**Control Engineering**

**Prof. Madan Gopal**
**Department of Electrical Engineering**
**Indian institute of Technology, Delhi**

**Lecture - 40**

# Feedback System Performance based on the Frequency Response (Contd.)

The summary could be given in terms of the specifications or the measures which we can get from the open-loop frequency response data. You know that from the open-loop frequency response data the closed-loop performance specifications which we can easily get are the phase margin, we can get the phase crossover frequency, the gain margin, the gain crossover frequency.

We have particularly seen that if we take a standard system then phase margin and gain crossover frequency are related to zeta n omega n. Let me call this as omega gc. So this gain crossover is a function of omega n and zeta and phase margin is a function of zeta. Therefore if we have the phase margin and the gain margin for a system we can see the performance we can visualize the performance in time domain because the approximate values of zeta and omega can be obtained from this information.

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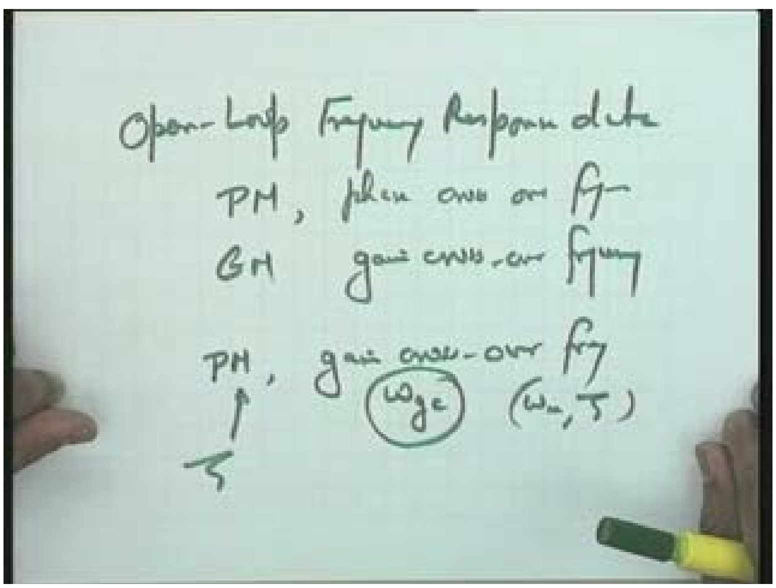


Identically if I give you specifications in terms of zeta and omega n you can translate those specifications in terms of phase margin and gain crossover frequency and then carryout a design in frequency domain so that the required specifications are met. This is your open-loop frequency response data and the gain margin and phase margin you can get as you know from the Nyquist plot or the Bode plot; the Bode plot being more convenient because construction of the Bode plot is easier.

Taken this concluding example on this discussion let us say this is the system I take and the gain db verses omega on the semi-log axis and this is minus 180 degrees and omega. In that particular case as you know that this is the point at which the angle is minus 180 degrees and this is the point at which the magnitude is 1. The point at which the magnitude is 1 which is equivalent to 0db is omega gc the gain crossover frequency.
This is the important specification you see because it is a function of omega n and zeta for a standard second-order system.

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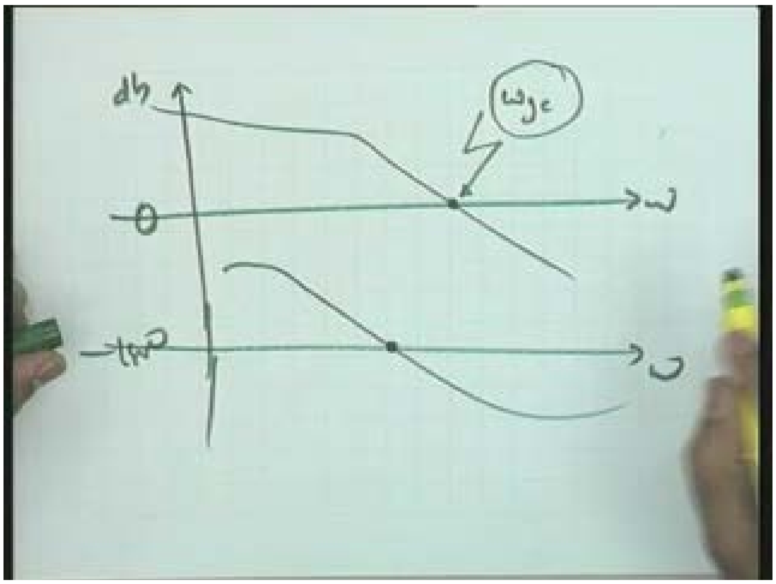

Now look at the phase margin. So, at this particular point if I measure the angle with respect to minus 180 degrees this is your phase margin. In this particular case the phase margin is negative it means whatever plot I have made over here without any transfer function in front of me has turned out to be the open-loop plot for a closed-loop system which will be unstable because the phase margin is negative in this particular case so the system will be unstable.

Now this particular frequency (Refer Slide Time: 4:00) at which it is minus 180 degrees is your phase crossover frequency and if I calculate the db at this particular point this is your gain margin and the gain margin also in this particular case has turned out to be negative so this particular system is an unstable system.

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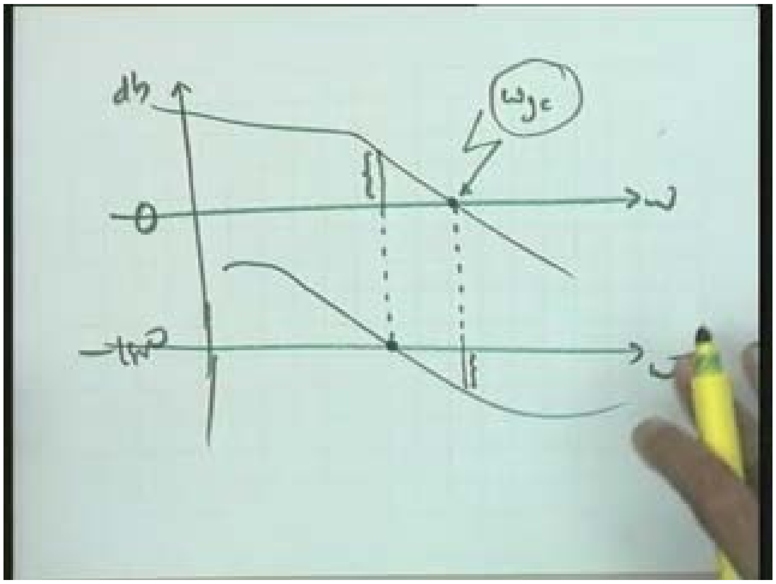


For a stable system you know let me take this as this point. for a stable system let me take a sketch form, this is your phase margin which is positive (Refer Slide Time: 4:30) if I take this as minus 180 degrees this is a positive phase margin and this is the gain crossover frequency an important parameter and here if I take this value of db this is your gain margin which is positive so this much of margin is available before the system becomes unstable and hence this is a sketch of a stable closed-loop system.

An important point to note that from open-loop frequency response characteristics you are able to obtain the characteristic of the closed-loop system and these are important indices for design as well; particularly the phase margin is a very important index.

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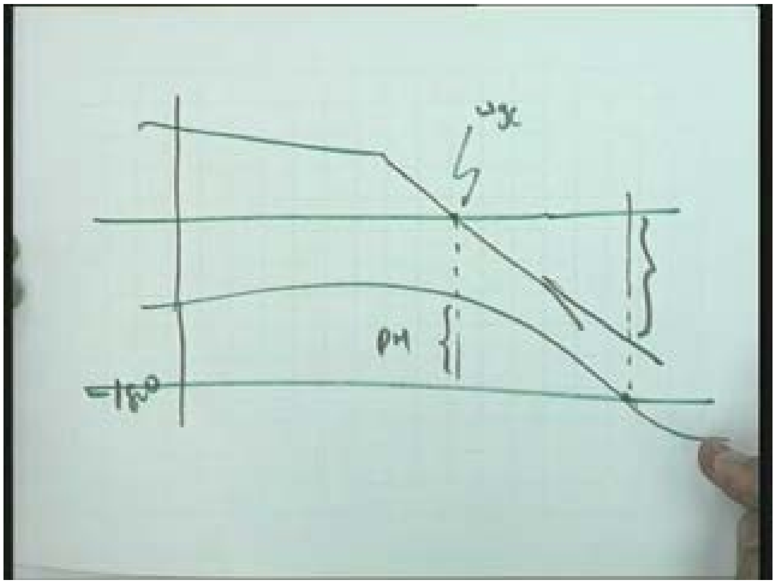


Now I remember there was a question that if the polar plot turns out to be this form what is the value of the phase margin how do we interpret the phase margin. There is no direct intersection in this particular case. You see that you can make an equivalent Bode plot sketch also for this particular system you will get some value of phase margin more than minus 90 degrees. The statement I had given that time that this particular system is stable for all values of the system parameters and therefore relative stability measures carry little importance that statement is right there is absolutely no doubt.

However, mathematically if you apply the logic what is the phase margin and what is the gain margin; like in a type-1 second-order system we get gain margin is equal to infinity in this system also you will get a phase margin which will be more than minus 90 degrees. However, the interpretation of that the meaning of that with respect to the closed-loop system stability is not that much and therefore for a system which is inherently stable for all values of tau 1 and tau 2 relative stability study has hardly any meaning.

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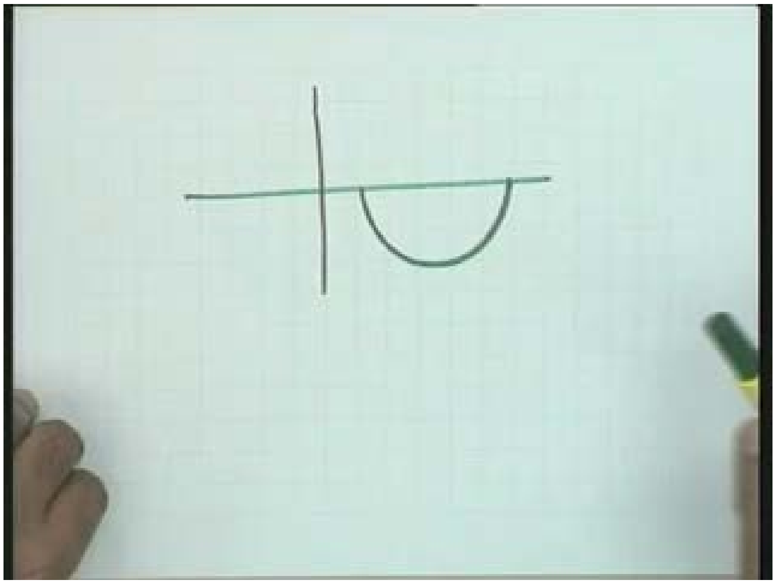

Now going to the closed-loop frequency response measures closed-loop frequency response as you know that you experimentally obtain data as G(j omega) and your closed-loop frequency response is 1 plus G(j omega) H(j omega) this is your closed-loop frequency response M(j omega). And if I have a typical sketch of this we have concluded in our earlier discussion this is my 1 here, this is M magnitude and this is omega frequency so this is M r and the frequency at which it occurs is omega r the resonance frequency this is resonance peak and this value at which the magnitude is 1 over under root 2 is omega b.

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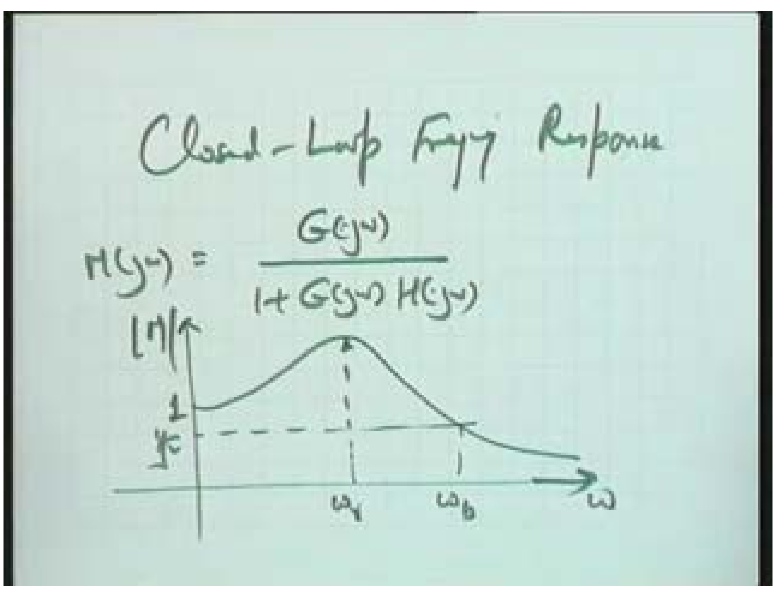

You may be saying that there is you may be feeling as if there is no need of any repetition of this; I am repeating this because my next point is how to obtain these values the analysis problem. The phase margin and gain margin you know, you will immediately make a sketch the Bode plot sketch and from there give me the values of phase margin and gain margin.

Now my question to you is for which the answer is to be sought is that given the open-loop frequency response data either the experiment has been conducted on open-loop system or the open-loop transfer function is available to you you give me the indices M r, omega r and omega b for that particular system how to get those values is the question.

You see, the question is this that if I have the computer there is no problem I will get the value of G(j omega) over 1 plus G(j omega) H(j omega) I will plot it M magnitude verses omega and from that plot I will be able to measure all these values of omega r, M r and omega b. But analytically without the use of computer you can just see this point that with paper and pencil design it really will become very difficult to get the closed-loop response given in open-loop frequency response data. So it means some sort of graphical methods are required, some simple techniques are required and those techniques have been developed, using those techniques we should be able to get the values of M r, omega r and omega b.

This question please; set this question in your mind that I have the open-loop frequency response data like in the earlier case where phase margin and gain margin were calculated and from the open-loop frequency response data I want to get the value of omega r, M r and omega b.

One more comment I like to make the phase angle plot of M(j omega) I am not making it does not mean that the phase angle plot of the closed-loop system is not important it simply means that in design algorithm normally the characterization of the system is done in terms of these indices M r, omega r, omega b, phase margin and gain margin. The phase margin gives you the characteristics of the closed-loop phase response.

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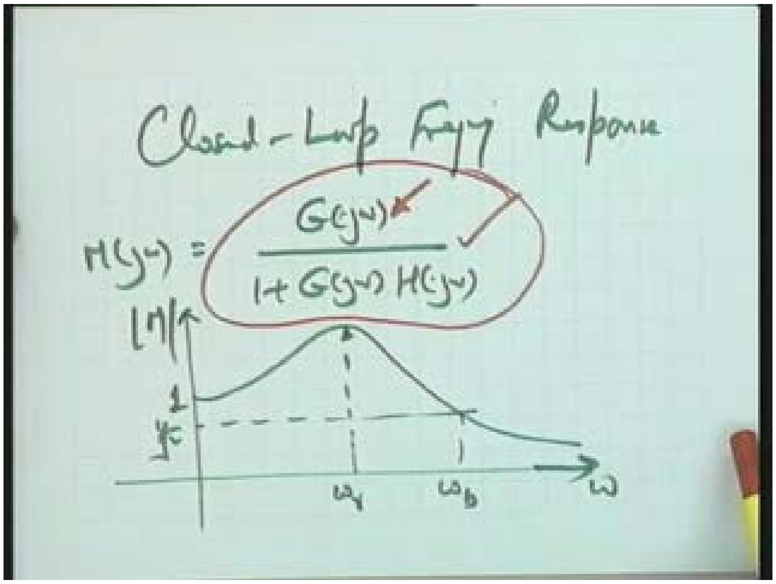


You see every time I am making only the magnitude response and not the phase response (Refer Slide Time: 9:54) for a complete frequency domain characterization of the system. If you want a complete frequency domain description of the system you will naturally require both the magnitude and the phase response. I am only making the magnitude response because we are normally using these indices the phase margin index is bringing into our design algorithm the basic phase features of phase characteristics of the closed-loop system. That is why I am interested only in the magnitude response and the values of M r, omega r and omega b are required.

First of all I break up this into two cases. Case 1: a unity-feedback system. The problem I want to solve is an analysis problem: given the open-loop frequency response how to get the closed-loop indices M r, omega r and omega b in particular. So I first take the unity feedback system so it means the closed-loop transfer function is M(j omega) G(j omega) over 1 plus G(j omega) something absolutely new is coming and therefore I need your attention here please you might not have heard of what is a Nichols chart for example so I am going to use the Nichols chart an important graphical tool for frequency domain design and this will come through this particular open-loop unity-feedback system M(j omega) is given by this where H has been taken as unity.

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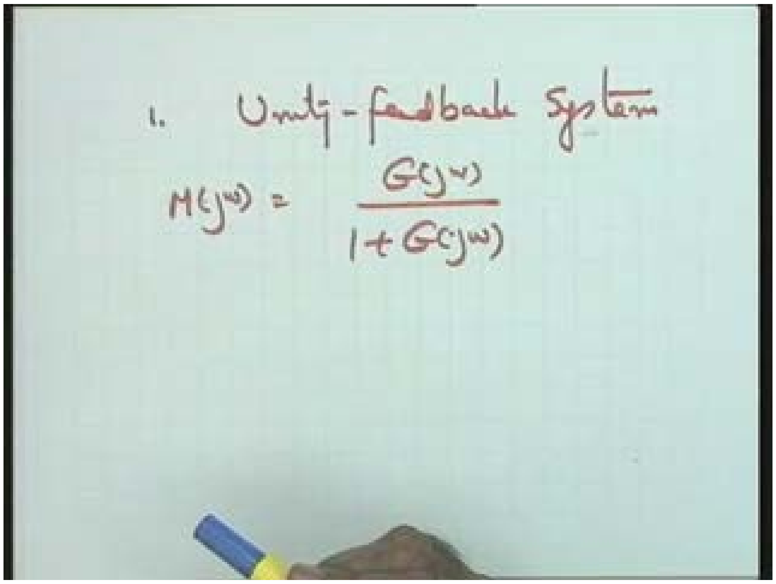


The second case: when it is non-unity how to handle that particular case? I am going to deal with this later. So in this case now let me say that G(j omega) is converted into a vector x plus jy. I transform this into this vector. In that particular case your M(j omega) becomes x plus jy 1 plus x plus jy.

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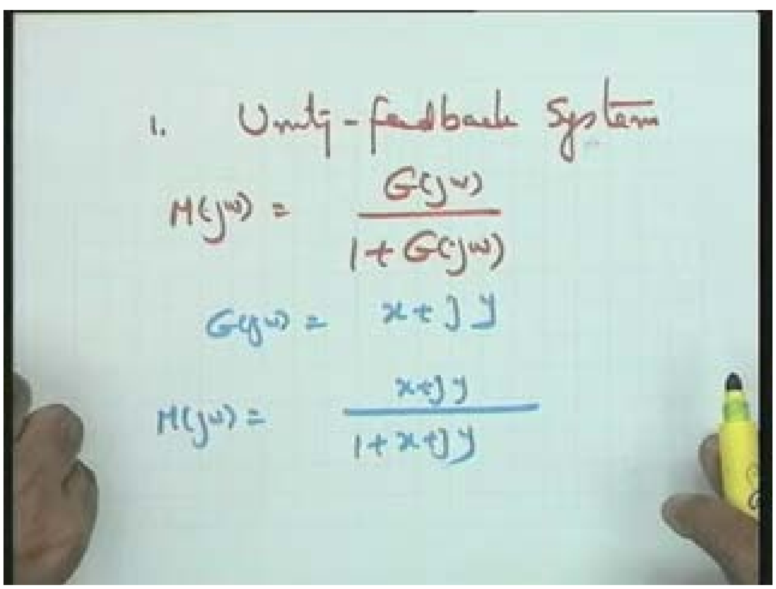


Hence since the interest is only in the magnitude and at present I am not interested in the phase angle so let me concentrate on the magnitude response. In that particular case I write: x squared plus y squared under the root over 1 plus x squared plus y squared under the root. Let me simplify the notation let me call it M. I think I can bring the final expression to you instead of deriving it because it is just the manipulation of this equation. if I manipulate this equation I am going to get x minus M squared over 1 minus M squared whole squared plus y squared is equal to M over 1 minus M squared whole squared. This particular equation is just rewritten this way. Couple of steps in between and you can easily verify that this can easily be transformed to this format.

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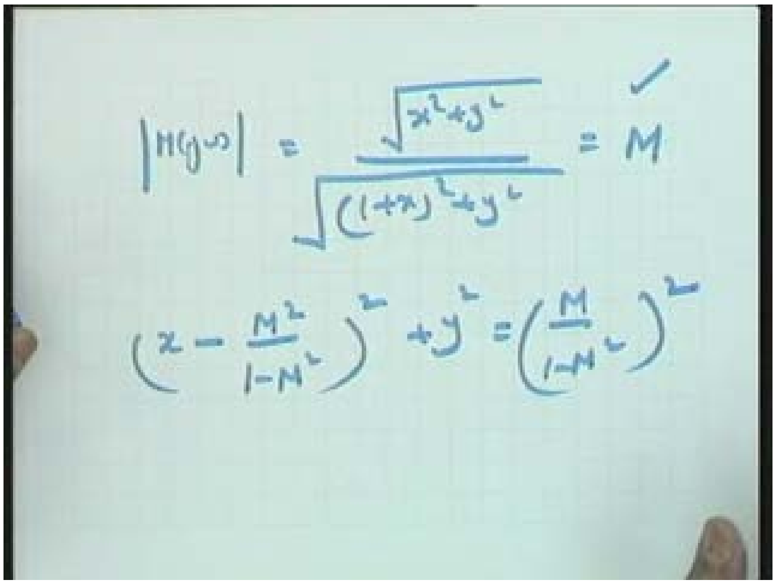

Help me please what is this equation?
You will note that in this particular case this is the equation of a circle with radius given by M squared over 1 minus M squared 0 sorry center given by this and radius equal to M over 1 minus M squared. with the only exception that what happens when M is equal to 1 you find that for M is equal to 1 it is not defined and if you substitute M is equal to 1 and solve this equation please see it is very easy to verify that for M is equal to 1 let me write it here itself this equation gives you x equal to minus half.

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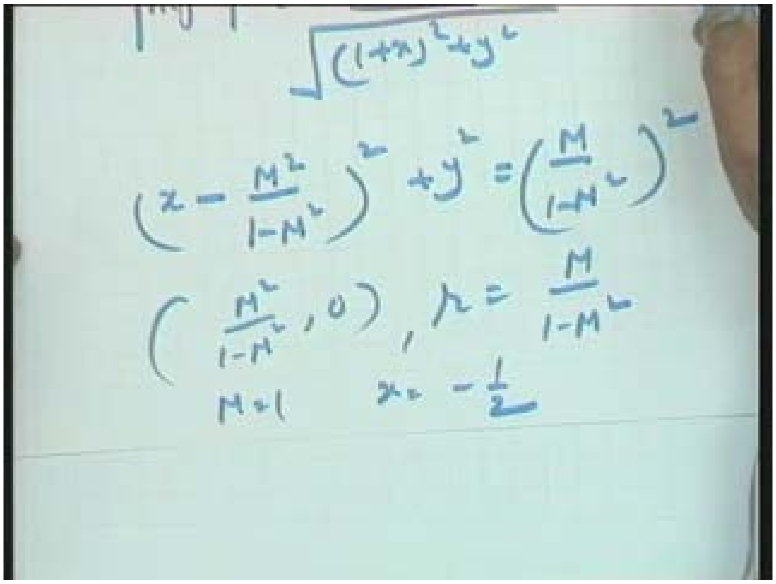


From this equation just manipulation of the……… because this I cannot use for M is equal to 1 and therefore I am putting it here; x is equal to minus half will result if I substitute M is equal to 1. So it means for all values other than M is equal to 1 I can use this equation and for M is equal to 1 I can use this equation please and this way I am able to get for different values of M the plot of this particular equation that can be represented in the complex plane like this (Refer Slide Time: 14:26) sigma J omega let me first draw minus half here this case corresponds to M is equal to 1. Let me make other cases. Just writing that equation for different values of M.

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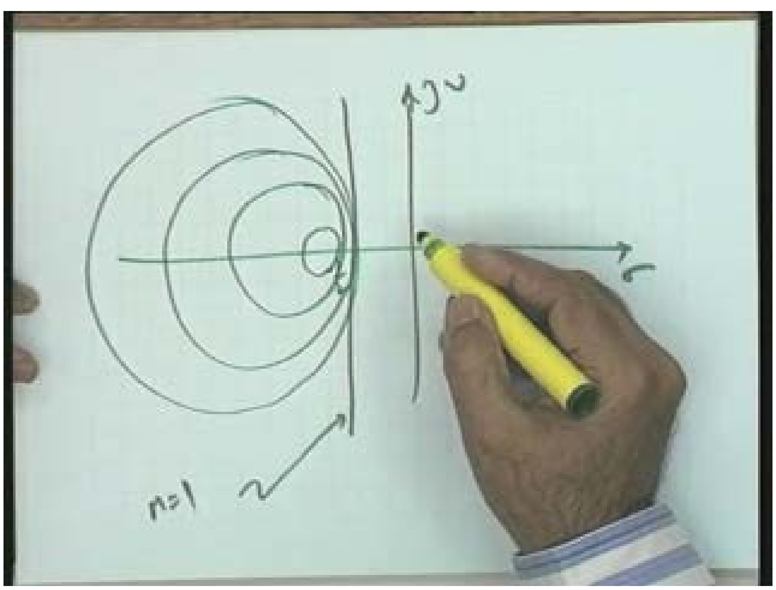

On the other side if I take up the sketch is going to be of the following nature. Yes, I think I can roughly give you this sketch. These are the M circles as they are called in the literature constant, M circles. Please do raise a question if the point is not clear, constant M circles I have seen, what is M? M is the magnitude of the closed-loop frequency response this is what we have taken M equal to…….. magnitude of the closed-loop frequency response.

What are the typical values?
Typical values let me take M is equal to 1.2; M is equal to 1.3; M is equal to 2 and so on. On this side let me take the typical values M equal to 0.85; M equal to 0.75; M is equal to 0.5 and so on. You see that here the limiting value is M is equal to 1 and for M less than 1 the circles the center comes on this side of this particular line and the circles take this shape. I hope this is clear. I have drawn a locus the loci of constant M where M is the magnitude of the closed-loop response.

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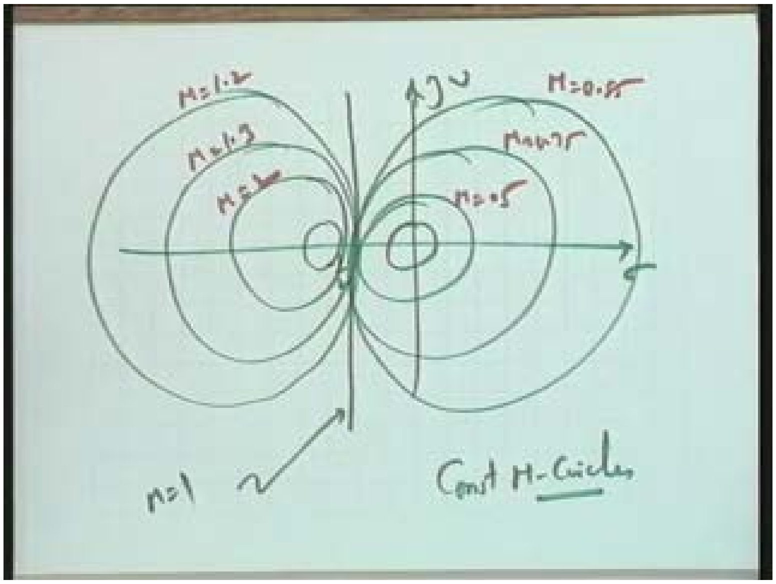


Now what I do, once if I have these things available, you see, on this particular plot you superimpose your open-loop frequency response. Open-loop frequency response is available to you you know so I make let us say a polar plot of the open-loop frequency response, let me say that this is the polar plot of the open-loop frequency response (Refer Slide Time: 16:26) and this you know this is omega is equal to 0, 2 omega is equal to infinity these are the points I have as far as the polar sketch is concerned.

Now this data is available and here I have a data for constant M, please see this point. The first point of intersection you know its frequency omega 1 because the polar plot is known to you. It will simply mean that at frequency omega 1 the magnitude of the closed-loop frequency response is 1.2.

I think let me make a sketch here omega verses M magnitude and now you have a point at omega 1 the magnitude is 1.2. You go ahead, you take another point of intersection let me call it omega 2 it is 1.3 so at omega 2 I have the magnitude 1.3 so that way I have the intersection and you will naturally see that this is the point; I need your attention here where this is tangential to a circle, this is the value of M which gives you the highest value of M and this value of M you can call as M r the resonant M because you just see that as you travel along this Nyquist plot with increasing values of omega the magnitude of M is increasing and at this particular point the magnitude of M is maximum. now what you do is you take the next point the magnitude of M is decreasing now, take the next point the magnitude of M is further decreased at this point the magnitude of M is 1 and now it is becoming 0.85, 0.5 whatever values you are taking.

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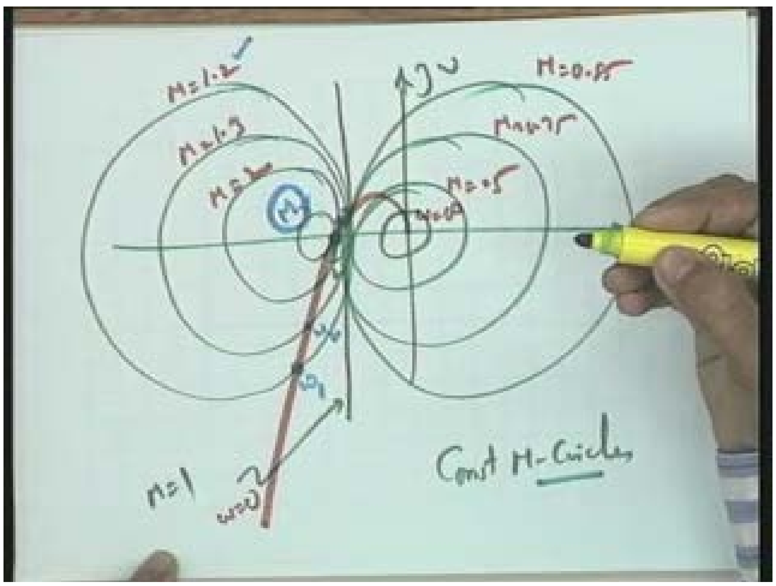


Therefore, I find that as I travel along this particular Nyquist plot from omega is equal to 0 to infinity the magnitude of M is increasing, becomes maximum and then starts decreasing and therefore from these particular circles I can make a sketch of this type which is the closed-loop response of the system.

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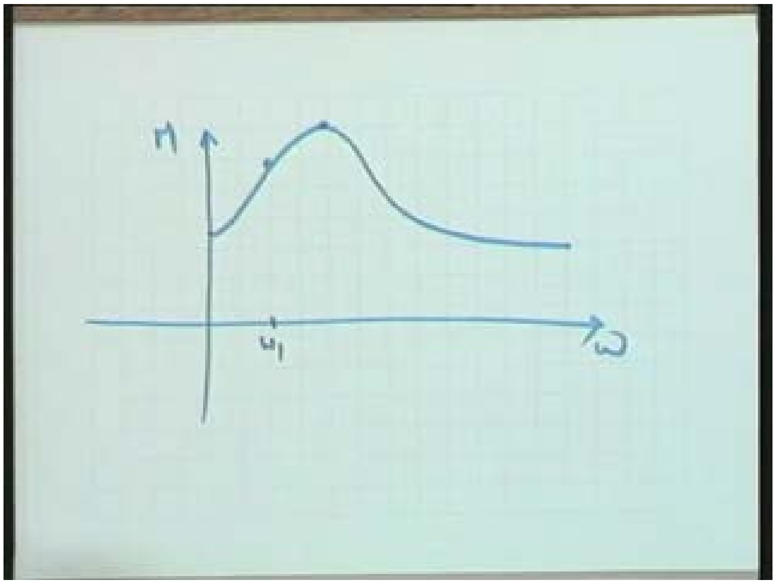


This is the closed-loop response of the system and the only advantage in this particular case is that I have not done any calculations for G over 1 plus G. You can have this, these are the standard circles, the constants and circles can be made or a standard graph can be made available to you because this is not system dependent. You will please note that the constant M circle are not dependent on the value of G, you can just see from the equation these are general circles you have seen the circles for constant M ranging from the value of 1 to 0 and giving you the peak overshoot also. So that way you take any frequency response here the Nyquist plot and the Nyquist plot here, see the points of intersections at the point of intersections you can get the magnitude of the closed-loop frequency response. That way for a unity feedback system it becomes easy to get the response without calculations.

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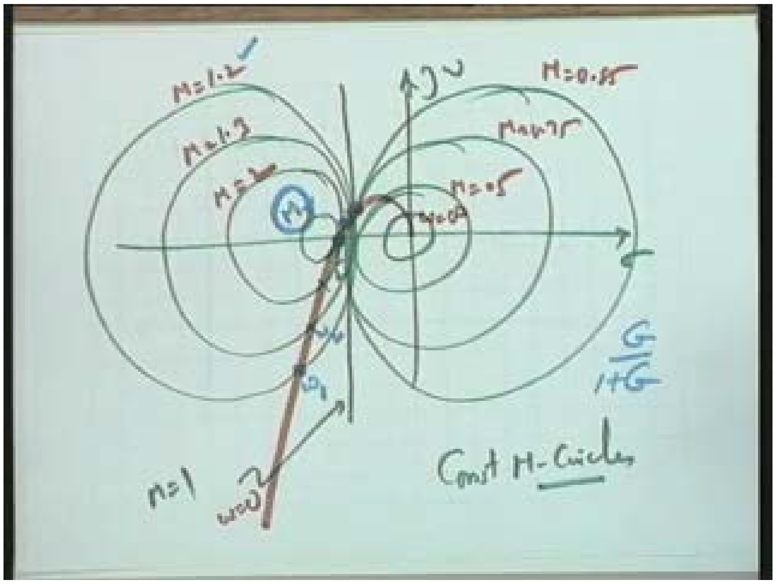


Yes. Question please? [Conversation between Student and Professor – Not audible ((00:19:50 min))] you are right, the frequencies at the points of intersection you definitely will have to find exactly. It means……. want to say probably that as far as the constant M circles is concerned it may not turn out to be a big help compared to the exact calculations. I reserve this question, yes, there is an alternative method, I also agree with it, it is not a big help because in that case as he has said that the rough sketch if it has been made than at every point you will have to find the value of omega. But one thing is there that if this question could be answered this way also if you have open-loop frequency response data it means this data is really available at large values of frequencies. May be you see it is available at the crossover points at the crossing points or nearby points so that an approximate closed-loop frequency response can be obtained.

However, an alternative method which I am going to give you will answer his question that is it will turn out to be simpler than this method. This normally we do not use, this is a root to that particular method called Nichols chart because that is more practical and that is more easy to implement. However, this will provide the necessary root for that. So, to understand the root very carefully please see that I conclude my discussion with this that you just find out the circle to which your Nyquist plot is tangential that particular circle the value of M corresponding to that circle is your resonant peak.

Yes please? [Conversation between Student and Professor – Not audible ((00:21:28 min))] you see that in that particular case I will like to say that if you are interested in the indices M r, omega r, omega b then in that particular case as earlier phase margin gain margin indices we have got approximately little variation of this is tolerable because after all it is pre CAD software analysis. So I definitely do not say that any of these methods will give you exact values. But normally if you know how to do this without computer then the possibility of making errors when you use the CAD software will be minimized as I have been saying that with the CAD software available now the entire discussion in the class room is only to prepare you to use the CAD software the final result will never come from paper and pencil design. You will not like to use it you see. When the CAD software is available why will you like to use it?

So your question I hope is answered with that that it is approximate no doubt and even his point I said if the frequency response data is available nearby frequency will also do because you have an approximate idea at least. However, a better method is available.

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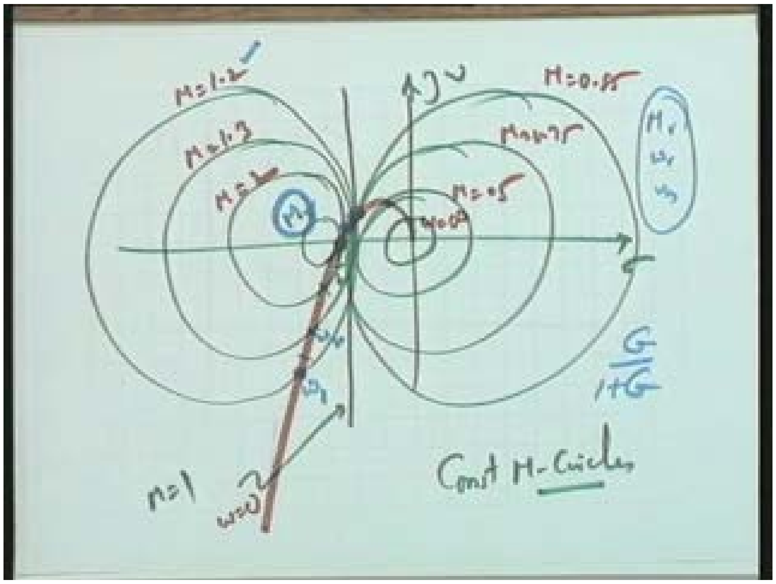


If this point has been well taken can you tell me from this very plot how do I get the bandwidth of the system. Bandwidth also is a closed-loop frequency response characteristic. Bandwidth of the system is a closed-loop frequency response characteristic. [Conversation between Student and Professor – Not audible ((00:23:01 min))] that is fine. I think it is very clear, in this particular case let me make it somewhere here, somewhere here let me make it the 0.707 between 0.5 and 0.75 and this is the point of intersection, the frequency at this particular point is nothing but omega b again it is a valuation that may turn out to be difficult. But yes, at least the root is clear that if I want to use this method the intersection is at this particular point and therefore the frequency at this particular point is going to be our system bandwidth.

With this now though I am going to give you an alternative method and alternative to M circles I have concluded that all the indices: the phase margin, the gain margin, M r, omega r and omega……. this corresponding frequency is omega r of course where it is tangent so these three indices all these indices now we are able to obtain from the open-loop frequency response data. So as such our analysis problem is complete, our analysis problem is complete.

Now here a passing comment you see like we have done our exercise for the magnitude plot so that the complete magnitude plot here I have made can be plotted without actually doing the calculations of G over 1 plus G, same argument is applicable on the phase angle plot. You can make the phase angle sketch by doing this type of exercise and the equivalent exercise in the literature if you read or from your text book you will find it is constant N circles N standing for 10 alpha where alpha is the phase angle so you get constant N circles and from the Constant N circles you are able to get the phase angle of the closed-loop system from the Open-loop frequency response data for different values of omega.

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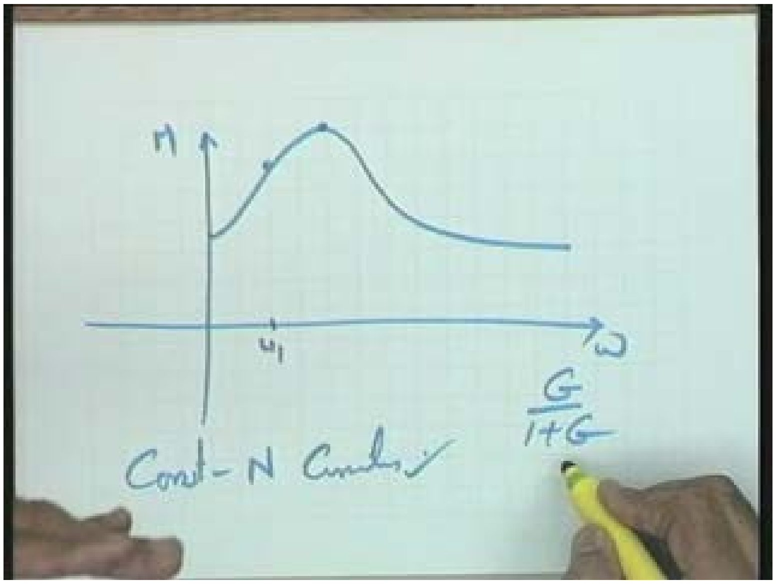

However, in my discussion I am not bringing in here because we are not going to use it for our design and for the purpose of analysis for the purpose of seeing the total response of the system I think we will leave it to the CAD software better than doing it this way because in our design I am not using constant N circles that is why I am missing it. So in your text book if you find the discussion and constant N circles you will definitely find so please see that I am now leaving it hoping that the point is clear because with the CAD software that analysis is hardly needed.

Now, the last point is the following that getting the M r, omega r and omega b from the constant N circles is a difficult proposition. So the answer to this problem has been given by Nichols and is extensively used. Not only the constant N circles the problem is plotting the Nyquist plot is very difficult compared to Bode plot. So He suggests that you make a sketch of this type on this axis you take phase angle see alternative presentation of data phase angle and on this side you take db (Refer Slide Time: 26:24). This sort of plot phase angle and db of the constant M circles is nothing but the Nichols chart.

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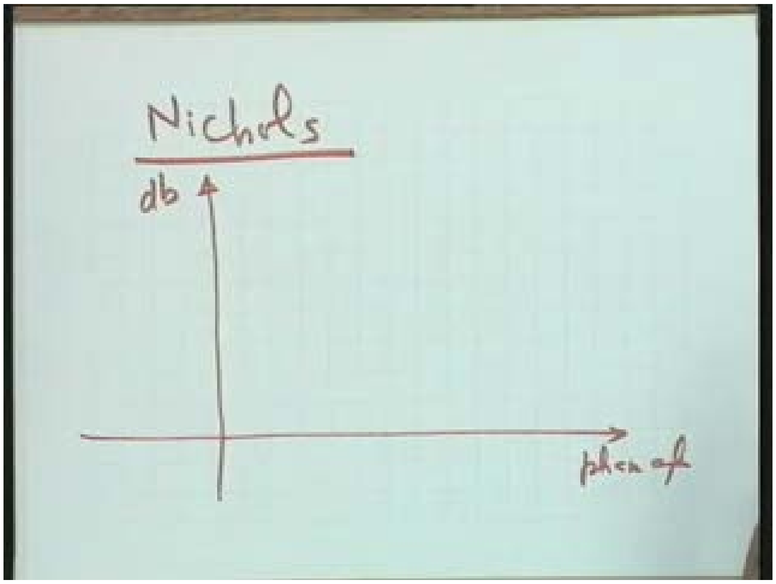


How do I do it; I will take a vector and show you phase angle and db. Let us say that I am making a sketch for 1.2, take one typical value 1.2 I am taking I want to make a contour for 1.2 take a point on this. What is the magnitude; this naturally you are going to take with respect to……. this is the vector you see so it means this much is the magnitude, I am plotting all the points here of M is equal to 1.2 on a new plot in which one of the axis is a phase angle and the other is decibels that is the only transformation I am doing rather Nichols has done that transformation and standard charts are available.

I am simply telling you the method; this magnitude is available to me, this phase angle is available to me (Refer Slide Time: 27:25). You keep on taking various points on this particular circle so it means for M is equal to 1.2 you have a table magnitude and phase angle for different values of frequency, for different points, frequency is not important frequency is not coming in the picture at all, it is only magnitude and phase angle table you can generate and if I translate this information on to this (Refer Slide Time: 00:27:49) magnitude verses phase angle plot I am going to get a plot of this nature: M is equal to 1.2 I am taking you can write it equivalently in decibels also; 1.2 rather db in terms of db normally it is written as far as the final plot is concerned.

Therefore, in this case now I can say it is a constant M contour. Naturally it is not a circle and it is not a specific shape; in this case s the shape is like this; I simply say that it is a constant M contour so if I transform the information of a circle on to this particular plot in terms of phase angle and db I get the constant M contour here.

Yes please, [Conversation between Student and Professor – Not audible ((00:28:36 min))] M is equal to 1.; it corresponds to M is equal to 1.2 so it means if you want to convert in db it will be 20 log 1.2 naturally so this circle corresponding to M is equal to 1.2 has been translated here. Let us not convert into db let me write it, M is equal to 1.2 does not matter but all these values are db verses phase angle. For example, take some other value let us say that this is M is equal to 5, I take another value (Refer Slide Time: 29:10) this is M is equal to 1.1 and so on these are the values.

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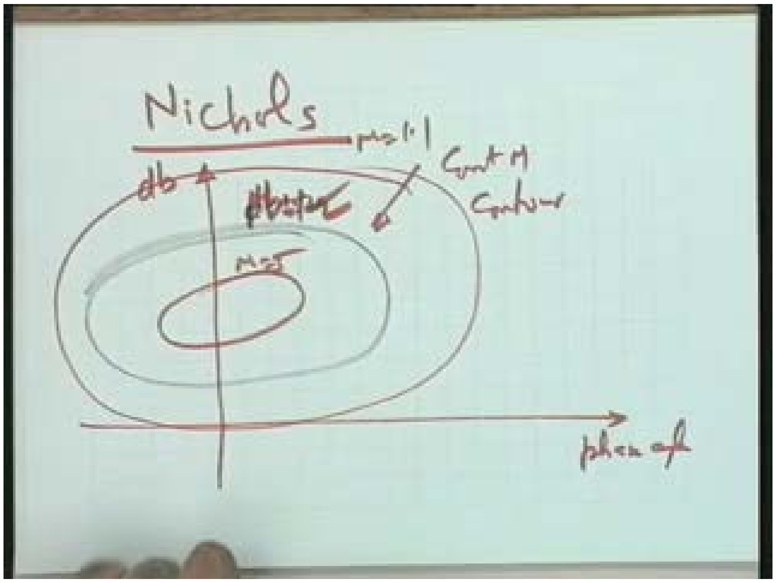


Now I think I can project the Nichols chart.

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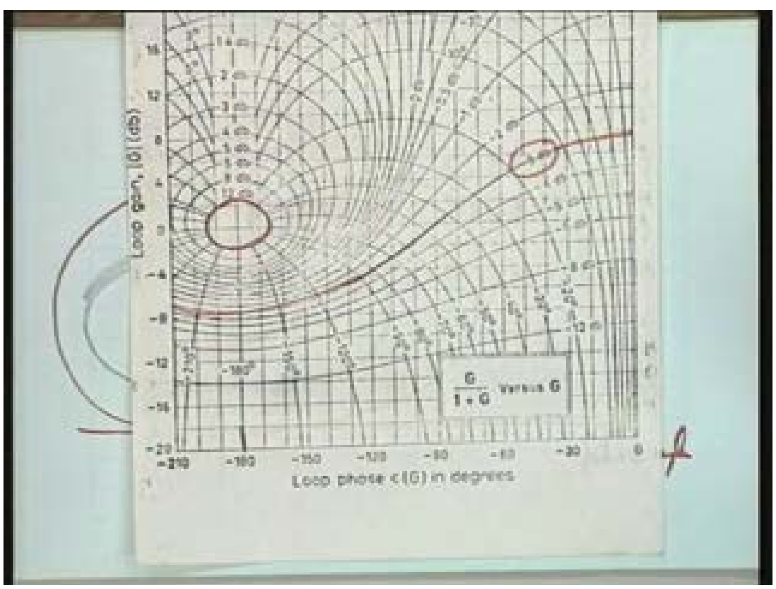


Nichols chart: this is the standard chart as suggested by Nichols. You will find this chart a little clumsy because there in addition to the magnitude lines the phase angle lines are also shown. If you ignore these phase angle lines and look at only these magnitude lines then the plot will be less clumsy you see.

Look at this that M is equal to 1.2 1.1 which I am saying (Refer Slide Time: 29:48) here the calibration is in terms of db. So 1.2 means the corresponding value is written here 20 log 1.2 that is all; the calibration on the Nichols chart has been given in decibels it does not matter.

You will see that this I think I can put a mark over here this is the contour corresponding to M is equal to 20 decibels corresponding non-decibel value corresponding absolute value you can calculate if you are interested in. And this next is m is equal to 8db, next is 6db, 5db, 4db, 3db and so on and you will go like this (Refer Slide Time: 30:23) this way up to certain point 0.25 decibels.

You will note one point; here the complete axis is around minus 180 degrees because normally working area is this so I have taken a xerox of a page where the Nichols chart is with respect to minus 180 degrees with more working area available in this region but otherwise your Nichols chart is available for 0 to 360 degrees so there is absolutely no difficulty here because these lines are symmetrical; the symmetry I have not taken so that the scale becomes better and the errors are less the graphical errors are less.

So minus 180 I give no guarantee that it will not come beyond minus 210 it can come beyond minus 210 it means in that particular case you need a complete chart. This chart is between 0 and minus 210 depending upon the phase angle range you are going to use otherwise your total phase angle which is symmetrical with respect to minus 180 degrees line can be made available.

Now look at this these are the different dbs so after 0.25 you come over here 0db particularly which corresponds to M is equal to 1 this curve please 0db curve, this is 0db I hope it is okay then after that you go to these values and the db which is again of extreme importance to you is minus 3db which is I think I will like to make a darker this is the contour corresponding to minus 3db it is important to me because it will give me the bandwidth. M is equal to 1 by under root 2 is equivalent to minus 3db in decibel scale in db verses phase angle plot and therefore this contour is of importance to me. So this contour (Refer Slide Time: 32:24) is the contour from where I will get the bandwidth.

Now let us see what is the use of this particular……. I hope the Nichols chart is clear. You ignore these (Refer Slide Time: 32:35) these are the lines corresponding to phase angles. So, for the time being you ignore this because as I have told you that the phase angle and magnitude curve both are needed only if you want to get the total closed-loop frequency response which I am leaving to CAD software.

So if this is the case……. now let us see whether his point is answered that is using the constant M circles getting the value of M r, omega r and omega b was difficult. Let us say whether the Nichols chart has made it easy or not and for that you just take any typical example any typical example the one we have taken in the tutorial class for example G(s) equal to some k I think it was taken as 10 s(s plus 1) into (1 by 4 s plus 1) or you take some other example.

You know that getting the Bode plot for this open-loop frequency response is easy. This is the Bode plot. You will recall it was minus 90 degrees, minus 180 degrees and here it is minus 270 degrees. I hope that beyond minus 210 degrees your point of intersection will not come, I hope, otherwise you require the complete Nyquist plot that is all.

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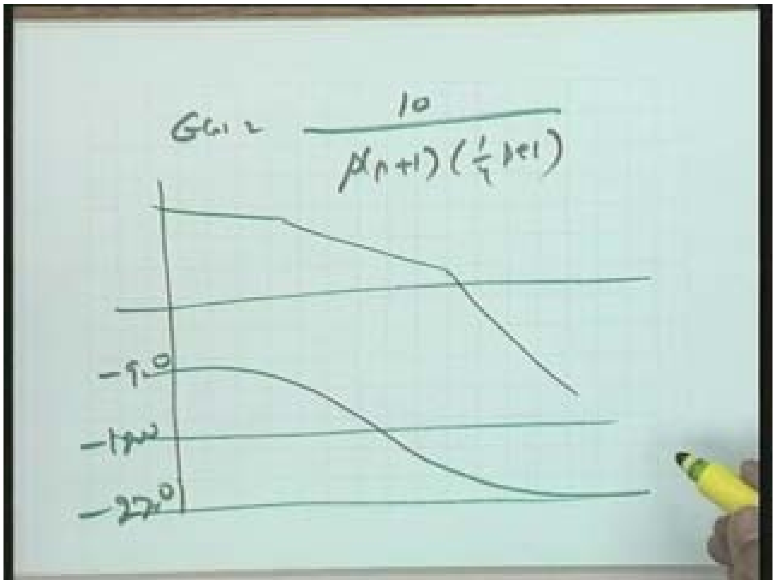

So you see that the advantage is this that in this particular case reading omega for a particular value is easier compared to the Nyquist plot I hope you will agree with that. So what is done in this particular approach? Now let us see the sequence the steps; given the open-loop frequency response data or given the open-loop frequency response transfer function oh open-loop transfer functions I will first make a Bode plot and I feel that this hardly needs any calculation because asymptotic plot with angle with db corrections can be made and angles if I have the two asymptotes and couple of points in between I again can make an approximate angle plot. So with this magnitude and angle plot available to me you see on this omega scale omega verses db omega verses phase angle what I do is I take some points on this axis and read off the magnitude and the corresponding phase angles at these omegas.

Again please note that the total range is of no interest to me. If your analysis demands (Refer Slide Time: 35:06) only the bandwidth then you look for those omegas which come in this region of the contour which gives the bandwidth. You see, again you have to use your intelligence to optimize on the effort. The total frequency range need not be scanned to get the values of bandwidth for example or the total range need not be scanned to get the value of M r you should indentify what is the range in which the resonant peak or the bandwidth will lie and from that particular range only you should use to get the accurate data.

Therefore, what I want to say is this that for different values of omega you read off the magnitude and the phase angle and make a sketch. Let me say that this is a typical sketch

(Refer Slide Time: 35:53) I am just making any rough sketch. This is a typical sketch which results from the given Bode plot obtained from the given open-loop frequency response data or open-loop transfer function.

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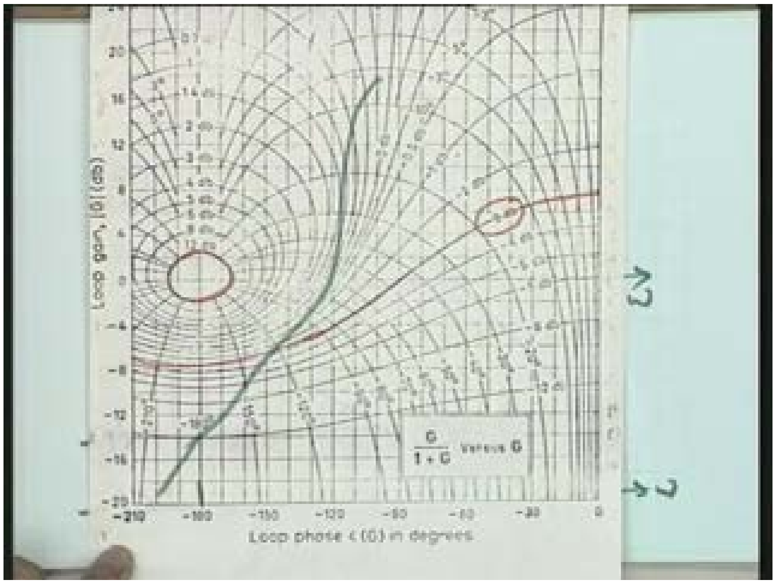


Once you have made the sketch let us read off the corresponding values hoping that it is going to be more advantageous compared to the Nyquist plot. See first of all the bandwidth which is of great importance to me. You have got this point you do not know the frequency at this particular point fine but reading this frequency from the Bode plot is easy because at this particular point you have got the magnitude and the phase angle. Take one of the data magnitude or the phase angle or the both just to verify that it works and read off the corresponding frequency from the Bode plot this gives you the value of bandwidth omega b.

I hope you will agree that this is an easier method and the constant M circles was simply a root that is why the Nichols chart is an important graphical instrument in our hand as far as the frequency domain design is concerned. Because reading off the bandwidth is easy or……….. think of M r in this particular case please see that in this case if we agree the plot is tangential to this particular circle the plot is tangential to this particular circle and I can get the corresponding value of M r and if I have to read the value of omega r naturally I will take the magnitude and phase angle and read these values on the Bode plot the magnitude and phase angle will be available to me. So this way I think I am tending towards conclusion of my discussion on the feedback response.

I say that given the open-loop frequency response data or the open-loop transfer function you can get the values of all the indices the phase margin, the gain margin, M r, omega r and omega b. Yes I remember one point I have to make before I declare it off; I had taken I had called it case-1, case-1 was unity-feedback; help me what we will do for case-2 non-unity-feedback. In the case of non-unity-feedback what we are going to do.

You see that in this particular case M(j omega) is equal to G(j omega) over 1 plus G(j omega) H(j omega). Please see the M circle and from there the Nichols chart you have got for G over 1 plus G and not for G over 1 plus GH. Unfortunately the symmetry does not work out for the closed-loop system for the non-unity-feedback system. So if we have a case of non-unity-feedback system what can I do; either I will make certain approximations or one thing we can do please see; let me introduce a new function F(j omega) is equal to G(j omega) H(j omega) divided by 1 plus G(j omega) H(j omega). Let me introduce this, let me call this as F(j omega).

Now the Nyquist plot method that is the constant M circles or the Nichols chart both are applicable because this can be treated as an open-loop transfer function. Now it is of the type G over 1 plus G. So, if it is GH over 1 plus GH it is applicable there is absolutely no difficulty but you are interested in M(j omega) please see M(j omega) will come from F(j omega) divided by H(j omega) now. So it means first using the Nichols chart you will have to get the function F(j omega) H(j omega) you already know so it means the closed-loop frequency response will then come from the information on F(j omega) and H(j omega) manipulation of this.

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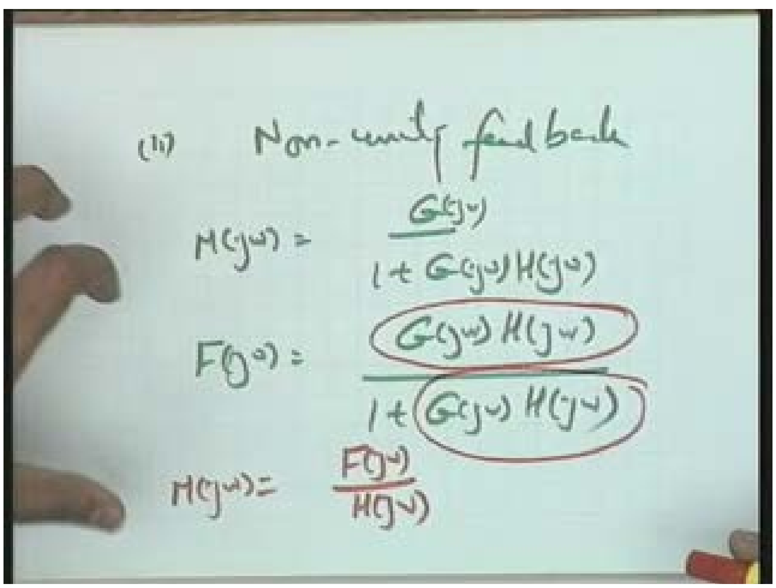


I personally feel this is my personal design experience that for the unity-feedback system if it is turning out this way then probably it is easier or it will be more conducive to design the system using phase margin and gain crossover frequency and K v as the performance measures. You know that all these performance measures can be obtained from the open-loop data. phase margin you know is an indicative of zeta; omega gs is an indicative of omega n zeta so it means both the requirements the requirements of relative stability and speed of response can appropriately be translated in terms of phase margin and the gain crossover frequency and the phase margin and gain crossover frequency design can be carried out on the Bode plot using the open-loop frequency response data, K v of course can be checked. Once I have done this I want to see whether the requirements M r, omega r, omega b if any naturally omega b requirements may be specified by the user. So whether the requirements on omega b are satisfied or not in that particular case I think partially I can take the help of the CAD software and immediately check what is the corresponding value of omega b whether the value of omega b are satisfied or not. Because you see the graphical or the help which I am getting from the approximations that help is not available from this type of manipulation F(j omega) over H(j omega) I think we can have a suitable compromise between the paper and pencil design in availability of the CAD so I make the complete design and I get the feel of the design from the paper and pencil work itself; the first feel of the design is available to me using phase margin as an index for zeta, omega gc for omega n and K v of course for the steady-state error.

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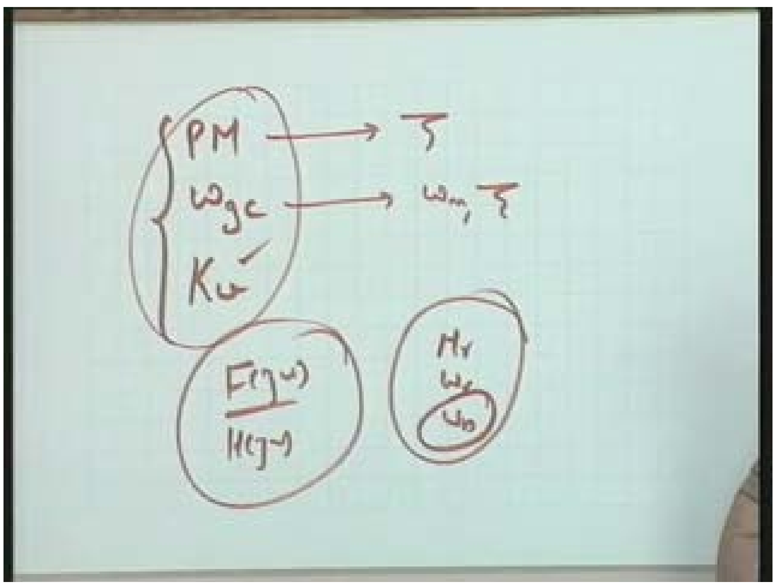


Once I have made a preliminary design then I can go to the CAD software and omega b or any other value which I want to see whether it satisfies the user requirement or not can immediately be seen because the software has the facility that for any value of G and H it is going to give you the values of M r, omega r and omega b by solving the equation G over 1 plus GH directly or you can write your own program you see. After all you can make your own partial software which supplements your requirements of the paper and pencil design.

Whatever comments I have made over here in terms of these designs please see, you see, if you consider different books different comments will be there; this I am giving my own design experience this is what I feel works better assuming that some help can be taken from the software for the calculation of omega b in the case when I have non-unity-feedback system.

Any question please? Yes [Conversation between Student and Professor – Not audible ((00:43:13 min))] F(j omega) will be the total response for G(j omega) H(j omega) over 1 plus G(j omega) H(j omega) it is the total response not that M r you will divide you will get the total response from here. So if you have omega for this if your omega verses F, if your omega verses phase angle and H(j omega) is already known to you omega verses H omega verses phase angle of H then it is an algebraic manipulation. It is simply algebraic manipulation F by H. The magnitudes will get divided the phase angles will be algebraically added. Yes, yes, yes, it is an exercise which normally is not easy to do and therefore it will be better to write the software immediately so that it is usable for calculation, that is why I am making a comment.

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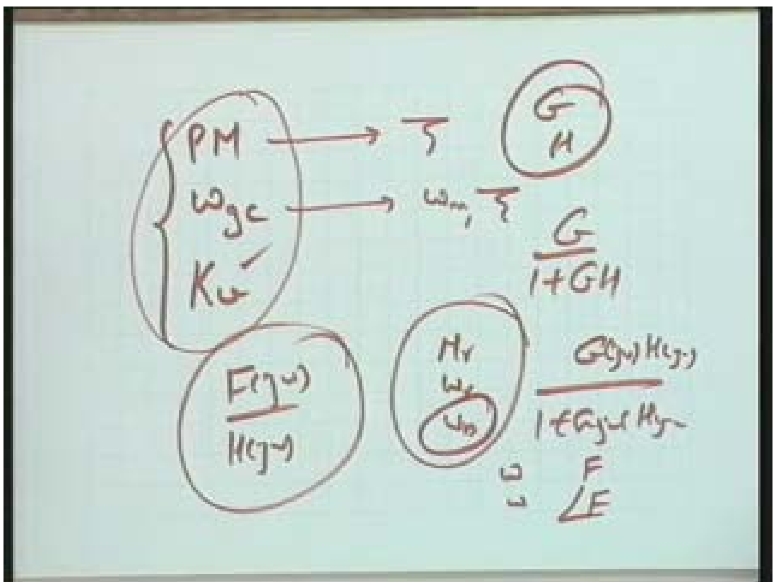


Any other point please; any other point here?
Okay then; I think with this we conclude our discussion on the feedback system performance and our next discussion will be on the lead and lag compensation in the frequency domain. Thank you.