Analog Circuits

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Week -05
Module- 01
Gain Margin – An example

Hello, we are now in week 5 of this course analog circuits, and in the past week we had covered the modules on gain margin and phase margin, so we saw that gain margin is a measure of how stable the system is higher the gain margin the more stable the system is similarly phase margin is also measure of how well the how stable the system is higher the phase margin the better more stable the system, so ideally I also mentioned in the last module that the phase margin should be somewhere between 45 degrees to 180 degrees.

Now in this module, we will be covering of an example of a typical analog circuits and see how depending on the feedback the amplifier or the system he analog circuit will be in the stable region or in the unstable region so let us recollect once again.

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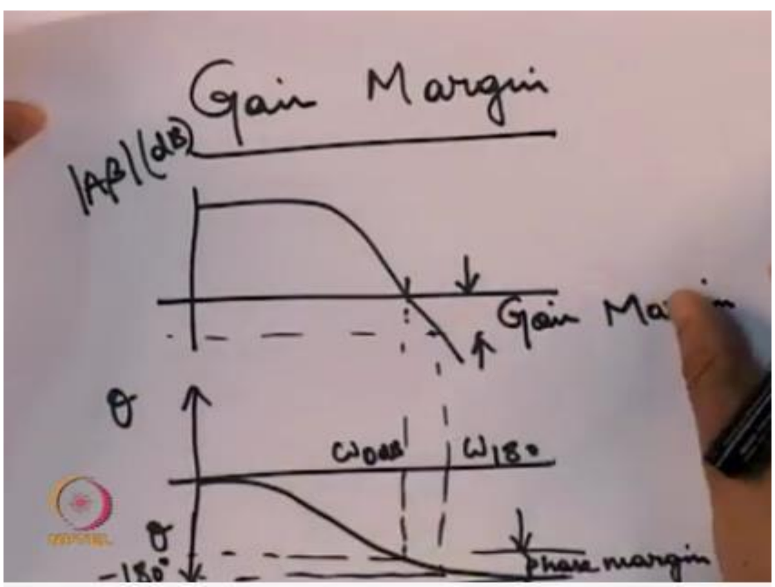

Gain margin, so gain margin I will just once again just repeat this figure so this is theta this is mod A beta this is the point where your magnitude of AB becomes = 1 so this is on a log scale this will be 0 so this is A corresponding to theta and this is - 180 degree corresponds to the frequency so this is umm my omega 180 and this is omega 0 DB okay so here what we see is that this is my phase margin and this is my gain margin now an alternate way of representing this magnitude of A beta = 1 could be this.

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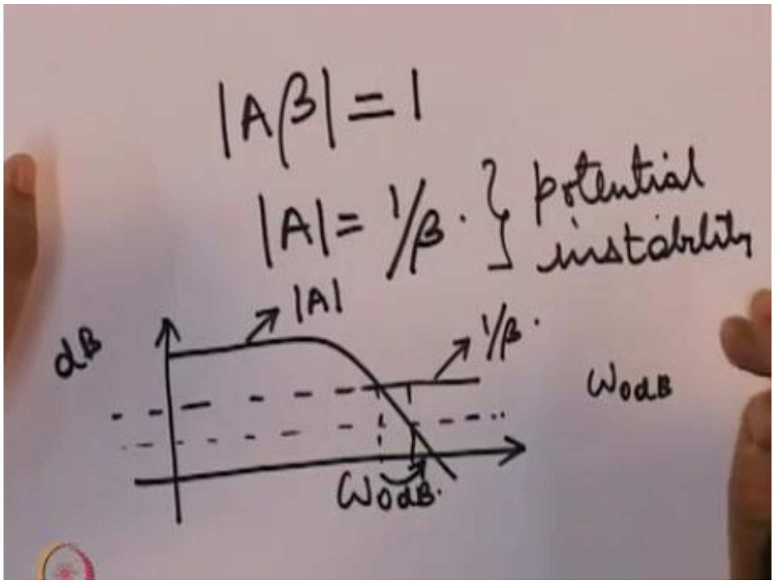

So we know a potentially unstable situation arises when my magnitude A beta is = 1 here we have I have many times said that this beta is frequency independent, so I can write this equation alternatively like this then if beta is frequency independent it is just a scalar quantity then for at the point of potential unstability potential instability not that the system is unstable yet but if this condition is satisfied that is magnitude A beta = 1 which alternatively is written as magnitude A = 1 upon beta.

Then it is a case of potential instability that is there is now it is no longer unconditionally stable there is a possibility that the system can become unstable, so then instead of measuring so if I have a plot like this in this is my magnitude of A plot ok this is in db and this represents my 1 upon beta then can I write that instead of so can I represents my omega 0 db point as that frequency where these 2 intersect so this is my omega 0 db okay.

So this kind of representation now gives us an easy way of analyzing various systems so here what we have done is we have separated the open loop magnitude the magnitude of the open loop transfer function from the feedback network from the gain provided by the feedback network and this way now so irrespective of what my feedback network is the this line the solid line remains the same but depending on what my feedback factor is this dotted line will change.

For example if I change my beta make it lesser then this line will shift downwards so now with this in mind and so in that case when it shifts downward my omega 0 db will shift here, so now with this in mind let us let us see a system with the transfer function given as follows like this.

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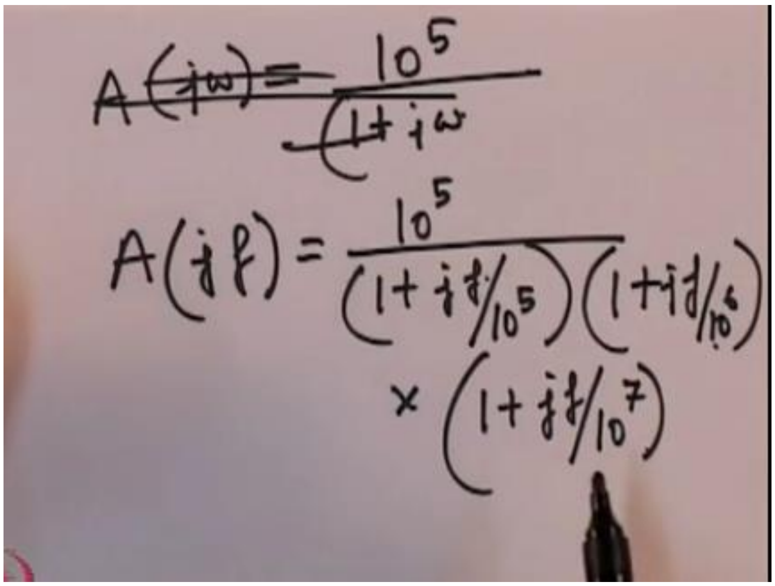

A of j f it I have replaced omega with F upon 3 poles one at 10 raise to 5 another at 10 raise to 6 and another at 10 raise to 7 so if I draw the bode plots for this particular transfer function this mind you is the open loop transfer function so the bode plot will be something like this.

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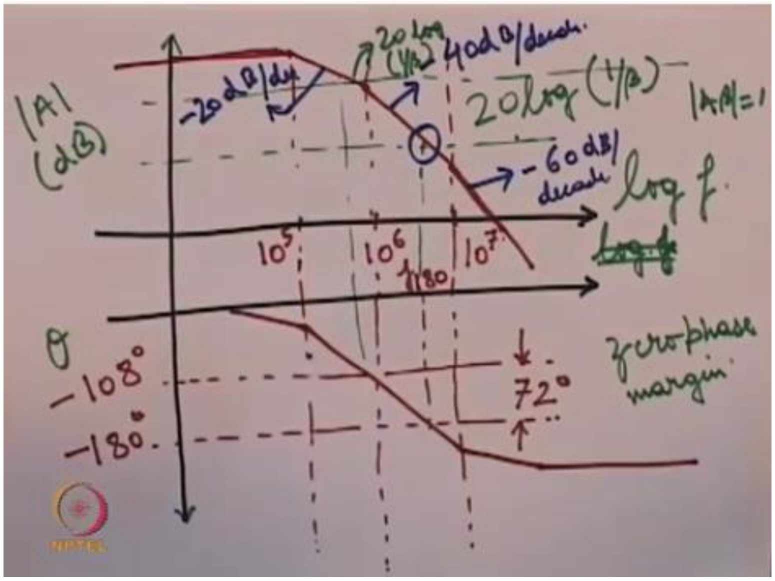

So this is my magnitude plot, the top half and this is my phase plot, so I can maybe label it as this is my and this is in log scale so this is log of log of F rather this is log of F now first consider the case when suppose my1 upon beta line passes through this one, so this is my log of 1 upon 1 beta line here this log of 1 upon beta crosses so this green line which represents log of upon beta crosses the red line which represents log of A or A in db so this is actually 20 log of 1 upon beta at the frequency F 180.

So F 180 is the frequency where the phase of the transfer function becomes = 180 degree, so at that frequency itself the contribution of the feedback network represented by this 20 log of 1 upon beta, so at that frequency itself it crosses the red line so what does that mean it means that the feedback is such first of all that there is 0 phase margin and note that in this region where this green line crosses the red line here the slope is - 40 db per decade here the slope is - 20 db per decade and here it is - 60 db per decade.

Now from the discussions that we had in the last lecture we know that this - 20 db per decade corresponds to the region where only a single or there is the contribution of only a single pole, if the contribution of this feedback network represented by this green line passes through this region this - 20 db per decade region then the system will be unconditionally stable.

So for example suppose here this is also 20 log of 1 upon beta suppose the feedback network is adjusted so that this green line shifts from here to here and here as you can see the phase is - 108 degree corresponding to this frequency then the system will be unconditionally stable the system will be unconditionally stable because even though the magnitude A beta is becoming = 1 but the phase but because the feedback network line passes to the - 20 db per decade region.

The phase will never exceed - 180 degree, hence if we have our feedback network such that it passes through the - 20 db per decade region then we can say that the closed loop system will continue to be unconditionally stable once again I will repeat if we ensure that a feedback a negative feedback system such that the contribution of the feedback network this 20 log of 1 upon beta line passes through the - 20 db per decade region then the close loop system this - 20 db region mind you is that of the open loop transfer function.

But if this green line passes through the - 20 db per decade region then we can guarantee that the closed loop system will also be stable why because even though the magnitude A beta = 1 at this frequency because the feedback line is passing to the - 20 db per decade region the phase will never exceed 180 degree since the phase can never exceed 180 degree the system will continue to be stable.

However that is not the case here when your feedback network is such that your it is passing to the - 40 db per decade region there is a possibility that the phase can exceed - 180 degree and hence the system can become unstable similarly is the case if the feedback network line runs to the - 60 db per decade region, so then our goal of any feedback circuit design should be that this feedback network should pass through preferably through the - 20 db per decade region.

If we want our closed loop system to be unconditionally stable then it should pass to the - 20 db per decade region fine okay the other thing is so then why don’t we do that always isn’t it if that is the conclusion then why not we always have our feedback network pass through the 20 - 20 db per decade region and note that when you are passing your feedback line to the - 20 db per decade region your bandwidth is decreasing this is the frequency at which your 0 db loop gain is being obtained.

Hence the bandwidth of the system is much lesser as compared to the case when the feedback line is passing through the - 40 db or - 60 db per decade isn't it here this is the unity gain bandwidth this region from here to here in this case the unity gain bandwidth is from here to here so that is when disadvantage to make the system more stable we have to compromise on the bandwidth so that is one problem of this system.

Now coming back to the circuit this red line this lower red line represents the phase response and we see that this - 180 degree phase is obtained only when we are passing through the - 40 db per decade region this tally with the discussion we had in the last module where we said that this - 40 db per decade region corresponds to the 2 pole case that is the region where the impact of 2 pole is there and therefore the - 40 db per decade region is a potentially unstable region for the feedback line to pass through and as we see in this case.

When this green line passes through this - 40 db per decade region the phase is indeed exceeding - 180 degree, if it had been a little lower then here it is same as my 180 degree had this line be a little lower and the phase would have exceeded 180 degree so in conclusion we see that for stable closed loop system it is for a stable closed loop system to be unconditionally stable it is necessary that the feedback line passes through the - 20 db per decade region.

In the next module, we shall see how for a system where such a thing doesn't happen still we can achieve the stability by what we known by a technique which we refer to as frequency compensation so that is what we will cover in the next module, thank you.