Analog Circuits
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Week -02
Module -03
Bode Plots

Hello, welcome to another module of this course analog circuits. In the previous lecture we had covered the various and non idealities of an op amp, in this module we will be covering what are known as bode plots?

So bode plots are a mathematical tool for analyzing the frequency response of various systems not just analog circuits, they are also used in control systems and just like transfer functions which we had studied earlier which are a tool to analyze this response of linear systems, these are also a tool but as compared to the transfer functions which operate in the S domain the bode plots always operate in the omega domain. So let us see what are bode plots?

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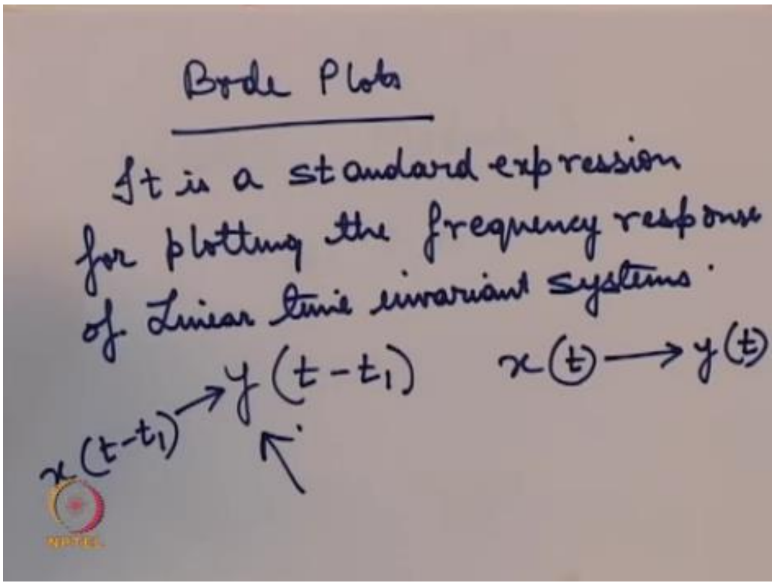

The definition of this bode plot is, it is a standard expression for plotting the frequency response of linear time invariant systems, so we had already seen what is the linear time invariant system in the previous lectures. I think we had introduced, what is a linear system? Nut not what is a time invariant system?

So time invariant system is a system where an output like this is produced for an input, so if the system produces if the for input of the systems is xt and for that and output yt is produced then for a linear time invariant system at a for an input xt-t1 the output will be yt-t1.

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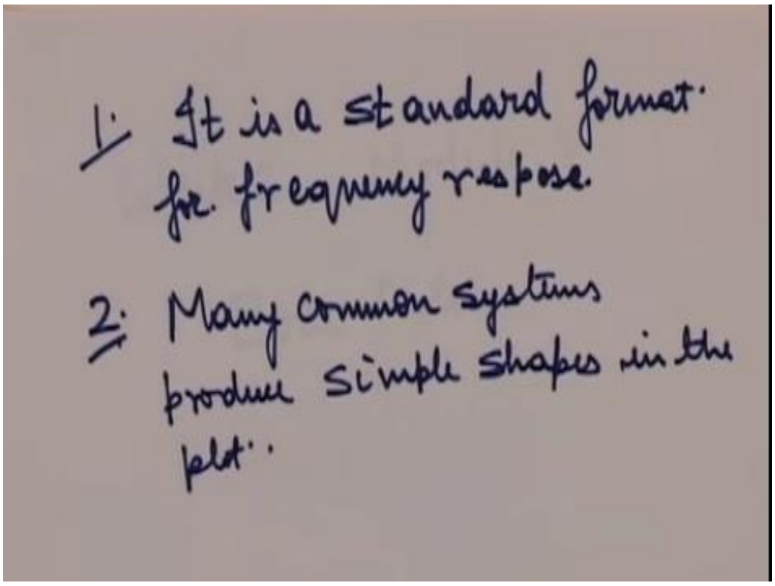

So with this in mind the 2 important characteristics of a bode plot is that, number one it is a standard format okay it is a standard format for frequency response, it is easy to communicate you know if a designer or an person is analyzing a system wants to see also communicate with another person what is the frequency response then bode plot provides a standard format for there and many common systems produce simple shapes in the plot, so just by looking at the bode plot, the response of the system can be predicted.

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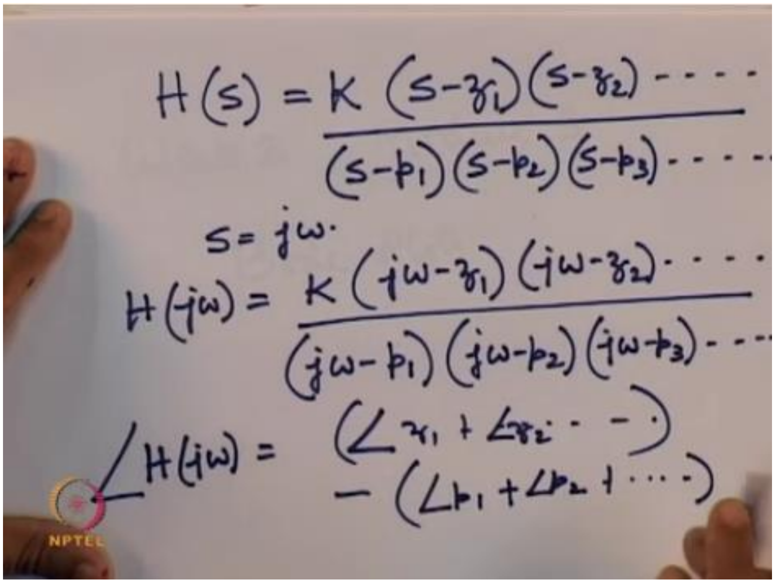

So let us start with a simple transfer function, say we have a transfer function H of S given like this and so on upon S-P1 S-P2 S-P3 and so on, now substitute S = J omega then you get H of J omega is given, so we are just substituting in place of S with J omega so this is given by J omega-Z1 J omega-Z2 and so on upon J omega-P1 and so on.

Now the total angle or if we want to find out the total argument of this H of J omega then that is the summation of individual angles of each of these factors like this minus the summation of the angles, due to each of these factors which I represent it like this similarly the total magnitude of this transfer function modulus of H of J omega will be the magnitude of each of these factors K divided by the magnitudes of the factors in the denominator.

Now in a bode plot of course we plot this magnitude on a log scale, so this we had already discussed you know while discussing the unity gain bandwidth about plotting on a log scale. The bode plot, what we are plotting there was the bode plot kind of, so let us see some examples of how to plot a bode plot then that will become clear instead of going on explaining about the properties of the bode plot it might be better to just consider an example.

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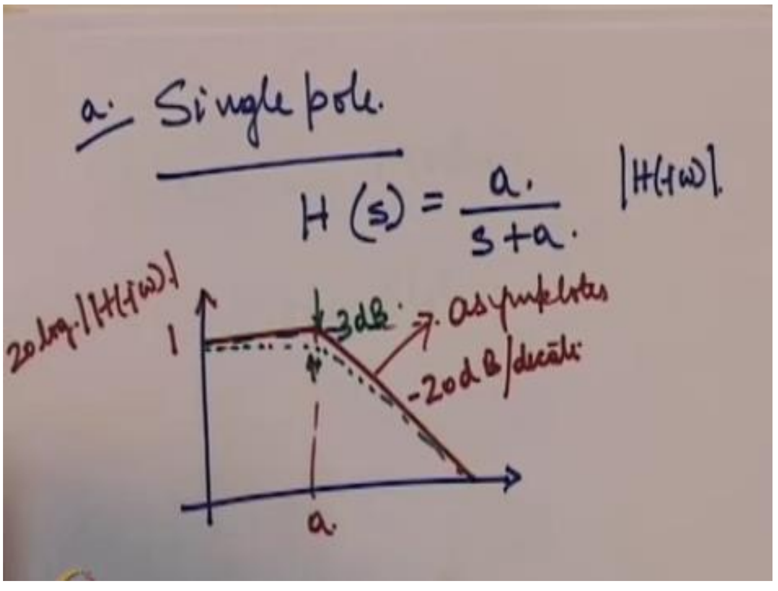

So suppose we have a transfer function with a single pole so you have H of S is = a upon S + a, so then the bode plot is like this if you plot the H of J omega plot it will be something like this that suppose this is a, so till this point the magnitude H of J omega we have 20 log of this H of J omega till this point it will be unity okay beyond this if we just draw a straight line which is -20 db per decade and then the so the bode plot so this is these are what we call the asymptotes, you know these red lines and the asymptotes.

So we were discussing about these lines now these lines are known as asymptotes, these kind of follow the outline of the main plot these are not the real bode plots these lines follow the bode plots actual border plots and by asymptotes it means what the bode plots would look like? When say the frequency was infinite, so the real bode plot that you get is somewhere between a draw like this I am using this green pen and at this frequency where the pole is the magnitude will be less by 3 db ok so this is what happens for a single pole case now.

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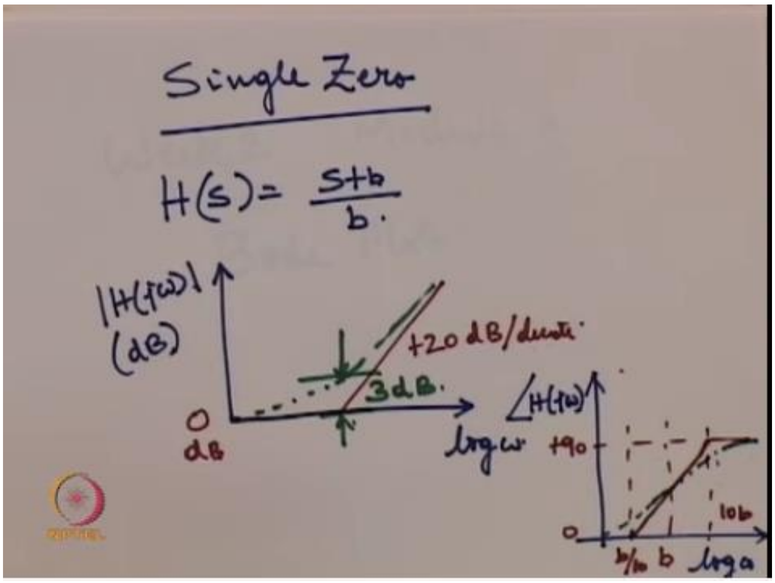

If you have a single zero, then what happens in that case just the reverse of what was observed will happen you will get your this will be + 20 db per decay just one correction here the in the previous slide the magnitude will be 1 but the plot will be 0 on a log scale, so 0 db it will be just wanted to make this correction here also we will start from 0 db okay and then at the 0.

If we now draw the complete bode plot at the 0, the magnitude will increase by 3 db okay now in the previous case and in this case we didn't see what happens to the phase plot, so this is the magnitude plot let us see what happens to the phase plot, so to draw the phase plot again you draw so here we are drawing the magnitude of H of j omega this omega now at at suppose this is the A or the frequency now what you do is you take the points A upon 10 and 10 A.

Now till A upon 10 the phase change will be 0, then you draw the asymptotes like this and like this, so then the total bode plot will be something like this or the phase plot will be something like this, similarly for this case also if we are trying to draw the phase plot what you do is first you plot the log of omega the H of j omega then at B you plot you so we have this is B this is B upon 10 and this is 10, so you your plot will start.

I just want to add something in the previous plot so this is 0 and it will end at -90 degree so your phase change will be from 0 to - 90 degree, in this case the phase change will be from 0 to +90 degree this is +90 degree, so you plot the 2 ends 0 and 90 degree and then draw a line from this B upon 0 to this 10 B and your real bode plot these are the asymptotes by DL, I mean the actual bode plot not the asymptotes will be something like this okay so this is the phase plot.

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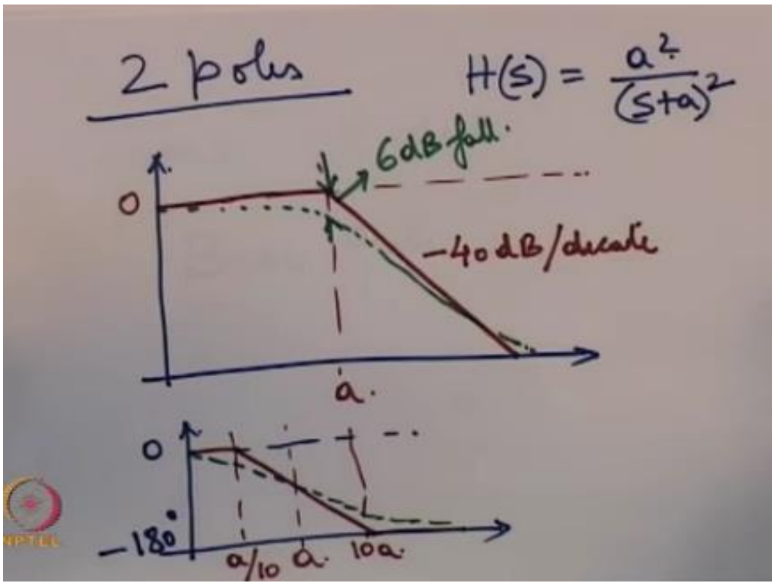

Now suppose you have 2 poles present, then what happens if you have 2 poles present then the magnitude plot becomes something like this instead of a -20 db per decade it will be a -40 db per decade so your transfer function in this case is like this you have 2 poles at -A and your actual bode plot will be something like this there will be a 6 db fall.

Here now this 3 db and I hope you understand what is the significance of this 60 db and 3 db, 3 db means the magnitude becomes half at this point and 60 db means it becomes one fourth okay and how will the phase plot look like the phase plot will be very similar to that single pole case except that the variation is now between 0 and -180 degree or +180 degree whichever and so just like the previous case you have A, A upon 10, 10 A will be like this okay.

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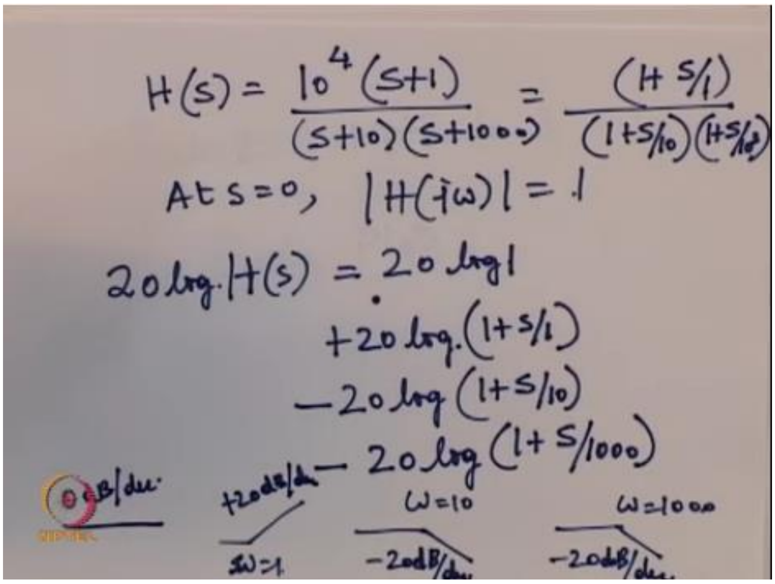

Let us take a further more concrete example that will illustrate all the concepts that we have discussed so far more better so we have a transfer function given like this, the first thing you note that at S = 0 that is the DC this magnitude of H of J omega is = 1 so it will start from a 0 db.

If we take the you know the magnitude of this it will appear something like this, let me write it in a different way so this will be like 1+S over 1 upon if I divide both the numerator and denominator by 10 raised to power 4 then it will be 1+S upon 10 multiplied by 1 upon S upon then raise to 3 ok so then 20 log of HS will be = 20 log of 1+20 log of 1+S over 1 and then minus this component is from here the numerator and from the denominator you have - 20 log of 1+S upon 10-20 log of 1+S upon thousand.

So now how does this component look like, so this looks like a straight line how does this component look like this looks like a at S = or omega = 1 then this component looks like this at omega = 10 and this component also looks like this at omega = 1000 this is -20 db per decade this is also -20 db per decay so we +20 db 4 db and this is 0 db per decade will of course see the phase plot later on as we progress but let us see how it looks like how the overall bode plot looks like.

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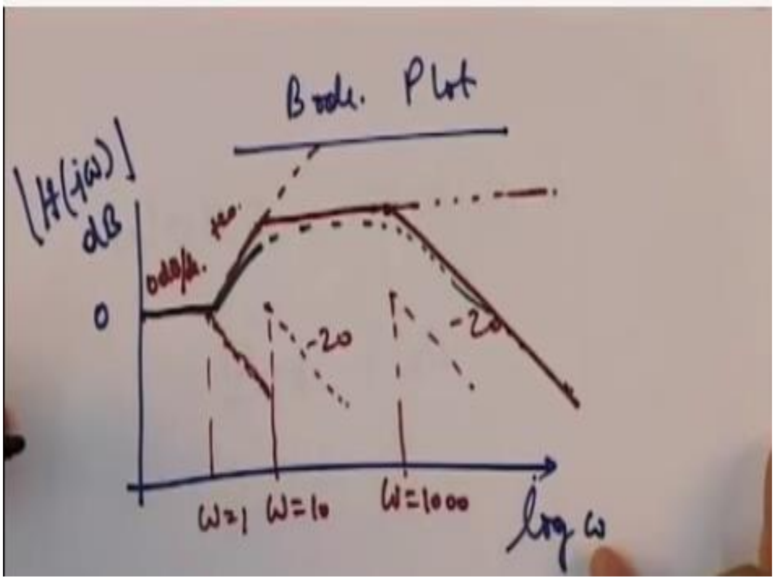

So bode plot will be start from 0 db this is modulus of H of J omega in db this is log of omega, so we first start with 0 and at this point we note that we are first of course plotting only the asymptotes at this point there is this -20 at omega = 1 there is this fall due to S = the I beg your pardon there is the there is the rise sorry this is a rise at omega = 1 is a +20 db per decade rise.

Due to the presence of the 0 and then at omega = 10 there is a fall okay and then again at omega = 1000 there is a fall, so how does the whole thing look like so if we plot the whole asymptotes it will be like to be go till here for 0 db per decade then at this point there is a rise +20 db per decade and due to this pole at omega equal 10 rise which should have been like this instead it becomes flattened and then from this point due to this -20 db per decade.

So this is again 20, -20 it is a flattened for the okay like this so then the overall bode plot looks something like this like this and so this is the magnitude plot how when the phase plot look like.

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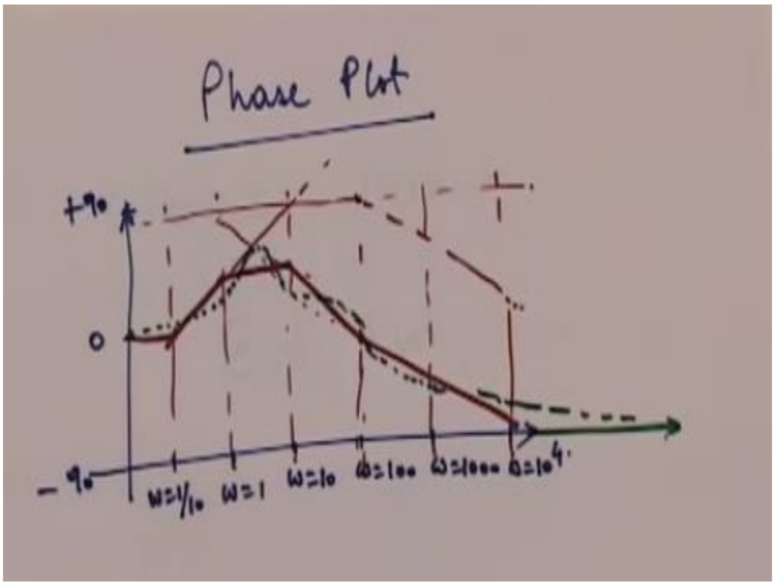

Say we are starting from 0, here this is -90, this is +90, this is omega =1 this is omega = 1 by 10, this is omega = 10, this is omega = 100, this is omega = 1000 and this is omega = 10 raise to 4. so the due to the numerator again we will have so let us first draw the asymptotes.

As I said in order to identify the asymptotes at omega = 1 where there is a 0 you first identify omega = 1 upon 10 and omega = 10 and then draw the first asymptote, so it should start increasing from omega = 1 upon 10 then you see that there is a there is a pole at omega = 10, so that means if there is a pole at omega = 10 then there must be a fall starting from starting from omega = 1 to omega = 100 okay.

Then at omega = 1000 there is another 0, so that means there must be another fall starting between omega = 100 and omega = 10 raise to power 4, so if we start plotting this whole thing, how will it look like? It will look like something like this like this goes till omega = 1 okay at omega = 1 because of the other pole present here becomes flattened here it goes all the way till omega = 10 from omega = 10 there is a fall because of this pole and then again it starts continuing all the way till omega = 10 raise to power 4.

So overall the total phase plot will be something like this, of course nowadays it’s very easy to make this plots using a computer based program like MATLAB, but still these were some methods which were used in olden days and still serve a lot of purpose this hand calculations, so with that we end this module, thank you.