Analog Circuits
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Lecture – 10
Frequency Response of Amplifier

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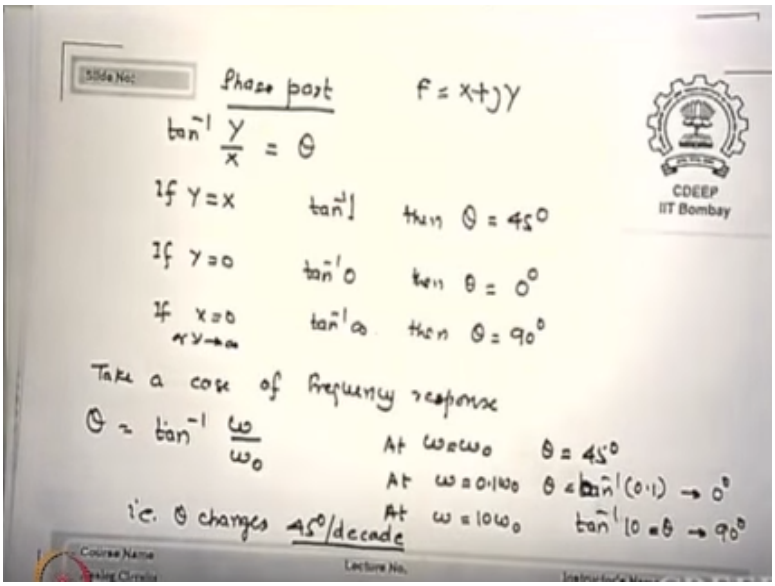

Okay, so we were looking yesterday about the pole zeroes we will come back with this for some few minutes about that again okay, if you take please if you take an arbitrary function X+JY the phase of this function will be tan inverse Y/X please remember what I am saying I am taking an arbitrary function f=X+JY okay.

Then, the phase for this function is tan inverse Y/X and we call that as a phase angle theta and we can see substitute some values, if Y is X tan inverse 1 it is 45 if Y0 tan inverse 0 is 0 and if X is Y is very large in closing tens and hundreds tan inverse infinity is 90 degree, so it approaches 90 degree it does not reach 90 unless it is infinite but to say that means one can say Y is large the phase is 90, if Y is 0 is it 0.

If Y is 1 Y=X essentially what I mean then it is 45 so you can see the phase will vary from where to where from 90 towards 0 degree as the omegas vary as the frequency, let us say similarly we

can write Omega/Omega 0 so as the frequency changes and you can see for every pending ten times the frequency the phase shift by how much 45 degree okay.

You can do a part if I for this point one is very small, so 0 10 is very large so 90 so you can say what was the gain function was changing with frequency 20dbs per decade and what is the phase will change 45 degree per decade, so every times the frequency changes by ten times the phase will go down by 45 degree and gain will also go down by 20 is that okay.

So this is something you should realize that every gain fall okay will be associated with phase going down okay, so from 90 to 0 it will actually run down and typical figure which for a what we call as a phase diagram of phase response is this is I am plotting theta versus frequency, so different frequencies your phase.

So what are these points these points are the same points at which gain was changing from say 20 DB to 20+20 40 DB+40 D, so every time it follows 20 DB per this phase also will follow is that clear and that is this together and same corner frequencies are they were together this amplitude diagram that is the magnitude in D beats and phase in theta is called bodes plots okay.

These 2 are together called bodes plots please remember we are we actually should do as I some to take values real life, but since we are not interested in how much exactly at this frequency otherwise we want to know from where it falls where it becomes 0 those 2 or 3 measure frequency.

We want to know so these were called corner frequencies and bode suggested that for any - as we shall see later the things we want to know what are the corner frequencies by mathematic they belong what are these corner frequency, we say they represent poles the transfer function that is transfer function becomes infinite at that value of frequency okay.

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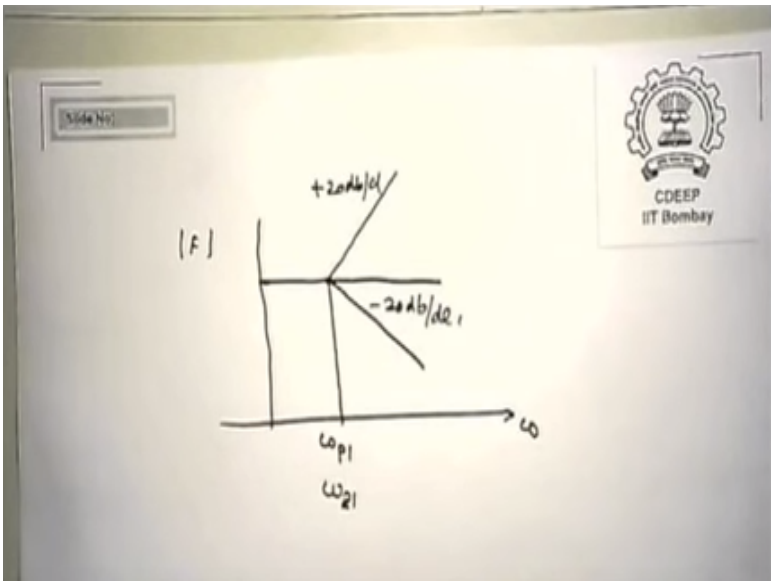

We did not talk in this so far anything about zeros we did not talk it so, if simple case can be thought let us say I have a pole let us say magnitude some function and it has a somewhere here at some frequency we call Omega P1 and let us say at the same point, I have also A0 that is the numerator also becomes 0 at the same frequency some reason then from here up to this it will be same and 0 will be actually going plus 20 DB because its numerator.

So the value will increase 20 DB for a decade this is minus 20 DB per decade so after Omega 1 P 1 equal to Omega or which is I am using he same what will be the actual gain actual gain will remain constant is that idea clear to you. Zero means the numerator and if you do something as we did for pole every decade of frequency the gain will increase by 20 DB for a pole.

It will decrease 20 DB down from this frequency onward +20 and -20 will keep canceling per decade is that clear is that clear but let us say there is only single zero here and there is a another pole occurs here which is say Omega P2 and there is no other 0 then, so what is the slope of this can anyone tell me the second pole down -24 this plus another 20 from the other pole.

So, it is -40 DB per decade but that means at this frequency gain will start because this 0 will actually put it to 20 DB per decade all the time but what is again falling, now here -40 DB so the together if I do it then from this point onward you will have -20 DB per decade is that point clear I repeat I have 1 0 and one ball at the same frequency, so they are compensate the word is

compensate okay 0 compensates full are also in other word 0 null snow pole null means cancels it null stink good this is called pole 0 compensation.

This is why I am showing you this initially because I want to tell you we want to actually increase gain for higher bandwidths, so there are there are possibilities in which the for what is the bandwidth essentially means what is the definition of a bandwidth argue till which the gain is constant from this frequency down the gain is not if there is no 0 gain would have fallen, so this is our initial bandwidth but if you have A0.

This will continue bandwidth is including so if I can sell a pole I have actually increased the bandwidth but at this point says the 2 poles and one zero are occurring onward the gain will start following from here itself. How many DB-20 DB per decade, so what is the new bandwidth now Omega P2 because beyond that only gain will start falling so my circuit way if device is fixed.

I do not have play on that, but I can hang our circuit if I can create my choice 0 than poles ok then I can tailor my frequency response of an amplifier is that part clear but deciding where should I have my pole shift 0 it is of course they will be limited by the intrinsic property of the transistor how much is gm.

How much whatever I did but apart from them whatever is normal amplifier I had I can monitor I can add some RCS somewhere say are these pole 1 upon RC is the frequency of a pole or time constant, so if I add us do something a RC time constant part of mine, I will be able to change the bandwidth is that one clear, so something you have to understand that circuit people are always smarter enough okay.

Even if they are working in an adverse circumstance they may still be able to give you something which you are looking for okay is that clear this is something tricks of their trade in all analog designs now question is why you have to solve, so many problems in analog because what every circuit you are given their pulse will be different.

So for every one of them you will have to think redo it again is that correct this better happen in digital hardware why because once a gate is ax or gate r and I am gator and or gate do whatever it will remain that function irrespective does that feel and I love this does not happen and therefore it is challenging in a way that every problem you have to take it independently.

There is no some force various correct rules are known but you will have to solve for every case to do something what you are asking for so there is no standard design available okay I want to know of this kind, so oh just buy it from some it is not like that for bad required to redesign all of it you say something change.

I will have to redo it again okay that is why analog designs or analog circuit are much more interesting if I say otherwise than the digital so is that why we are doing all this because we should be able to tailor our language for the human someone wants to lose 100 what do, I have only one circuit and I have to play games on that okay.

So there are tricks which you should be able to know and will see the or not one there are 3 kinds but when we do all this there is another term which will add later, which is called stability this one we shall come little later after feedbacks and we will say if you do some mischief otherwise the way I shown you it will lead to unstable situations okay, we will see why they are called unstable okay.

So it is not that you can do a randomly anything and get away you know you are doing suddenly your fine amplifier is not giving constant gains or signals are shooting like left and right okay, so this is another parameter and that time we say will lose another theory which is feedback to stabilize a circuit.

I mean use feedback at the cost of something and I may use some 0 whole composition technique or something to improve the bandits even then but something I mean lose in doing all of it is that correct, so please remember there is nothing there is no free lunch as we say or there are no free lunches same in circuit you cannot achieve something greater unless you do somewhere something okay.

So at every point what is at stake that is asked for and what then I can give you okay if you do not mind here then I will you this okay, so this is what analog designs are of interest to everyone because they are you are to keep thinking this place should not go too low which is demanded by them or should not still you want improvise.

I say okay if you give me 10% here I will give you 50% accept it like this so there are design issues which this course as I say I am not really looking into but I just want to do participate prospect you for a perspective of this course why are we doing this analysis so many times because at then I know how to design somewhere hardware for them okay.

That is electronic engineers job that we should be able to design any system for them they go on finally on a single chip that is another issue but design has to be first prompt okay and therefore the tricks of analysis must be known to actually designing hardware that is why we are actually looking into theory must seriously okay.

So I have not told you we are discussed first day one full circuit here is another circuit okay, so how much kappa how much capacitor how many capacitances where they never first circuit one capacitor, so how many poles it give one because one RC time constant gives me one pole is that here we are not going to discuss zero.

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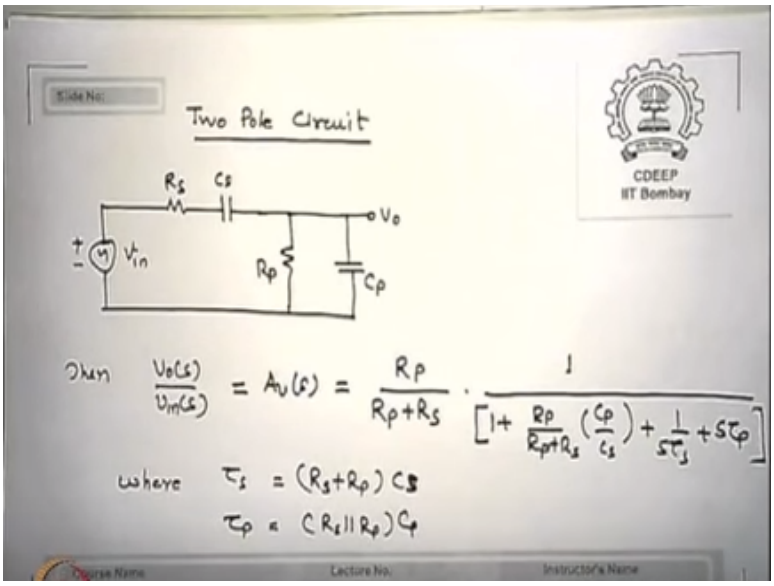

We will see of how 0 appear, but right now we are only looking into poles now I another circuit in mind in which we have 2 codes why 2 poles I say how many capacitance should have per 2 poles 2 capacitor 2 time constants I must be able to create to have to, so here is a circuit which is called a 2 pole circuit.

I have an input source which are the series resistance RS and I put another capacitance CS in series to this s really series world okay then there is a pass resistance RP which is in parallel shunted by a capacitance CP okay that okay a simple circuit there in one time what we do either we had this or we had this now I have put both of them CS and CP are both present simultaneously is that okay.

Is there clear both capacitances are simultaneously present with 2 resistances this is a simple Network once again, so if I solve V0 about the end I can solve as we did earlier how do I solve take a parallel combination of this take a series combination of this and what is V0 this upon this Plus this into Vin is that correct.

That is it equivalent to saying Z1 well you did not say resistance Z1 Z2 this is V0 this is Vin so V0 is Z0 Z2 upon Z1+Z2 x V is that okay so I will calculate this I calculate parallel combination of this and then just take a ratio of that it is called potential divider just divide it and you get V0/Vin transfer function and what is the transfer function here.

We are looking it is a voltage gain why it is called voltage gain because V/V output by input voltage, so the transfer function here is AV s and why I am talking of this S word because the frequency dependent term capacitance into s is B1 upon CS is the impedance of the capacitance or rather CS is called admittance of the capacitance.

So if I do this V0/Ben and if I define 2 time constant tau s is RS+RP x CS this s is subscript okay otherwise it will no it is not subscript sorry no nice okay but now if not it is a subscript okay oh maybe I should rewrite yes and the other is RS parallel RP x CB do get the point.

Why this how this parallel combination will come if I see a resistance from the CP side what is the resistance CP will see when I see from output what should I do should be grounded, so this RSCS will come into parallel and for the resistance that will occur if you separate the terms it will be essentially coming from that circuit okay.

So this is the 2 time constants I have defined one is RS+RP x CS the other is RS parallel RP into CP why are you fine from there because I am seeing those functions here so I define it from there okay, so then I write this as a function so how many could you see this is a quadratic s term is appearing this is a square.

This is s plus this is that good this into S1+S square tau P tau S+1 x S, so there is AS square + S+BS+C is in denominator is that clear can you write such functions which I did earlier.

For example if I have a function S S square+S+1 let us say I can always write this as S+S1S S2 of course.

This may become some different value because when you connect it not right now it will be one but if you want to separate what is the way you can separate these 2 functions by partial fractions if necessary you can you put a partial fractions right now one can find this is equivalent of this can sees S S S square S1 S+S x S1 S2 ok and divide as well.

So you will get some kind of similar expression so maybe here let us see so I can see any such product in denominator can also be represented as this if I take S1 S2 outside then I can write s upon S1+ S upon S2+1 you can also write this way is that correct please remember as one as to R constant.

So I can take them out and then I bet I can get a function which is 1+S is Omega S 1 will get also in terms of M R Omega so 1+ Omega/Omega 1 x 1+1+Omega/Omega 2 kind of function I can create if I have a transfer function denominator of this form is that clear so whenever there are 2 pole or 2 capacitance but how many bowls it will give you 2 codes is that correct it is a square term appearing they always give you 2 is that clear.

So this fact has to be understood whenever there are 2 time constants involved there will be 2 boots please remember it may also create the 0 which in this there is avoiding there is no equivalent source I have put to create A0 for that but I can see I can add A0 alpha by some other trick right now I assume that there are no zeros here.

So this fact has to be understood as soon as you write the transfer function and you get A S S squared terms in the denominator it is a square +S+ something you can always represented this as a product up to such S+ kind of terms and they say there are 2 poles S1 and S2 omega is that clear this is a method of solving any circuit any transfer function.

Now I say any because it is voltage the voltage tomorrow it may be voltage by current third time current by voltage or current by current or it can have a mechanical system velocity force connected it can although this is a control system part anything has a transfer function output by input what is the stimulus stimuli you understand any energy source you put any stimuli is immaterial for us okay.

Transfer function has nothing to do with voltage current or something it can be true for every one of them however in our case we are only looking into electrical functions is that okay so this technique is universal is that correct this technique is yes okay, if SI J Omega so J Omega/s1 will be constant so 1+JOmega/S1.

Now you can find its magnitude and pull very easy is that correct when you want to find a magnet will it will be much easier for me to do that is that this is that no compulsion you can do otherwise but then also if that ton will come out finally when you do that so instead I did initially okay I am not telling that this has to be done but this will come anyway.

So I showed you is much easier to start with ladies please do not take it that this is has to be done as now you have a function you can break into any of the search form and what automatically terms will come out or come in okay so you do not have to if you have seen you will get everything correct this is the way I am explain you how to do things okay.

So having shown you this transfer function I have done this I am not going to swallow it fully but just to give you some idea on that so week one can see Taoists, which is essentially RS + RP x CS it is called open circuit time constant is that what why it is open circuit what does it mean 1 upon CPW is infinite that is the impedance at the output from the capacitance P is open much larger.

So where it can occur assuming CP when CS are equal values are not very different where it can occur at higher frequency and low frequency much lower frequency 1 upon CPW will be much higher, whereas if you see the other time constant which is RS plus this comparatively so this as I say is called open circuit time constant by similar logic.

We can serve powers represent time constant associated with cs and the rich called short circuit time constant sorry Taoists is also called short circuit time constants why it was called short circuit if you short circuit the output and see what is the time goes it is RSC affiliated only so it is related time constant only to only to RS and only to capacitance s and not to the CV.

So this fact that I can define sorry oh I am sorry oh sorry that was a similarly tau P is called short circuit I am sorry I am I wrote it correctly and then in hurry I said something wrong similarly by similar argument, I can say tau P is called short circuit constant because at that time the series capacitance I want to short, so well this can occur very high frequency is that clear to you.

1 upon CS Omega will become close to 0 only when Omega is very high Omega is very high so what does do get now pole separate frequencies from this frequencies 1 is very very low frequency another H very high frequencies so one can see if they represent somewhere the poles the one pole is very close to 0 side the other pole is very far away from this other side it is going towards infinite side of it is that clear to you.

So whenever there is s capacitors available depending on of course the value of CS and RP and the frequency are SRP frequency one of the pole may be dominant over other word which is the dominant will come from here 1 upon tau P will decide R.S I just said you know if S is infinite only then this will start dominating this will short circuit.

That means the pole which is decided by much higher frequency the other term dominates at much lower frequency CP is going away it is only CS, which is dominating is that correct so one can say the poles and 0 are normally not at same value they will automatically get split this is called splitting of poles, what is it called splitting up this is a theory.

I am trying to why I brought the circuit so another technique which I am using going to use by a proper choice of RS RPCSCP what can I do so initially let us say some simple figure I can draw again for the same thing which I am doing again let us say honest I will come up here this is my Omega P1 and this is omega P2.

This is dominant this is lower this is low and this is high but I can change the both and both side what can I do I can bring this on this side and can bring this on this side I may actually bring them together or I can also shift the first pole towards lower side a second pole and first pole Miami shipped out this is called pole splitting.

I can actually decide which pole is dominant for me is that correct how do I do that by proper choice of ours and scenes this is another method what we will see later have A dash of this amplifier can get you by splitting poles one method what did I say l 0 mulling something the other way are you the splits.

How I split by varying the value job typical RC networks which I put there so that I can change my pole positions is that correct so these 2 techniques tell you another one will come and you finally so is that technically you understood that these are not constant per SE for a given circuit in analysis means you solve it whatever values come but in real life if someone ask me know I want here then I will think.

What should I do now additionally that I can do what he is asking for so to do this is called design what is design the customer tells me I want this and I am asked to design for him but to design I must know what should i do that i can meet respects okay, so our course is all that I am talking about analysis but you must be remembering every time that this is not analysis interesting course.

We are not doing for the sake of interest alone because tomorrow you may be designers and you must know how to design so you must know which way one can design to get this fixed someone is asking and split will not be your hand because someone else will tell you on this okay so applying you must know how fair this is what I am reading but he wants this so what should I do I have learned one professor or taught me like this.

I use this technique and let us see what happens okay this is what is all about in real life okay no one actually tells you to solve problems in diagrams as we did here in the real industry anytime but they will come this product will be marketed this is the date at which if market value is high.

So please put this product in this time then you have told this is what I want at that time of course this you will do in graduation or PhD much more detailed me but right now 2 menu why we are doing it you know a few years ago everyone used to ask me sir if my analysis number can take you.

So I am now trying to every class I am now telling know each other elements in the end of your career it is start of your career because there at that time I will not be there books will only give

analysis okay, so you can see my even the book which part I am even it is sick 400 500 pages every time you cannot carry 2 or 3 books every male at that time only.

This helps and therefore the tricks I have explained okay yes because that will very small yeah but that is that means that we will start dominating one upon RC of that will start dominating smaller the value okay one upon our C is smaller is the first time gain will start falling the amplitude with that is called the dominant pole is that clear.

Now I will not say it is 0 0 are an infinite are the extreme values there will be a finite value of CSS also then we will define and earlier CPP also okay, so it is a way still will be a ratio but which one will dominate numerically by magnitude is that clear you do not get that word 0 or infinite as the actual values because then there is no system letters is that clear that is them anytime.

I show you an arrow to you tending to infinity okay tending to 0, otherwise if it is shorted and open then there is no there is no component there what we shown that is that clear okay having told you if i show you these 2 frequencies which i just talk one is called FL 1 upon 2 pi 2S the other is called FH 1 upon 2 pi tau p the first one since being lowered it is called the lower corner frequency FH is called the upper half corner frequency or higher corner frequency.

If I plot the gain versus frequency by bode technique we are not plotted full Bode right now I only archive I figured out what are the corner frequencies so one at here one at here in between we say the value of V0 VS is constant below FL again will fall beyond FH also gain will fall V0 by gain means B0 having both side it will fall.

So what is this frequency from f l2 f it should be called where V0VSR is constant is called mid band or essentially the bandwidth essentially called the bandwidth in most cases FL may be very small close to say 1 hertz or 10 hertz is that yeah in many cases the cutoff frequency may be as low as few Hertz at that time FH itself is your bandwidth because FS 100 mega 10 Hertz is as much L 100 megahertz is that clear.

A 100 mega odd dash, 10 Hertz is as much as 100 megahertz, so if this values are very small then the normal bandwidth is a fetch well now can you think little more from this kind of figure which I have drawn you can see from here, if I have a network from anything below a cell the gain is falling sharply 20 DB per decade okay and any free just forget about FH right now anything ahead the gain is higher constant.

So what is the equivalent I could say again maybe we use fresh paper what I am saying I have 2 functions I am now drawing this is my F L okay this is gain versus frequency so below FM gain is very small or zero, I am 8 step function kind and beyond FL it is large and constant by same argument up to FH gain is constant and below beyond FH gain is 0, so can you think what is it what is this actually doing I have a circuit.

I do not know what is it has many frequencies F1 F2 FN okay what it will do or at the output from input to output if it passes through this it will not allow frequency below FL okay so which what are the frequency it is passing higher frequency, so it is called high pass filter it is called high pass filter.

What is this up to a fetch it will pass all the in frequency as it again and beyond I fetch it will not allow any this so it is a low-pass filter, so this is high-pass filter and this is low-pass filter can you think 2 filters out of this before we go to solving 2 more filters from the same figures can be created what will be bandpass this is what was the band pass this is essentially your band pass okay from FN to FH is the band in which this is there beyond that roughly it is 0 0 okay.

So the band pass filter has something like this F 1 and if so it is F2-F1 is the band in which it is passing the rest all frequencies so what will be the 4th one it is called band reject, so what should be done where you can see same combinations now I put okay I would serve one is here which one will be this filter this is HP this is LP the only thing is yeah.

We will talk in a minute LP for malaria or HP of its frequency k on their band reject over CAF F Jaffa who score either that is FL is larger than fh I told you by circuit I can change FL and FH

value here FN is lot smaller than a fetch here FLA swallowed that sorry if one of 2 is a my pillages however here Bode sign, I will be FL higher than fh is that correct.

So in between the frequency now what is a big game is how much or signal is zero so this is called low power high pass this is no power sorry no passes here first and high pass is the head and this is called bandpass this is called band reject is that correct, so from the same low-pass bandpass a high-pass theory by adjusting time constants I can create four filters low pass high pass band pass band reject okay.

All that I had to adjust is the value of FL and FH and they are functions are warn RNC so by proper choice of network values I will be able to design any filter which will be of kind which you are looking for I will not give an answer but just think where do you think this will be useful okay you can filter her that I interesting here.

I bring a fun fetch very close okay I bring FL FH very close maybe here and so I have transfer function versus very close to each other what did this filter should be called not filter saying all of this game what is important what is that we are talking. I just your transformation values with RNC's and you can create all kinds of filter you are looking for that correct.

There is another printer shrill is study properly it is something like this what is it called all pass now question around this why such a filter is it required at all okay is that clear of us all frequency puzzles still we put that filter so I am like hang on talking of a monitoring network annual gains right.

Now I am only talking crossover can be 0 by the way there is no amplifier there is no transistor right amplification can only come there is a active device in this anywhere and did I show you any transistor no these are only transfer functions passive networks. What are these passive networks along with then we may put the amplifiers or something to get something more out of this filters.

Because you need driving you need many things but basically filter has nothing to do with active device okay we can always create a filter using passive networks this is also required all pass something will show you in the using an opamp we do need an all pass filter in open circuit sometimes we need all past but still them on there still we want that to be there.

So is that where filter theory filter does not give basically it is only a RC network combinations which can allow certain frequency signal to pass and certain other request signal not to pass okay or which are a combination of the 2 this is the technique but then why I am doing it this is a technique I may use it rather than my filters okay.

So I just told you to do itself that all this tricks I use an actual circuit theory anywhere I will use I will just follow this okay this I had to adjust output so next time if I show you some network as I said this is a low pass do not ask me why I told you how it will believe us is that clear right now I show you how it works as a low pass high pass band pass man is that okay.

So, something this basic thinking which I thought I hope that Network purely people should have done that so at least my course since I need this later, so I do not want to miss it that under yellow path getting better there is a key on that okay filters jump and I guess it passively will they are active filters.

That means there will be transistors or open source um active device will be there okay not that without them we do it but basic network is a filter means something is passed something is not pass is filter okay, let us revisit I have a normal amplifier except C here s the same which I have discussed there is an input capacitance C in there is an output capacitance CL okay.

This is a series resistance of the source there is a load resistance Rd okay, which is the drain resistance RD and it says unless another white with and mass transistors okay have you seen what is the circuit first forget about CC the all other is a standard amplifier okay and now I add if capacitance between output and input what is the output point this drain point what is the input point this is the gate point.

So, high introduced of capacitor between drain and gate what should be called feet feedback gate drain to get I have connected now okay, now this word is why I brought this again you can see there are 2 where the signal can go which are the two-way signal can go from grid drain and gate it may go from gate to the drain then it is called feed-forward.

What is it called feed-forward the signal goes from here like this it is called feet forward but if the signal returns through the same path to the gate it is called feedback is that correct but capacitor to do no sorry concept there, so how do we in real life we will prefer feed forward be stopped and feedback be allowed okay what is the trick we are going to play later I want to reduce feed forward problems because he would probably the big problem will show you and I may allow feedback to occur is that clear.

So, but in this circuit do not you see that the signal can go this way or it can come this way yeah who can stop it okay, now who can only stop it provided this voltage as are such that signal can go from one side to the other only is that clear to you that clear if there is this potential is smaller then this may go there is will go.

So we must now look for the potentials and the 2 ends so that signal can go either way of me is that clear this is the trick again we are going to clean please remember between 2 nodes signal can go from 1 to 2 or 2 to 1 feet forward feedback either is possible and as I say if there is a feed-forward what is the problem is yes sure ok.

We can say right now by associated time constant one of the poll said they input okay without CC is one upon RS scene so what is the trick, I am not showing you foot pose then are they accurate ones if CC is not there what is the time constant at the input RS scene, so that it should give you one pull okay at the input side okay.

Now I have a problem which I say there is a famous theorem which is called Miller's theorem this is the famous theorem which is called Miller's theorem it is essentially says if you have a poop or network and on the one of them is the impedance Z okay then this Z can be split into and let us say what is the input.

If you are input a signal is V1 at the output you have a signal a V1-AB1 it could be plus anyone also it does not matter but a V1 a is the gain function if this is your 2 port Network can you think where it can be a bit of the high circuit does make a hassle, I am using this you have a signal V1 at the output your amplified signal a AV1 okay.

In between output and input there is an impedance Z is that okay it can be capacitance it can be registered it can be RC together or it can be even inductance or it can be LCR anything Z according to Miller's theorem. What is Miller is saying this could be split into it pi kind of circuit non PI kind of circuit 2 port kind separation the first components.

l1 is essentially equal to 1-A x that is this Z can be split at the input side as 1-A x 7 is minus please take it is minus, so it is 1 plus a magnitude wise is that correct and if a large you can even neglect 1, so it is gain times the third is seen as the input please remember where it is with in output and input yarn impedance Z.

So it will reflect the input side as gain times that value please remember this – is+ actually is - so 1+A have magnitude wise is that clear is - so 1-A1+ magnitude YZ okay, so this is larger or smaller J is larger is a gain function so larger than at least n 2110 okay, so this impedance at the input will come much larger at the input side.

However if you see equal and on the right side of that is at the output side this z2 is a upon this minus IR removed now H+ of 1-A1+E what now is ah yes you know it is positive here means this with minus a is the gain is equal to minus V2/V1 assume the you know there is a phase shift in all ok.

This minus sign is only taken care for opposite sign V0 is -VMR is that correct so it is that it is positive and that is the so that is what I say ok if you feel, so much worried ok that is apt again it is positive is that ok now so essentially it is gain times the Z will reflect at the input but gain upon 1+A is how much one almost one that way into Z will be reflected at the out this is called Miller's theorem.

So any such network connecting between output and input can be split in 2 part in the input part at the output please remember the condition of Miller's theorem and if that is not true then the Millers theorem is not how do I how can I derive this can you do me how can I derive this do not use this values this is Z1 this is Z2.

You evaluate write an equation for this and find what will be impedance seen here and what will be impedance here equated and you will get this expression just shuffle all of I am in and I hate o many we can do either please try okay. The most important part of Miller's theorem which most books are while telling you is this the minister ohm is only and only valid only and only.

If there are 2 parts from input to the output is that correct Millers theorem is only valid if there are 2 parts from input to the output if there are no 2 parts the Miller step that means if this is not a times something which I showed V1 and V2 this cannot be split is that clear if this is because of the transfer function of the some active device if there is no such active device sitting there are no such to pass created there the Millers theorem is invalid.

So what I am saying then say this is V1 this is V2 so this will be split this is not possible okay so what is the equivalence I am asking for Miller's to be valid there should be a gain term or some function through, which input can go one part and this is the other feedback path or feed forward path is that clear to you.

So if you are the 2 parts only and then the Miller split is allowed is this condition here to you if this kind of circuit is not possible in this that is why I have put it here indirectly is that correct that aim is essentially a gain function coming from if that does not exist no such split is possible this theory if you will someday I will give you some one hour lecture on Miller.

So this is only nutshell I brought you actually theory is very interesting long issue not to prove my all points right now I am assuming something and saying it is proved but I can show you without a few minutes okay, so some other day so in mm clear so if you look at this is what I am going to use very often.

So can you see from where I can use now Miller's theorem for which component yes which component I can use Miller theorem CC output to input is the only component is CC how many parts you can see from here one through here one through here is that clear so there are 2 parts available and that is why CC could be split now is that correct yeah so CC.

So you come to equivalent circuit your point of is understood well but let us wait few seconds one is through transistor gate to drain J Omega is minus -gm if current or understand gets a get my videos like a tub drain current - times I am do that with path you throw external path the other capacitors had your noggin.

It always corresponds to external feedback in transition even internal feedback is always there which is the component which is always connected between gate and drain CJD CJD so that that is also there but if C C I put it additional to see GD to add CG do to CC so total capacitance between drain and gate ACC externally put Bernie okay.

So, there are now 2 parts one the transistor other through CC is that correct and this will give me again with a phase of minus 180 degree is that clear and this will be another one so I am now looking into this situation and therefore I can say now CCS splittable what is the amplifier gain our case just look at it leaving all capacitances what is the amplifier again B.

Now castruccio Bologna she simply forgot n kit now there are zero in infinite money so GM already -gm already parallel are 0 if you wish so the gain of this amplifier is -gm already please remember R0 is paralleled with that but since already that is much smaller normally are 0 but in real life what should you know it already parallel are zero okay okay so it is -J mod is the gain okay.

So what is this value I have got that a word which we are seeing is this gm RD is the value which I got for the gain function okay so can I now write an equivalent circuit using I know the gain I know CECE.

So, I can now write an equivalent circuit what I said so far is the exactly what I wrote there is no difference in what I said is that okay so Miller's theorem is valid for work is okay so at the more one that is at the input side what will be their capacitance C now one is seen one please look at your circuit what is the first capacitance I are given input capacitance of a transistor seen one.

So that exists as it is please whatever the node one I am talking the gate terminal I called no one the drain terminal I called node 2 okay so first is seen 1 and shunted by it how much is the capacitance will be 1-gm RD x here 1+gm RD times CC+C in 1 if actually the input capacity this becoming larger or smaller earlier seen maybe order of say 0.1 puffs.

How much 0.1 or even less than that filmed over right maybe 10 to 50 farad's let us say gm id is 100 okay that says he see his point 1 so how much I am 10 perf I am adding to some femto farad's how much initial capacitance I have few sent over I've seen one I had a hundred times CC even if it is 0.1, I say or 100.

Now come to garage even then it will add now tens of puffs so what is the very value capacitance has increased enormously if there is a resistance here per se equal and something what will be the time constant will increase or decrease increase so the 1 upon time constant will increase or decrease decrease is that correct because larger 1 upon RC is larger 1 upon RC.

It smaller sorry Li gong-gong key yeah just feedback make capacitance if you pull the pole on the input side will go lower value and higher value, but we said it will move she has increased 1 upon RCC has increased so P will become lower value so the first pole has if I would not have put this but said there is no CC there would have been my pole are into scene 1.

If I put a CC where when the pole shifted hundred times on the left or whatever sigh evaluate Julia is that correct left me smaller is that correct so do you see that I am now tailoring my FL FH values by just putting a CC there I have brought down one pole to the very left side okay how much I can do it that will be decided by which values by the by the Hardys and by the CCI connect.

Generally, I may not play too much on gm RD why I will not play too much on gm already because that is again I do not want to play too much on gain so I will only change the value of CC so CC may tell me where should I put my pool please remember scene one will be very small compared to CC 1+ this sciences.

So, essentially it is the CC which may decide the pole at the input is that correct unless of course there are additional capacitances are available at C1 is that point clear seeing one is larger than you may see how much is probably total some of that but in case it is only cg d CGS then that may be smaller than 1+gm RD x.

I see okay and in that case we say CC may now start defining the pole at the input side is that kind of so how I tailored it I changed this is what design is all about I present it I think ok I can tell you yeah all of them ok see the next cell at the output side there is a node capacitance and how much is the capacitor and it will reflect at the output I said a upon 1+M is 1 only.

So it is CC only so the output capacitance is CL+CC, so the second pole will be 1+RD x CL+CC please remember 1+gm RD x EC is very large but CC may not be that large or small I mean that large so is low may be external I do not know it may be larger is that clear.

So this pole will be generally smaller or larger than the earlier PL CIN CC will be comparatively smaller some of them is that clear RD is typically a few key loans are tens of kilos RS is in few hundreds of homes there C are increasing there so which pole is earlier than the second one P1 is a P2WP1 is much earlier compared to P2 this did you see I split it.

So I moved P2 far away or I brought P1 away from the Peter is that clear if I do not put CC then what will happen this CL and CN may be opposite please save it what can happen if CL is comparatively high all that value are seeing may be large A1 upon R scene may be larger compared to 1 upon RD.

So then what will happen the output pole may start dominating overhead input coal now what did I do I met input Pole dominate over the output Pole by putting CC is that I remove a CC then it

may possible value of CL and RDS such that this probe may come earlier than RSC in one okay that we say okay output pole is dominant.

Now than the input one but by putting a CC what did I have confirmed you that the input pole will always be dominant over the output boots is that clear so CC is going to decide there should have my bandwidth is that correct why it is called bandwidth point because I beyond that the gain will start following 20 DB down cold means gain will start 20 DB done.

So this is the value is that clearly bandwidth I am controlling through what CC external capacitance I am controlling it now is that clear these are the tricks which all amplifier designers use where do I put my pole is that correct say 1 is 1 upon RS x C in C now I increase by CC because gain time CC is appearing is missing hundred ohms and this is the gain is high.

I am gm RD x CC is also high enough so this value may be let us say gets to say one key one kilo Hertz okay this is certain key loans and this is CLA Z equal to something like this and this goes to let us say 10 kilohertz because of RDR this combination so this pole has started dominating which is this one tenth of this but if this scene a scene one only okay.

Which is 100 times less than that and iris is smaller than the P1 they become larger than the people in which case I would said output pull my dominant but by putting CC I guarantee made save something that the input pole will dominant is that clear to you so both why I didn't want to try on the output side can you tell me.

Why because the CL is not known to me many times so I don't know what bandwidth I will use is that clear to you why I am always looking at the other side is that point clear because CL is something unknown to be in my analysis I put some value okay but in real life where it will get connected.

I had no idea and then that should not decide my bandwidth is that correct unknown quantity where my this amplifier is going to draw you should not decide where my bandwidth is so by putting CC what did I do I have decided my bandwidth independent of what is ahead is that clear

to you this is called what you want can you get without the output telling us what I should do but in analysis.

We need not do all that we just calculate for all capacitance all resistance what are C we get and fine which is higher or which is notice okay hurry up arrive it is that clear so in analysis, which will do one you need not worry all this which I am telling you why I am telling you this tricks, but this is how I will design is that clear CC designs deep bandwidths which is external means I am putting it there.

I do not know, but this amplifier I am designing so I am adjusting CC value for my bandage the resumption is here will not be so small or something which will start that may still happen otherwise then so some conditions I must meet but generally begins are larger and CC's we put around one point one pot to 112 this will always on the left side input pole will dominant but please.

Do not take it that every time input pole will dominate over output poles is that correct you have to calculate and find but by tricked by the roughly will always occur for general techniques is that okay this clicks I am telling you because I have figured out over the years that people always feel that why do we do so much of this so I am now explaining.

Why we do that is that kind of so we will swallow a circuit in which this has nothing to do with actual knowing where the poles are what we'll do is we live a network will find all our sees and calculate whichever is Omega 1 Omega 2 Omega 3 okay then we may substitute the given values and find for where is Omega 1 where is Omega - very dominant is that clear.

So in real analysis we are done bothered which dominates but in design I want to know where I control myself last but not the least before we go yes okay I made a mistake he may be right but why okay do not say that because the I think he was right I didn't want to that time agree it is an admittance essentially capacity is an admittance 1 you are very good.

Thank you for correcting me said bye-bye sorry that there is therefore RNC add an L by a squad admittance because I is the one upon that man so I made a mistakes thank you very much okay okay there are another important issue we are seen polls so far okay now people say why should occur what is the transfer function 0 means at the output V0 should go busy there is a 0 in a transfer function and the output goes to 0.

Now output can only go to zero if there are 2 signals opposite fits and equal magnitude if s a current a you see note the opposite current they are equivalent please note that the potential 0 can be in the same 2 paths opposite polarity gives the same magnitude then I will create output zero is that good I x RI x R cancels minus RR+RR1 RR2 may be different but I1 and 2R and I2 x R2 opposite faith R1 R2 may decide they may cancel at some point is that clear.

This is exactly what zeros are on the board just now I showed you there are 2 paths equivalent Li we say one is the path through a transistor let's say an input V into and the other path is let us an input V in one which actually when one is both are same but even if they are different I don't care the other path is this feed-forward output per bulb at minimum is 8x signal say CC capture of Sarah Dutra transistor candle se RA gm times RI, but transistor always give me.

How much fish-shaped - with 180 degree shift so this is always given me 180 shift this is direct is that correct if the values of IR for here hi al from this R such that at this potential output is balanced because of this because of this then we may say because they are opposite polarity there is a possibility of those values cancelling each other is that point clear x8 180 out of path it Kanaka value same nickel via opposite polarity men.

So the net and may be 0 for that is that clear so Vgm0 will become 0 so output will become go to 0 is that now clear y 0 can occur walk reopen a CC and you say okay I shifted the poles who did very great thinking isn't it when I put a CC I was think you are great look I shifted poles and all that but this problem is suddenly seen by me now I say if such magnitudes occur then I may actually get a 0 is that clear.

Zero means 20 DB per decade gain enhancement cone is 20 DB per decade going down now where is this 0 and where is this poor if that occurs at the same first frequency than you nothing has happened actually a death cancel each other so now I have to start looking into where this 0 Falls is that clear where this 0 is occurring at what value of RC and gm this can occur is that correct what value of these 3 zero can occur.

If that goal value still the dominant pole is Omega P1 fine otherwise I will have to say are there then I am not gaining anything is that clear so this was a pole and at the same frequency if the 0 starts okay same frequency then this is the pole 0 has canceled each other so the whole purpose of shifting that pole has lost is that clear.

You can see then only it will start volume so the purple fa0 may not be as good as we think it may be actually bad oh sorry in one being to only to show you 2 paths being can be seen they are same you connected here if fish green one is same as B into it is only to show you 2 parts is leaving Alex with you okay.

What are you saying that said you are like a say may be a miracle this is just to show 2 putts yes mam no see this note as I said are equal this node and this node are same that's what I said you only show 2 shoe path I made it separate what you are asking is correct if they are same like this now it's okay.

So the point I am trying to say that whenever there is a feedback capacitor between drain and gate not only you will get a different pool but you may also land intoA0 is that color there will be A0 associated with this feedback capacitor every time and those values may actually change your bode plot anyway is that correct.

So you thought only pole I can adjust then you realize that not only pole but now this zero is also coming okay so here analysis you must also figure out varies at 0 now okay and how it will come into expression in the numerator somewhere term must go to 0 that will be 0 is that correct if they are at a given frequency numerator must become 0 okay.

If that occurs then we will say there is a 0% and the value of F0 and value of the pole you are shifting should not be same is that ok this is what where as I am not done so far amplifier very schematic this is what we want to do ok actually, but all this today we did is general theory how do I bring 0 will have an holes what do they mean okay is that ok so today we only need a general theory ok for poles and zeros next time we will do an amplifier and you.