Circuit Theory

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Lecture 44

Problem Session 10 : LC Driving Point Synthesis

this is the forty fourth lecture and problem session ten we are going to work out problems on LC driving point synthesis [Noise] ah someone else who came late you can pickup from here problems on LC driving point synthesis and in the problems that i have circulated to you [Noise] we start with problem eleven point two

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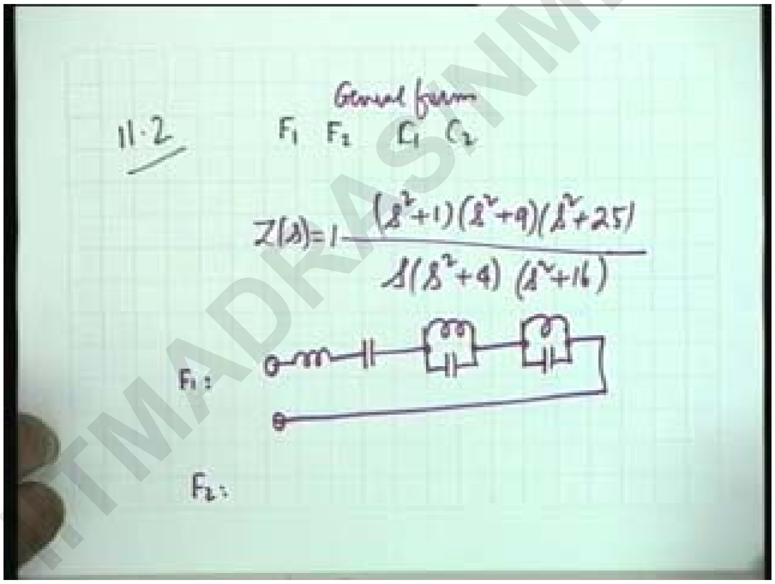

the first one you skip

eleven point two says indicate the general form of two foster and two cover networks F one F two C one C two [Noise] only general forms are needed

that could be used to synthesize the following LC impedance Z of s equals to s squared plus one s squared plus nine s squared plus twenty-five and the denominator s times s squared plus four s squared plus sixteen [Noise] there is no need to calculate the element values of the ((phone)) (00:01:28) networks just the general form we have to draw

and one proceeds like this foster one ask yourself whether there is as a pole at infinity yes there is so you shall have an inductance is there a pole at the origin yes there is there is pole at the origins so there is a capacitance [Noise]

and there are two pairs of internal poles corresponding to four elements and so two LC networks in parallel two LC parallel networks in series and that’s it this is the general form

as a verification you check whether the number of elements is equal to the number of the specs specs are one two three four five and the multiplying constant which happens to be one so six specs that exactly six elements [Noise] for F two you take the admittance function

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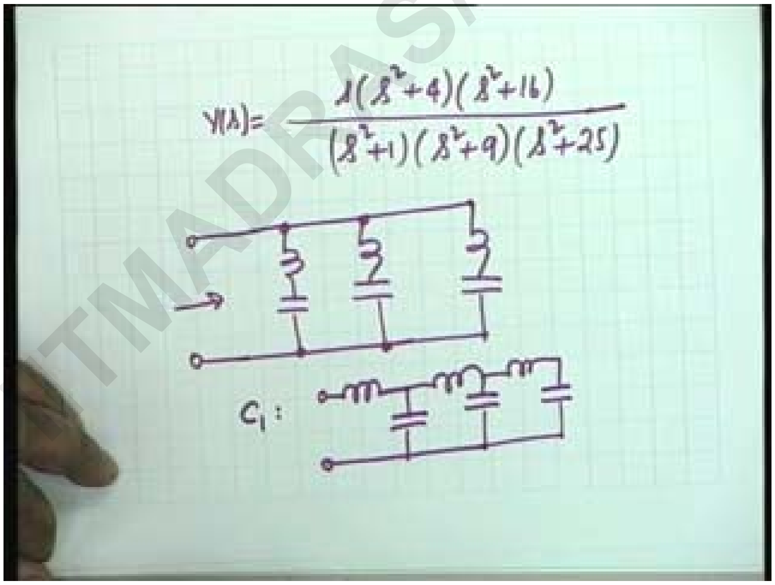

Y of s is equal to s times s square plus four s square plus sixteen s square plus one s square plus nine s square plus twenty-five

no pole at the origin no pole at infinity it cannot have because the impedance had impedance had this poles therefore admittance must have zeros and therefore all we have is three series resonance circuits in parallel that’s it exactly six elements [Noise] can you tell me what this products of LC would be this L and C

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this will be one and next one one ninth and one twenty fifth okay so this is the general form for F two now F uh (00:03:41) C one C one starts with can you start with the impedance shall we start with impedance or admittance C one that is the point to be decided

the function has to have a pole at infinity and therefore it is the Z of s and there are exactly six elements and therefore you start with an inductance pole at infinity then a capacitance and you go on doing this till you get six elements that's it you can do it blindly

as a check has a check does it satisfy the condition that there is a pole at the origin that is we are checking the last element is the last element a capacitor yes there is a pole at the origin therefore this is the correct network alright

in order to get C two [Noise]

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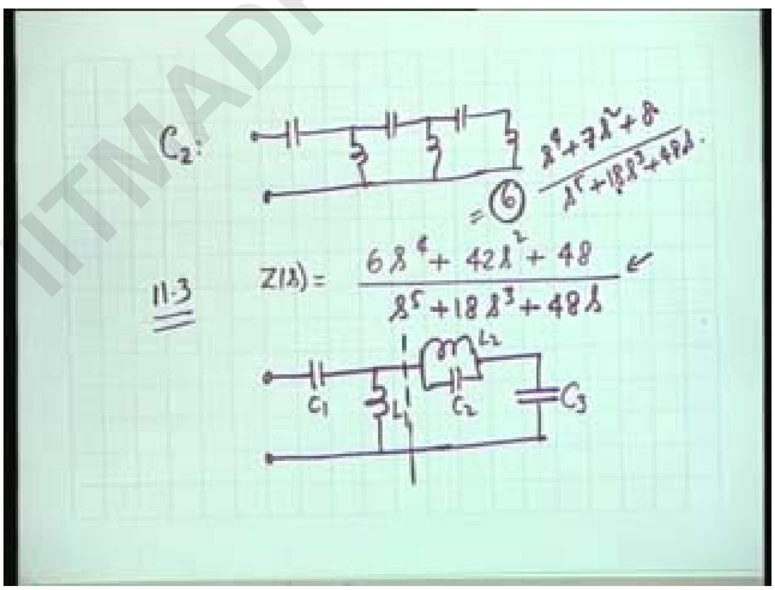

C two will start with the function that is a pole at the origin which means the impedance function

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yeah

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if we had six elements we didn't have a pole at infinity well then the position at

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pole at the origin but no pole at infinity okay then you start with a capacitance we cannot have six elements there it has to be odd number of elements [[Laughter] okay

there are various checks this is one of the checks there are other checks also okay as per as C two is concern you have to start with with impedance [Noise] we have to start continued fraction expansion with the lowest powers starting from impedance

therefore you have a you have a capacitor in series and then you go on doing the ladder till you get six elements and finally at infinity at infinity does it have a pole yes it does [Noise] okay so there is a check that's a eleven point two let's go to eleven point three

which is very interesting [Noise] and that why i didn't skip one i wanted to do eleven point three

eleven point three say synthesize the LC driving point impedance impedance is given Z of s equals to six s to the fourth plus forty-two s squared plus forty-eight divided by s to the five plus eighteen s cubed plus forty-eight s [Noise]

it says synthesize this LC driving point impedance in the form shown in the figure[Noise] the architecture is given architecture is you have a [Noise] a capacitor then an inductor then a parallel LC and finally a capacitor C one L one C two L two C three the architecture is given okay

now [Noise] you can see that it's neither foster one nor foster two nor cover one nor cover two it's a combination it's a combination ah you can mechanize this you can start with cover two go up to two stages and then the rest of the function goes to foster

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one alright you can do that [Noise] or you can do it by successive pole removal that is {dif} (00:07:33) no but before that before that is this a valid architecture is it a valid architecture well how many specification are there one two three four five six there are exactly six elements no [Noise]

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[Noise] five specs

this is not a spec

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yeah we can take six common constant then we have s to the four and {da} (00:08:12) ah the denominator s to the five so there a four other four other constants you have exactly five it is it is a valid architecture

no not so easily [Laughter] is there a pole at the origin yes there is pole at the origin so it is infinity is it a zero at infinity

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yes it is this is short this is short this is short and therefore (( )) (00:08:37)

so this is a valid architecture the number of elements {sati} (00:08:39) satisfy pole at infinity pole at the origin

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yes okay [Noise] by looking at the function what is not clear the number of elements

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okay number of elements you can write this as six times s to the four plus seven s squared plus eight divided by s to the five plus eighteen s cube plus forty-eight s so the number of specs is one two three four five and there are exactly five elements

alright then we check whether {the}(00:09:16) there is pole at the origin yes this structure has a pole at the origin we check whether there is zero at the zero at infinity yes it has a zero at infinity okay now [Noise] as some one said we can develop this by having cover two up to two stages then changing over two foster one [Noise] well we can do that this is a mechanization okay but the full no the the one the procedure that is full proof

you cannot make a mistake suppose suppose instead of foster one i am sorry suppose instead of cover ah two okay you use cover one where you cannot you use it but suppose you make a mistake in the continued fraction or finally it's inversion isn't it

the reminder impedance that you take it must be of this of the proper dimension and so on what i am saying is there may be a possibility of a confusion and mistake but the full proof method is if you go term by term that is first

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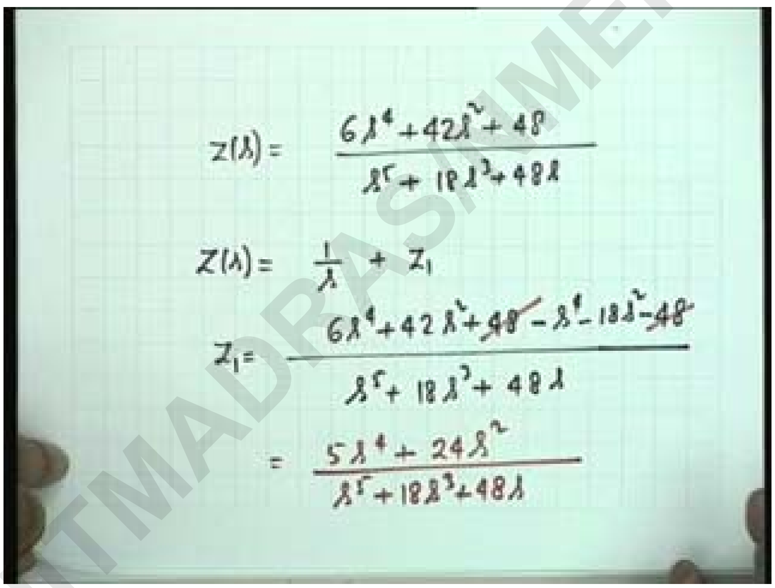

you look at this Z of s equal to six s to the forth plus forty-two and the effort involved is is nothing nothing ah much higher effort involved is almost the same and thinks ah come out almost by inspection okay

look at this s to the five plus eighteen s cubed plus forty-eight s what you are trying to do is we are writing Z of s as equal to it's pole at the origin which is obviously one by s agreed pole at the origin that is if you put s equal to zero forty-eight by forty-eight s so the residue is obvious plus some impedance Z one and you can see that Z one is s to the five plus eighteen s cubed plus forty-eight s [Noise] and the numerator you shall have six a s four plus forty-two s square plus forty-eight minus Z one is Z minus one over s

so you have take s out of here s to the four minus eighteen s squared minus forty-eight and you see that forty-eight and forty-eight cancel they have to there is no other way because you are removing the pole at the origin there must be a zero at the origin for the reminder function

so these two cancel and i get five s to the four plus twenty-four s squared divided by s to the five plus eighteen s cubed plus forty-eight s that is more in store more cancelation because the pole at the origin has been taken away so the factor s should cancel and if i do that then my [Noise] my function that remains

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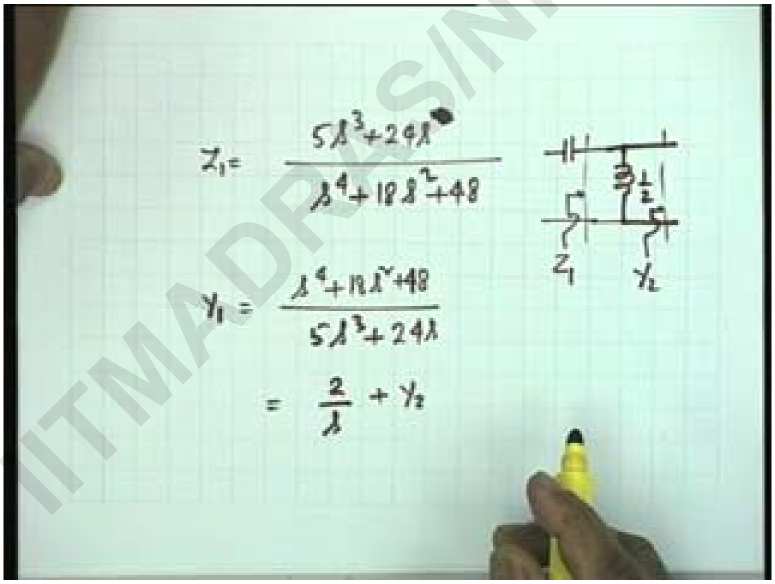

is five s cube plus twenty-four s square divided by s fourth plus eighteen

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twenty-four s correct s to the four plus eighteen s squared plus forty-eight okay [Noise] now

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no eighteen s squared [Noise] okay s squared because s is canceled

now what i have removed therefore is a one farad capacitor and the rest of the function is Z one what we have to remove now is an inductor i require an inductor an inductor in shunt represents a pole of the admittance at the origin and therefore what i should do is take Y one in fact Z one has zero at the origin

so you inverted i get Y one equal to s four plus eighteen s squared plus eighteen divided by five s cubed plus

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plus forty-eight okay don't allow me to make mistake twenty-four s and i am going to write this as k by s which is obviously two by s plus Y two which means that the next inductor is half Henry [Noise] and the rest of the admittance is Y two alright

now let see what is Y two

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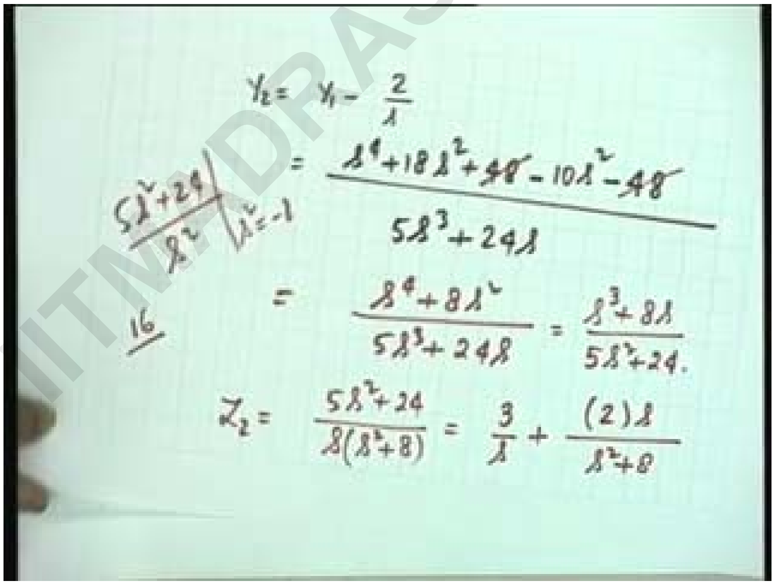

Y two is Y one minus two by s so this is equal to s five s cubed plus twenty-four s then s to the forth plus eighteen s squared plus forty-eight minus

you take out a s from here and multiply by two so you get ten s squared agreed minus [Noise] minus

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forty- eight once again you see that the constant terms cancels so it’s it’s quite ah it’s quite comfortable forty-eight cancels and then you get s to the fourth plus eight s squared divided by five s cubed plus twenty-four s from which s shall also canceled

so you get s cubed plus eight s divided by five s squared plus twenty-four okay and after Y two now you are perfectly safe to shift to [Noise] foster one because you [Noise] look at the function Z two foster ones means you take the impedance Z two which is equal to five s squared plus twenty-four divided by s times s squared plus eight there is indeed a pole at the origin which will take a count of the capacitor C three and that pole what is the ah residue three three by s plus

what you will have here is s squared plus eight then s and a constant what is this constant it is five s squared plus twenty-four divided by s squared with s squared equal to minus eight

so sixteen divided by eight that is two alright therefore [Noise] therefore my network is the follow

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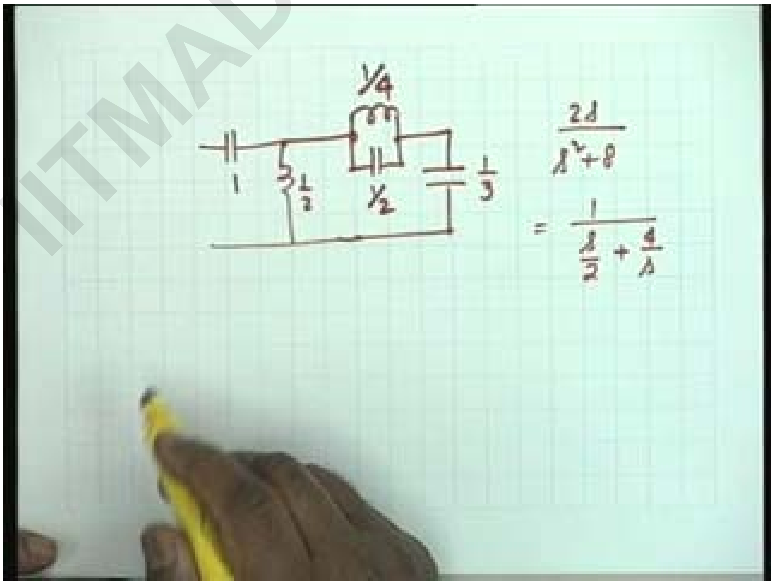

what was this C one one half then i shall have a parallel LC and the capacitor C three C three is obviously one third and what about this i always prefer to do it like this there is absolutely no scope of a mistake

s by two plus four by s and this is an admittance so the capacitor must be half and the inductor must be

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pardon me

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one by four the product should be one eighth is it okay the product should be one eighth LC products so one forth and half is one eighth and the problem is solved there is as i said there is no scope of mistake in this step by step procedure and as you can see the numbers involved there are a cancellations there are a cancellations of constants there are a cancellations of s which have to come naturally cancellations have to come naturally because if the function does not have a pole it must be zero alright

so this is a ah a [Noise] consequence of the properties of an LC network the next problem is eleven point five we skip one

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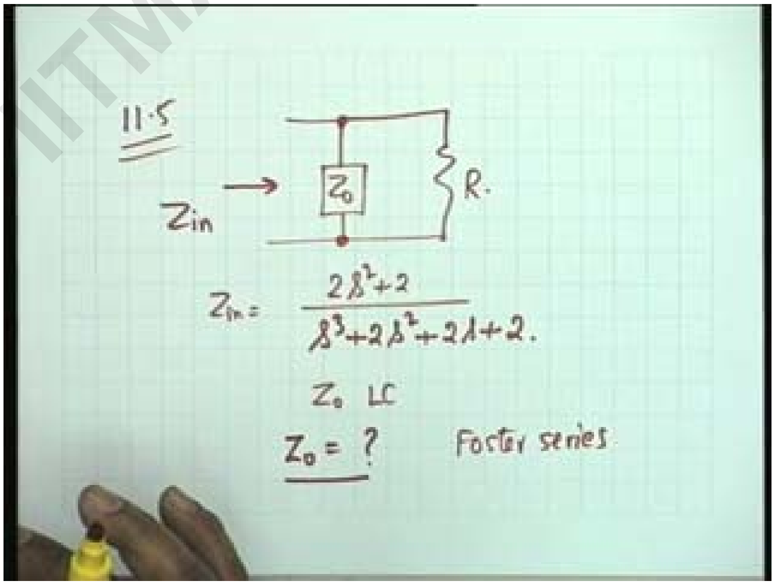

eleven point five is a ah slightly tricky problem it says the input impedance for the network shown the network is this you will see that almost common sense will solve this problem

this network input impedance of the network shown is Z in equal to two s squared plus two divided by s cubed plus two s squared plus two s plus two and it is also given that Z zero is an LC network Z zero is an LC network you are required to find out an expression for Z zero [Noise] and a synthesis for Z zero in foster series form that is foster one okay

this is the problem given the configuration and given the input impedance ((is this)) (00:18:59) input impedance is not purely LC because it contains a resistance Z zero is LC but i**ts** an LC network parallel by a resistance you are required to find out and expression for Z zero and a foster series realization okay capital R is ((not)) (00:19:20) known but it can be found out okay this is the this is the common sense that one has to apply

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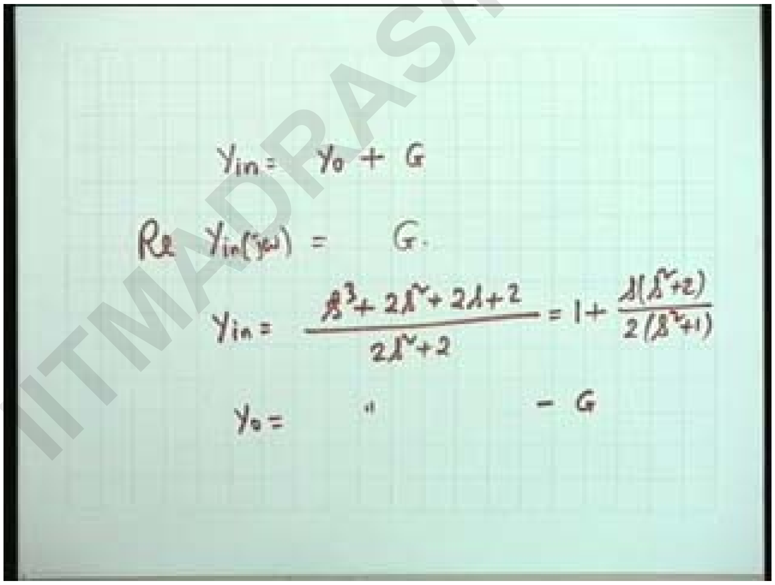

you see Y in the admittance equal to Y zero they admittance Z zero plus G okay is a some of Y zero and ((Z)) (00:19:42)

so Y in of j omega okay real part obviously is equal to G alright and you notice that the expression for Y in is s cubed plus two s squared plus two s plus two divided by two s squared plus two alright

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[Laughter] what is (( )) (00:20:21) how do you know

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you have to say for Y zero is this minus G and you have to find the value of G such that Y zero is LC it is obvious from here that if you subtract one from here then you get s into s squared plus two divided by two s squared plus one is this obvious and this is LC

okay

this is an LC admittance and therefore G must be equal to one or R is equal to one

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yes we can find out from here yes we can find out the real part but [Noise] a common sense helps because we do observe that this can be written as one plus this otherwise you would end up in finding m one m two minus n one n two

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denominator is real

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okay

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right sir right sir in any case common sense is the strongest instrument that an engineer has and you must not hesitate to apply it wherever you apply it it is rewarding okay anyway so you know G equal to one and we incidentally you also know what is Y zero

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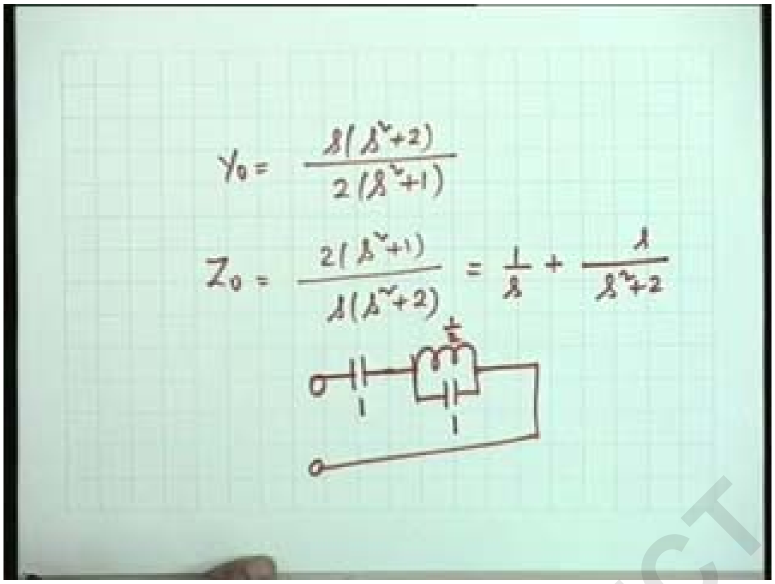

Y zero is s times s squared plus two divided by two s square plus one and at this point at this point many of you forget that a specific form has been wanted you can expand this in partial fraction and get a realization but that will not be the correct answer because it specifies that synthesis is zero in the foster series form

so do not realize this take a ((Z zero)) (00:22:23) take Z zero [Noise] two s square plus one divide by s into s squared plus two and you expand in partial fraction because we want a foster series form and obviously the residue at the origin there is a pole at the origin residue at the origin is one okay two into one s into two plus is there any pole at infinity no

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so s squared plus two s and what is the coefficient one okay so Z zero is oblivious it is a one farad capacitor and a parallel combination of one farad capacitor here and [Noise] and half half Henry the product has to be one by two [Noise] the problem is solved [Noise]

the next problem is eleven point six [Noise] eleven point six okay

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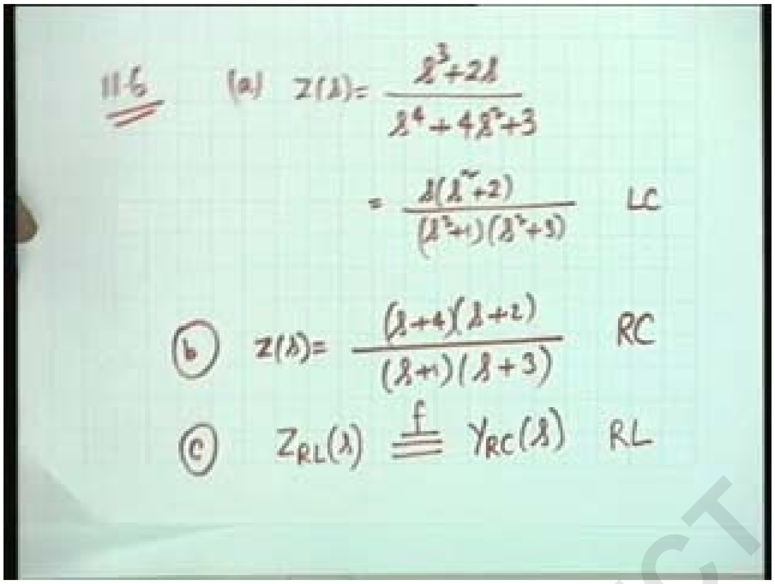

we will not do all of them let's look at a it says indicate which of the following functions are either RC RL or LC impedence functions since we have not done yet RL we can answer RC and LC let us see

the first function is Z of s it is an impedence equal to s cubed plus two s divided by s to the fourth plus four s squared plus three now [Noise] you have to decide whether it is RC LC or RL

if it is RL we don't know yet but let's look at it now obviously you see it's an it's an odd rational function isn't that right it's odd therefore it cannot be RC or RL it has to be if it is (( )) (00:24:37) it has to be LC

let us look at that s times s squared plus two if you can factorise do that s squared plus one s squared plus three so it can be realized as an LC because the poles at zeros alternate zero one two three okay [Noise]

part b b is Z of s now this is a polynomial divided by polynomial it's a bi-quadratic [Noise] if you can find the poles at zeros obviously the numerator s plus four s plus two and the denominator is s plus one s plus three

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no it is not odd therefore it cannot be LC it cannot be LC it’s either RC or RL first critical frequency is a pole the last critical frequency is a zero and the pole set zeros alternate one two three four so RC okay

part c is simply the reciprocal of this and you shall see later that that it is RL RL has exactly the the ah RL impedence is exactly the property of an RC admittance let me put it down here to be shown

Z RL s is we use this symbol triple line with an f form equivalence is the same as YRC of s and in the morning {wish} (00:26:20) we saw that YRC s has (( )) (00:26:23) the first critical frequency a

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zero and the last critical frequency of pole and therefore c qualifies as RL

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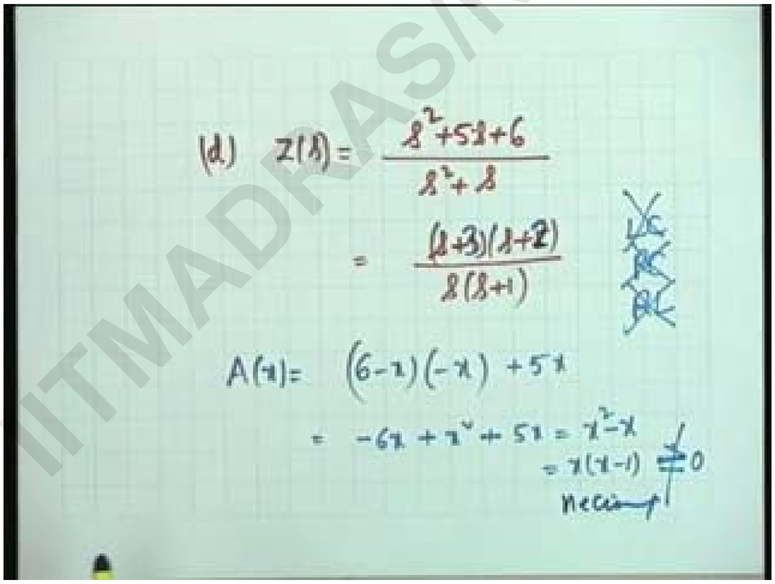

[Noise] d now this is a common sense question s squared plus five s plus six s squared plus s

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it is not an odd polynomial right it is not an odd polynomial but

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denominator is not Hurwitz why not

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s square plus s is not Hurwitz where are it's roots s times s plus one it is Hurwitz now as i then said the common sense you notice

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you notice that there is cancellation [Laughter] no further efforts are needed you see this is s plus one s plus five

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oh okay there is no cancellation s plus three and s plus two now

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zero zero one two three now poles and zeros do not alternate

so so what is the conclusion whether it is RC whether it is RC or RL whether it is RC or RL poles and zeros must alternate they do not alternate so it is not LC it is not RC it is not RL can you say that it is not realizable

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no you cannot say because it could be RLC how do you determine whether it is RLC or not whether it is realizable or not give me one test which will determine other things are obvious

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yeah positive realness but positive realness requires several testing it requires to check whether the function is real for [Noise] ((s real)) (00:28:35) whether it is j omega axis poles all all other things are obvious isn't it it's real for s real there are no poles on the j omega axis or there are

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there is [Laughter] a pole on the (( )) (00:28:50) at s equal to zero there is is the residue real and positive yes residue is six therefore it is real and positive that part is satisfied what else all the only real part

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that's right so you have to find out A of x which is m one m two minus n one n two

so it is six minus x then minus x alright m one m two minus n one n two that is plus five x is it okay alright

i have skipped those steps i have not written six minus s squared s squared equal to minus x no six plus s squared and s squared equal to minus x

so six minus x in the denominator s squared that the minus x then m one n one n two five s squared minus five s squared so (( )) (00:29:44) plus five x this is equal to minus six x plus x squared plus five x this is equal to x squared minus x equal to x into x minus one

this is not necessarily greater than zero necessarily and therefore the function is not pair it's not realized in that way okay

if a function is not RC is not RL is not LC it does not necessarily mean that it is not realizable you have to apply the pair function testing then e

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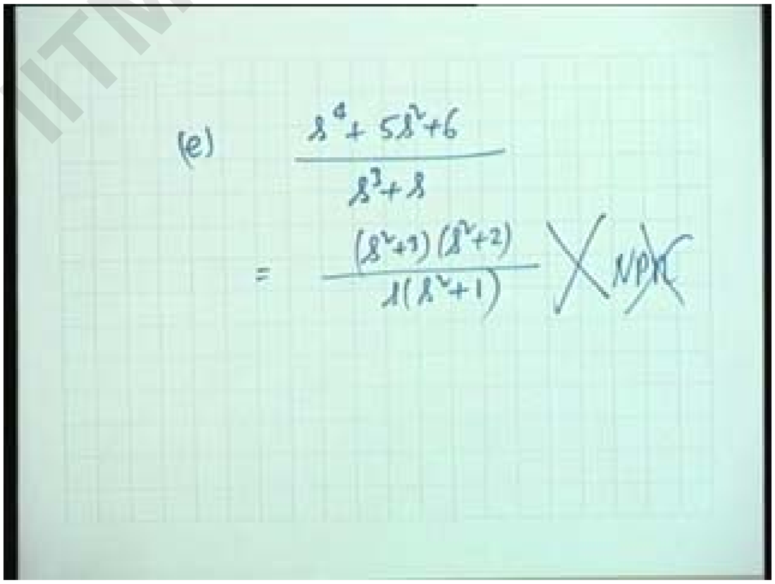

e as you can see is simply the reciprocal a simply the reciprocal of the function at d since d was not realizable e is not realizable either

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oh i am sorry alright then we we require a consideration i i am sorry i i ignored the

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it is LC let us write it down s squared plus three s squared plus two s times s squared plus one

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because poles and zeros do not alternate can we say that this can this can still be pair can be still be pair [Noise] can this still be pair

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if it is an odd rational function it can (( )) (00:31:22) it should be realizable with LC it is an odd rational function not realizable by LC therefore it is not pair it's a non pair is the argument clear logic clear [Noise] all odd rational functions which are pair can be realized by LC alright

if it cannot be realized by LC it cannot be pair [Noise] okay if i repeat it twice i will create sufficient confusion so we will not [Laughter]

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realize d

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d is not even by odd no d is denominator is s squared plus s [Laughter] okay the next problem is ah eleven ten

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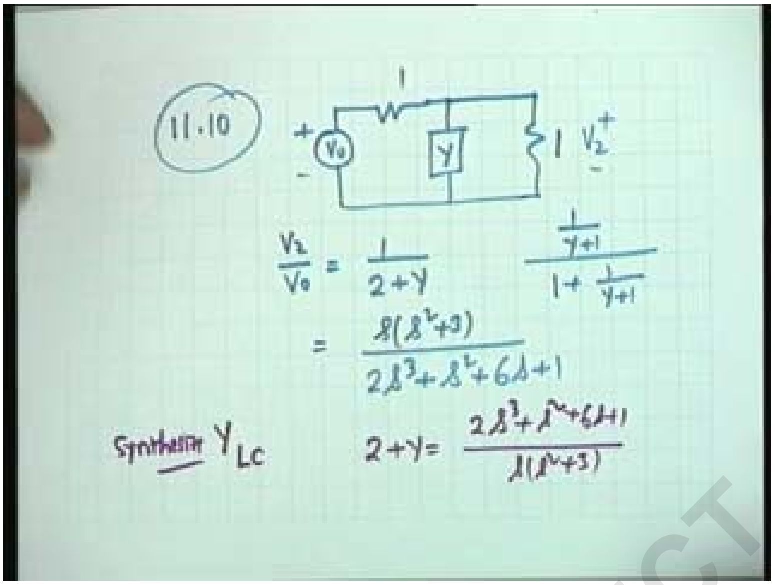

eleven ten [Noise] because others involve RL functions so we will not do that eleven ten for the network shown there is a network V zero one ohm impedance and admittance Y and a resistance one the output is V two it is given that V two by V zero is equal to one over two plus Y is this obvious that it is two plus Y

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they admittance series Y plus one to the impedance one by Y plus one you see one by Y plus one divided by one plus one by Y plus one which is exactly two plus one and this is given as s times s squared plus three divided by two s cubed plus s squared plus six s plus one you are required to synthesize Y as an LC admittance

so the first thing would be to find Y [Noise] two plus Y two plus Y equal to two s cubed plus s squared plus six s plus one s times s squared plus three find Y from here and synthesize it i will skip the algebra and

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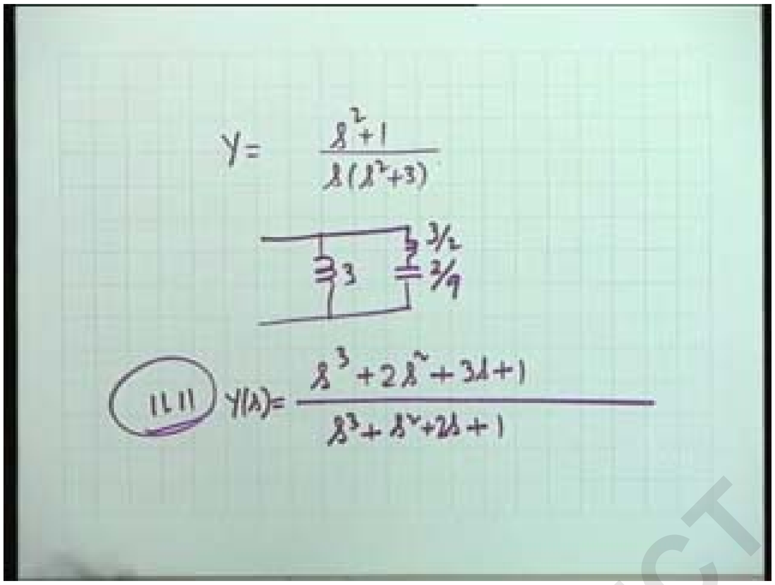

Y my solution is s squared plus one divided by s into s squared plus three and ah the solution in the Y form any solution is okay

so i take foster two i am sorry ah yes foster two and the solution is three then a series combination of i hope i am right two by nine

i have worked out some other problems but ah i want to take the time to solve a more interesting problem ((no now)) (00:34:55) let's look at eleven eleven first (( )) (00:35:02) okay

let's take let's solve eleven point eleven [Noise] eleven eleven says synthesize by continued fraction the function Y of s equals to s cubed plus two s squared plus three s plus one [Noise] divided by s cubed plus s squared plus s two s plus one [Noise] there is nothing much in this ah it just turns out that [Noise] if you carry out the continued fraction expansion continued fraction expansion the final result is this

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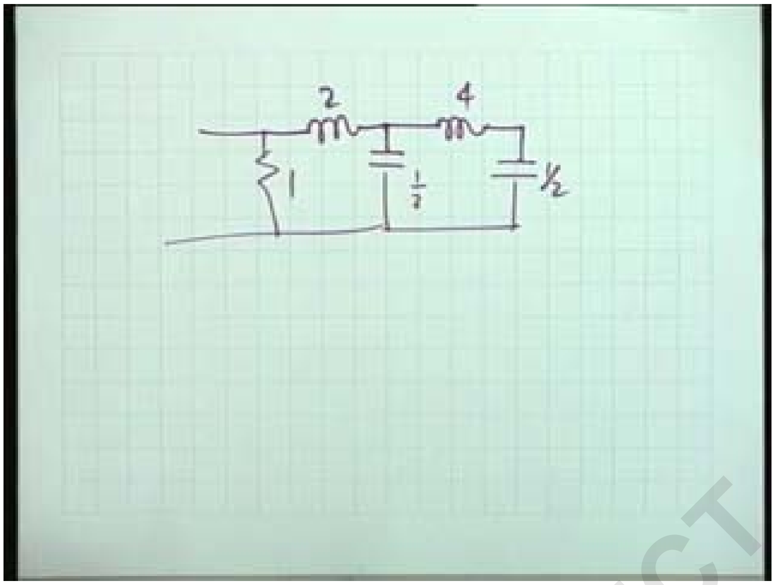

it is a likely a pair that is works here it may not work this is the final result [Noise] but as a said i want to take a more interesting problem and this problem is as (( )) (00:36:19) in the rest of the time that's why i looking at the watch [Noise]

we have been given a pole zero plot this is in fact the last question of this chapter chapter eleven last question but it's not here it's not here i forgot to do the third page there is there is another page and anyway let me ah pose the problem to you and then try to solve there is lot of common sense that is involved in this solution of this problem

i have been given a driving point impedance function which has

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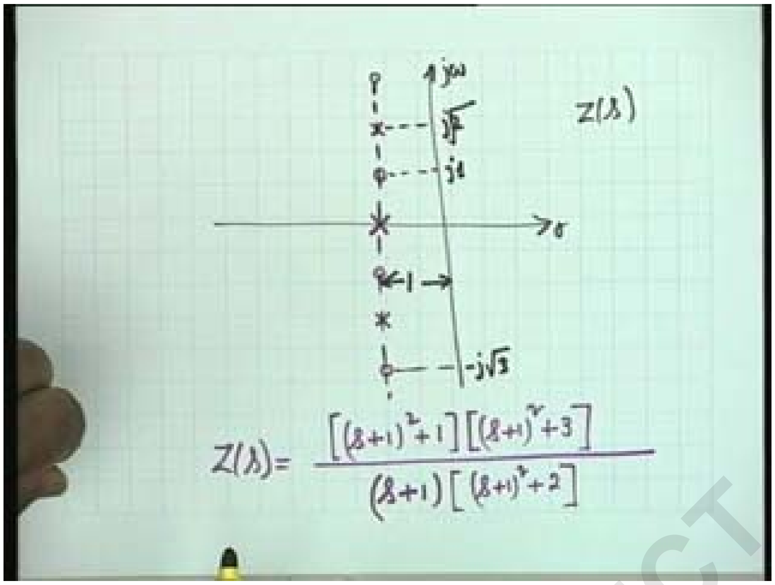

not been specified to be LC RC or RL but it's poles and zeros are given and the poles and zeros are located all often are located on a line parallel to the j omega axis parallel to the j omega axis at a distance of one from here alright and it is given that there is a pole here that there is pair of zeros here where this distance this point is j one naturally this point to do minus j one

i will not show that then there is pair of poles here where this distance is j two j root two not two j root two okay and finally there is pair of zeros here where this distance is minus j root three i am writing it below because there is no space here okay that's all that is known about the impedance

now you are required to synthesize this impedance obviously do you understand the problem ah the synthesize the problem formulation is not complete there is something missing can you tell me what is missing

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the constant

so so what we can do is to synthesize it two within a constant multiply [Noise] okay and we will assume that the multiplier is one to for this problem one is the simplest number is a very nice number ah so the first thing is that we can synthesize two within a multiply a constant multiply second a poles and zeros are neither on the j omega axis nor on the real axis they are there are complex poles and zeros okay

so let us see what we can do about it let's write the {transfer} (00:39:28) the impedance function two multiplier constant multiplier

so let's write the impedance function the pole there is only one pole at minus one which will contribute to the factor s plus one the two zeros at plus minus j one that shall contribute to s plus one whole squared s plus sigma zero whole squared plus omega squared that is equal to one agreed

there is a purpose why i am writing it in this form instead of s squared plus two s plus two i could have done that also then the poles the next pair is a pole s plus one whole squared plus two and the next factor (( )) (00:40:19) is a zero at s plus one whole squared plus three do all of you follow this impedance function

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how i wrote this by inspection by just looking at it that's why i chose this nice numbers root two and root three so that the square could be a whole number okay let me write it down

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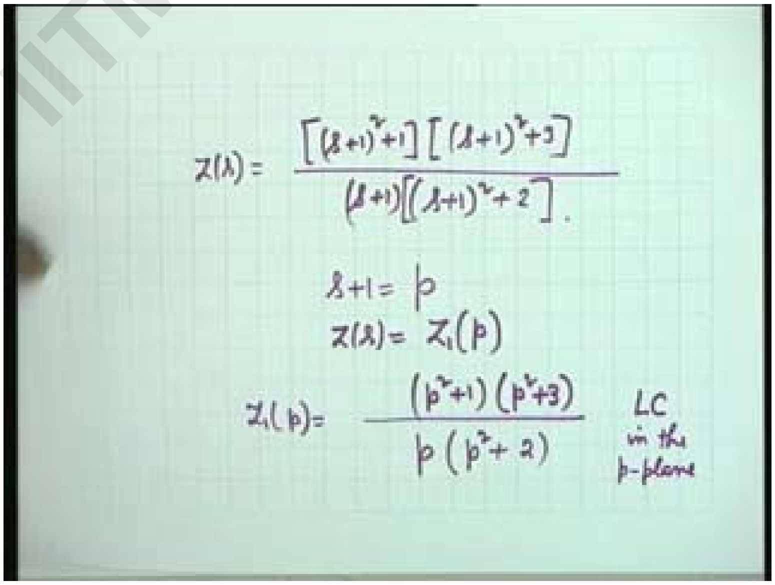

Z of s equal to s plus one whole squared plus one s plus one whole squared plus three s plus one s plus one whole squared plus two obviously the function if at all realizable if at all pair it would be realizable as an RLC neither LC nor RL nor RC whether the poles and zeros are in general complex

therefore RLC network now [Noise] we have not learnt RLC network synthesis in general but this problem is of a time which can be solved by a knowledge of LC networks because you see

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that if you put s plus one as a new variable p okay and you say Z of s equal to let’s a Z one of p then you notice that Z one of p is equal to p a new complex variable p times p squared plus two p squared plus one p squared plus three and this an LC network in the p plain in the p plain okay therefore i can synthesize Z one of p in the p plain finally i shall replace p by s plus one let us see

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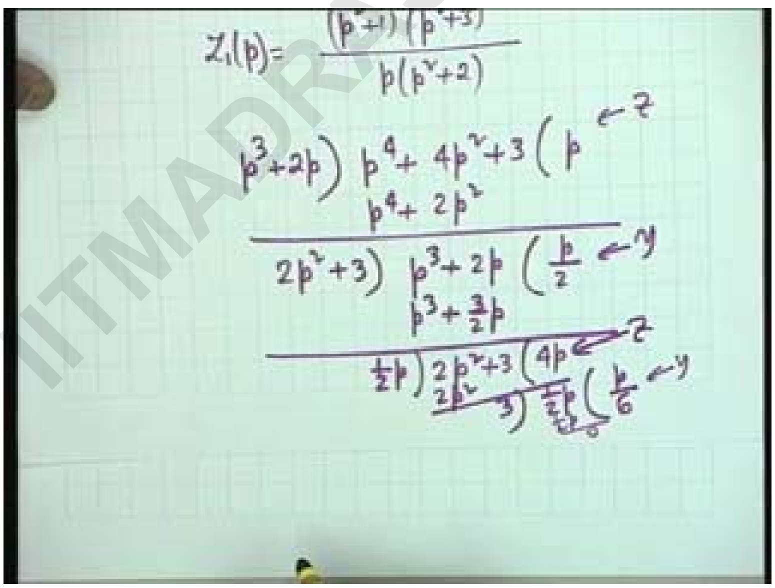

Z one of p have you understood the philosophy of this

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why did it occur because the poles and zeros were on an axis parallel to the j omega axis similarly had we be given poles and zeros on a line parallel to the real axis negative real axis okay

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we could have done an RC or RL okay

this is a very popular question okay Z p Z one of p p squared plus one p squared plus three p times p squared plus two what ah would you like chose for it's form foster one foster two cover one and cover two there is something

something interesting there also minimum amount of calculation i don't' want much of calculation

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f one even cover is not bad look at cover one p cubed plus two p p four plus four p squared plus three let's see this is an impedance so p four plus two p squared two p squared cover one continued fraction starting with the highest powers we could do that because the function has a pole at infinity otherwise no

so two p squared plus three p cubed plus two p p by two this is an admittance so we get p cubes plus three by two p three by two so half p remainder two times to is four minus three okay half p that divides two p squared plus three

so we get four p is that right two p squared and this is an impedance [Noise] then three divides half p so we get ah p by six p by six isn't it okay this is an admittance and half p the remainder is zero so my network therefore

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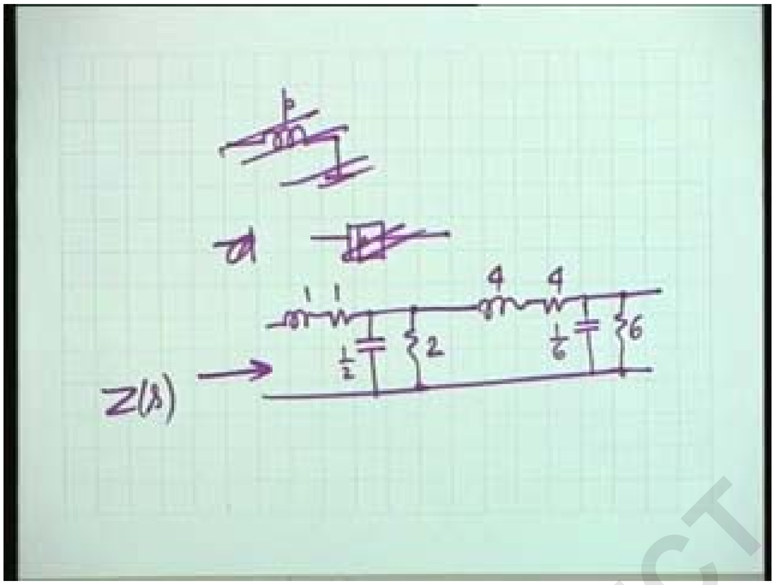

shall be and inductance of one Henry in the p plain okay in the p plain no we this is this will be confusing so we write the impedance impedance and the admittance for the for the ah capacitors this is no we don’t do that to confuse

you don’t confuse we simply write we simply write just a minute you simply write p shall [Noise] i do their

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there is also is a confusion

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i write directly in terms of s why go to all these you see i need an impedance (( )) (00:45:25) s plus one

so i get one and one s plus one then i need and admittance of p by two which is s plus one by two so i get ah

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parallel combination of a capacitor and a resistance tell me what is the value

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half and two not one [Laughter] okay the next one is four p so i get four Henry inductor and four ohm resistor four s plus one the next is p by six so i get a parallel combination of one by six and a resistance of six and the rest is an admittance zero which is impedance infinity and therefore the function is done okay and that’s all for today [Noise]