Basic Electrical Circuits
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Lecture - 148

Now, another way of see the reason is the reason we do this things is the phasor diagram is very useful for visualizing phasor relationships at a given frequency. So, that is why we draw that. Now, when we have this circuits which are frequency dependent thing change that is thing change is a frequency. So, you also want to have some ways of figuring out what the circuit does in different frequencies. So, the different representation, the same thing.

Now, you can just all the information is already there in the algebraic expressions, but there is a reason you draw pictures, because it is lot easier to visualize certain things from pictures than from the expression. So, for a given frequency the phasor diagrams are useful. Now, you also want to know what this does to signals of different frequency that is I apply sinusoid and I start from very low frequencies may be you one d c and then sweep the frequency to very high values. So, what happens?

So, now, you already did that by the way, but we drew three different phasor diagrams, one for low frequency case, one for high frequency case and one for 1 omega equal to 1 by R C. But, it is lot more useful to draw the magnitude and phase as the function of frequency. So, in that case instead of drawing the phasors at a particular frequency, what will do is, we will plot the magnitude and phase of the phasors at different frequencies I mean I will plot the magnitude and phase of the phasors versus frequencies. So, that also we can do here.

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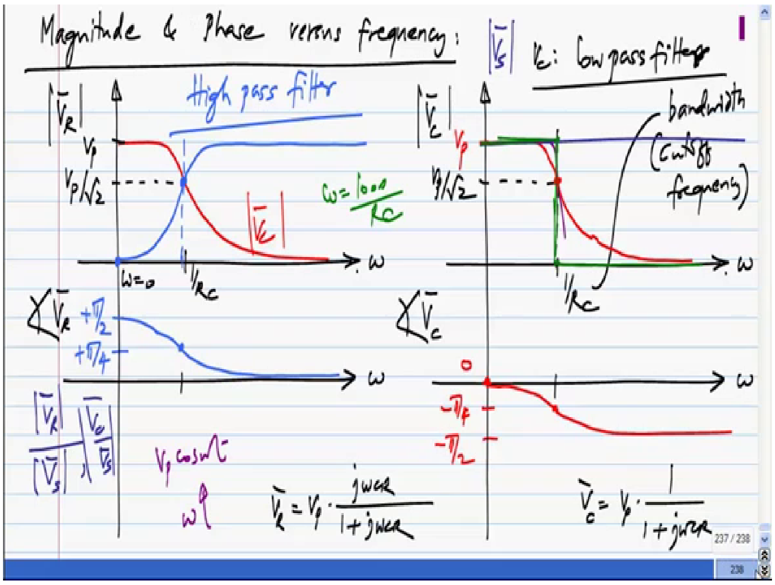

So, let me make these axis and here I will plot the magnitude of V R and the angle of V R and I will also make the corresponding plots for V c. Now, I see that actually I will noticed the lot of you are not very comfortable drawing pictures of various things, but sketching is an extremely good where to get intuition about many things, you cannot do any sketches accurately to find solutions and so on.

You cannot draw a non-linear curve and then see where it cuts this and say that the solution is x equals to this one that is not what is useful for. But, it is lot more useful for getting intuition when the expression may be just, so complicated to solve that or even if you solve it the expression even a quadratic equation solution looks quite messy and if you go to higher order stop fit may not even be possible to write it or even if you do you won't get any inside from it.

So, lots of times sketching the solutions or sketching possible solutions is a very good way to get intuition or even to find the solution itself, you sketch different parts of the let us say you have an equation, where you say some f of x plus g of x equal to 0 you can plot f and g separately and approximately to scale to at least find where the solution lies after that you can go and do a exact analyzes. So, it is a very, very important to be comfortable with this as well and the way to do this is by taking some limiting cases if I....

So, I already have the expression for V R, what was it is the expression of V R?

Student: ((Refer Time: 03:35))

Now, if I say draw the magnitude and phase of this of course, I can write the expression for the magnitude also that is very easy I just take the real part plus imaginary part I mean squares of real and imaginative parts some together. But, you do that, but the way to sketch things you also look at extreme values, like what happens when omega is very small, omega is 0 let us say an omega equal to infinity and so on. So, let us do this V R, what is the value of V R at low frequencies?

Student: ((Refer Time: 04:10))

Let us say omega equal to 0, what is it.

Student: zero.

Zero, so let us say this is omega equal to the omega equal to 0, this is 0 and what is the phase angle.

Student: 90.

90, we already evaluated this, it is plus 90 and what happens as omega increases.

Student: ((Refer Time: 04:42))

What happens to the magnitude?

Student: Magnitude increases.

Magnitude increases and what happens to phase?

Student: Decreases.

Decreases, what is the another value omega for which we know the answers.

Student: 1 by R C.

1 by R C omega equal to 1 by R C what is the value of magnitude.

Student: V p by root 2.

V p by root 2, so let me call these V p and V p by root 2 may be somewhere over here. So, it will be there and what is the phase at 1 by R C.

Student: 45 degrees.

45 degrees and what is it very high frequency.

Student: Magnitude.

Magnitude will be V p, so what happens is start from low values and then it rises up like that and finally, just saturates to V p is this fine and the phase does that. So, correspondingly for V c what is it.

Student: ((Refer Time: 06:15))

For low frequencies what is the value of V c magnitude of V c.

Student: V p.

V p and for omega equal to 1 by R C.

Student: ((Refer Time: 06:28))

So, it is in fact, the same value V p by square root of 2 and for very high frequencies 0 and phase what are the reflect.

Student: ((Refer Time: 06:58)).

In this particular case we know that V c is simply V R minus 5 by 2 it is the same curve shifted down by 5 by 2, it is start from 0 and reaches minus 45 degrees and goes off to minus 5 by 2 is it fine. So, again even for more complicated circuits, where the expression will be complicated you should be able to draw this plots. Now, what is the purpose of these plots? Again the information there is no more than the information in the expressions.

But, clearly you see that let us say I take the capacitor voltages the output and I speed frequencies what does it say, it is says that at low frequencies it led the input signal and without changing there is some phase change, but the all of the input signal will come out, the amplitude of the outputs sinusoidal is also V p at low frequencies. So, now, and at very high frequencies it is simply blocks the signals, even if you apply signal of amplitude V p at very high frequencies output amplitude is 0 or nearly 0.

So, this is a very useful function as well and that is known as filtering, where you selectively allow or block certain frequencies and V c in particular this is a low pass filter, it meaning it passes low frequencies and blocks high frequencies of course, ideally you would like to allow completely up to some frequency and then completely block after that, but no real circuit can do that. So, this 1 by R c omega the frequency 1 by R c is sort of the boundary between what is being allowed and what is not being allowed, although it is continuous it is not that just below omega equal to 1 by R c it allows the signal completely and just after that it completely blocks that it is not like that you cannot do that.

But, it still a low pass filter and this 1 by R c this known as the band width or a cut off frequency of the low pass filter. Now of course, the exact values of the phase and so on at this frequency depend on the circuit. Now, typically the frequency at which the amplitude goes to 1 over square route of 2 of the maximum value that is defined as the band width, the some reasons for it we do not have to worry about it that is called the magnitude.

Similarly, this V R where could also say V R is my output that is I connect I have series combination of resistor and capacitor, but I take my output across the resistor. In that case this is a high pass filter and again the cut of frequency is the same is 1 by R C. In fact, you can see that these two are complimentary to each other, if I due the capacitor cover on the same I would get something like that cut of frequencies 1 by R C. So, it does not allow d c at all and then it kind of blocks low frequencies and it completely allows high frequencies.

Student: ((Refer Time: 10:40))

Which one.

Student: ((Refer Time: 10:43))

V c.

Student: ((Refer Time: 10:45))

Well, I mean it is clearly not it is always continuously decreasing, because it is a continuous function of omega but that depends on what scale with draw it in.

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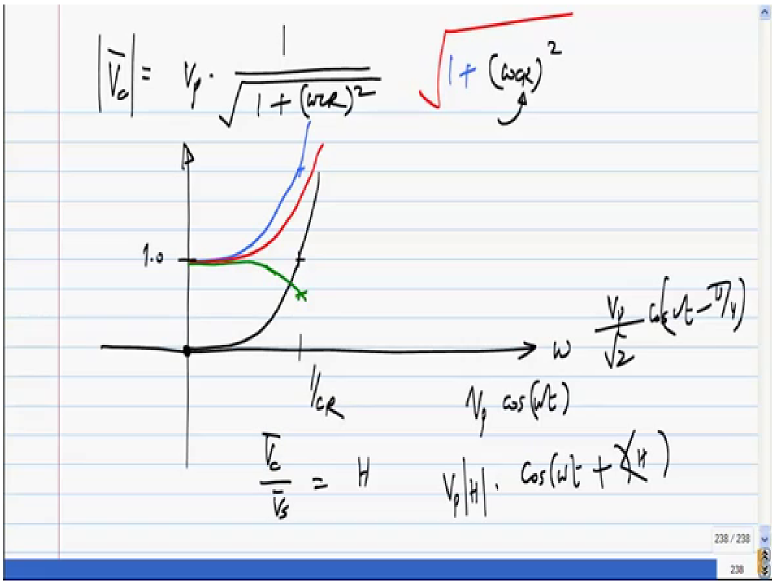

So, the magnitude of V c is V p times 1 by 1 plus the magnitude of V c is this. So, now, here look at how this behaves. So, first I will plot only this omega c R square, what will be that look like, what is it just this function omega c R square.

Student: ((Refer Time: 10:50))

Which goes as omega square it is at 0 here and then at omega equal to 1 by c R what is it.

Student: one.

One, so let me say this is 1 and also it goes something like that, this slope continuously increases also. Now, I add 1 2 that what will that look like.

Student: Shiftier version.

Shiftier version, so it will... So, the vertical spacing should be the same between these two and I take the square root of that what will that look like.

Student: ((Refer Time: 12:30))

What will that look like?

Student: Slope decreases.

Slope decreases, so it is always below the blue curve or above it.

Student: Below.

Below, below. So, it will do something that now a plot the reciprocal of this you can kind of visualize that the it will be constant here and then it will start slowly falling out and at this point it will reach 1 by square root of 2. So, it will look like that because a plotted the y axis in a linear scare, y axis on a linear scale and in this function is it has some square roots and omega squares and so on that is why it is like look like on.

In fact, if you can it turns out that with appropriate arrangement of a higher order circuit you can do something like that, which is the type of ideal filtering you are looking for as you got a higher and higher orders you can try it make it more and more steep.

Student: ((Refer Time: 13:28))

Inflection, what is point of inflection where the second derivative of 0 is it I do not think. So, I mean this is the monotonic this function I you can calculated I do not things it is a right down.

Student: ((Refer Time: 13:50))

Not capacitor low pass filter in the R C circuit, if I think of the input to the capacitor voltage that function is low pass filter.

Student: ((Refer Time: 14:00))

No.

Student: ((Refer Time: 14:09))

The capacitor have a short circuit that is why the voltage across it is very small, listen it you have a resistance and you have a capacitor which is almost the short circuit a at very high frequencies. So, the voltage across the capacitor very small at high frequencies.

Student: ((Refer Time: 14:30))

No, the function low pass filter simply says that it allows low frequencies and block high frequencies that is all.

Student: ((Refer Time: 14:39))

I mean if you look at this what is this plot of now applied V p cos omega t and sweep omega. So, that is I am applying some constant amplitude sinusoid and I am sweeping omega from 0 to infinity and at the output I am getting basically sinusoid of amplitude V p up to some frequency and at very high frequencies I am getting nothing. So, although I am applying the same amplitude sinusoid, what is the input let me plot the input as well.

If I just plot at V s let us say magnitude of V s what is it.

Student: ((Refer Time: 15:20))

Thus V p, so I apply this and I get this. So, I am getting what I have applied here and I am getting much smaller that here. So, it is passing low frequencies and blocking high frequencies. So, that is what low pass filters, normally what you do is, you will not plot V R and V c by themselves, but you would plot V R divided by V s and V c divided by V s. So, this will take out the amplitude it will tell you exactly the ratio of the output to input. So, in that case instead of V p this would be 1 and here also it would be 1 the rest of it remains the same.

Student: ((Refer Time: 16:00))

That is what I said it is not an ideal, so ideal an may be a wanted the filter to be like this. So, now, that function you cannot realize, because if you see that is a function of omega which has a derivative which is infinity. Now, you cannot realize this with any finite order polynomial that on basically means that you cannot realize it with a circuit of any finite order. So, it first order you will get some approximation if you can possibly make a second order circuit that becomes steeper and tenth order circuit that is much steeper, but you will never get that infinity slope.

So, here it is only an approximation, but it is let us say you look at omega equal to 1000 by R c. So, the output amplitude will be 1000'th of the input if you apply 1 volts sinusoid you will get 1 milli volt, you can calculate that approximately 1 milli volt. So, that I will say I will neglect it and say that ((Refer Time: 17:01)).

Student: ((Refer Time: 17:02))

No, no what is that the frequency is the same as the input frequency always whatever frequency applied the input you will get the same frequency that is the whole business of this face of analysis sinusoidal ((Refer Time: 17:18)) and so on. Some of the basis of that, that we can do it.

Student: Amplitude is the changed.

Amplitude is the changed, so if you take this function V c by V s and let us say I call this H not the magnitude even the complex number, this I can call the transport function of the circuit. So, it is the ratio output to input just like a voltage divider has a I mean resistive divider has a voltage ratio, this is also the same kind of ratio except that this is the complex number. So, now, what it means is if you apply a sinusoid V p cos omega t at the input at the output you will get the sinusoid of the same frequency which means that it is cos omega t, but it is faces altered by angel of the this complex number and magnitude is altered by the magnitude of that complex number.

So, that it is tells you what happens to the sinusoid. So, if H is 1 by square root of 2 and it is angel is minus 45 degrees what it means us that if you apply V p cos omega t you will get V p by square root of 2 cos omega t minus 5 by 4 this what happens for this circuit at omega is 1 by R C. So, this transfer functions are very useful whenever you have a filter you would describe things with transfer function, because I mean I did plot the V R and V C by themselves versus frequency, but you can do, but it is probably better when you are looking for transfer functions when you are looking for what happens to the signal to plot the ratio output to input than the absolute output itself.

You can think of it as the same curves when V p equals 1 that is all. Any questions about any of these things. So, you can do this now there is a better way of floating this what happens is that if you plot this magnitude on a linear scale. So, you can kind of see I mean at least visually also may be this is V p or if this is 1 let us say up to 1 by 10'th you can kind of see on, on paper may be 1 by 20'th and so on, but after that you cannot say what is happening.

So, when you have quantity is the change by large amount, where is the magnitude itself is going down monotonically. Because, the function is this the omega goes on increasing this will indefinitely go on decreasing. So, when you have quantity is the changed by very large amounts what you do to plot the.

Student: Logarithmic.

Logarithmic scales and similarly for frequency also the way it is now we start from 0 the cut of frequency is here and after that there is an infinite range frequencies. So, what we will do is, we will put the same plots on logarithmic scales and that is what is known as got a plot we will see that may be on Monday, actually the tutorial has some problems about this you can omit them for now and then we will them later or may be Tuesday.

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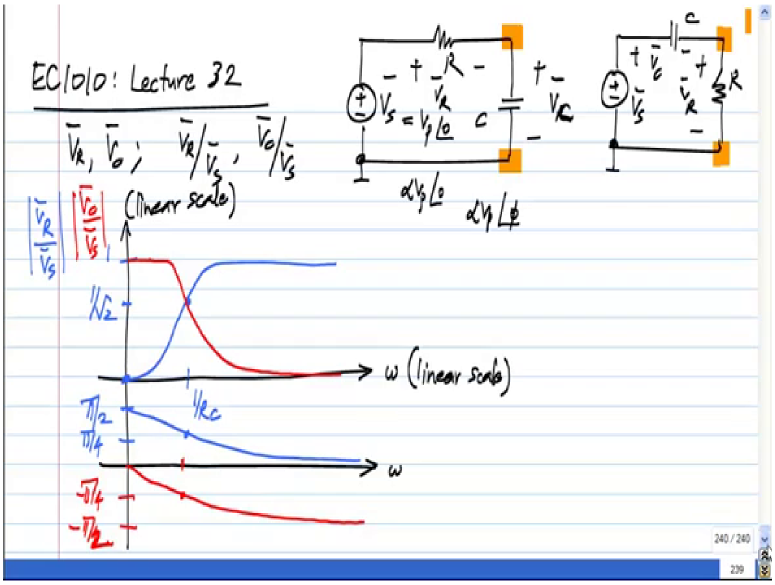

The previous lecture we will looking at magnitude and face plots how to draw them versus frequency. So, these are all useful representations of circuits which have inductors and capacitors, because have frequency depend behavior it is useful to draw the magnitude and face of certain quantities versus frequency. So, that is what comes out of these, some another plot that will discuss earlier was phasor diagrams, where you depict the magnitude and face at a particular frequency, but what you are looking to a show is the relationship between magnitude and faces of different voltages of currents in the circuit at the same frequency.

Here, we are looking at for a given quantity at different frequencies, the example circuit we took was this let us say this is V s R and C. So, we are looking at this capacitor voltage V c and the resistor voltage V R and of course, the quantities will be the same in this circuit if you inter change R and C, so then this is V R and this is V c. So, the only reason to draw both of these that in this case you can think of V c as the output and in this case V R as the output coming out of this side, then what it be have we can plot either V R and V c or V R by V s and V c by V s.

So, let us say this phasor V s, this is more useful in the sense that if you change V s by certain amount certain factor the output will change by the same factor, you know that because of linearity. So, instead of plotting the absolute values of V R and V c you normalized it to be and then plotted. So, when you want a characterize circuit that is why you do it I mean this is something like the gain of the circuit or the transfer of the circuit from one side to another.

You also know that if there is some pay shift in the signal V s, the output will experiences the same facial that is what I mean us V s is let us say V p angel 0 you will get a certain output, if V s is alpha V p angels 0 the output simply BIGGER the factor alpha and if the input V s is let us say alpha V p angel phi, the output also experiences the same pay shift phi. Because, in the complex domain the pay shift of phi is like simply multiplying it by exponential j phi that also gets multiplied I mean output also get multiplied by the same factor.

Of course, the movement we say phases and all of these things we are talking about sinusoidal study state response. I already explain to why this is useful even if this is only part of the response, it is quite useful in many situations. Because, it use the sinusoidal signal for testing, because all the reasons I explained earlier and it posses for a long time and it is responses sinusoidal etcetera, etcetera and in all these in many of these circuits the transient response dies out and finally, the total response equals the sinusoidal study state response.

So, we drew the magnitude and space plots I will draw slightly differently now instead of drawing it for V R and V c I will do the plots for V R by V s and V c by V s, this is omega and I will first plot here what is this plot look like, what is it for very low frequencies V R by V s.

Student: ((Refer Time: 24:55))

1 why?

Student: Zero.

Zero, so there is no voltage across the resistor at very low frequencies. So, it starts from 0 and at omega equal to 1 by R C, what is it.

Student: ((Refer Time: 25:13))

1 by root 2 V p by square root of 2, but you are normalizing in to V p now and it very high frequencies.

Student: one.

One, so this is 1, this is 1 by square root of 2, so does that and the phase angel, what is the phase angel at very frequencies.

Student: pi by 2.

Pi by 2 at 1 by R C.

Student: pi by 4.

Pi by 4 and then quite look like a ((Refer Time: 25:29)) it is basically the tan inverse curve, the tangent curve you know how it is starts it is ((Refer Time: 26:07)) infinity for this is the same thing rotated it is a inverse of and if I plot V c by V s it is a compliment of this it is 1 at very low frequencies also reaches 1 by square root of 2 at omega equal to 1 by R C and then goes up to 0, it never quite goes to 0 it goes to 0 at omega equal to infinity, but it goes off to very small values.

The phase at low it is basically the same thing shifted by shifted down by pi by 2, it is starts with 0 goes to minus by 4 at omega equal to 1 by R C and then goes up to minus pi by 2 asymptotically it is fine. Now, these plots are sometimes you do plot them like this, in this case both it is implicit I mean normally when you say plot this is what you do, so this is on a linear scale and magnitude is also on a linear scale.

Now, the disadvantage of this is first of all you are sort of detail coverage from 0 to 1 by R C, then from 1 by R C you can draw to some extent depending on the how much length of paper you have, but you can go to very large factors, you cannot at 100 by R C you cannot figure out on this sheet of paper or even 10 by R C it will be somewhere here, so the range is limited.

Similarly, on the y axis it is it ((Refer Time: 28:02)) good detail up to here may be when it this is 1 down to 0.1 or so 0.01 and so on I mean you cannot even see what is happening. So, of course, the normal thing to do when you are interested in plotting something over a wide range is the large scale to use the large scale and it is use, so widely that it is worth while discussing that.

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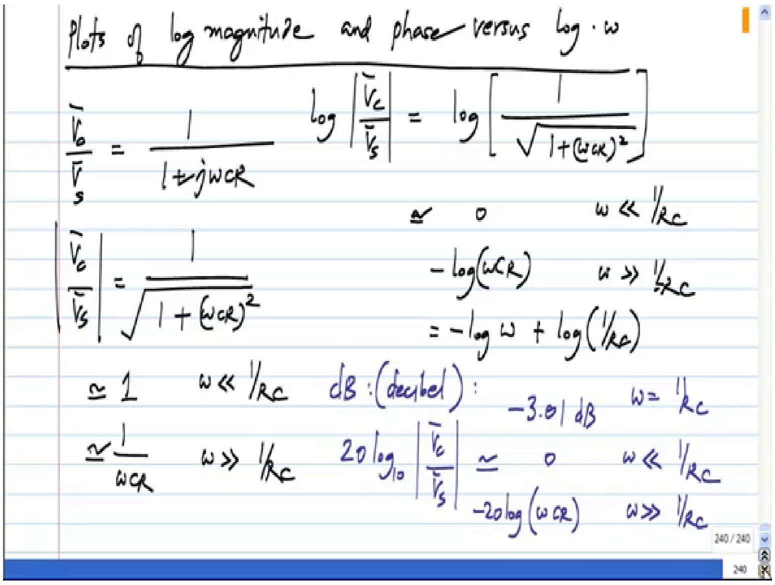

Now, the magnitude of these functions changes over a wide range, the phase does not the phase or still changes only by range of pi by 2 or so. So, that you do not show on a large scale and also you have this problem that if the phase goes towards 0 the showing on a large scale is problem as well, log magnitude or phase versus log omega. So, this is what you do.

In fact, it is quite easy to arrive a draw this plots impact easier than in the to draw the linear plots, linear scale plots. So, first of all V c by V s what is the expression for this, what is the expression for V c by V s forget the magnitude.

Student: ((Refer Time: 29:35))

1 by 1 plus j omega c R, so the magnitude of this is 1 by 1 plus omega c R square and the square route of that. Now, the key in drawing these things is to identify some assume thoughts, where this is approximately 1 if omega is much less than 1 by R C and it is also when in the other case what is it, omega much more than 1 by R C.

Student: ((Refer Time: 30:20))

1 by omega c R, basically whether this number is much smaller than 1 or much larger than 1 which much smaller than 1 you neglected the answer is 1 which much larger than 1 you neglect 1 and the answer is 1 over omega c R. Now, also this of course, you can plot, but when you take the log of this as log of this whole thing of course, at which is basically approximately 0 for omega will much less than 1 by R C and what is that, what is it for omega much more than 1 by R C.

Student: ((Refer Time: 31:23))

Minus log omega c R which of course, is minus log omega minus log or maybe I will write as plus log 1 by R C. So, either why I mean quite easy to interpret, I will define a new quantity for the magnitude, which is basically the I will familiar with disable units d B what is it.

Student: ((Refer Time: 32:10))

It is 10 log of what?

Student: ((Refer Time: 32:14))

What is I?

Student: ((Refer Time: 32:16))

Intern city, we have worked in terms of intern city. Now, in this case we use 20 log why.

Student: amplitude.

Amplitude, so.

Student: ((Refer Time: 32:30))

Amplitude is not intern city square intern city is amplitude square. So, the intern city of light is related to the square of the amplitude of the electric field and the magnetic field which of the electromagnetic radiation. So, to represent the same I mean the same number let us say minus 10 d B represents either 1 10'th in intern city or approximately 1 3'rd in the amplitude of the field.

So, the decimals when you are applied to voltage ratios or current ratio is defined with 20 log to base time, first of all everything we did now a does not matter what the bases, but this d B or and decimal unit is 20 log to base 10 of some magnitude at does not matter what it is and this is approximately 0 for omega much less than 1 by R C and what is it for omega much more than 1 by R C, what is it.

Student: ((Refer Time: 33:44))

So, it is just the same thing, so just multiplied by 20 and also at omega equal to 1 by R C what is it, it is the value of.

Student: ((Refer Time: 34:05))

Minus.

Student: ((Refer Time: 34:15))

No, I want the decimal stuff what is it.

Student: Minus 10 log 2.

Minus 10 log 2 minus 20 log square root of 2 how much is that.

Student: ((Refer Time: 34:25))

Usually we neglect that 0.01 and call it minus 3 d B. So, half of the power corresponds to approximately 3 d B reduction in at 3 d B reduction. So, this band width where the game reaches 1 over square root of 2 of the maximum, you can also exposed it as 3 d B small of then the maximum. So, that is why it is also called 3 d B band width as you can see these I said that this could be a low pass filter, but this is not something where it passes certain frequencies completely and then after it completely blocks them.

So, what you call the band with the up to you, you could also define 1 d B band width if you wish to, but conventionally you would define the 3 d B band width which is the same as where it reaches 1 over square root of 2 and for this particular circuit it is equal to 1 more 1 over R C.

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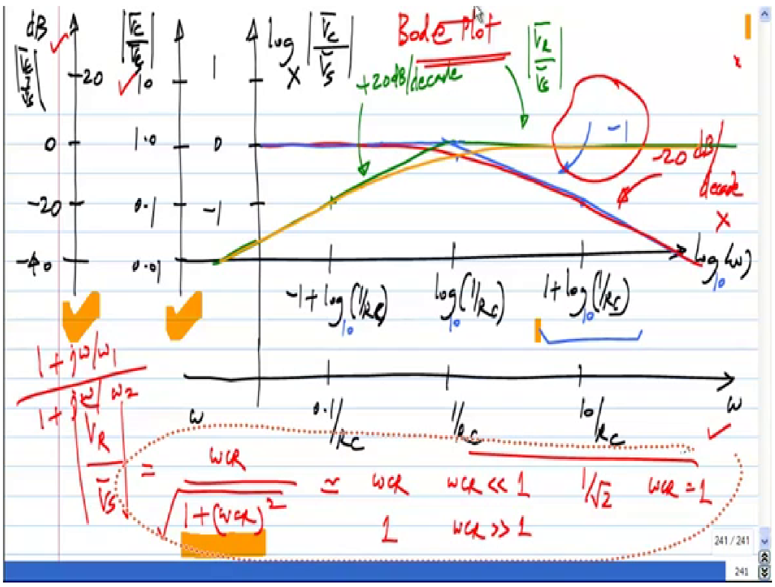


So, what do we do now let us say I could do draw the various plots which are really the same plot, but different marking of the axis. So, let us say a plot log V c by V s versus log omega, naturally if I have logarithmic axis the number 0 is not represented it is at minus infinity. So, let us say I call this 0, 1 and minus 1 and similarly I have 0 here and minus 1 here 1 here and so on.

So, what is this picture look like log of magnitude of V c divided by V s, what is look like V. Kannan, Kannan what is this plot look like for I mean in this range I want some ranges, you understand the question. So, what is the answer actually I think should this is not correct let me call this log 1 by R C. So, what is the plot look like, it is the same plot just translate the scale, we have absolute value of V c by V s versus omega all I have done it is the stretch the x and y axis.

What it the earlier plot look like and goes to 0, so you look at this and tell me what this also look like Rajath.

Student: Start at 0.

Start at 0.

Student: ((Refer Time: 38:24))

Minus.

Student: ((Refer Time: 38:28))

Minus 3 minus half log 2, how much is that minus 0.15 for high frequencies I may it is simply that all of these are log 2 base 10 straight line, approximately at this point what frequencies does it corresponds to this particular 0.10 by R C. What is the gain? What is module of V c by V s at this frequency approximately? We have the approximately expressions, just look at and tell me, what is it 1 10'th the gain is 1 over omega c R, if omega is 10 times here this is just 1 10'th.

So, where is it on this log skill.

Student: ((Refer Time: 39:24))

Minus 1, so I could draw this line here and then I can draw line there this what is the slope of this minus 1, because it is a because it is just minus log omega does what is in the expression is not it, the number multiplying this log omega is this slope. So, the slope is minus 1 that is all. So, roughly speaking the plot consist of two straight lines, one which is horizontal and one which is falling off with the slope of minus 1, this is.

Student: ((Refer Time: 40:07))

No, no this is with the approximation, the only where place where the approximation is in error is around here. So, it is should actually do that, so for away from this point the approximation is good enough.

Student: ((Refer Time: 40:28))

What is the idea.

Student: ((Refer Time: 40:30))

So, this is just numerical approximation, so 1 plus omega c R square, the omega is very small it is approximately one. So, you cannot see the difference anyhow, where the approximation is worst in this point at this point. So, for I mean you can plot this on a computer and see. So, at frequencies much lower than 1 by R C it is approximately 1 or the log magnitude is 0 and at frequencies much higher than 1 by R C there magnitude is 1 over omega c R or on the log log plot it is line of slope minus 1 is this fine.

Now, one thing is that it is very incontinent to have the x axis like this to plotted verses log omega as you could see while trying to plot this. So, what I will do is I mean this is also very common thing you must have seen step like that instead of marking the x axis like this I will mark omega itself, but graduated in logarithmic intervals that is all. So, this is 1 by R C, 10 by R C, 0.1 by R C and so on, you must have seen graph papers like this where their spacing is non uniformed, this is lot easier to read because then I can just ask you what is the gain at this frequency 1 by R C instead of saying what is the frequency where the log of the frequency is log of 1 by R C and so on. So, it is just lot easier, but the plot is exactly the same you understand.

So, you could plotted like this and similarly why should I plot log of mod V c by V s, I could plot mod V c by V s and then marked this as 1, this as 0.1 and so on may be this is 0.01 etcetera and if I had something where it could go up 10 I could also do that, this is clear it is a plot of log magnitude versus log frequency or you can think of it has both magnitude and frequency axis are graduated in logarithmic intervals. The third alternative is to mark this in d B usually it is represented as V c by V s, but you a put d B there, what is this correspond to this particular point here omega d B is that.

Student: ((Refer Time: 43:02))

0 d B, it is the logarithm of this it is 0 degree basically it is the number on this axis multiplied by 20, this one is.

Student: Minus 20.

Minus 20 and you could have minus 40, where it is reach minus 40 at what frequency.

Student: ((Refer Time: 43:24))

100 times 1 by R C, 100 by R C this is going with a constant slope in the log scale so; that means, it going down by equal factors for equal factors of frequency. So, from 1 by R C you go to 10 by R C the gain drops from 1 to 1 10 from 1 by I mean from 10 by R C you go to 100 by R C, the gain drops from another factor of 10. So, minus 40 and could also have plus 20. So, now, of course, normally you do not do this at all, you do not use you do not plot log V c by V s you either to this or that you can either plotted in d B or just the magnitude, but you graduated in logarithmic intervals.

The plot is the same any of these x axis or y axis you choose, you understand that and then I will also plot it like this I want plotted like this. Because, you just to come or some to do this, because I want to see the plot and say a the gain at 1 kilo hertz is so much 20 kilo hertz it is so much and I do not want to convert this like go back and 4 could be in log and so on. And the decimal unit itself is use so widely that I can plotted that way as some question.

Student: ((Refer Time: 44:37))

Either one I want say lots of time you will see decimal plots, but it is I mean I do not see that much difference with between the 2 probably you will see decimal little more often, but I want put down the other thing. Now, if I do plot it in on the decibel scale, what is the slope of this.

Student: Minus 20.

Minus 20 that is all, so this is minus 20. So, this type of slope it is called as minus 20 d B per decade by decade you mean a factor of 10 rise in frequencies or factor of 10 change in frequency. So, what it means is when you go from 1 by R C to 10 by R C that is in this part of the curve in this during this straight line segment, if you change frequency by factor of 10 the magnitude changes by factor of 10 or it is changes by 20 d B and then minus signify is that it is falling, if it was rising you would do plus 1 this clear.

So, please plot it both this and this for V R by V s quickly, so just as practice there is nothing very profound about this, but you are to understand the definitions and not get confuse by the log and so on. So, what you get?

Student: ((Refer Time: 46:20))

What does this curve look like?

Student: ((Refer Time: 46:25))

It just complimentary to this. So, if I draw the straight line as in told it will look like this here and then like that the actual step would be it will follow this for low frequencies and it will deviated it will fall down by 3 d B at that frequency and it will look like that. So, this is magnitude of V R by V s and what is the slope of this.

Student: ((Refer Time: 47:06))

Plus 1 or I mean the way we are doing we are not doing log V R or V s we either do it in terms of d B or the module us. So, in terms of d B this is plus 20 degree per decade, so that only means that in other words that the magnitude is proportional to omega in that range. So, that is what you should plus 20 d B you proportional omega square you will get plus 40 d B and so on. The first order system you will not get that, but in a higher order system you could get either proportional to omega or omega square or omega cube etcetera in higher order system.

Similarly or proportionality to 1 over omega 1 over omega square and so on. So, you can have these straight line as in told of different slops and where the as in told meat it will be most inaccurate, but even the straight line parts themselves or good in up given idea. what is happening in the circuit is fine.

Student: ((Refer Time: 48:10))

So, for this it was omega c R by square route of this. So, this is approximately equal to omega c R, when omega c R is much smaller than 1 and it is approximately equal to 1 when omega c R is much more than 1 and it is also equal to 1 over square root 2 when omega c R equals 1. So, this omega c R will be 20 log 10 omega minus 20 log 10 1 by c R. So, that is basically means that it reaches 0 d B when omega equal to 1 by c R that expression.

Then the slope is plus 20 d B just tried out it is the same as I mean is the same in spirit as other curve any questions about this. So, now, you should be able to draw this kind of plots, this type of plot very plot d B versus log omega is known as a bode a plot. So, after this person Hendrik bode who it a lot of work on circuit analysis and analysis of feedback system and so on, this is one of is a very minor contributions, but ((Refer Time: 49:44)).

Of course, you complete this where also draw the phase also versus logarithmic axis, but we will do that. Now, the key to drawing this what is a plots a is identified break points, I mean the break points or meeting points of this as in thoughts. So, typically you will end up with this expressions of this sort 1 plus some functional omega. So, this other term whatever is depending on frequency can be much smaller than 1 or much more than 1 break point is basically the point between that.

So, this omega equal to 1 over R C sort of separates regions, where this is smaller than 1 and larger than 1. Now, this as in thoughts are very good approximations when you are far away from the break points, what when you close to break points in are in activate. So, if I draw only this straight line parts you are 3 d B of which is significant number, but still that shape is useful measure of what is happening in the circuit, this fact now I mean after you understand the details you can also kind of like a drew with this orange line you can make a better fit to backs will curve by goings slightly below that and so on.

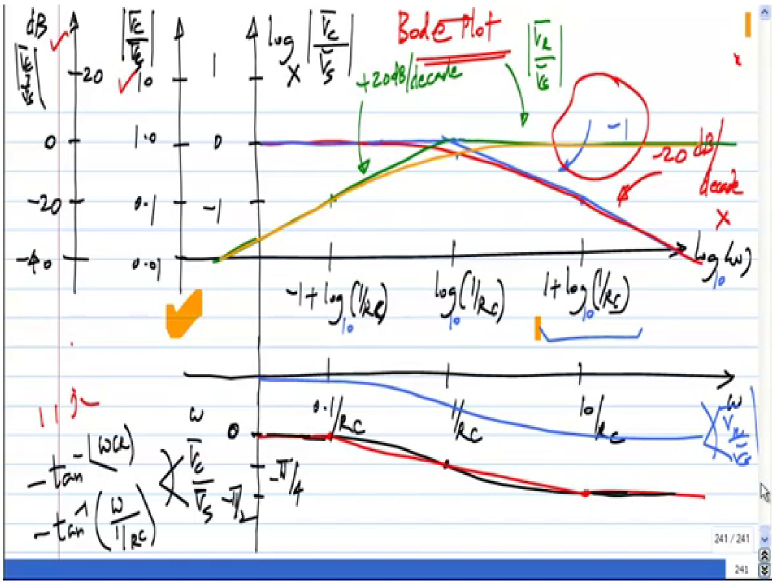
Now, you can try this for other circuits that are given in the assignment. So, you may have more than 1 break point, because you may have expression of the type 1 plus j omega by omega 1 divided by 1 plus j omega by omega 2 and so on. So, what you do is you first draw the as in told, if the break points are very close to each other, the actual as in plot will be in accurate, but that and then you try to fill in the rest of details, this is also we useful when you see any data sheet let us say you have an amplifier or something you by on audio amplifier and you look like the data sheet it will be full of plots like this there will some d B and versus some omega and usually on a logarithmic scale.

Student: ((Refer Time: 51:49))

Anything any quantity this is just plotting, this is just plotting versus omega can do it fine anything you can first of all you could have done it for V c itself instead of V c by V s by it sort of make more sense to plot the transfer of function of the circuit rather than absolute values. Because, you know by linearity that if I apply 2 volts I will get double the output etcetera, this is like plotting the output voltage with a phase are 1 angle 0 apply to the circuit and you can do it for currents ratio of the currents anything I want.

And the same way ((Refer Time: 52:21)) for plot phases corresponding to voltages and currents also any other complex quantity, such possible as well is this fine. So, now, the next question is let me try to reduce part of the space.

(Refer Slide Time: 52:55)



So, what I want to do is also to plot angle of V c by V s verses log omega, what is that look like, what is the expression for angle of V c by V s.

Student: ((Refer Time: 53:25)).

This is minus tan inverse omega c R or minus tan inverse omega divided by 1 by R C or 1 by c R. So, now, what can you tell from these what is the value add omega equal to 1 by R C minus pi by 4. So, let me say this is minus pi by 4. The function is like this minus tan inverse omega c R, what can you tell volt shape of the plat form, specifically what is the quantity at 0.1 by R C verses what is the quantity at 1 10 by R C.

Student: ((Refer Time: 54:26))

This is a tangent, tangent has a certain cemetery, what is that you must this things that.

Student: ((Refer Time: 54:43))

So, I mean that part of not even in this plot where you approximately equal to x and x is near 0 which is not in this plot. So, now, one question is how do you draw the access normally in linear case you will the point of inter section x as the 0 0 clearly 0 0 is not here or you can put it anywhere. Now, for this particular case plot is d B there is 0, so I could put the x axis starting from here, but as long as it is marked I want worry too much about it, but we may be I can plot the x axis marking from here, but the y axis I can putting any where, it depends on my interest.

If it is 1 by R C is let us say 10 to the 6 there is no point putting into 1, because than I am wasting this part of the paper, it is based on convenience that is all, you will I mean on x axis there is no 0 at all. So, you cannot put it at 0, so normally you will do it. So, that plot fits in the first quadrant I think that is another strategy to drawing plots. So, phase what is it mean now the symmetry of tan x it has geometric symmetry it is looks a same way before and after with flip what is in.

So, what I mean is that, so here again I should probably draw the access starting from here at this point, but I do not have rooms. So, I will say this is 0 and this is minus 5 by 2 for frequencies much lower than 1 by R C it will be approximately 0 and for frequencies much more than 1 by R C it will be approximately minus pi by 2 and then it will be a symmetric curve like that. And if you want to do the symptoms for this what you can sometimes it is done I think I would be quite happy if you draw the curve like this.

But, up to let us say 10 times below the break point you have a constant 10 times above the break point you have a constant 10 times above the break point you have a constant and you could joining this straight line, but this is straight line versus logarithmic x axis does not mean it is a linear variation it is something else what day it does some it has some smooth variation like this, but the point is it is symmetrical about this 1 by R C.

So, again the idea here is to identify some key points like at 1 by R C what is it much will be 1 by R C what is it much above 1 by R C what is it and then join them by smooth curve and you can more than 1 break point so; that means, that you have to exercise you are judgment by how to do is probably. So, try it for the problems in the tutorial it should be quite simple.

Student: ((Refer Time: 57:32))

which one, the red line is an approximation where from this point to this point I do the straight line instead of the actual curve it is. I think all of you access from some over a plotting it. So, you can also plot these things and see plot the approximate values actual values and see what happens. Any questions about this is spent a lot of time on this, but you should be able to draw these things cleanly and then also interpret them.

So, and you will do more of this later and networks in systems as well, but it is a plots are very important, because this is are you can defeat transfer ratios when the transfer ratio are complex, you have to draw 2 plots some of I mean you draw the plots or real and imaginary parts, but there will be completely in compressible meaning the real in part could be big the imaginary part could be small and so on it is not an infinitive it this is much more infinitive in that you can say that most of the signal comes through here, most of the signal is accumulated here accumulated meaning reduced and so on. And the phase it comes with no phase shift here and then almost 90 degrees phase shift their small.

Student: ((Refer Time: 58:42))

That is this, this is the angel between V c and V s now what is the angel between V R and V s, what was it x plus 90 that is all. So, the whole thing is shifted up by 90 degrees that is all. So, in case of phase the y axis is linear mind you only the x axis is logarithmic simply I work up wherever. So, that is the angel of V R by V s any questions.