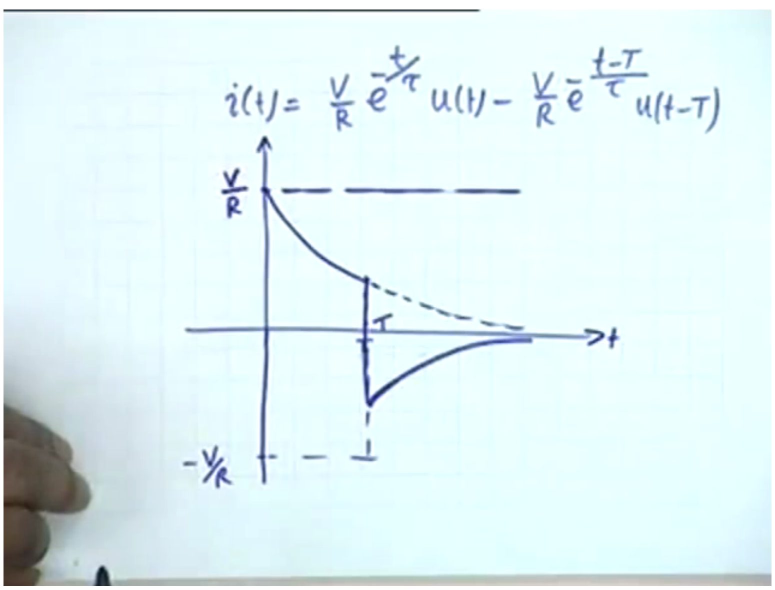

Now if I sketch this if I sketch the current waveform my current waveform i of t is V by R e to the – t by Tau u of t – V by R e to the – t – capital T by Tau u of t – capital T. Now if the versus t if the 2nd term was not there then the current would have started falling from V by R okay, it would have started falling like this. But as soon as capital T the time is capital T it is joined by a negative current and this negative current starts from – V by R and goes to 0 like this okay this negative term goes to 0 like this, so what do you think will happen at t = capital T, the current shall suddenly come down by how much, this – this in other words this much, it will come down by this much so it will go somewhat like this and then what will happen?

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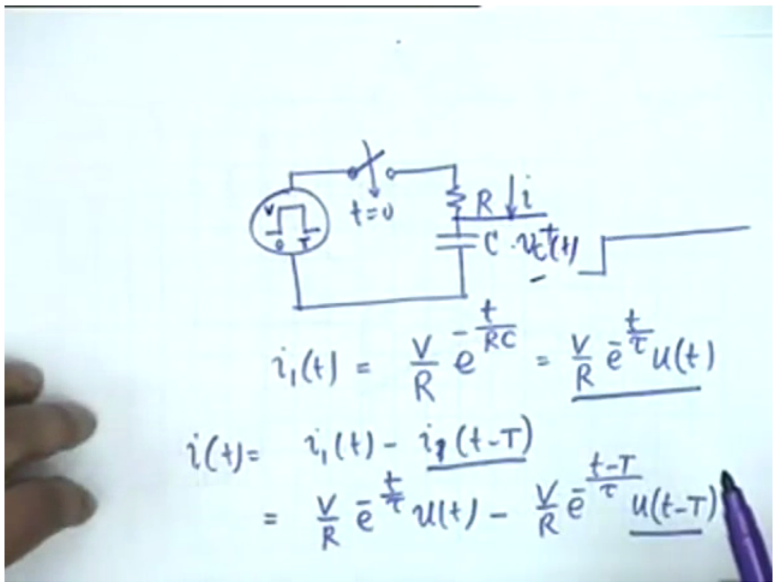

As t tends to infinity it will go towards 0 as t tends to infinity both terms go towards 0 so this will be the current response and you see there is a jump in the current response di dt has a jump here di dt is discontinued at this point at the point t = capital T alright. Suppose we wanted to find out is this point clear the pulse response, basically the current is, if the current is continuous di dt is continuous. Suppose instead of the current we wanted to find out the voltage V sub c what would have happen V sub c if left if only the 1st term was there that is if only there is a step excitation then what will happen to this voltage, this voltage would start from 0 and go to V at infinite amount of time alright.

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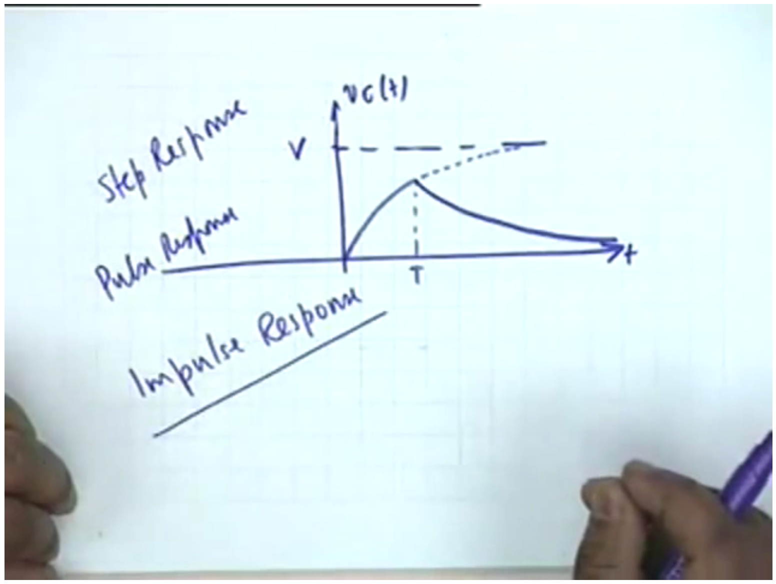

In other words without writing the equation V sub c of t versus t and let us say this is capital V then the voltage across the capacitor would increasing like this and it would have gone to infinity would have gone to capital V at infinite amount of time. Now at this point when the time is capital t what happens? It is joined by another term which is negative but it starts from 0 and then goes negative goes to – V and therefore what will happen to the capacitor voltage, it will gradually decrease and go to 0 at t = infinity, so this will be the capacitance voltage, is this okay? So you know how to determine the pulse response.

We have introduced 2 terms one is step response which you have understood is simply switching ON a battery step response, we have also found out pulse response which is equivalent to switching ON a battery and then another battery in the opposite polarity at some time later. Now there is also a 3rd term called impulse response which I want you to understand carefully impulse response, but 1st let us define what an impulse is okay.

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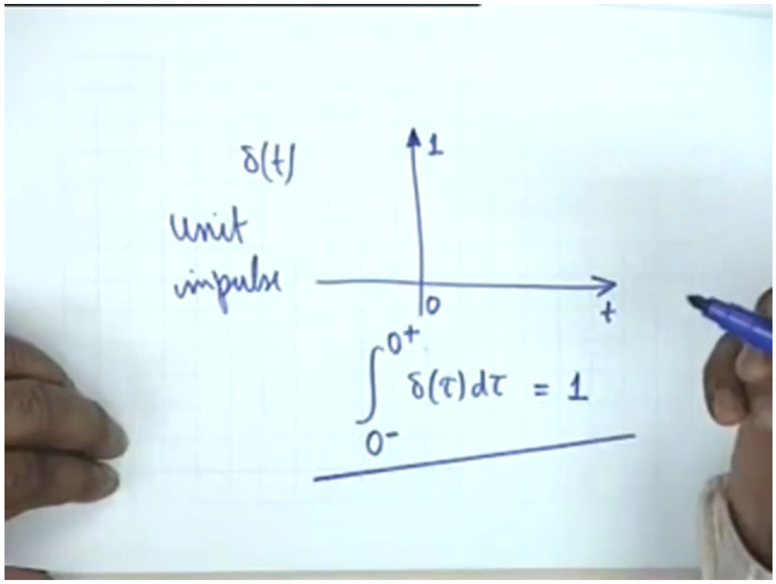

Suppose I have a voltage v of t which is a pulse like this which is a pulse like this 0 for t less than 0, this is t 0 to capital T and let us say this height is capital V. The area under the pulse area is equal to capital V times capital T alright. Now suppose I keep the area constant, allow capital T to decrease, capital T to decrease then naturally when the when capital T has become t 1 the voltage will become v 1 such that this area remains a constant area is a constant v 1 t 1. What happens when capital T tends to 0, capital V shall go to infinity capital V shall go to infinity, this limiting case which cannot be generated in the laboratory you cannot generate any infinite voltage alright you cannot generate a voltage which stays only for 0 amount of time capital T tends to 0.

But nevertheless it is a physical concept which is extremely useful in the analysis of signals and Systems. This is true this analysis is true whether it is a Mechanical system or a chemical system or whatever it is because most of them shall be simulated by means of an electrical circuit and therefore the concept of impulse is extremely important. An impulse can be thought of a limiting case of a pulse whose width tends to 0 and height tends to infinity in such a manner that the area is constant and in this context we define a quantity known as unit impulse a unit impulse Delta t is represented by an arrow here arrow occurring at t = 0 just an arrow.

We cannot represent infinite amplitude on a finite two-dimensional plane and therefore you simply represent an arrow and we denote the area under the impulse but if you want to distinguish, make it a make it a solid arrow like this let us represent the axis by means of an open arrow whose back is open, here the back is close. The area under the curve or under the pulse whose limiting case is the impulse is written here is written by the side of the arrow, this simply means that integral Delta t Delta Tau d Tau, it exists only at t = 0 and therefore you go from 0 –to 0 + = 1 this is what it is.

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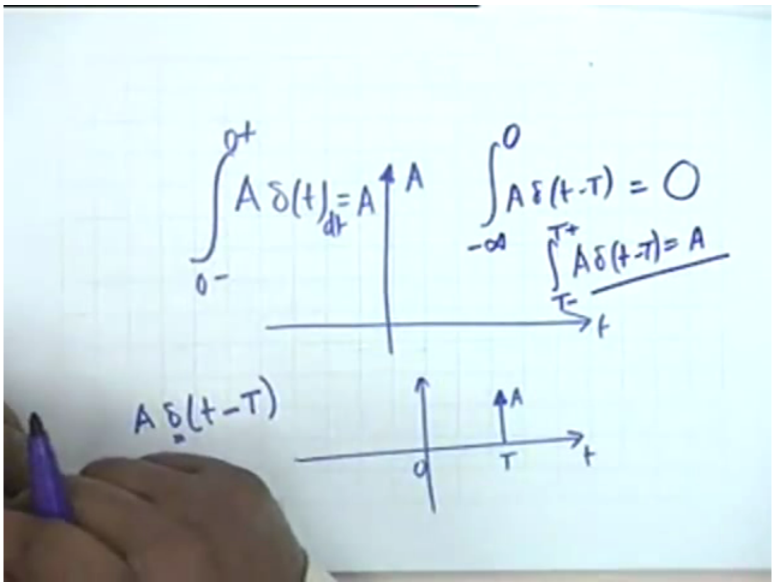

If I have an impulse whose area is capital A as in the previous voltage pulse was, then an impulse of strength A shall be denoted by A Delta t and it shall be represented by an arrow solid arrow with its strength or area this area is also called the strength of the impulse written by its side, which means that if you integrate this from 0 – to 0 + that is over basically an infinitesimally small interval then this would be simply equal to capital T there must be dt here alright, which means that if the impulse instead of occurring at t = 0 suppose it occurs t = capital T it strength is capital A T alright, then this impulse representation will be A time Delta t – capital T, the delta function or the unit impulse function exists only when its argument is equal to 0 that is it occurs at t = capital T.

Now if capital T is greater than 0 and you integrate, you integrate this impulse let us say from – infinity to 0 what would be the value? 0 because it has not included capital T. The integral from T – to T + shall be simply equal to A, this is not a conventional function in the functional sense of the term, this is a concocted function nevertheless it has great importance in theoretical physics and in engineering and this function was introduced by the famous physician PAN Dirac and therefore this is also known as Dirac's delta function alright.

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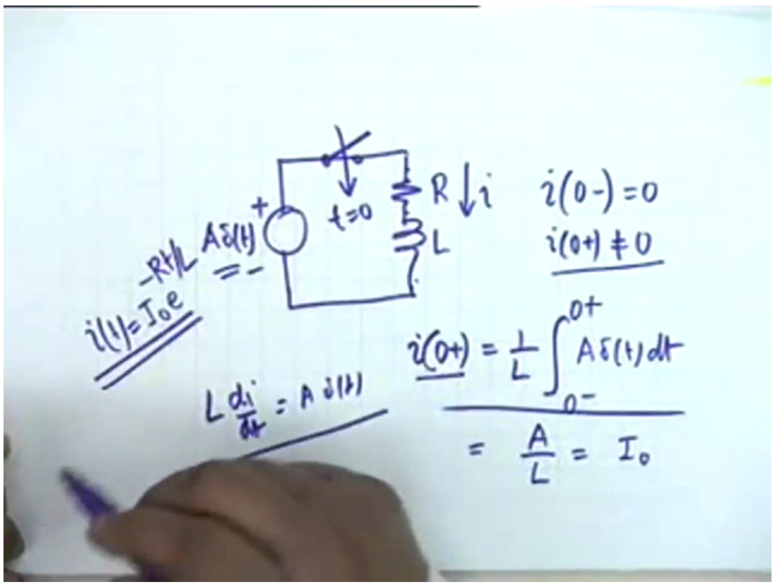

Now suppose I have an RC circuit, now come to the come to the plane, suppose I have let us say an RL circuit and I have a voltage which is a unit impulse which is a n pulse of strength capital A alright. I owes to find out the response of this, this is switched ON at t = 0 and I owes to find out the current I, now comes contradiction to our hypothesis which we have been working so for, i of 0 – is 0, i of 0 + should have been 0 is not that right because an inductor cannot change its energy instantaneously.

But this is a calamity situation a crisis situation, you see if you are standing at a slope and the slope is sufficiently low well you can resist the force of gravity but you cannot obviously stand when the slope is very large, it is like a piece of ice coming down from a hill and you are sitting at the bottom of the hill, you can stop it but when it is an avalanche you cannot and therefore you will be carried along. This is an avalanche situation, and infinite amount of voltage is applied over infinitesimally small amount of time. The inductor has no other way but to accept an energy alright, this is a crisis situation, it does not obey the ordinary laws that we have so far, this is not equal to 0.

And to find out i of 0 + to find out i of 0 + what we argue is the following that i of 0 + cannot be infinity because we are giving a voltage which exists only infinite amount of time, it may be infinitely large but the current cannot go to infinity current must finite. If the current is finite then obviously the drop in R shall also be finite and therefore the A Delta t the voltage source must be fully dropped across L and therefore the current i 0 + must be 1 over L integral V dt which is A Delta t dt from 0 – to 0 + and you see this is simply A by L let us call this I 0, is the point clear? It contradicts our common sense but as I said it is a calamity situation.

There is a voltage source which goes to infinity but stays only for 0 amount of time infinitesimally small amount of time, so the effect is at t greater than equal to 0 +, the voltage source is gone. Now what would be its effect left in the circuit? Obviously the effect cannot be the infinite current it must be a finite current, if it is a finite current then the drop across R shall be small compared to the drop across L because L is multiplied by di dt and di dt is infinitely large, there is no current, suddenly a current is established and therefore, L DI DT must be equal to A Delta t because the current drop across R is finite, any infinite drop obviously shall swab the finite drop and therefore i of 0 + shall be L di dt = A Delta t and if you integrate this equation, this is what you get.

And the integral of Delta t dt is unity and therefore the i of 0 + shall be i 0, so after the pulse has after the impulse has gone away that is at t greater than equal to 0 +, the inductor sees that it has accumulated an energy analogy of half L i 0 square and this becomes a short-circuit then, A Delta t is 0 and therefore the natural response will come into effect, i of t would be equal to I 0 e to the power – R t by L is that okay, and this is called the impulse response of the circuit, so we have introduced today 3 terms; step response, pulse response and impulse response. Next time we will look at impulse response from a different point of view as the limiting case of the pulse response and you will see that you get the same result alright.