Circuits for Analog System Design

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Lecture No. # 30

Ratio Transformer Technique to Measure Resistance and Capacitance

In the previous class, we are discussing about high resistance measurements, because we had started at how to make resistance measurement. In that connection, we discussed about how to make high resistance measurement, like 100 ohm, 100 megohm, 10 megohm resistances are there, then, how to make measurements, that is what we are discussing.

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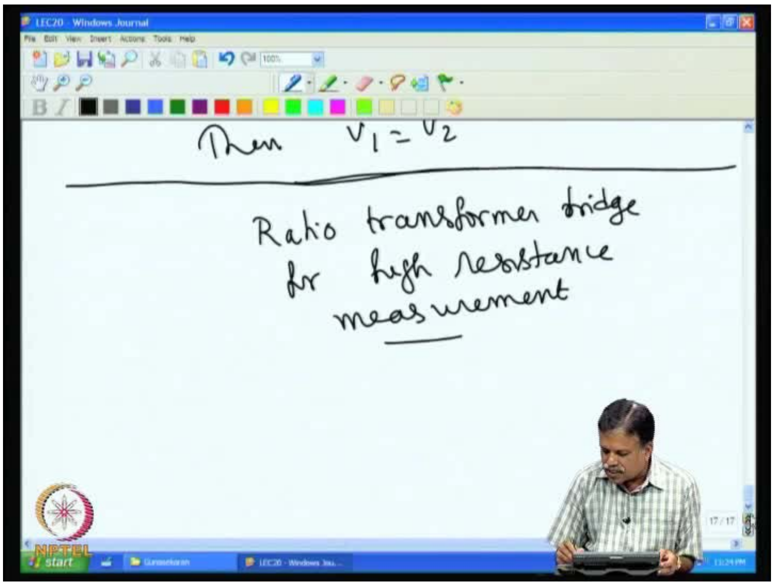

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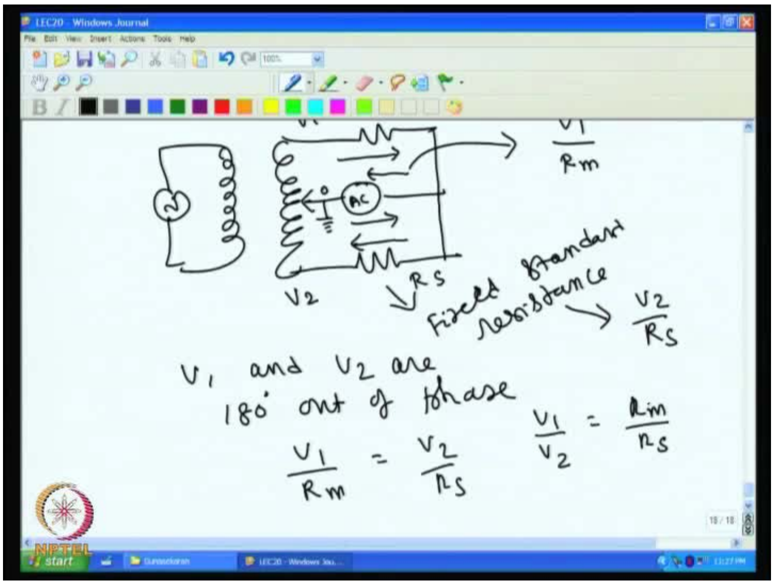

Now, in that connection, we are using Ratio Transformer Bridge. So, using ratio transformer, how to make high resistance measurement. So, basically, we are use ratio transformer, that is primary will energies with the AC source; then, you have center tapped transformer with both sides we connect the resistance, and then, we connect a, say basically AC volt meter, and then, connect this, and then, this center tap that variable tap is connected to ground. So, this is high resistance under test. This also high resistance, but it is a fixed standard resistance.

So, essentially, the basic working is like this, if this is taken as 0, then if this taken as V 1 and it is taken as V 2, then this current that is coming here, actually goes through this and then, this V 1 and V 2 are 180 degree out of phase. So, V 1 and V 2 are 180 degree out of phase.

So, that makes this current and this current are opposite; so, this current is flowing like this. So, if you take this current is flowing like this, then this current is flowing like this. So, essentially this current comes like this, and then, this current comes like this. So, we have two opposite currents, such a line in this; one is given by this. So, this current is given by V 1 by R measurement, say R m and this is R s; so, V 1 by R s R m is the current flowing here, in this form, and then, V 2 by R s is the current flowing in the opposite direction. So, at balance both are equal. So, this current, actually fixed resistance current, is actually V 2 by R s.

So, at balance these two currents are equal, that is, this current is equal to this current; so, I can equate these two. So, essentially it becomes V 1 by R m actually equal to V 2 by R s. So, one can, if I have provision to vary the center tap, the midpoint winding, then this voltage and this voltage will be varying and V 1 by V 2 will give you R m by R s actually; so, that will make V 1 by V 2 would be equal to R m by R s actually.

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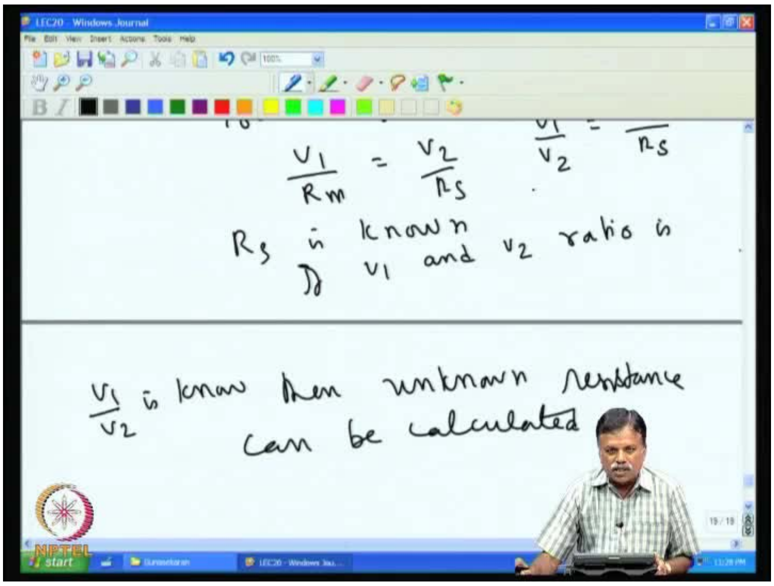

So, essentially one knows V 1 and V 2, we can find out the R m the unknown value because R s is known. Since R s is known, R s is known, if V 1 and V 2 ratio is known, ratio is known, ratio is known, that is a V 1 by V 2 is known, then unknown resistance can be calculated.

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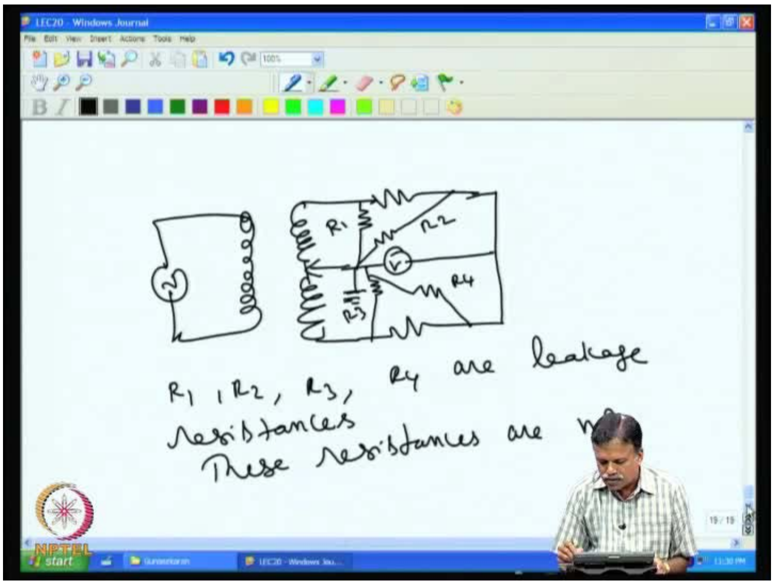

Now, that is how it is working, but then the question is why it is very popular, and why it is specially good for measuring high resistance values. Now, the beauty of the bridge is that leakage resistances, because when you are dealing with high resistance, there will be a leakage. For example, if I take the circuit again carefully, look at it, we have the resistance connect it here, voltage source connect it here, and then, you have the two, you have the center tap, and then, we have the two resistance here connected, and then, this point is grounded and the volt meter is connect at here.

Now, it is possible that you will have leakage of this resistance, from this point to this point to ground. Similarly, there will be a leakage from this point to ground to this point; similarly, there will be a leakage from here to this point and then leakage from here to here.

Now, these are the four leakage resistance that is possible; that is I will call R 1, R 2, R 3, R 4. So, basically R 1, R 2, R 3, R 4 are leakage resistances. A normal case, normal case R 1, R 2, R 3, R 4, all will affect the measurement. In this bridge, these leakage resistances will not play any role in balance in a bridge and net result is that is leakage resistance is no effect on the resistance measurement. That is why this bridge is popular and one can measure 100 megohm or even 1000 megohm using this bridge, because these resistors - R 1, R 2, R 3, R 4 - are not contributing for the balance. So, these resistances are not contributing for the balance. So, these resistances are not contributing for the balance.

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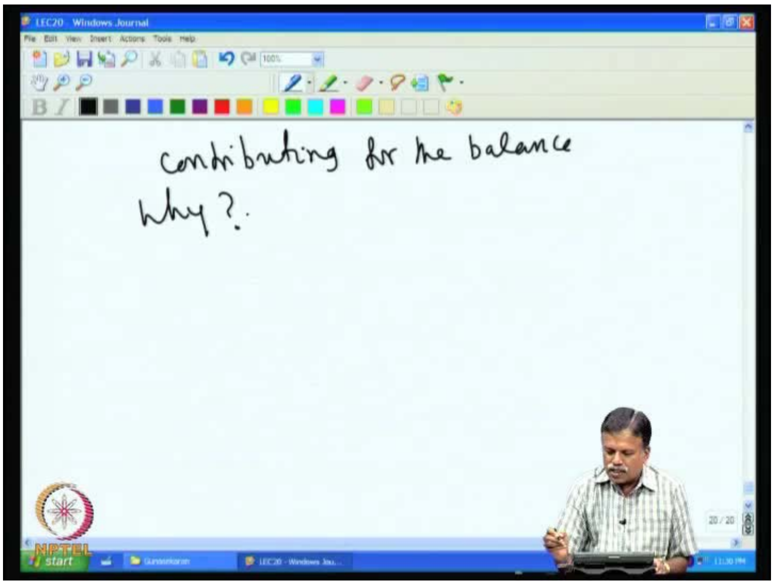

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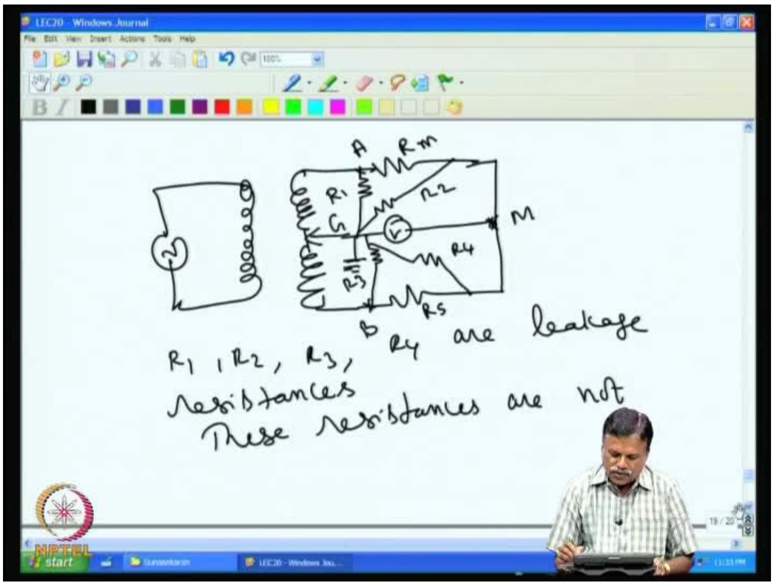

Now, the question is - why they are not contributing for the balance. Now, if you look at the circuit carefully that the at balance, this point, say this point, as say take is ground point is G and this midpoint as M. Now, at balance, voltage across G M is 0, because you know, we are adjusting the center point and balancing the bridge to find the value of unknown resistance. This is unknown resistances R m and then this is the center resistance R s. So, we are balancing the center tap and finding out the R m and R s.

Now, at balance, essentially, M is at 0 potential that is M as 0 because there is no voltage across this. That makes across R 2 also, across R 2 also 0 volt; across R 4 also you get a 0 volt, that means no current is flowing through R 4 and R 2 that means these resistances are not contributing for bridge balance that is bridge balance is not affected by these resisters, resistance values.

So, the, that means, the balancing point is not affected by this resistance. Now, if we look at R 1 and R 3, now, the, this is a transformer and the impedance of these transformer is very low, the, if we take as voltage source, the output implement of the voltage source is this transformer is very low. So, if we take this leakage is R 1 and R 3, the merely loading the transformers. This currents are not actually flowing through this; so, this, the merely loading the transformer secondary's.

Since the impedance of this the voltage source impedance equal to voltage source impedance of the transformer is very low and the current actually flowing through this is creating no effect on the voltage at this point, because the impedance is very low. So, whatever the current that is flowing it is deliver by the winding and that is no effect at the voltage at this point and this point.

So, essentially, voltage at this point say A and B are unaffected by the resistance R 1 and R 3 that means, the balance not going to get affected by the R 1 R 3. So, essentially, all these four resistors - R 1, R 2, R 3, R 4 - are not contributing in anyway balance of the bridge. The net result is you will get the resistance value R m accurately. That is why this resistance can be even 100 megohm or 200 megohm, you will get accurate result which is not possible in other circuits.

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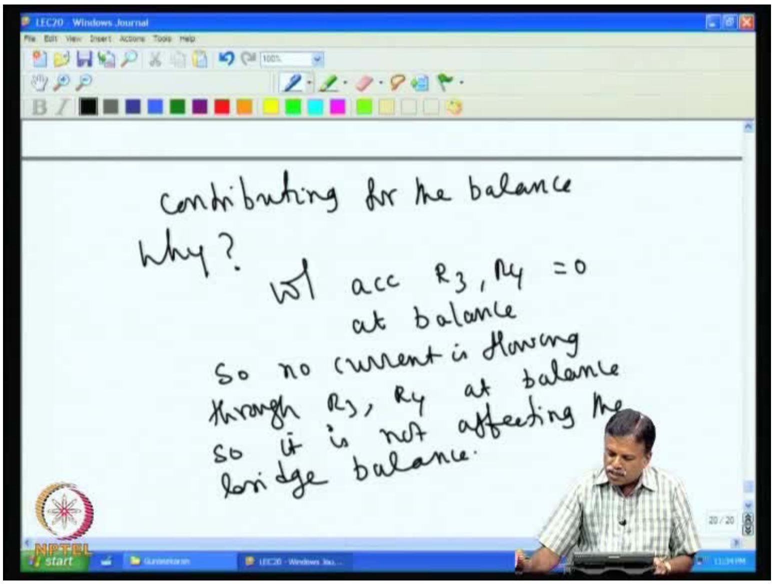

So, this is the celebrated circuit originally used for capacitance measurements. This can be used for resistance measurement. So, these effectively these resistors are not contributing for the balance of the bridge, why? Because, if look at it, this resistance R 2 R 4, see, why, voltage across, voltage across R 3, R 4 is equal to 0 at balance.

So, no current is, so, no current is flowing, flowing through R 3, R 4 at balance. So, it is not affecting the bridge balance. Similarly, if I look at R 1 and R 2, R 1 and R 3, so, these R 2 and R 4, voltage across R 2 and R 4 equal to 0 at balance. So, R 2, the, so, no current is flowing through R 2 and R 4.

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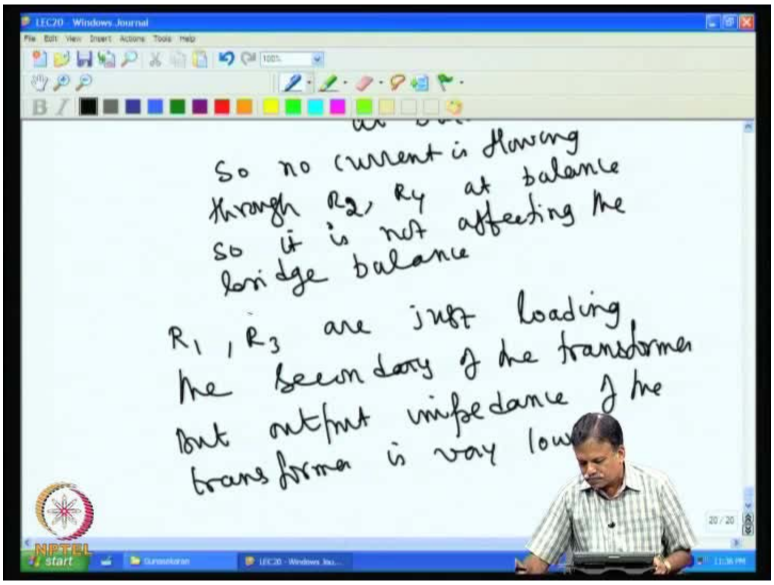

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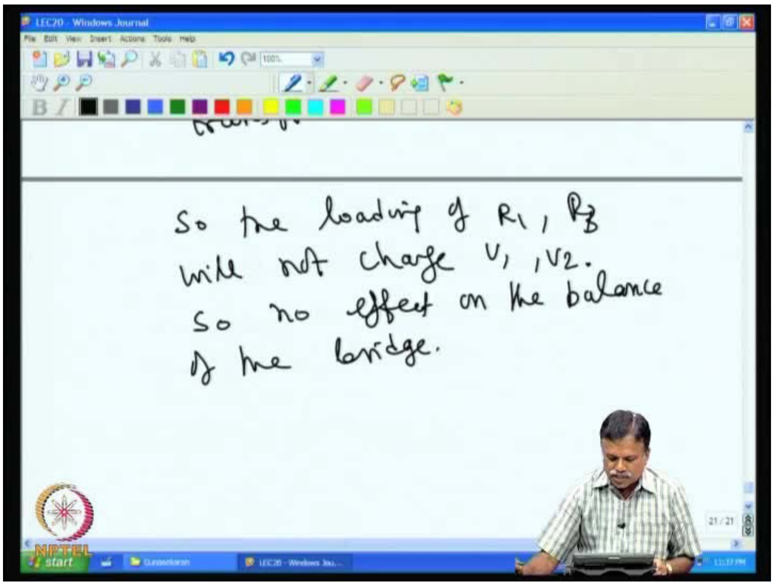

Similarly, if you take R 1 and R 3, R 1, R 3 are just loading the secondary of the transformer, but the output impedance of the, output, output, output impedance of the, of the transformer is very low. So, this loading is not affecting the, so, this loading is not affecting low, so, the loading of R 2, R 4, the loading of R 2, R 4, I think the loading of R 1 and R 3, sorry, loading of R 1, R 3, loading of R 1, R 3 will not, will not change V 1, V 2.

So, the secondary voltage are not getting affected by the loading, so, no effect on the balance of the bridge. So, because of this, since these leakage resistance is no effect on balancing of the bridge, this method of measurement is very accurate; that is why it is the very popular circuit, and it is essentially used, essentially used for high resistance measurement, and it was originally developed for capacitance measurement. We will discuss about this later - how the capacitance measurement can be done using this bridge accurately.

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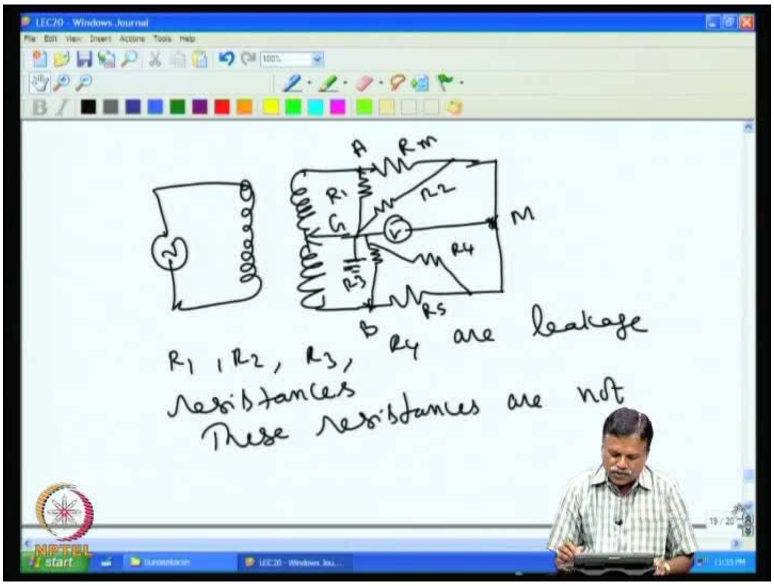

Now, only problem this is that how to balance the bridge, because if it has to work well, then somebody have to manually balance this, then only it is it possible to find what is the ratio of V 1 and V 2. Essentially means that we have to balance this and measure the voltage V 1 here and V 2 here, V 1 by V 2 will give you R m by R s, but when, of course, one can manually balance and then one have to measure this voltage and this voltage.

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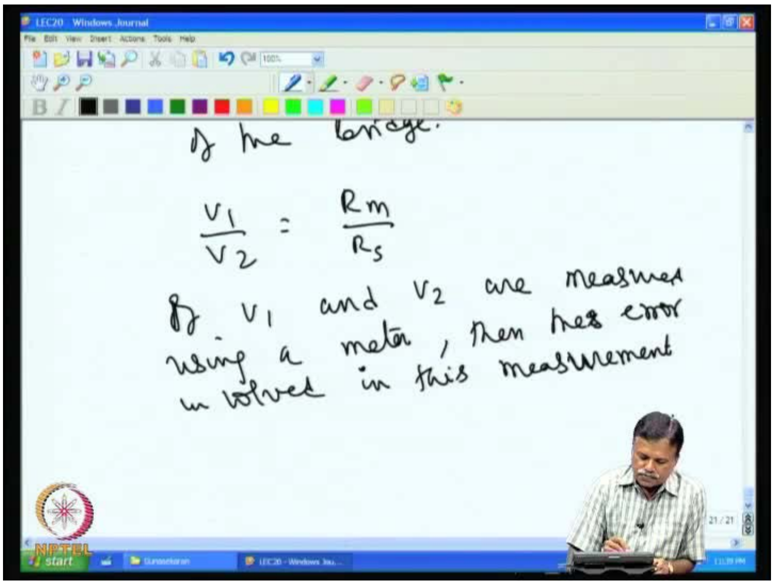

Now, let us see how this measurement of voltage can be easily avoided by modifying the transformer slightly. So, that one need not worry about measuring this voltage, because once you start measuring, then the error in V 1, V 2 will get in and that will make the bridge not accurate. So, how to avoid making the measurements? So, essentially, now, if look at the measurement, so, V 1 by V 2, that comes as R m by R s, how to avoid measuring V 1 and V 2? That is other way around, if V 1 and V 2 are measured, if V 1 and V 2 are measured using a meter, then, the, these errors, the error, the error involved, involved in this measurement, in this measurement also to be consider, also to be consider.

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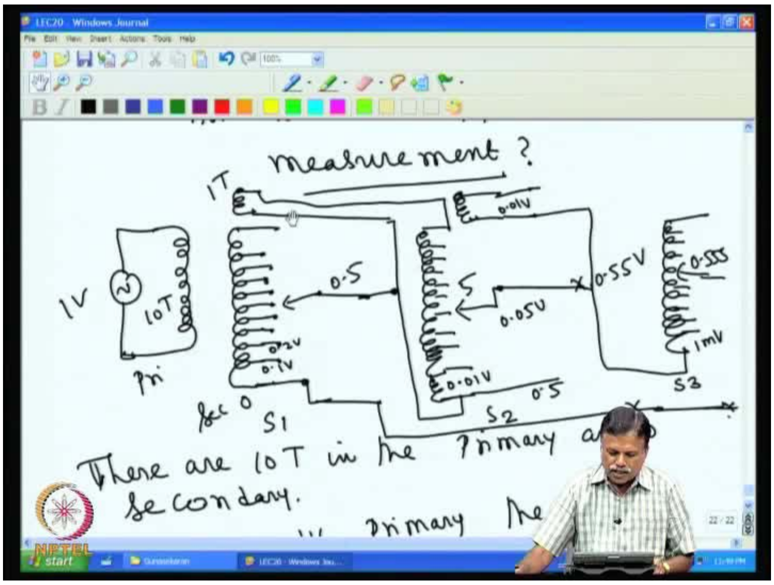

So, the measurement of V 1 and V 2 can be avoided were modifying the transformer. So, the measurement of, so, next is how to avoid the measurement of V 1 and V 2, how to avoid V 1, V 2 measurement. This can be achieve by modifying the bridge, that is, what can be done is that we can modify the ratio transformer slightly; what is done is you keep the primary of the transformer same, you energized with the AC source, - low frequency AC source - then wind the first primary, assume you have 10 turns here, that is, you have 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 turns. So, we have 1, 2, 3, 4, 5, so, we have 1, 2, 3, 4, 5, 6 7, 8, 9, 10 turns, so, we have turns from, this is 0 turn and this the 10th turn, so, 10 turns I put that means whatever voltage at given here, assume that this also having at 10 turns. Assume, I have put 1 volt here, this is 10 turn and I also have 10 turns here. For at each turn, I taken 1 tap, so, I have taken this, so, that means, this voltage across this will be 1 volt. If I give 1 volt here, then total voltage across 10 turns will be 1 volt, then each 1 will be 0.1 volt, each 10 will have 0.1 volt, so, 0.1 volt 0.2 volt and so on. Each 10 will representing 0.1 volt.

So, if we write it, that is, voltage at there are 10 turns in the secondary one, 10 turns in the primary as well as in the secondary, in the primary and secondary. So, for 1 volt primary, then voltage across each turn of secondary is equal to 0.1 volt. So, each turn will have 0.1 volt, we, across each turn of the secondary, you will have 0.1 volt.

Now what we can do is that we can use center tap which is actually movable from one point to another. So, we can select here. This center tap can take, if it is making contact, if this movable tap makes conduct here, then you will get 0.1 volt; if it makes it here, at this point, then you will get 0 volts. So, 0, 0.1, 0.2, 0.3, and then, when it makes contact here, you will get 1 volt.

So, voltage across this, whatever we are getting, voltage across this depends on to which terminal it is making contact. Now, to make it more accurate what is done is, you had one more turn here, what you do is, normally what is done is, you take this rewind in just 1 turn, this is 1 turn.

So, voltage across this also will be 0.1 volt. Now, this can be taken, this can be taken, and then, this can be connect at this, so, what, another 10 turn is own, you wind one more 10 turns here, so, you have 10 turns. So, 3 4 5 6 7 8 9 and 10, so, you can have a 10 turns and this 10 turns can be connect to energies this 0.1 volt.

So, now, we have the one more secondary winding, that is, we have one secondary winding we call this one as S 1 and the another one secondary winding is S 2. So, S 1 is having totally, S 1 is having totally 10 turns and voltage across this each one is 0.1 volt, and there is a another secondary added to this, this is only 1 turn, so, voltage across this also 0.1 volt. So, that will applied to this to the second secondary S 2, and the total voltage across this is 0.1 volt, and you have a 10, 10 turns in this, that means voltage across each one will be 0.01 volt, because the total voltage is 0.1 volt and divided by 10 that gives you 0.01 volt. So, voltage across this is 0.01 volt, and what is done is that this point is connected to, this center point is connected to this, and this has its own secondary point center tap.

Now, if I take this point and this point, if I look at the voltage across this, so, if this is, for example, if it is at the midpoint 0.5, then the voltage at this point is 0.5 volt, because it is at the midpoint, this is 0, this is 5th winding, so, that means the voltage at this point is 0.5, and then, this is 0.5, and if this is sitting at 5th winding, then assume that this is the also at 5^{th}, then this voltage is 0.05.

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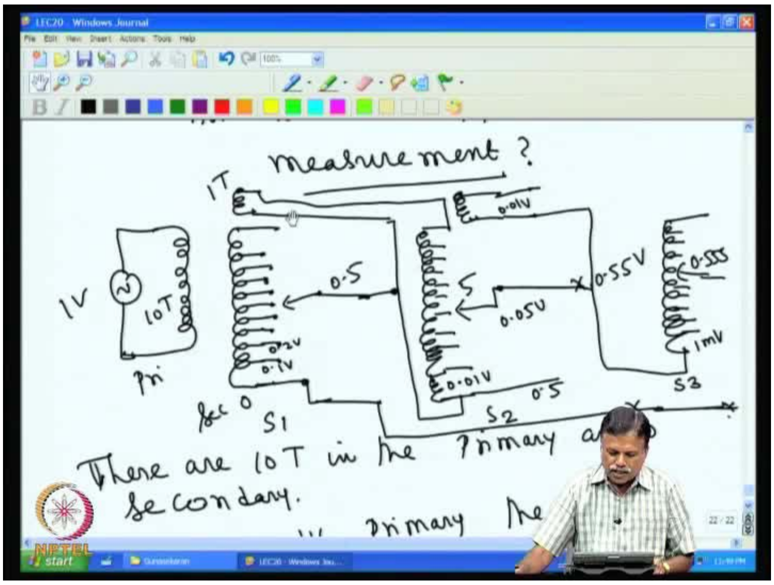

The each one is 0.01, so, it is at the 5th terminal. So, voltage across this consume 0.05 that means, if I take this as 0, then this is sitting at 0.5, this is 0.05, so, that means this would be 0.55 volt. Voltage at this point becomes 0.55 with respect to this point.

Now, for example, I can now, I can move, suppose if I keep it at point 4th terminal, then I will get 0.45; if this is at the 5 and if this is 4, then I get 0.45; if it is, the, this one at first one 0.1 and if this is at 5th one, then I will get 0.15 volt, like this I can, if I want, I can even add one more winding to get it more accurate; all that I need to do is that I had one more, for this I output one more 1 turn.

So, voltage across this, you know, voltage, this is actually 10 turns are there, and voltage across the full 10 turn is 0.1 volt. So, voltage across this became 0.01 volt, so, that is 0.01 volt what you get across this, because this is 10 turns, this is 10 turns here and there only 1 turn here, so, voltage across this will be 1 10th of this. Since this is 0.1 volt and you get 0.01 volt, if you want add one more, I can energies this. Same thing I can do this; I can connect this to this; I connect to this. So, you can use this one as third winding S 3.

So, in S 3, you also you have 10 turns, and only thing is each one is 1 millivolt, each one is 1 millivolt. So, for example, if it is at midpoint, it will be 0.5, and this is at midpoint will be another 0.05, so, it will be 0.55, and if it is also midpoint, you will get 0.555 volt with respect to this point.

So, by this arrangement, by varying these, the, by varying the tapping, one can vary the voltage accurately, and one, there is no need to measure the voltage using a volt meter to avoid the measurement error. So, if you look at this, this is a commercial ratio transformer made, and then, these have the commercial transformer is made. If it is 3 decade ratio transformer, and one can connect the, for example, in these case, if you want connect the resistance, one can connect from the top and bottom.

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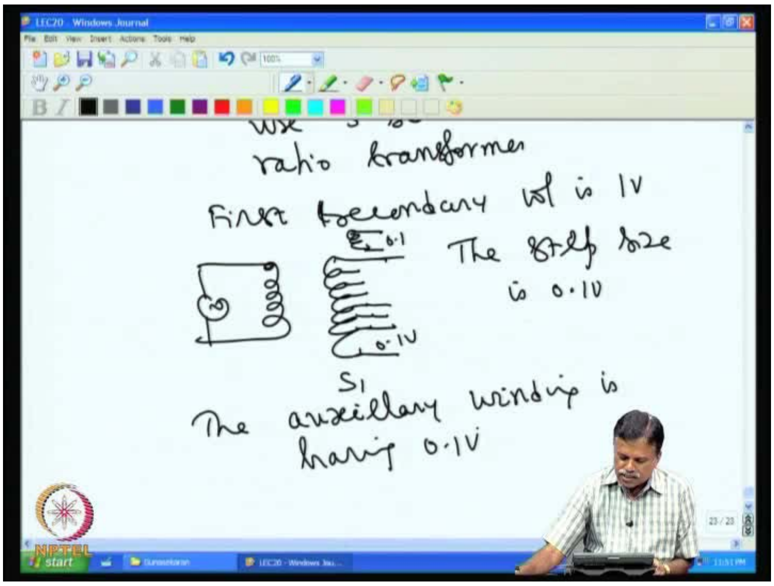

So, we will, I will put it in order now. So, to measure this, so, what is done is that, for 3 decades, for 3 digit accuracy use 3 secondaries in the ratio transformer: first one, that is, first transformer, first secondary, first secondary voltage is 1 volt, this is because you have 1 volt in the primary, and then, you have 10 turns, that is, S 1. First secondary voltage is the 1 volt; the step size here is 0.1 volt, so, each turn is having 0.1 volt. Then, another one 0.1 volt is added step size is 0.1 volt, the auxiliary winding, is having, is having 0.1 volt.

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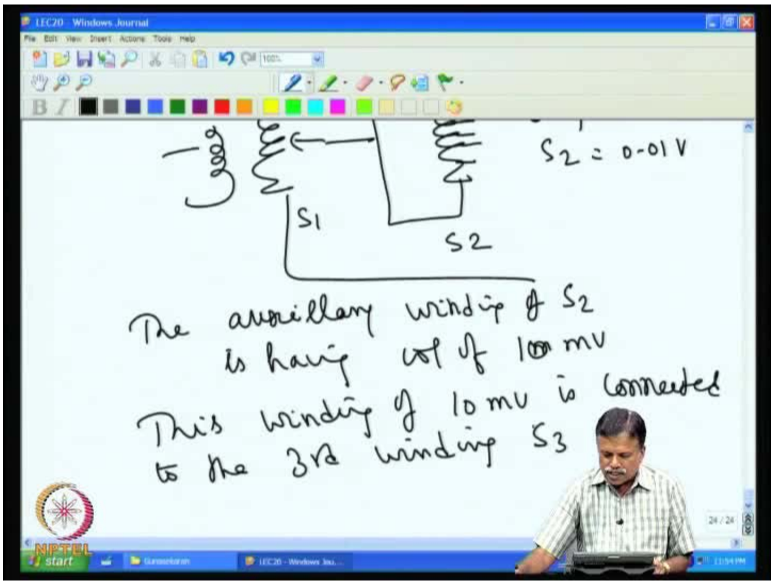

This 0.1 volt energizes the second winding. So, what is done is that this 0.1 volt, what we have from the first coil? So, first coil is here and that primary is here. This energies the second coil, so, this is S 2, this is S 1, so, this is 0.1 volt. So, voltage across S 2 is 0.1 volt step size, there are 10 turns here, step size, step size in S 2 is 0.01 volt step size, this thing is 0.0, step size in S 2 is 0.01 volt

Then, this S 2 also having its shown auxiliary winding. So, the here the voltage is 0.01 volt. The, the auxiliary winding of S 2, S 2 is having, is having voltage of, voltage of 1 millivolt, sorry, 10 millivolt. This, this is, this winding of 10 millivolt is connected to the third winding S 3, connected to the third winding, third winding S 3 .

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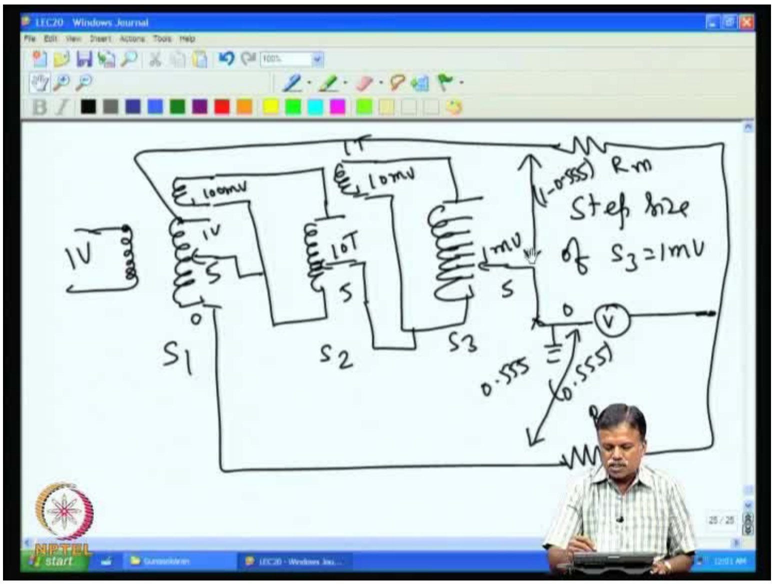

So, essentially, if you look at this, we got, third, three winding, so, we start from other primary, then we had a first S 1, and it has its own auxiliary winding, then this energizes this S 2, so, that is S 1, and then S 2; then S 2 has its own auxiliary winding which energizes S 3. So, this is 10 millivolt and this is 100 millivolt because, the, this is having only this is 10 turns and this is having only 1 turn. So, 1 tenth of this voltage is coming here, so, 100 millivolt is across this, so, you will get a 10 millivolt, and now, this is each there 10 turns, so, each one is having 1 millivolt. So, S 3, so, voltage across S 3, step size in S 3 is, step size S3 equal to 1 millivolt.

So, now we can connect the entire transformer together that actually looks like this. So, that means, if I can use the center tap, this can be connected to this and this will be coming as output. Then, and this as its own secondary tap, that can be connected to this and the final one is coming like this.

Now, for example, for high resistance measurement, one to standard resistance is connect at here, and then the other resistance is actually taken from here, and then, connected to this, and then connect the measuring meter here, voltmeter error. The volt meter is connected at this point.

So, this is standard resistance and this resistance under measurement. By this, by this ratio transformer method, one can measure the unknown resistance accurately without need to have any voltage measurement. Even this is need not to be accurate because we are only making a null method, that is, the, this one, we are looking for a 0 here, so, accuracy of this meter makes no, no contribution for the error, that is, the resistance can be measure accurately even if this meter is not accurate because we are looking at only the 0 point, and then, this supposed to be grounded, otherwise, the leakage resistance what we are discussed R 1, and R 2, R 3, R 4, you know, there all here, there leakage resistance are here. So, they have no effect on the measurement.

Now, that, I will remove this avoid the confusion. Now, for example, if I keep this one at 0.5, the midpoint set 5, and if this is at 5 and this is at 5, then if I take, you know, the, your, if I look at this voltage across this, this will be 0.5, 0.55, 0.5 because voltage at this point will be 0.555.

Then, if I look at the voltage at this point, that will be 0.5, because, you know, you have, this is 0, if I take this as 0, this is midpoint 0.5, this is 1 volt, so, you have voltage at this point coming as 0.5, this is coming as 1 volt.

So, essentially speaking that, you know, if I take this as 0, this as 0 point, if I take this as 0 point, so, this is taken as, this is taken as 0 point, so this is taken as, then automatically this becomes 0.5 because we know that this is at 1 volt, and if I take this as 0 point, so, the question is what is the voltage difference between this and this, because our interest is what is the voltage difference between this and this? What is the voltage difference between this and this?

So, this voltage is 0.555, and then, with respect to this point, this is 1 volt; so, with respect to this, it is 0.5 volt, that is, with respect to this point 0.55, and if I take this one, this will be 0.45. So, this will be 1 minus 0.55, that will be, I will put it like this, so, this will be 1 minus 0.555. That is because this is sitting at 0.5, this is 0.55, then automatically this becomes 0.45 and this 0.05 and that makes 1 minus 0.555. So, the voltage at this point is this much; the voltage at this point is known, and then, the ratio of these gives you the ratio of these two resistances, the ratio of these gives you the ratio of these two resistances. Ratio of these voltages nothing but the contact points what is used in the ratio transformer.

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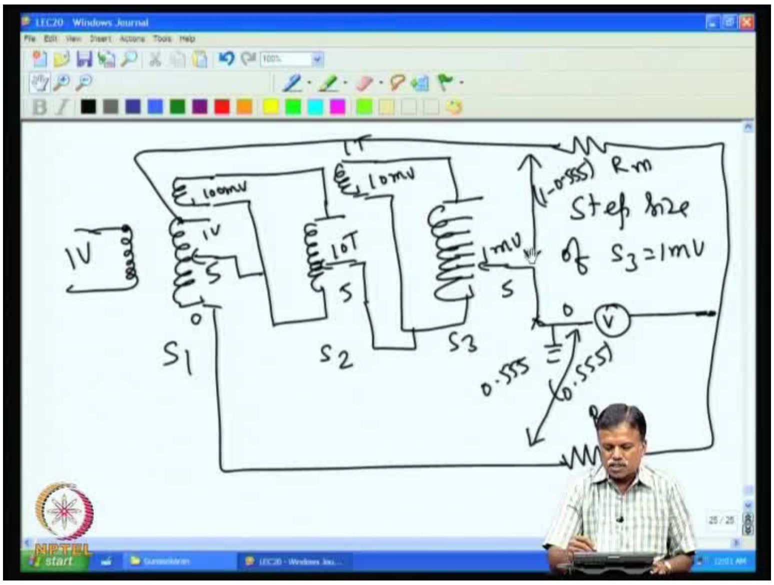

So, since we are only worried about at what turns, you know, each ones only at turns the integral number of turns, so, there is no question of any measurement error here and the reading will be is so accurate. Suppose, even if the voltage changes, suppose if the, we are given here 1 volt, and if this voltage changes, then all the voltages are equally changing, you know, the proportionally this voltage and this voltage proportionally changing, and this voltage and this voltage also will be proportionally changing, and that has no effect on the balance of the bridge. So, even if the excitation voltage changes that has no effect on the balance.

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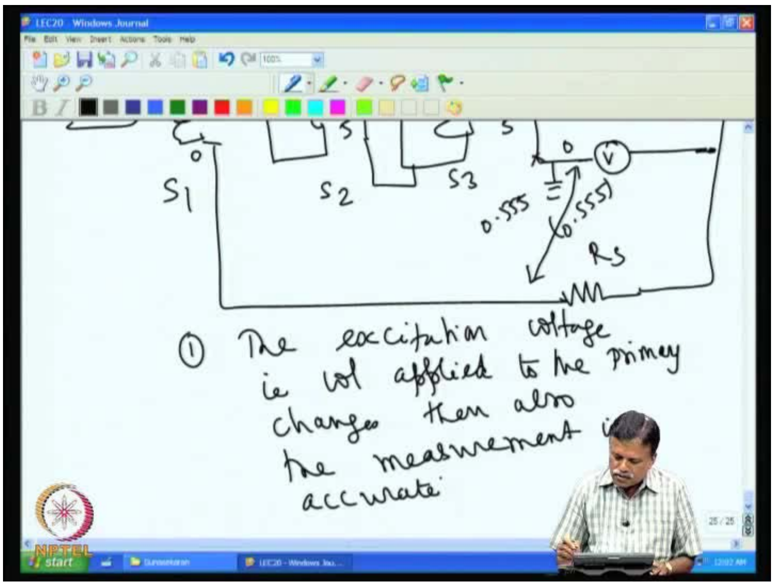

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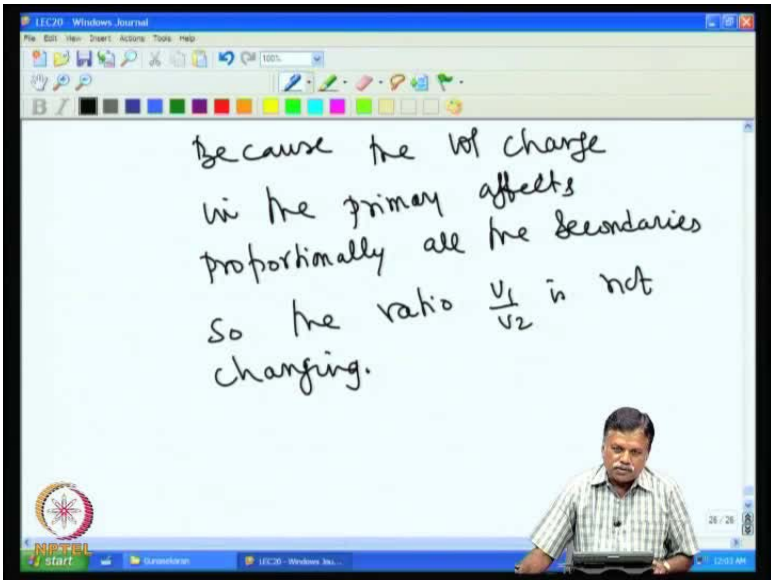

So, the excitation voltage change, voltage, that is, voltage applied, applied to the primary, primary changes, voltage applied to the primary changes, changes, changes, then also the measurement is, the measurement is accurate. This is because, because the primary voltage change in the primary, change in the primary affects proportionally all the secondary's.

So, the ratio V 1 by V 2 is not changing, so, the, there is no, because of this there is no measurement error even if the excitation voltage changes, and, the, and the volt meter used to balance also has no effect.

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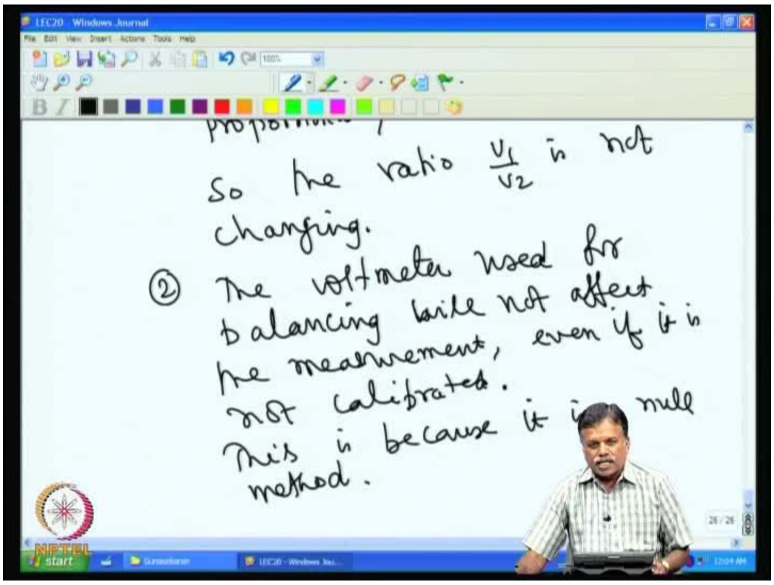

The second one is the volt meter used, the voltmeter used for balancing, is, will not affect the measurement even, even if it is not calibrated, even if it is not calibrated. This is because it is a null method, this is because it is a null method.

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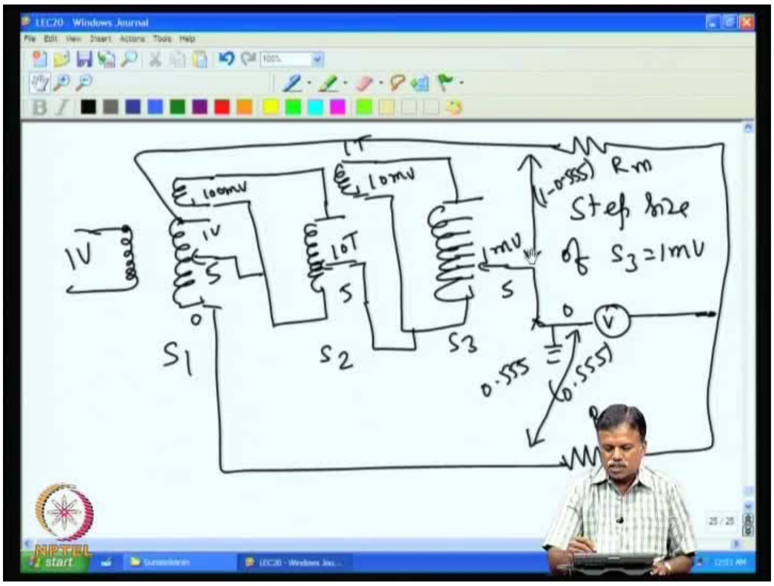

So, one can measure the resistance accurately, and then, the leakage resistance is no effect that we are already discussed. So, the leakage resistance has no effect and voltmeter what we are using here, for balancing, even if you, it has error, that will not produce any error in measurement. Even if the excitation voltage changes, that also has no effect on the measurement. So, this method is very accurate - one can go parts per million level of accuracy in resistance measurement particularly high resistance measurement.

Of course, this bridge can be used for median level resistance. For example, 1 k, 10 k, level of resistance if I want compare, I can compare and get it accurately, but if the resistance is too low, for example, if it is 1 ohm, 10 ohm like that, value to be measured. This method is not suitable, because in that case, there will large current flowing here and that will drop a voltage drop across the winding of this resistance, and then, large current flowing here will also to make it consider, the wire inductance involved in this; they will create error. So, this method is not suitable for very low resistance measurements, this method is suitable for high resistance measurement and median level resistance measurement.

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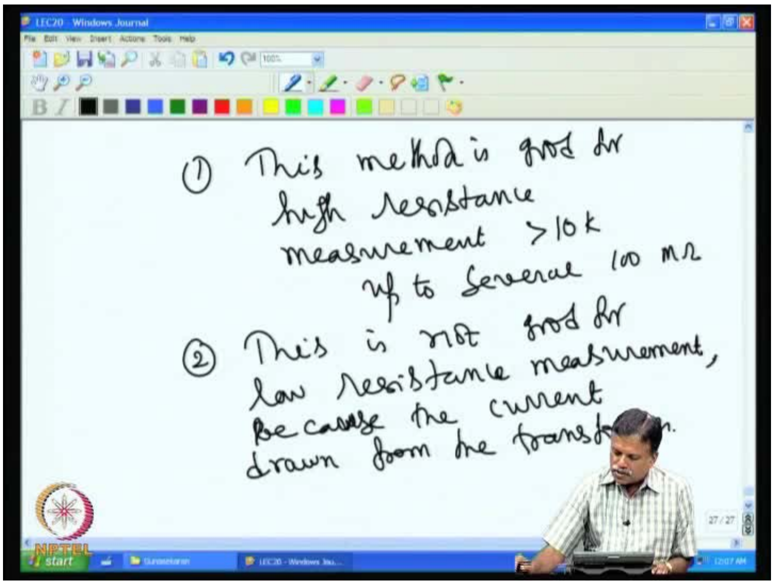

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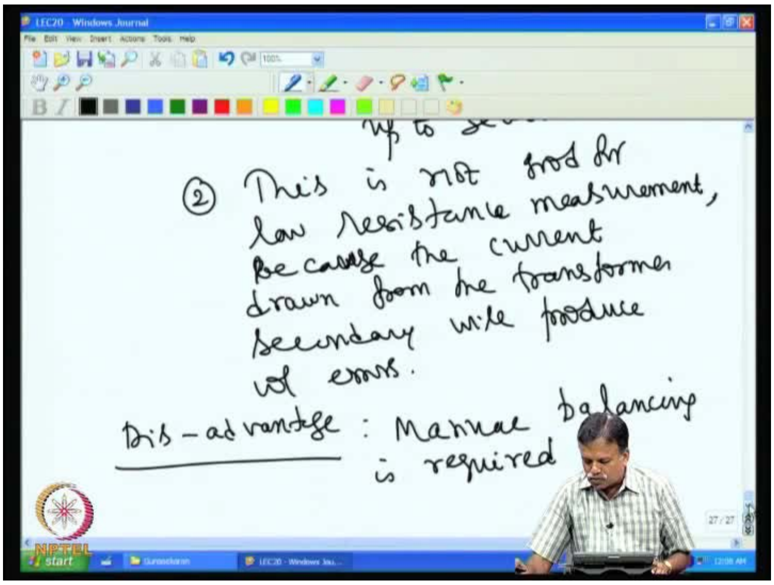

So, one had to be careful using this bridge. So, essentially, this method, this method of measurement, method is good for high resistance measurement, say probably greater than 10 k up to several 100 megohms. This is not good for low resistance measurement, not good for low resistance measurement, because low resistance measurement, because, the current drawn from the transformer secondary, the current drawn from the transformer secondary, so, they will produce, will produce voltage error. So, they, this is not good for low resistance measurement.

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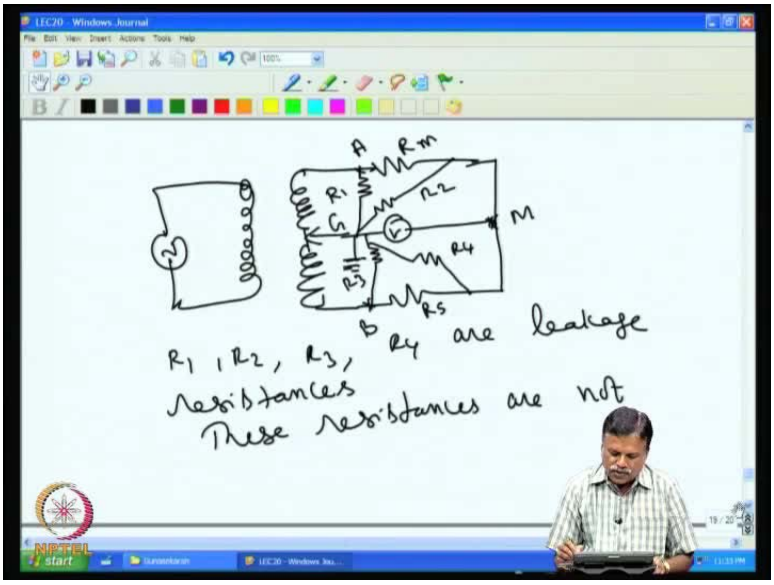

Of course, the main disadvantage with this method is that one have took manually balance this, that is, major disadvantage with this method is, major disadvantage with this, manual balance is required. Of course, electronic version of these also can be done without needing to balance the bridge manually, so, that we can do simulating the ratio transformer electronically. So, all that needed is we had to produce; if you carefully look at the ratio transformer, all that required is that we have to produce 2 voltage is V 1 and V 2 accurate. So, if I go to our original transformer and see, all that required is we at have 2 voltage is here, that is V 1 and this is V 2, you know, this voltage and this voltage, V 1, V 2 to be generated; there 180 degree out of phase, and then, I should able to this V 1 and V 2, such that, the balancing is a done.

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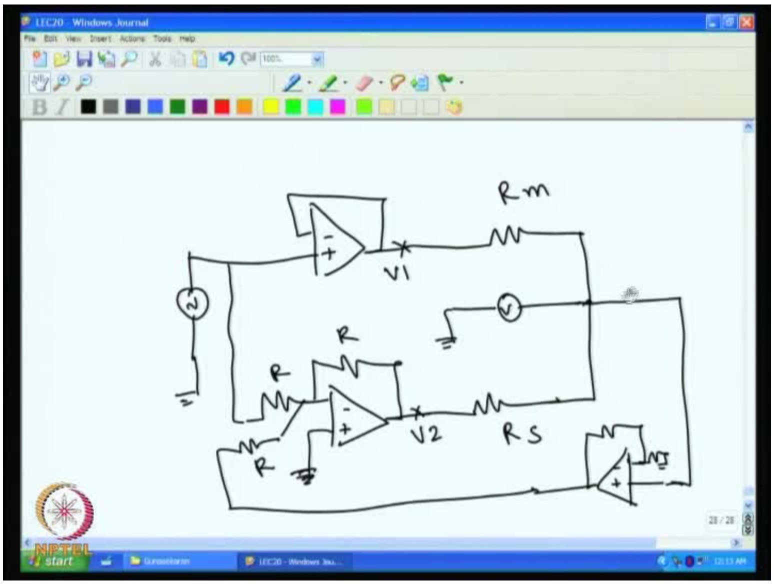

So, that we can achieve using operation amplifier, for example, I can show you how to make this measurement. This using operational amplifier, the same bridge can be obtained, but they are no need, it has the balancing. So, what can be done is that we can have a voltage source, - AC voltage source - then op amp the oscillator we can obtain a AC voltage source. Then, this voltage can be applied to the operational amplifier so that I can put a follower and get the voltage.

Since the output of the op amp is, impedance of the output of the, output impedance of the op amp is very low, so, this qualifies, you know, like our transformer output, this gives you low voltage, low impedance source that is the output impedance is low, and then, to get 180 degree out of phase, I can give this one to another op amp and there I can invert it.

So, I put the equal resistance here. So, I get this voltage and this voltage equal and opposite 180 degree out of phase, like that 2 secondaries of the transformer. Now, if I want make ratio transformer bridge using this, then I will connect similar to that the two resistances: one is that R m, another is that R s, then connect this, this is standard resistance R s, then I put the voltmeter here and connect this one to ground.

This actually we are now similar to it artificially the ratio transformer bridge because our aim is we want avoid the manual balancing, because the ratio transformer has many advantage, that is, you know, it is intensive for the leakage resistances, and then, the voltmeter error is not coming into picture, and even if this voltage changes, the measurement is accurate, it has no effect on the measurement.

So, we want take the goodness of the ratio transformer bridge, and then, I remove its main drawback, that is, one have to manually adjust, that is the main drawback of the ratio transformer which we want remove. So, that is what we are tried to do in this, so, we have done this. Now, what you do is, now we had to balance the bridge, that is, if the voltage across this should be 0; if it is not 0, then one have to vary this and this. Now, that we can achieve easily by taking this voltage, for example, I can do one thing, I can take this voltage, and if I know that this is a voltage, then I merely amplify this voltage, I just amplify this voltage, then I can connect this one to add this voltage to this.

For example, if this voltage is not 0, say it is not a balance, that will happening these two resistance ratio and these two voltages, I will put it as V 1 and V 2, this is V 1 and V 2, if V 1 V 2 ratio is not same as R m by R s ratio, then the bridge will not be balanced. Assume that this is plus, this voltage is a plus, then this plus voltage will be amplify, and then, it will be subtract. Assume that I put here, or so, this voltage, whatever is there, if it is plus, then it will make this voltage more, it will make the V 2 increase. We again we are inverting and giving, so, it is equivalently V 2 is increasing and V 2 is minus, so, the, it will, output will come down. So, as long as the gain is higher here, the gain of this is of higher, then the bridge is, you know, whatever small voltage is there, that will make this voltage is higher, and then, balance the bridge. Of course, still you have a problem of making V 1 and V 2 measurement, which was not there in the case of ratio transformer, because if I put it like this and if I have a large gain, the bridge will be automatically balanced, one need not go and balance it, because if it error is plus, then automatically it puts more minus. In case, if the error is minus, then automatically it puts, it reduces this voltage. Of course, this voltage remains same and that makes the bridge to balance automatically.

So, how close it get balance, it depends upon how much gain that we at given in this. Higher the gain and more accurately it will be balanced. All that one need it do is that I had to measure V 1 and V 2 now with the volt meter, or I can convert V 1 and V 2 into DC and make accurate measurements.

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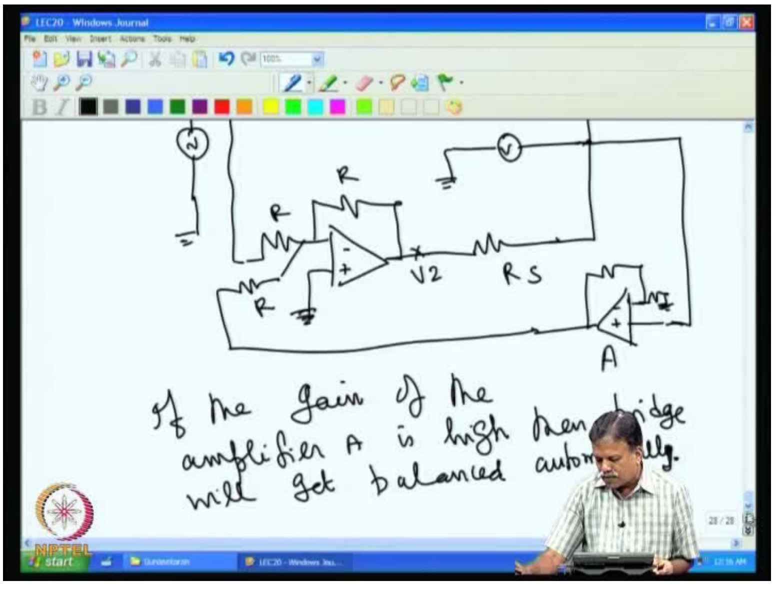

In that case, it will give correct reading, but that is no way that we can avoid voltage measurement similar to what we are done in the ratio transformer bridge. So, essentially, this bridge automatically balances. So, if we look at it is this, the gain is, I will call as amplifier A, if the gain of the amplifier A is high, A is high, then bridge will get balanced automatically, because bridge manual balancing is a problem and this automatic balancing that way helps us.

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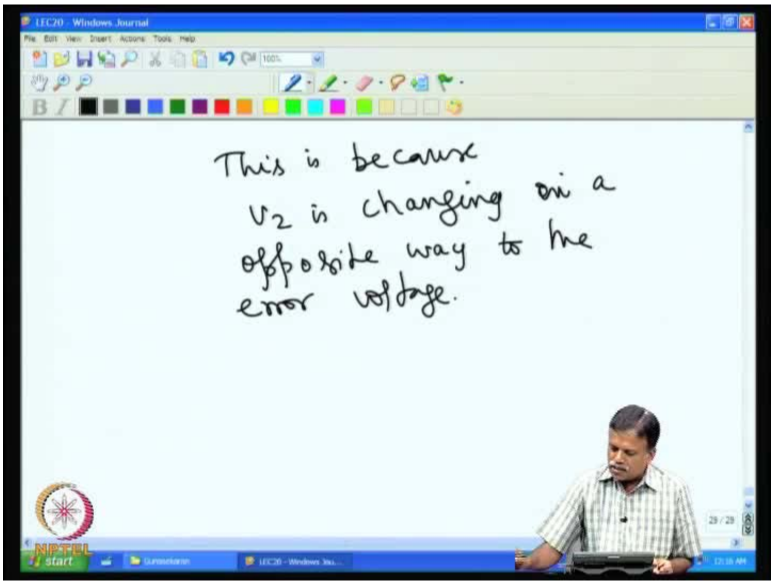

So, need not balance the bridge, so, bridge balance taking place is automatically. This is achieved by varing V 1 and V 2. This is achieved, this is because, this is because V 2 is changing, it is changing, opposite, in opposite way, in opposite way to the error voltage, that is, this is consider as error voltage, this is consider as error voltage.

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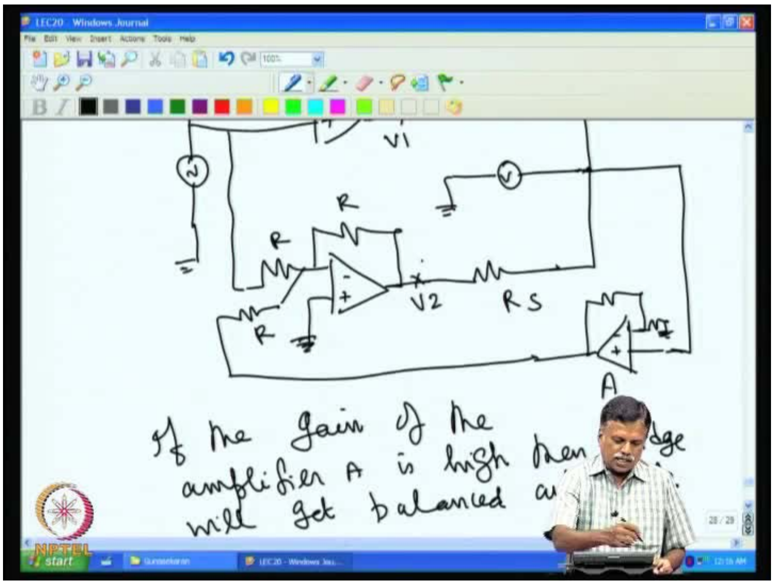

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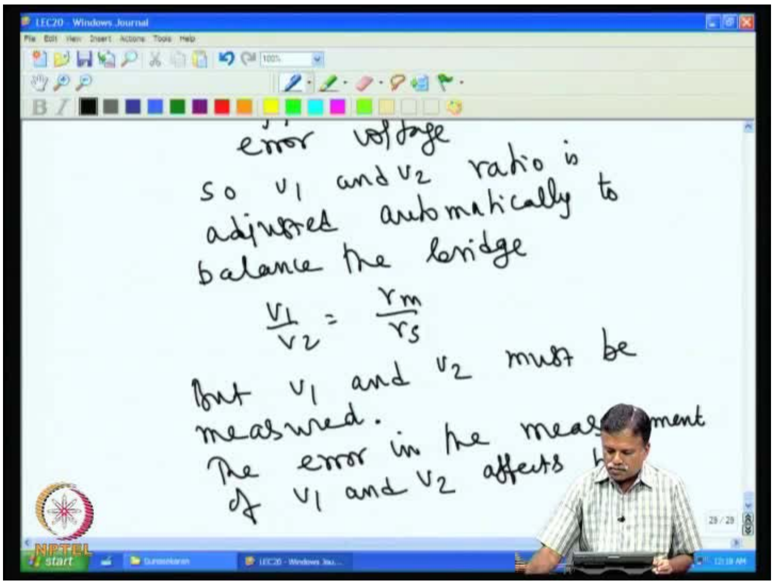

So, the error voltage is more, V 2 decreases - if this is decreases, this is increases. So, this error voltage, we call this is error voltage at this point. So, error voltage changes the V 2 and opposite way, that, that is why the bridge is balancing, so, the error voltage, opposite way to the error voltage.

So, V 1 and V 2 ratio is adjusted automatically to balance the bridge. So, automatic balancing is achieved and V 1 and V 2 ratio that automatically adjusted. Then one can find V 1 by V 2 is equal to R m by R s, but V 1 V 2 add to be measured, but V 1 and V 2 must be measured, which was not there in the case of ratio transformer. The error introduce V 1, V 2 will be added to the measurement error. So, the error, the erorr in, error in, error in the measurement of V 1 and V 2 affects the resistance measurement.

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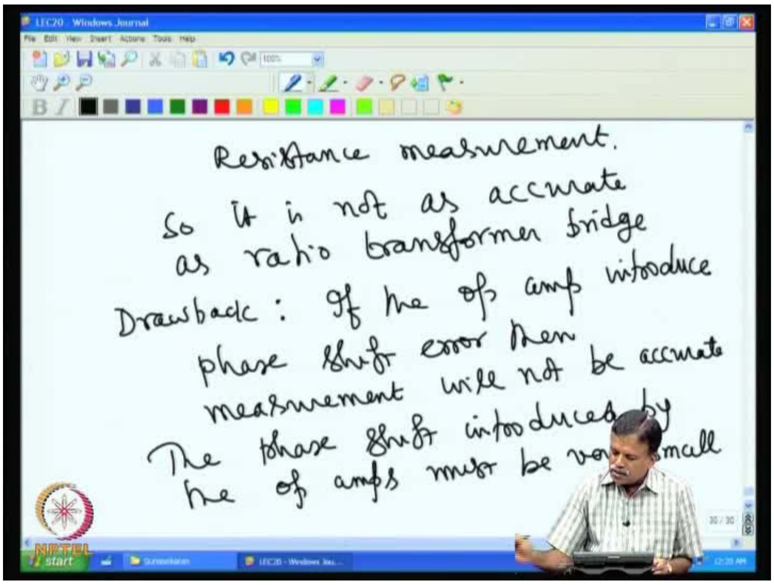

So, it is not as accurate as ratio transformer bridge, so, it is not, it is not as accurate, accurate as ratio transformer bridge. In addition to this, it has another drawback, that is, the drawback is, the main drawback, if the, if the op amps, if the op amps introduce, introduce phase shift error, then measurement will not be accurate, that means we have to see that phase shift introduced by the op amps are very small.

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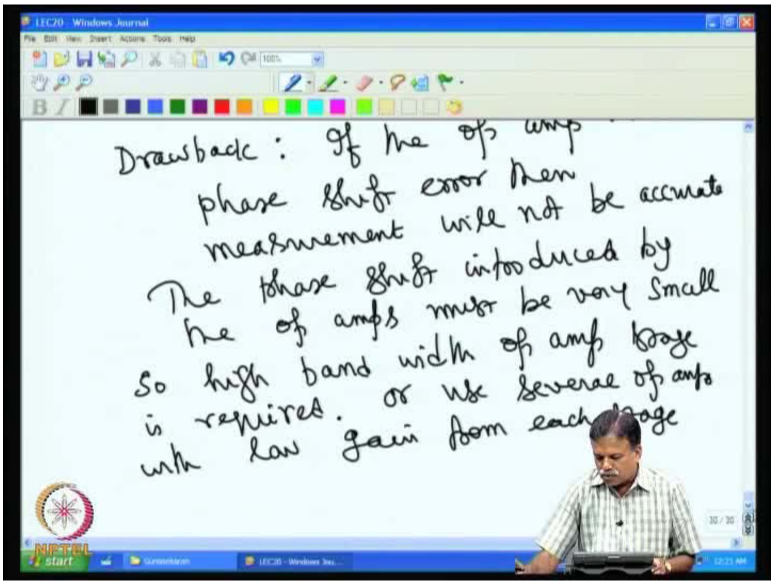

So, for this two work make sure the phase shift introduce by the op amp, the phase shift introduce by the op amp will be very small, op amps must be very small. This can be achieved by (( )) weight band width op amp. So, it is required, so, high band width of op amps required, stage is required, op amp stage is required.

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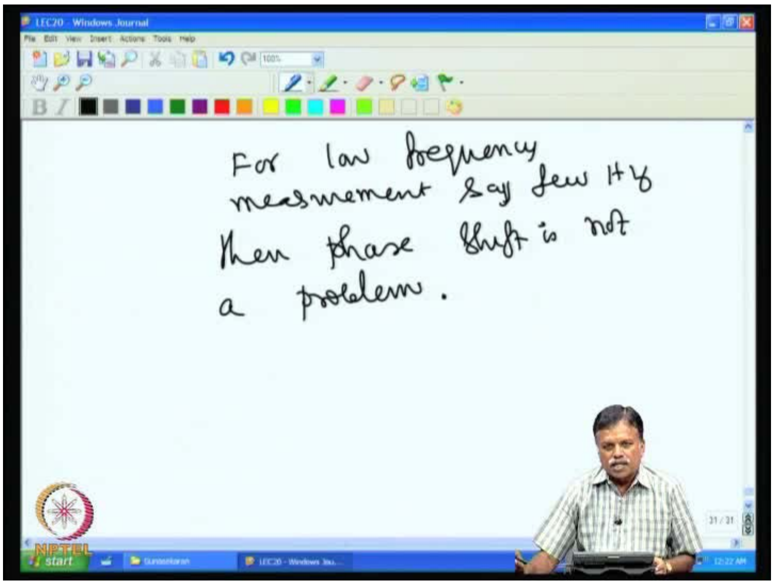

Alternatively, use op amp with load gain, you use or use several op amps, each one is with low gain from each stage, low gain from each stage, each stage. So, we will be discussing about this little latter how to reduce the phase shift (( )) the op amp. One way is that the frequency of the measurement is low; this is not a series problems. So, if one uses low frequency measurement, for low frequency measurement, this not a series problem. Frequency measurement, measurement, says few hertz, few hertz, then phase shift is not a problem, phase shift is not a problem.

So, one can use the op amp for automatic balancing, and of course, you had to measure V 1, V 2 to make the measurement accurate, and keep the frequency of the measurement low so that the error is small. So, this is have the high resistance measurement can be made which is not sustainable for leakage resistance and so on, and this method is very popular and is essentially used as a ratio transformer technique. Next class we will see the other issues of the bridge method.