Electrical Measurement And Electronic Instruments
Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 41
AC bridges– III

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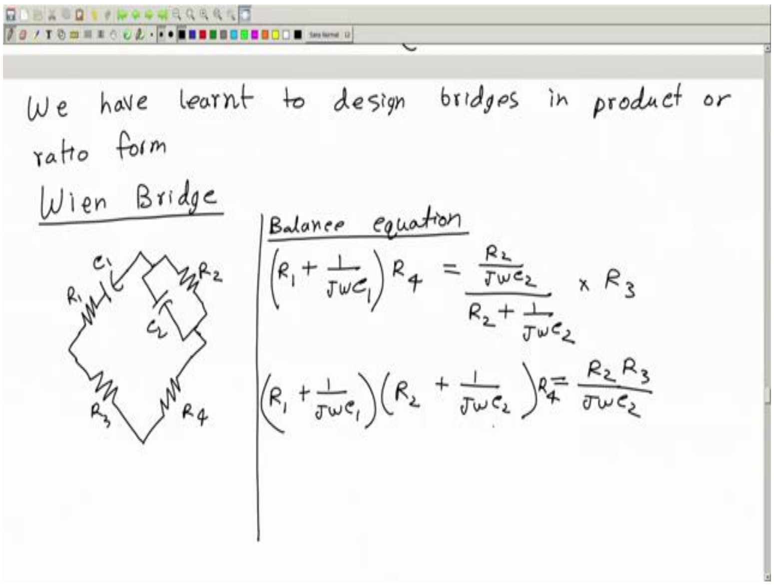

Welcome, we are studying AC bridges. And so far we have learnt to design bridges product or ratio bridges in product or ratio form ok. Now there are bridges also which are not in product or ratio form; neither in product form nor in ratio form. They have special reasons why they are in that form. So, we will see today, a bridge which is called Wien Bridge once again you need not remember or memorize, this names at all which bridge is which type this is only for your information.

So, this particular bridge is just a capacitor bridge, which has a two resistances and two capacitor branch ok. And had it been nice ratio bridge, we should have this element this branch as a parallel combination of capacitor and resistor ok then the balance equation becomes easy. But we will have the R and C in series this is a peculiar bridge this is not a nice ratio bridge, you may still call it a ratio bridge because the two adjust and arms are purely real ok.

So, R_1, C_1, C_2, R_2, R_3, R_4 this R_3 and R_4 are purely real. So, you may still like to call it a ratio bridge, but at least it is not a nice ratio bridge balance equation is not going to be very simple ok. This bridge this is a peculiar bridge which is called a Wien bridge.

So, let us see the balance equation, I urge you I request you that you try to derive it yourself by pausing the video and match the answer with me later ok. So, how do we pause it? We will pause it by the simple rule

$$(R1+ \frac{1}{J\omega C1}) R4 = \frac{\frac{R2}{J\omega C2})}{(R2+\frac{1}{J\omega C2})} R3$$

$$(R1+ \frac{1}{J\omega C1}) (R2 + \frac{1}{J\omega C2}) R4 = (\frac{R2\ R3}{J\omega C2})($$

$$(R1\ R2 - \frac{1}{\omega^2 C1\ C2} + \frac{R2}{J\omega C1} + \frac{R1}{J\omega C2}) R4 = (\frac{R2\ R3}{J\omega C2})$$

$$\frac{R2\ R4}{C1} + \frac{R1\ R4}{C2} = \frac{R2\ R3}{J\omega C2}$$

$$(R1\ R2 - \frac{1}{\omega^2 C1\ C2}) R4 = 0$$

$$\omega^2 = \frac{1}{R1\ R2\ C1\ C2}$$

$$\omega = \frac{1}{\sqrt{R1\ R2\ C1\ C2}}$$

So, you see this balance equation is not going to be easy, although we can derive it from the first principal that I mean product of this two should be product of this two ok.

But this is not going to be easy that is the problem with bridges which are not nice product or ratio bridges, but we can do it. And now if I make a small mistake the answer I mean the answer may come out wrong. So, please check the calculation also yourselves ok.

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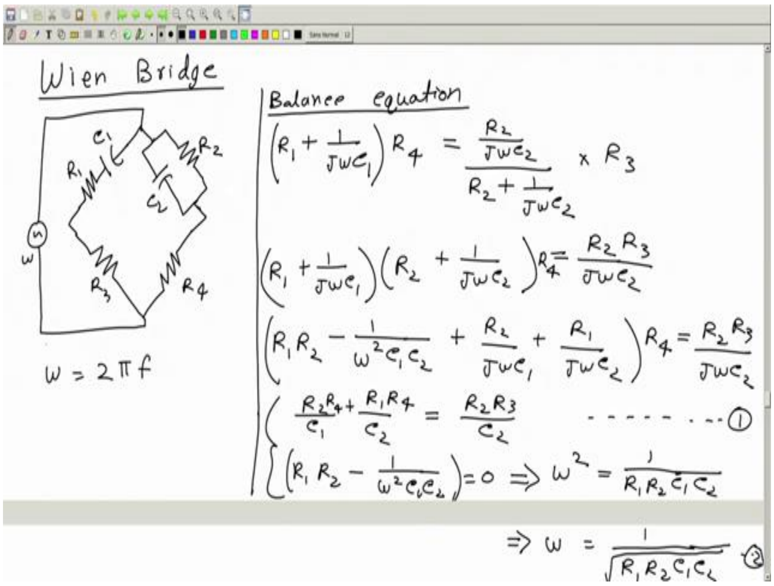

so these are the two balance conditions this is 1 this is 2 ok. So, please try to derive this yourself, if you just watch it do not practice then likely you are going to make mistakes in exams and in other places please practice please practice ok.

So, now, so these are the two balance equations which means, I mean if now we can adjust this impedances and get this balance bridge get this bridge balanced. And therefore, if one of this arm one of this sides is unknown say this these are unknowns then by adjusting this we can get the bridge balance and find the value of this unknowns using this equation that is possible. But the balance equation will depend on the frequency ok, if you see here the balance equation depends on the frequency.

So, we need to know, what is the frequency of the supply voltage? Then we can only measure the unknown impedance branch that is one was possible way of using this bridge. But this bridge is used for a completely different purpose; this is not used to measure an unknown capacitor or any unknown impedance this bridge is used to measure an unknown frequency.

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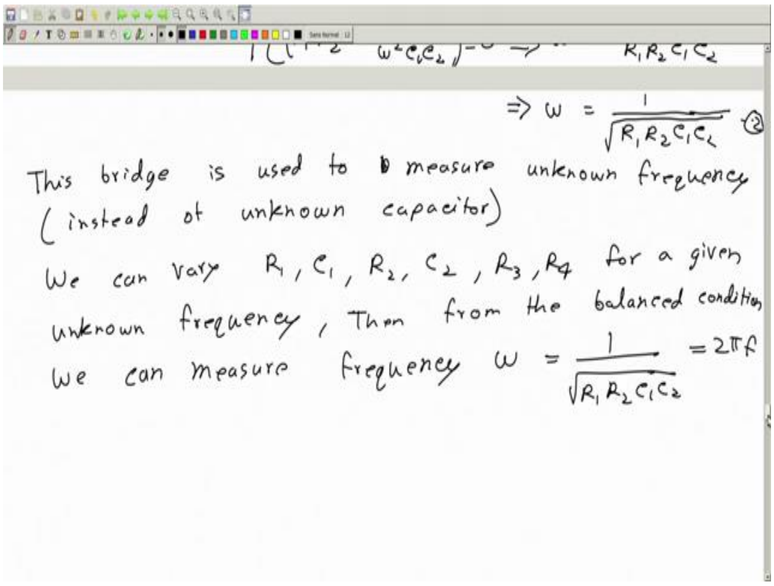

This bridge is used to measure unknown frequency, instead of unknown capacitor ok, because you see the balance equation depends on this frequency omega. So, therefore, you can also adjust the frequency of the supply voltage, if this is omega if this frequency is omega angular frequency is omega, which means $\omega = 2\,\pi f$, f is the frequency in Hertz this is in radian per second you can also vary omega so to get this bridge balance. Or if omega is an unknown frequency, then omega is constant then you can vary this parameters R C etcetera to get this bridge balanced and from that you can measure the value of omega.

So, we can vary this impedances R_1, R R_1, C_1 all these things R_1, C_1, R_2, C_2, R_3, R_4 for a given; that means, fixed unknown frequency. And once we get the balance from that using this equation you can measure the frequency omega. And then, from the balance condition we can measure frequency omega as this or if you want to measure,

$$\omega = \frac{1}{\sqrt{R1\ R2\ C1\ C2}} = 2\,\pi f$$

So, the lessons are there are bridges which are not simple product and ratio bridges. There are special purpose bridges like this Wien bridge which is used for frequency measurement. Another lesson is that, if the bridge is not a nice product or ratio bridge, the balance equation becomes difficult to find, but we can still find it using the first principal Z_1/Z_2 equal to Z_3/Z_4 so on like that ok. Now there are also other bridges which are not again simple product and ratio bridge.

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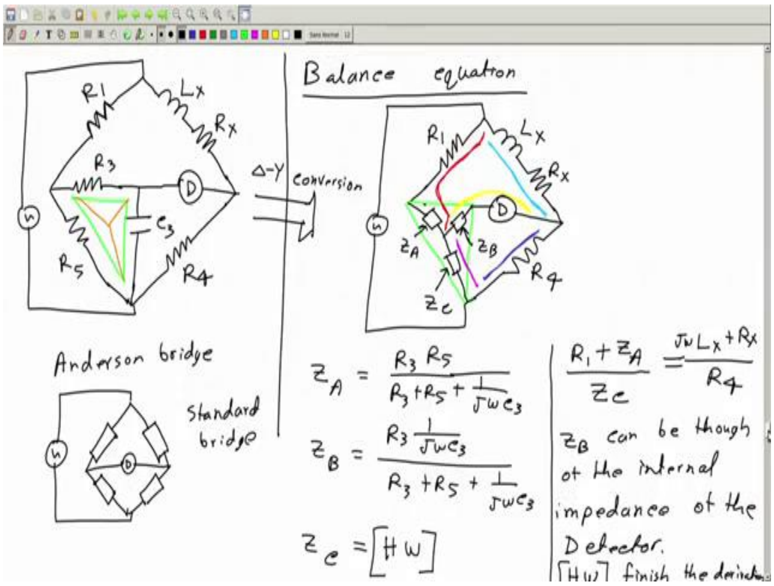

Let us see one such bridge, which is very peculiar so this looks like this is an unknown inductor x for unknown, this is R, R_1, this is R what do you want to call it 1 this we will call R_4 according to the notation that we are using so far 1, 2, 3, 4, but this part is peculiar now ok. Let me just name them arbitrarily R_3, C_3 R_5, the detector the null detector is placed here, and the supply is applied here this is the voltage source this is a peculiar bridge this is called Anderson bridge ok.

You are not at all expected to remember this bridge, we are not expecting that or we are not going to ask you that draw Anderson bridge how does it look like? No no no not at all do not memorize it, what we may ask you that given this bridge can you find the balance equation using the knowledge of circuit theory. Ok, so you are expected to find the balance equation of any complicated bridge you are not expected to remember this structure of this peculiar bridges not at all ok.

So, balance equation, how can we find the balance equation? This does not look like a 4 arm bridge 4 side bridge which we are familiar with ok, all the bridges that we have studied are all 4 arm bridges where the detector is placed like this and the supply is here this is the standard bridge, but this doesnt look like that ok. So, how do you find the balance equation? Using the knowledge of circuit theory we can convert this bridge into this form.

How? There are many ways, one possible way is this. So, look at these 3 arms R_3 C_3 R_5. So, they form a delta you can convert this into a star, if you do this conversion this delta two star conversion then this bridge will look like. So, using delta two star conversion if we do this then earth one will be as it is this will remain as it is, R 4 will remain as it is, this part will change its shape. So, currently it is like this, but now this will become some impedance here, some impedance here and some impedance here. So, this is the star ok, supply is here and you can find the value of this impedances call this as Z_A, Z_B, Z_C and the detector is here ok.

$$Z_A = \frac{R3\ R5}{R3 + R5 + \frac{1}{J\ \omega\ C3}}$$

$$Z_B = \frac{R3\ \frac{1}{J\ \omega\ C3}}{R3 + R5 + \frac{1}{J\ \omega\ C3}}$$

Now once you find this Z_A, Z_B, Z_C, then this bridge looks like 4 arm bridge which are this 4 arms this is one arm ok, from here to here. Then say this is another arm, then say this is the third arm of course, and then running out of colour this is the forth arm. The detector is between this, this Z_B you can think as a integral part of this detector or internal resistance of detector. So, Z_B this two you think together with the detector.

$$\frac{R1 + ZA}{ZC} = \frac{J\ \omega\ Lx + Rx}{R4}$$

So, now, Z_B has no role, Z_A is here Z_C is here you can find this values and put it in this equation. And from that you equate the real to real imaginary to imaginary you will get two equations ok.

So finish the derivation, this is your homework finish the derivation ok. So, it cannot do it in many ways.

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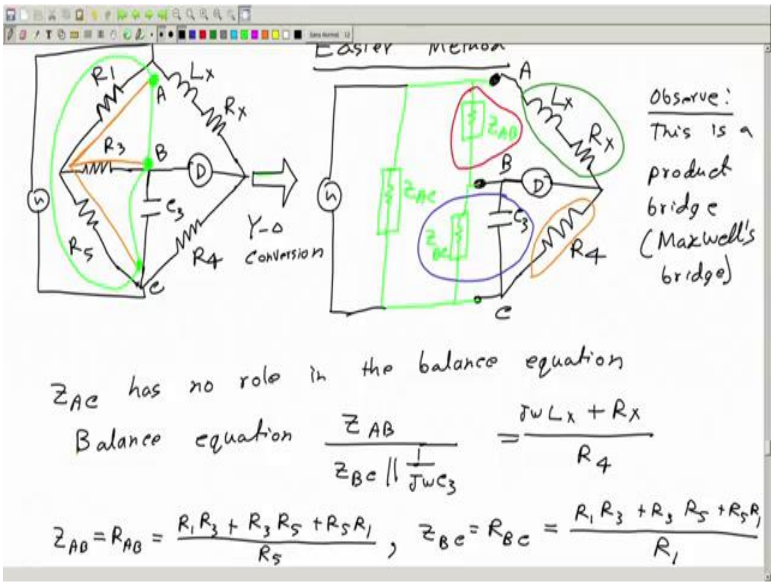

Now I will show you another way of finding this derivation, is balance equation which will be easier I feel. What we will do ok, so we are going to see a easy easier method, where instead of converting this delta into a star observe that this 3 arms they formed a star ok.

So, this 3 arms 1, 2 and 3 they form a star, I will convert this star into a delta like this; one arm, second arm and this will be the third arm ok. So, we will apply a star to delta conversion ok. So, this star is not easily recognized this delta I mean often we recognize this delta very quickly, but this star is not easy to recognized, but once you recognize, the derivation becomes easier how? Now ok, so let us draw the equivalent circuit in the equivalent circuit this branch will remain as it is, this will remain as it is, then the detector and even this even this capacitor will remain as it is.

So, this capacitor is not going to change, so C_3 as it is ok. But this three R_1, R_3 and R_5 they will change call let me call this terminals as A, B and C, point A, point B and point C, this is point A, this is point B this is point C. Now we will have a branch between A and B this branch, so this will be call it Z_{AB}, we will have a branch between b and C call it Z_{BC} and between A and C call it Z_{AC}.

Now the supply is here between A and C, so the supply is here ok. Now can we find the values of Z_A, Z_B, Z_C? Yes, that is simply delta to star conversion. And once we find this Z_{AB}, Z_{BC}, Z_{CA}, then you observe now that, Z_{AC} has no role this is simply in parallel with this voltage source. So, it is drawing some unnecessary current I mean not I mean some extra current which is not going through the bridge. So, Z_{AC} can be thought of as a integral part of this source system supply system.

So, Z_{AC} has no role in the balance equation ok, and this part is now a 4 arm bridge what are the four arms? The four arms are this is one arm Z_{AB}, this two together ok, so this is one arm this is one arm then this two together is another arm then, this is; obviously, the third arm and this is the fourth arm fourth side; one side, second side, third side and fourth side and between this two opposite terminals we have the detector and between this two opposite terminals we have the supply.

$$\frac{ZAB}{ZBC \,||\frac{1}{J\,\omega\, C3}} = \frac{J\omega\, Lx+Rx}{R4}$$

Now observe what are what are the this values of Z_{AB}, Z_{BC}, Z_{CA} these are all going to be resistances why? Because this three original star this three original star connected elements they were resistances. So, their equivalent delta will also be resistance of course,.

So, you can call this R_{AC}, R_{BC} and R_{AB} instead of Z we no they are going to be resistances and what is the value? The value is,

$$Z_{AB} = R_{AB} = \frac{R1\ R3+R3\ R5+R5\ R1}{R5}$$

$$Z_{BC} = R_{BC} = \frac{R1\ R3+R3\ R5+R5\ R1}{R1}$$

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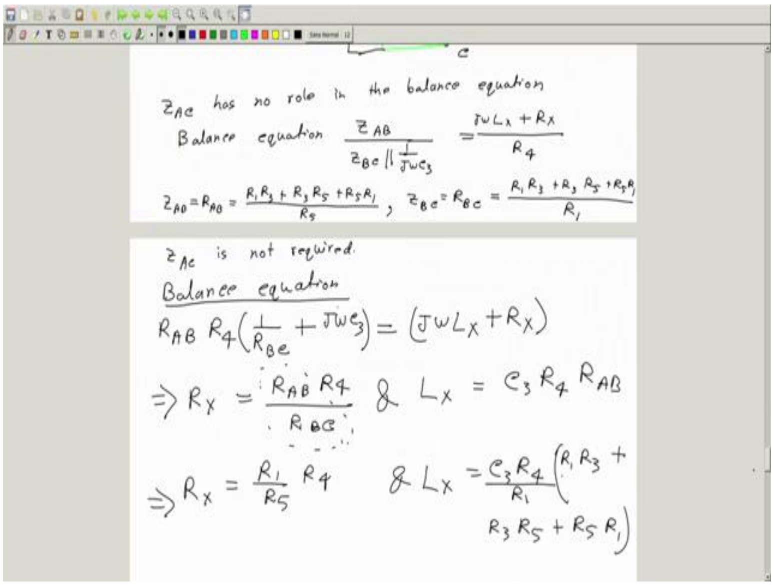

And Z C AC you can also find this way, but this is not useful because it is not going to be in the balance equation at all ok, Z $_{AC}$ is not required so ok. Now we can put this values in this sorry in this equation. So, you can put this values of Z $_{BC}$ from here and Z $_{AB}$ from here in this equation to get the balance equation.

But instead of doing it blindly let us do it cleverly, because observe that this is now actually a product bridge observe this is a product bridge, this two opposite arms this red and the orange one they are purely resistances ok; and this is inductance in series this is capacitance in capacitor in parallel. So, this is a simple product bridge actually this is Maxwell's bridge which we have seen before.

so let me go back and show you this bridge let me go back, so this was our Maxwell's bridge this is the Maxwell's bridge right or this one same this is the Maxwell's bridge. In R series C are parallel R_R same thing here L_R R_C R_R. So, we can actually do it much quickly by recognizing this fact. So, we can now write the balance equation,

$$R_{AB}\, R_4 \left(\frac{1}{RBC} + J\omega C3\right) = (J\ \omega Lx + Rx)$$

$$Rx = \frac{RAB\ R4}{RBC} \qquad Lx = C_3\, R_4\, R_{AB}$$

$$Rx = \frac{R1}{R5}\ R4 \qquad Lx = \frac{C3\ R4}{R1}\ (R1\ R3 + R3\ R5 + R5\ R1)$$

we have to do it cleverly we have to apply the knowledge of circuit theory cleverly, so that the calculation becomes easy that is what we learned in electrical engineering how to solve reduce circuits cleverly into simple ones ok. You are not suppose to remember the names or the structure of this complicated bridges. You are expected to be able to find the balance equation of any bridge; however, complicated it may look like this is one thing.

Second thing, you are expected to able to design simple bridges product bridges and ratio bridges to achieve particular purpose, like to measure an unknown inductor or an unknown capacitor. Under some constrains like, you cannot use a standard inductor, you have to maintain the safety of the operator these are the things you are suppose to learn. Last small thing I will add in this a class you may ask why do you use such complicated bridges, while when we can measure unknown inductance capacitance using simple product and ratio bridges.

Why do we have Anderson Bridge? If you recall we say bridges are designed using or keeping two factors in mind; one how simple the bridge is, how simple the the balance equation is and factor two ok.

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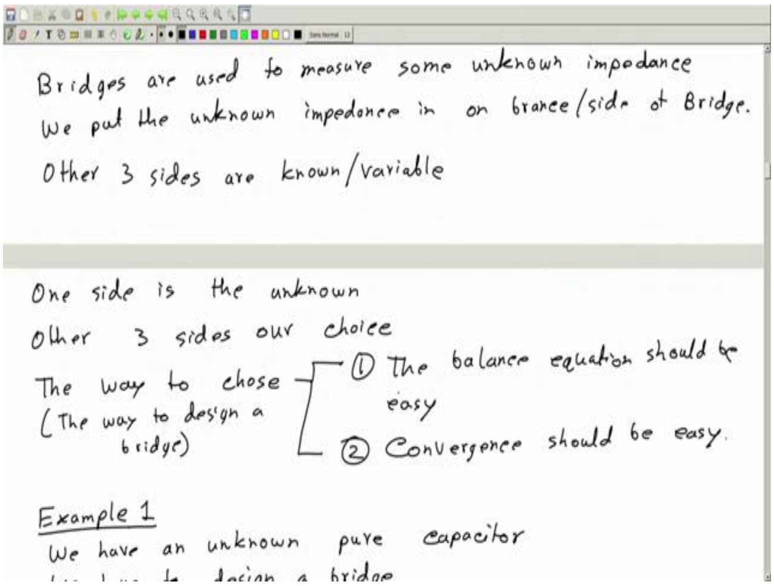

So, let me let me show you let me go back I wrote this once to the way to choose or design a bridge, depends on this two factors how simple the bridge is and the factor two how easily the bridge will converge.

We have discussed in detailed about the ease or simplicity of the bridge, but we have not take about the convergence of a bridge. Let me briefly tell you what I mean by this? What I mean is that, in a in an AC bridge we measure an unknown impedance and an unknown impedance has normally two unknown two variables ok.

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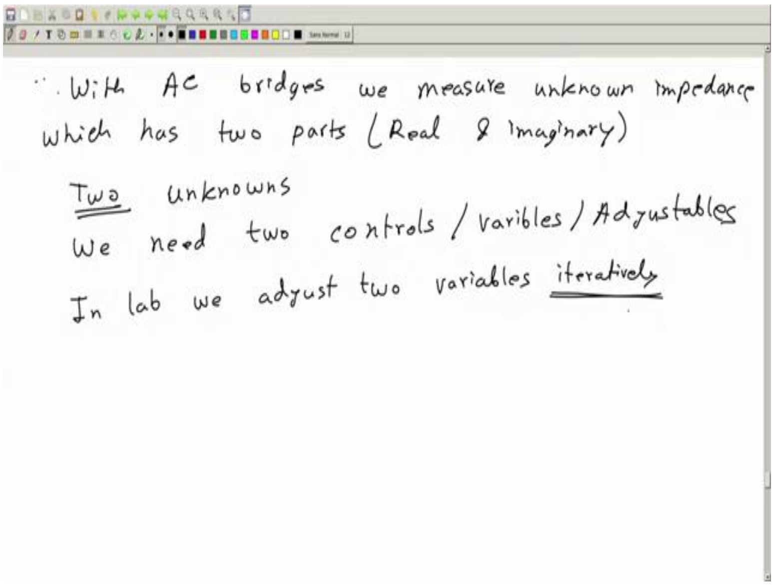

So, in AC with AC bridges with AC bridges, we measure unknown impedance which has two parts like, the real part and imaginary part. Or you can think the like the resistance and inductance capacitance and resistance so it has two parts; so two unknowns, actually two unknowns. So, therefore, we need at least two controls or two variables or adjustables to get the balance ok, at least two.

For example, let us talk about Maxwell's bridge. Here we have two unknowns L and R and we at least need this two to be variable R 3 and C 3 at least two we can keep this two fixed its possible in theory by keeping this fixed and varying only this to get the balance. Although sometimes it may be convenient to adjust this also, but at least this two at least two variables are to be adjusted ok, minimum two variables are to be adjusted and how do we do it? We do it iteratively in lab, so in the lab we do it, so in lab we adjust two variables iteratively.

Like first adjust resistance get the minimum deflection as close to null condition as possible ok, increase or decrease a resistance. And then when you go to the minimum deflection point, then keep that resistance fixed then change say another think like a capacitor ok. Then you go as close to possible to the null condition and then keep the capacitor fixed at that point and then adjust the resistance again reduce the deflection as much as possible and then again change the capacitor.

So, change the resistance up or down reduce the deflection to the minimum value then keep it fix then change the capacitor to some value; make the deflection as small as possible keep it fix then change the resistance again go to some value change the capacitor again since again go to some value this way we have to find the balance equation. It is difficult, it is boring and iterative in lab it is really very boring you have to change two things at least iteratively in case of DC bridges.

We have to choose only we have to adjust only one resistance DC bridge Wheatstone bridge, we can keep two resistances fixed and vary only one to get the balance that is easy. But here we have to choose we have to vary at least two elements iteratively one than other one than other and this could be very boring and time consuming and with the proper deign of the bridge like what to put in which arm resistance capacitance inductance with the proper choice.

It is possible to have a bridge which is easily balanceable which will go to the balance condition very easily by few only few trials two three trials we say the bridge will converge to the balance condition very easily. So, in early days I think 1930s or 40s when people thought about this bridges one of the considerations they had in mind is which bridge is easy to balance; where we can find the null condition very quickly ok. So, people thought about that also.

So under different situations people have therefore, deigned complicated bridges which are not simple product or ratio bridges ok, they are complicated bridges like Anderson bridges where people have thought about this convergence also how quickly we can go to the null? That is why we have this complicated bridges also, that is actually very interesting topic, but we can I mean we cannot cover everything in this course.

If possible in some additional video, we will talk about that something about that not very detail if possible ok. So, this is all about AC bridges which you are suppose to know for this course, if time permits and if you are interested we can have additional videos covering additional topics not for the exam, but for our knowledge if you want we will definitely do it.

Thank you.