Circuits For Analog System Design

Prof. Gunashekaran M K
Centre for Electronics Design and Technology
Indian Institute of Science, Bangalore

Lecture No. # 29
Various Resistance Measurement Techniques

Today, we will discuss about how to make resistance measurement, because in real world, the, we have to handle various signals, and some of them, you know, changing resistance to be measures; some of them, changing capacitance to be measured; and some of them, changing inductance to be measured, and so on.

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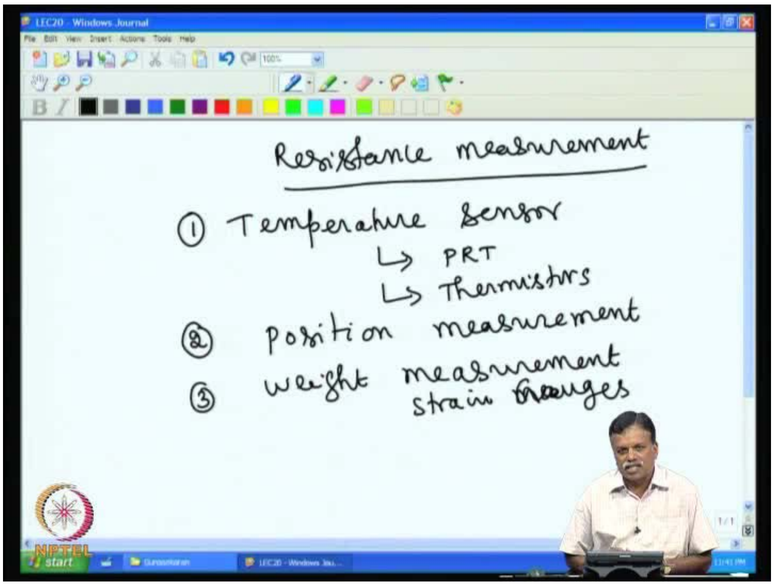

So, we will see how to make resistance measurement. So, resistance measurement will be our topic today. Now, this we have taken as because, there is, there are very many resistance sensors are there, like for example, we have a temperature sensors, pattern resistance, thermometer, and so on. So, we have an in temperature sensors; we have a resistance measurement that involve, actually, PRT pattern resistance thermometer, then thermistors.

So, change in resistance here give you temperature, and then, similarly, we have, in position measurement, we have resistance sensors. In position measurement, we have a resistance sensor. Similarly, for example, we have in weight measurement or in torque measurement, all this things we have a, for example, weight measurement, we use, here we use strain gauges, so, they are basically resistance sensors, strain measurement, strain gauges.

There, again resistance change is used to measure the weight or the strain and so on. Here and position measurement, we use potentiometers, and that temperature sensors, like that, we have very many resistance sensors are there. So, we will see how to make a signal conditioner for general resistance sensors. So, that means we divide this resistance measurement into three different reasons.

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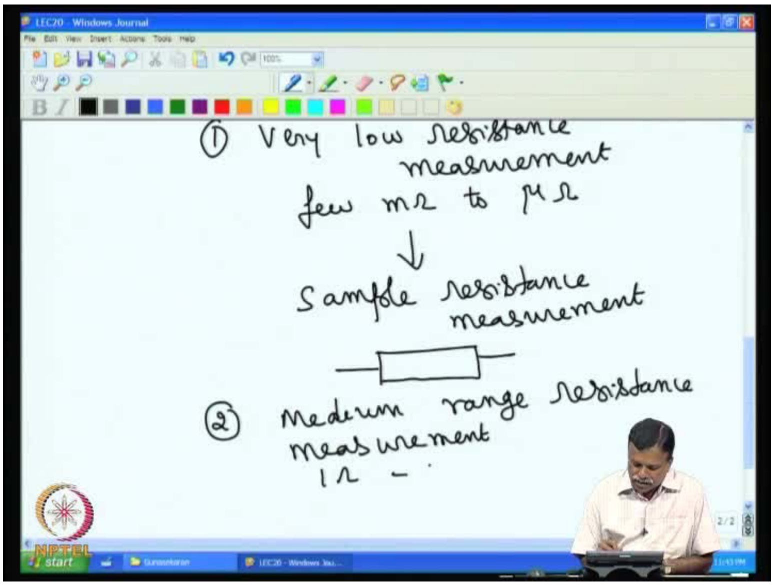

So, one is very low resistance measurement, that comes probably few milliohms to micro ohms level of resistance measurement. This is one range there, you know, we use this, this is actually used mainly for research purpose, for example, change in resistance, we measure accurately or prepare some samples, and then, measure the resistance of that, there it comes very low measurement. This example would be prepare some samples, sample resistance measurement, like, it will be more like a solid metal used resistance would be measured. They come at very low resistance value, and then, the second type would be medium range resistance measurement. There will be medium range, so, you have medium range resistance measurement.

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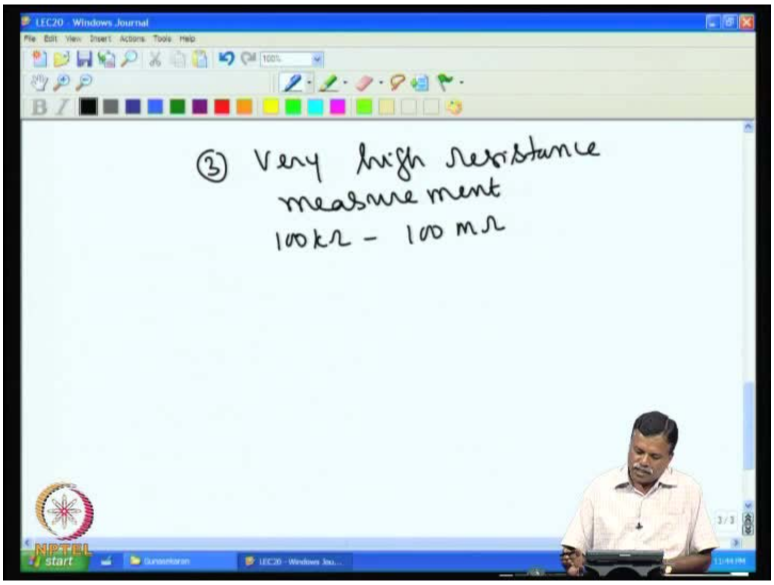

This comes in the range, for example, 1 ohm to, probably something like 100 k, that kind of a resistance like potentiometer used in the position measurement, pattern resistance thermometer, resistance measurement, or thermistors, all this things fall under this category. Then we have third type very high resistance measurement. This may be going 100 kilo ohm up, it may be even 100 mega ohm or even more.

This is more like a insulation measurement and so on. This is another applications where we at the measured high value resistance accurately. So, we had seen that three types of, actually, measurement, very low resistance, and then, medium range resistance measurement, and then, high range resistance measurement, and each one needs a different technique because what is applicable in high resistance measurement may not be good for medium range, and what is applicable for medium range resistance measurement may not be good for low range resistance measurement. So, we are not understood where the errors are coming, what type of circuit to be used for each case. That is what we will see now.

Now, if you see the general method, if you look at the earlier day measurements, there more or like if they followed the Wheatstone bridge technique.

So, we will, let us see, what was the advantage they had, what was the disadvantages they had, and see, what is the lesson that we can learn from there, and how best we can use them, and what modification we have do to do measurements in today's instrumentation volt.

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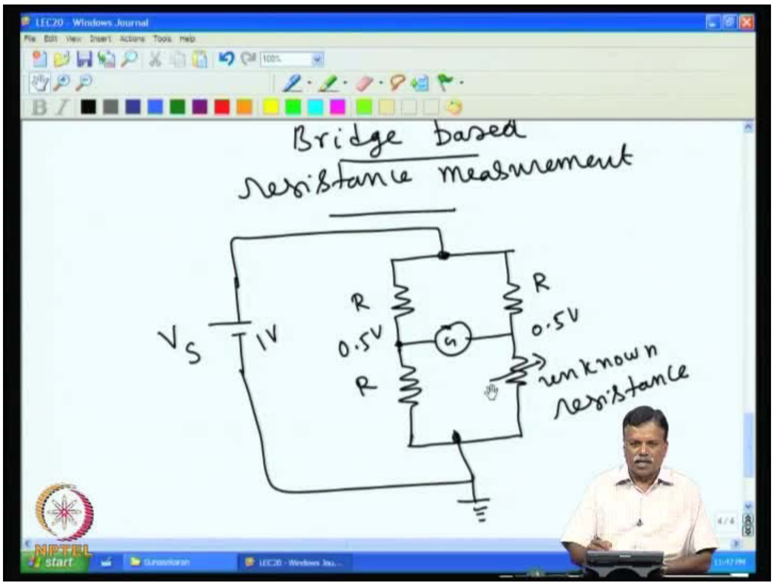

So, for example, the bridge based techniques. You will see the bridge based resistance measurement technique. In this method, basically what is done is they had a source of excitation. You have a source, and then, they had this four resistances connected in the bridge form, the well-known bridge - wheatstone bridge - is the basic technique. So, you connect, the, this, and connect the excitation, and then, you connect the, your galvanometer or detector here, in this.

Now, the basic if I have, for example, the whole idea is that if I have the resistances here R and R equal, then if this is the V supply and the galvanometer, you know, then we have resistance here R, and this is the unknown resistance.

Now, if you look at the this circuit, basically it is a voltage divider circuit, because if I leave this galvanometer, then this supplied voltage V S, for example, the applied voltage V S is basically divided by effect of 2 by these 2 resistors, the fixed resistance. So, you get, for example, if I have 10 k and 10 k, then, if this is a, if it is 1 volt supply is given, then I know this point will be at 0.5 volt, this particular ground I take, this is my reference point is ground.

So, this is basically voltage divider this will be sitting at 0.5. Then, assume that this unknown resistance value also equal to this, for example, this value is equal to this, then, obviously, this point also will be sitting at 0.5 volt, because this two resistance are equal, so the, whatever, one voltage that is applied will half of that appear here.

So, that means this is equal to this and this is equal to this, that is, in R, it can be all the four also can be equal. In that case, you get here 0.5 volt, here 0.5 volt, then the voltage across the galvanometer 0 and we called the bridge is balanced.

Now, that means one bridge is balanced, then we can take the resistance value here is equal to here. So, that is unbalance, we can, unknown resistance equal to R, at balance, unknown resistance equal to R.

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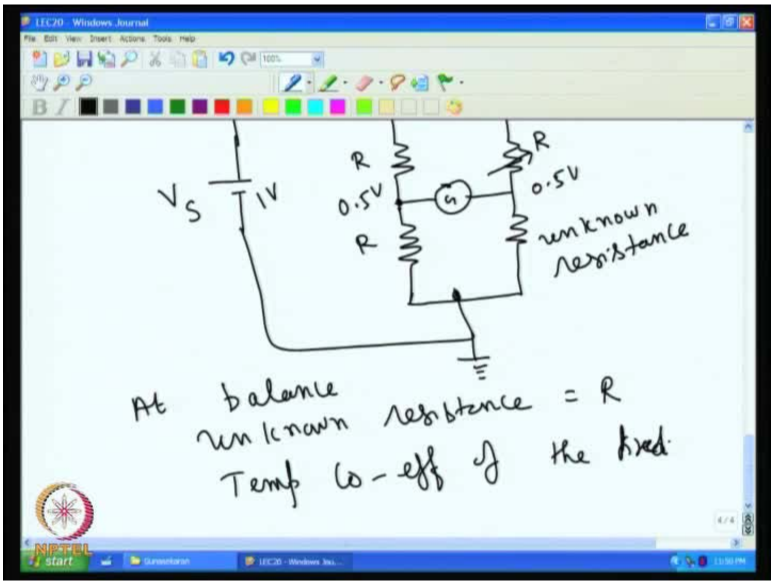

This is the basic Wheatstone bridge. Now, why it is so popular? You know, the, it is a very simple circuit, but then, it is easier to measure also that you can change this, you know, if you want know the value of this resistance, normally what is, if it is unknown resistance, normally what is there is I will actually, you know, we keep this unknown resistance. So, I will put a unknown resistance, and then, if I want know the value of the resistance, I varied this.

So, see, I varied this, so that the bridge is balanced the galvanometer, so as no deflection. Then, I will take this R is equal to unknown resistance. So, I will adjust R to get the null in the galvanometer, then I take this value equal to this value, and this is celebrate it bridge technique, and even today, it is used, and the reason is this is the most accurate way of measuring the resistance than any other technique that exists even today, and no one can beat the accuracy of this measurement with any instrument, even whatever instrument that you have, you will not able to beat the accuracy that it gives.

That is the beauty of this one. Unfortunately, the only drawback of this system is that some only have to vary this resistance and watch for the balance, and that is not possible in todays automated, well, that is the reason this is not used, but this is the most accurate method one can think of.

So, let us see why it is so accurate. Now in, when the used this bridge, normally what you have done was that they used this resistance and this resistance mostly constantan wires or the go for the magnum wires. So, the magnum wires, if you uses resistance element, magnum had very lower temperature coefficient. That is, you know, if I take the magnum wire and the temperature coefficient magnum wire is only 10 PPM per degree c. So, most the use magnum wire, so the temperature coefficient of the fixed resistors.

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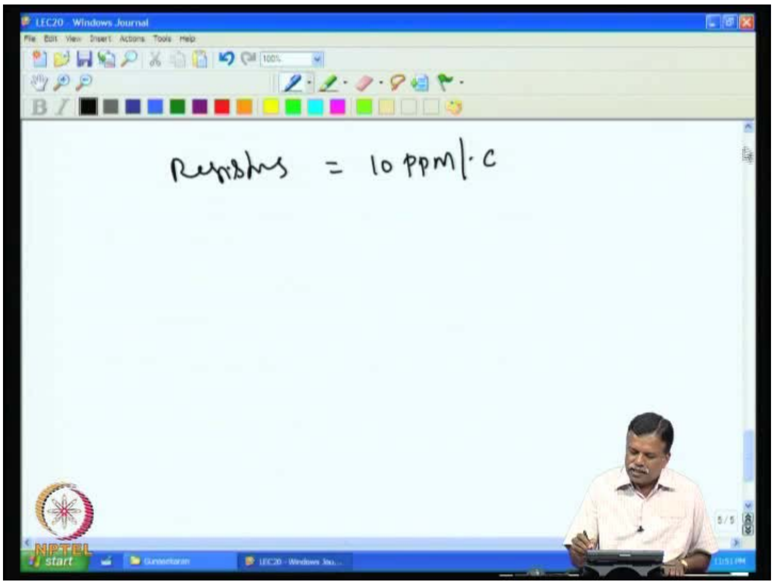

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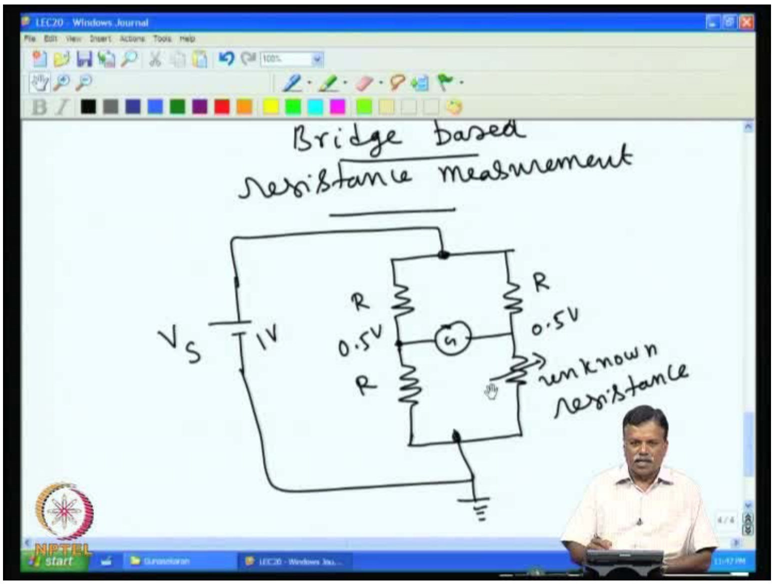

Fixed resistor is equal to 10 PPM per degree c, so, its temperature, the resistance change is a very small first of all, that enough the temperature changes, then the resistance drift is very small, and then, they put both magnum wires. Even whatever drift that is there, this and this will equally drift all that time. So, at whatever temperature that making measurement, you will find this is always at 0.5 volt as long as this is 1 volt.

Similarly, if this resistance also magnum wire and this as a very low drift, and then, if I see the, if this also assume that is the magnum wire only, we have used, assume that I am using this for some measurement, and then, used a magnum wire, then, define with temperature, this point also not changing. Assume this also magnum wire, this also magnum wire, this and this also magnum wire. Then you will find whatever may be the temperature of this elements, this, this will be at 0.5, this will be 0.5 as long as this is 1 volt.

So, the, if the room temperature changes, then the balance not going to getting to affect at all. So, as long as the actual resistances are not changing, there is no problem. With temperature, these resistances are equally, whatever change here, that same thing happening and here as well as here also same change occurring. We will find balance is not getting affect at all.

In case if the supply voltage changes, that also will not affect the balance of the bridge, because instead of 1 volt, if it goes to 1.1, then this will go to 0.55 and this also will go to 0.55 and the difference will remains same.

So, if I use all elements of thus same wire, probably, ideally if that has low temperature coefficient like magnum or constantan, then you will find the temperature change, the room temperature change will not of the balance and reading accuracy is not affected.

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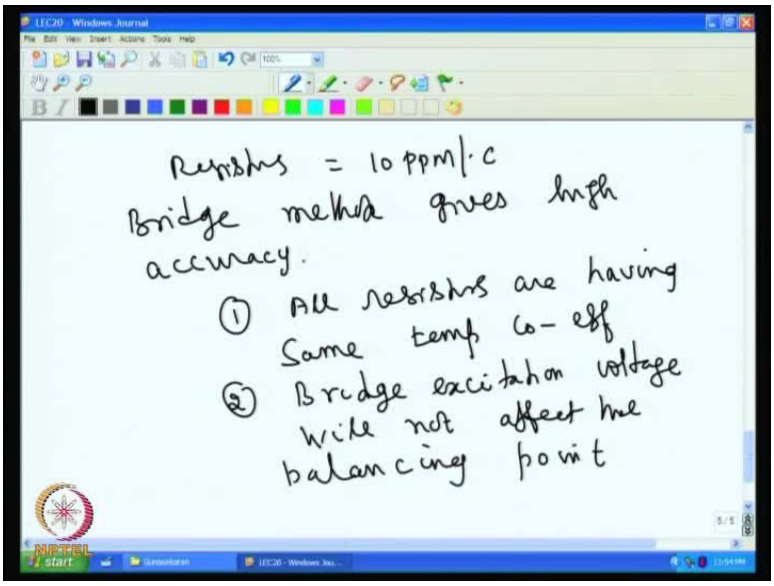

Similarly, the supply voltage change also will not affect the balance and will not affect the accuracy. So, you will get accurate measurement irrespective of room temperature change and the supply voltage change. So, bridge method gives high accuracy. In this case, it is 1 because all resistors are, all resistors are having same temperature coefficient.

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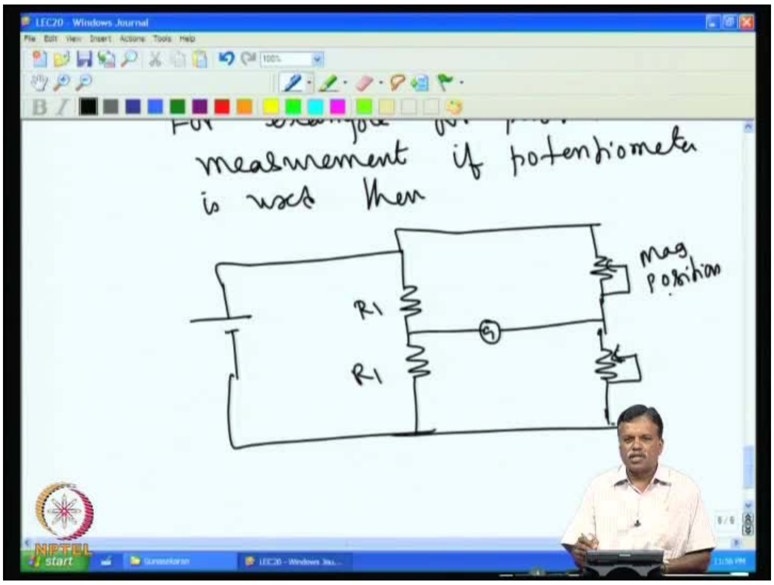

Then the second one is supply voltage, the bridge excitation voltage will not affect the balancing point, because of this 2 resistance, the bridge method is very accurate. For example, if you want make a position measurement, for example, for position measurement, if potentiometer is used, meter is used. Then, if I connect the bridge that is what I do is I will take the bridge, and then, connect this, then I put, here also these 2 are magnum resistance R 1 and R 1 are magnum resistance of equal value. Then I put the potentiometer was depending on the position, you know, the value changing. This also I put a magnum wire only, potentiometer, then, I have another resistance, another resistance, which is again potentiometer, again magnum resistance I put here.

Now, the galvanometer is put here. Now, if the, for example, if this position depending upon the valve position, assume that you know the potentiometer is varying, and the resistance value of this gives you the valve position. In that case what I do, I will adjust this resistance R, adjust this resistance R to get the balanced.

Once the balance is obtained, this value equal to this value. So, I know the position value from this reading. Now, the important point is that all of them have equal drift, so it has no effect, temperature has no effect on this, and then, even if this voltage changes, the position is the galvanometer value is not getting affected by balance is always balance, well, it is a null method, and then, the galvanometer error also has no effect, because even if the galvanometer is not calibrated or even if it has a 100 percent error.

Since it is null method, at 0 only we are seeing, and this galvanometer also has no effect. So, that way the three effects that is one: the effect due to the error due to the source; error due to the galvanometer; temperature change due to error resistance change due to the temperature. All three has no effect on the final measurement, that is why this method so accurate, and even today, whatever method you follow, one cannot beat the accuracy of the of the bridge method that one can get. All our attempts are only move towards the, this to get the accuracy that we can get from this bridge method.

So, even though this bridge method is so accurate and there is virtually is no error and it is a celebrated technique, it cannot be used in today instrument is an old is mainly because to know the value of this resistance, one have to manually varied this to get the balanced, and in automated equipment that kind of arrangement is not practically possible. That is why this method is a not using now a day's in automated measurements, otherwise, in laboratory measurement, this is the most ideal thing that one can get and it is also the cheapest way of making measurement.

So, because you know, one need not have highly sophisticated equipment with this can have any amount of error that error really resin matter and the source also need not be a highly sophisticated source even the variation here as no effect. So, obviously this is the cheapest that one can think of.

So, this is the bridge method that was there. Now, what is the technique that used and today's world? Of course, the error drawbacks in this bridge method, the main drawback is the voltage that you get unbalanced. Suppose, if you want measure the resistance using the unbalanced voltage, then the bridge is not accurate, in the sense that you know, if I try to see from this voltage, what is the deviation of this resistance, that kind of measurement it is not suitable, and then, this also gives lot of error, all the errors what it have discussed, you know the error voltage here is first of all non-linear, and then, error voltage various with the source and so on, all the errors that coming.

So, only at balanced condition this gives you the most accurate result. So, one have to use (( )) have a bridge, it is accurate, and then, it is cheapest, but then one have to go only for a null method, that is the drawback of this system.

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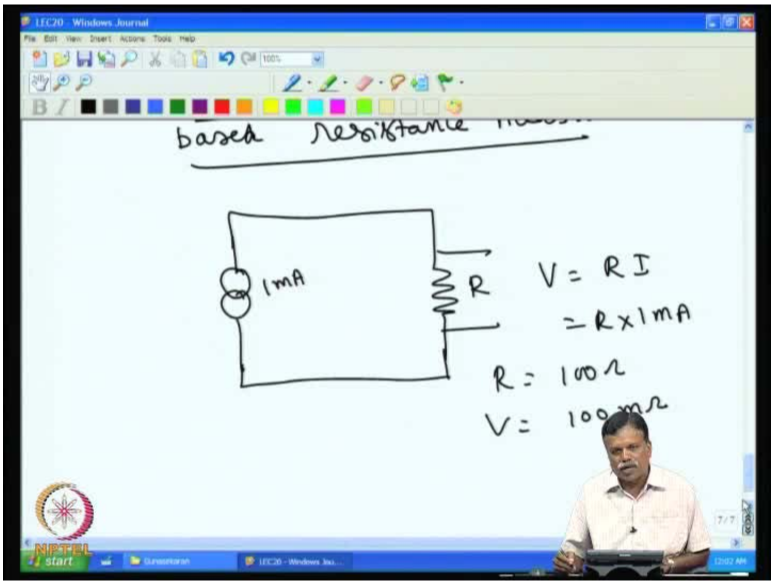

Now, let us see what is the most of the current instrument, what technique they used to make used measurement. The most popular technique is use of a constant current source. So, the constant current source using constant current source, make the resistance measurement. Current source based resistance, we look at the this technique that is the constant current source based technique, it is done like this, that is you use the constant current source you have, and then, this gives constant current and connect the resistance which whose value to be measure.

So, I have a constant current source maybe it is a 1 milli ampere current source. Then this is the resistance R whose value to be measured. In that case, if I know the current is constant, so the voltage across this will be R into I, so, in this case R into 1 milli ampere. So, for R is equal to 100 ohms, then you will end of, sorry, I will 1 milliamps, so, I is 1 milli ampere, then the V actually comes out to be and R 100 ohms, then I is equal to 1 milli ampere, then you will get V as 100 milliohms.

So, volt by measuring the voltage across this one, one can calculate the resistance because current is known and it is fixed. As so, you can make this measurement is alternative and this has advantage that there is no balancing is required, one just measures the voltage across this, and then, computes the resistance value that computation can be done just by scaling, or if a processor based unit, actual computation also can be done, and this is also linear and like a wheatstone bridge technique, where the unbalanced voltage is not a linear thing, unbalanced voltage is non-linear, so, this looks better for the measurement point of view.

But then, there are drawbacks in this. Now, we are depend upon this current source to be get this voltage, but then, we have obtain this current source using the circuitry, and that current what you have to be fixed 1 milli ampere, the, may not be 1 milli ampere at all the room temperatures, because the main problem in electronic circuit design is room temperature variation, because the room temperature variation can make the circuit performance deteriorate, it can deviate from, what, deviate from our design values, for example, I design the circuit for 1 milli ampere current, that current should be always 1 milli ampere, but the current will not be 1 milli ampere at different temperatures, may be at room temperature would adjust for 1 milli ampere; when temperature goes up, this current may go up or come down, because the resistance and the capacitors and the operational amplifiers all of the whatever I am using or the reference voltages that I am using, all of them will change with the temperature, and the net result would be, this current would be changing with temperature, and then, whatever measurement that we make, may not be accurate, and also, we will have to put some volt meter here or some measuring circuit here to measure the voltage, this also will drift with temperature.

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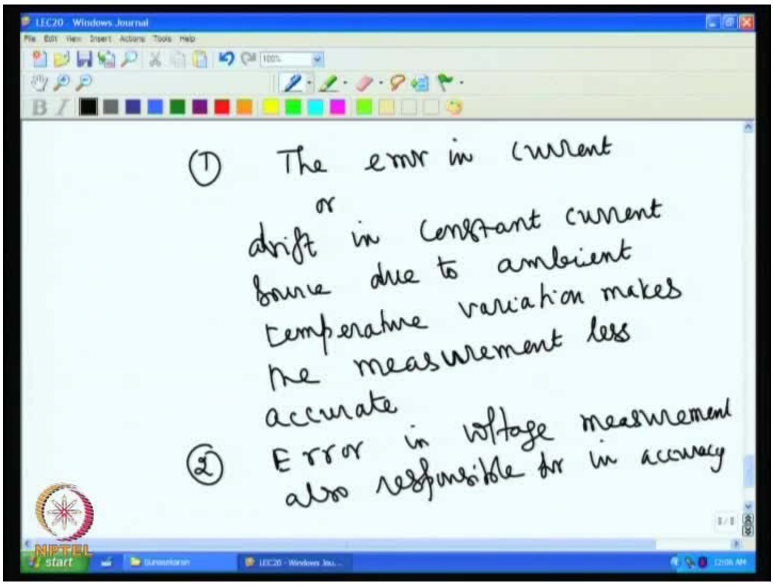

So, net result is you will have error due to this current change, error due to the error in voltage measurement; this will make the measurement not very accurate. So, net point is, the net result is that the error in current or drift in constant current source due to ambient temperature variation makes the measurement less accurate.

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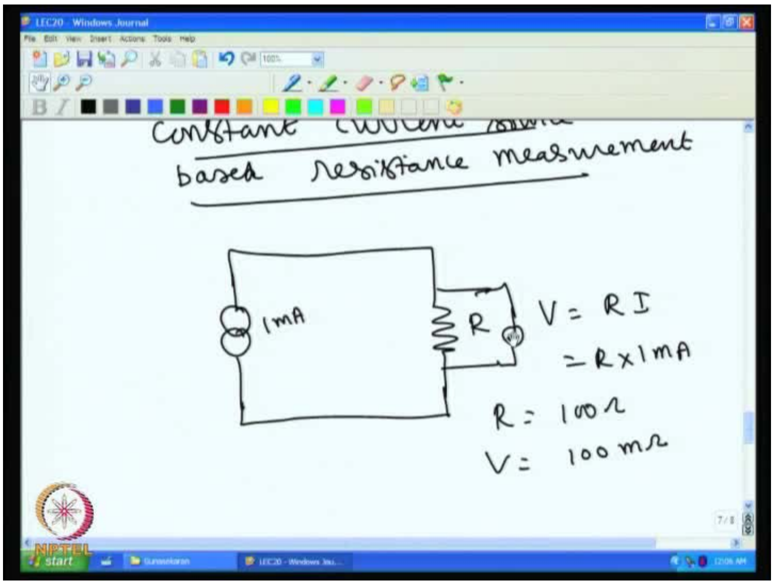

Then the second issue is error in voltage measurement also responsible for in accuracy. So, of course, if you want make it, then reliable then one have to make sure that we design the constant current source, you know, the constant current source which is not drifting, of course, 1 ohm make constant current source with 0 drift. Similarly, we will have a volt meter which has no error and volt meter also drifts with temperature.

So, temperature will play as a very significant error, and then, usual calibration error because what we have set is 1 milli ampere, may not be correctly 1 milli ampere even if it is not changing with temperature; the 1 milli ampere may be estimated wrongly, similarly, volt meter also will have calibration error.

So, all these things makes this is has less accurate compare to our bridge method which we discussed. Where, this problem is not there, no calibration error, there is no voltage drift error due to the voltage; even if the excitation voltage changes there produced no effect at the null point.

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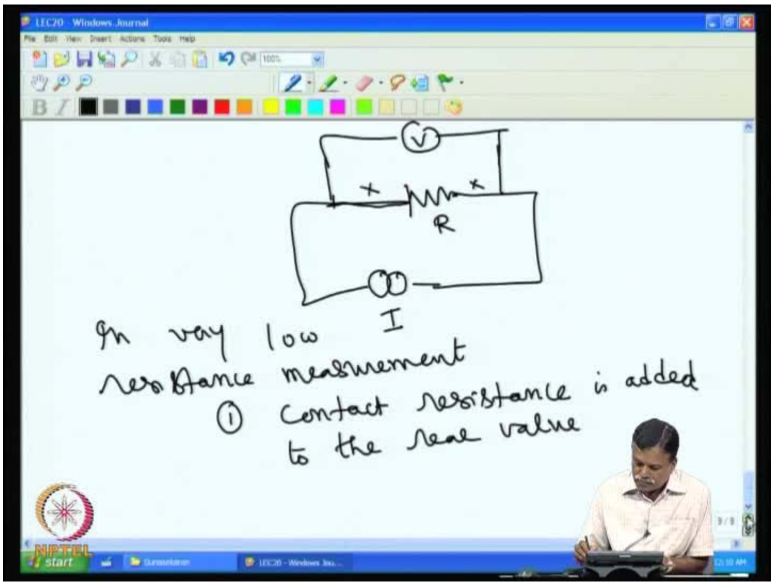

I hope now you understand why the bridge techniques stills surviving. In spite of such model development, the bids, wheatstone bridge still surviving, because it is a most accurate measurement that one can make. Now, let us see what other errors possible in resistance measurement are. Take for example, we have a low resistance measurement, take low resistance measurement is few milli ohm resistance; range: few milli ohms to few micro ohms. If you have this is the range of resistance that is to be measure. Then, what is the problem that one encounters in this kind of measurement.

Now, in this kind of measurement if I put of constant current source, and then, try to measure the resistance, then I put the constant current source, then, I try to I connect the resistance here, and then, try to see the voltage across the resistance, I put this, and try to see the volt meter, here I put the voltmeter and see this.

So, this is a constant current source and this resistance R to be measured. Now, in addition to the error due to the I, and then, error due to V, we have another error that is contact resistance, because we will be connecting this resistance to this through a wire, so, you will have a contact resistance; even if the make it small and to make it, you know, join this one and there will contact here. So, you will have a error due to this, so, there is a error at this resistance. Similarly, there is a error, this is a extra lens are coming, that means you will be getting a voltage at this point, that represent not only this resistance, that represent this plus this and, the, that is a error, and this error will be very high. If you are actually, if resistance value is very low, so, you have, we call contact resistance issues. So, when very low resistance, in very low resistance measurement, we will get the issues like this, 1: the contact resistance, contact resistance is added to the real value.

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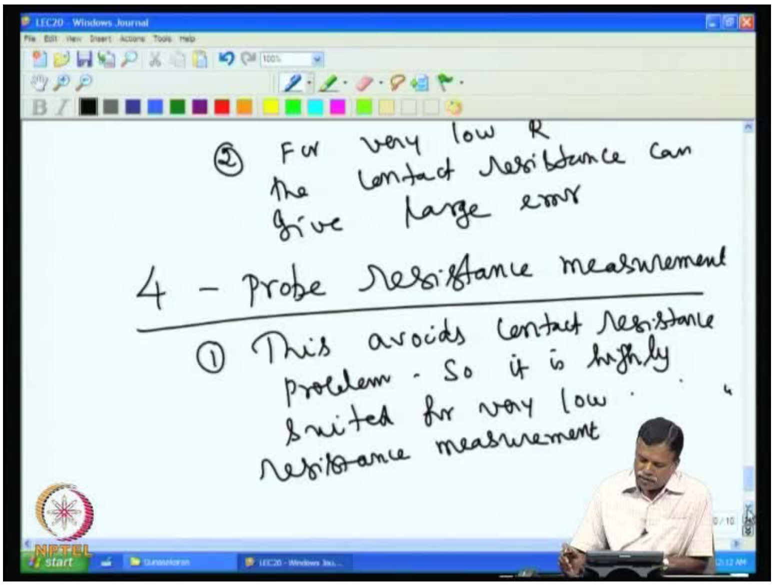

Then second: since it is not a null method, some small amount of current actually will be flowing to this, flowing through this and that will give an error and that any will leave it as earlier calibration error. So, eventually, if I use very, if I make very low measurement, then the contact resistance adds to the problem, add to the resistance value. So, for lower resistance, for very low values of resistance, very low R, the contact resistance can create contact resistance can give large error.

Now, this is the major issue, so, in the case of very low resistance measurement, one have to go for some alternate method to avoid this error; for this only the calibrated method is 4 probe resistance measurements.

This avoids basically the contact resistance problem, avoids the contact resistance problem. So, it is suited, so, it is highly suited for low resistance measurement, very lower resistance measurement.

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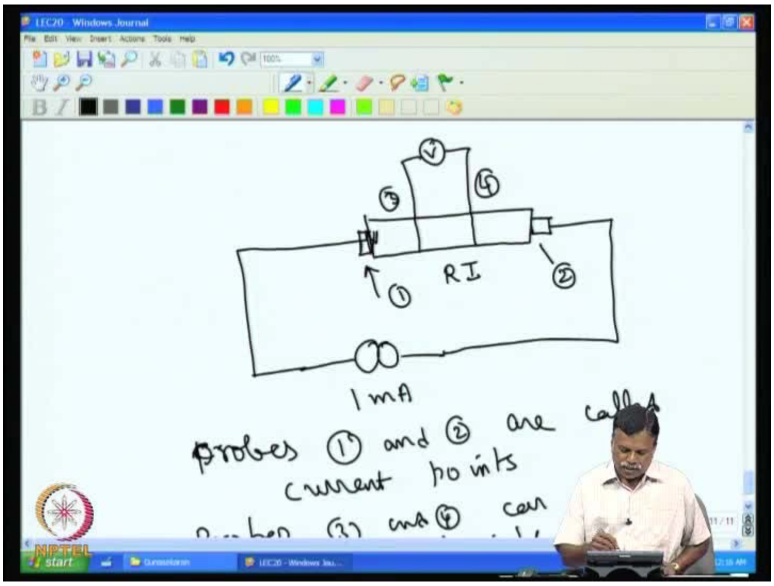

Now, let us see how this contact, how this 4 probe method avoid this contact problem. Let us see how this, a, 4 probe method, is a, how the measurement is made using the 4 probe method. So, in 4 probe method what is done is you have a current source, so, it is a DC source, then you set the current say 1 milli ampere. This current will be selected depending upon the resistance value we come to that quickly. So, you have this, then connect the, if you have, for example, if I have a long, for example, I have a rod whose resistance to be measured, I take the rod, I put as silver paste connect to here and here also put a silver paste connect this to this.

So, we have here one probe here; the second probe is here. Then, I connect the volt meter not here, I will connect the volt meter not at the end, then I connect the volt meter put up probe here and then make it, make a contact here.

So, third probe here, and the fourth probe here, so, that is the volt meter. Since there are 4 points here to probe measurement, there is one point here and one point here to connect the current source, so, 1 and 2 connect the current source, and 3 and 4, probably, you know, we have a at this point, we put a wire, and need not be, it can even be silver pasted or we can make even make contact but good contact to be a made with good mechanical contact also it can be made or it can be even put a silver paste in the permanent arrangement and connect that voltmeter which has a high resistance.

Then, now, that, that means 4 probes now 1 2 3 4. So, there are we called 1 and 2 contacts, 4 probes 1 and 2 we call, probes 1 and 2 are called current probes, current points; probes 3 and 4, 3 and 4 are called voltage points.

Now, so, the idea here is that if I passing the current here, here passing the known current through this, so, this current is always constant irrespective of the value of the resistance. Now, the current that is flowing through that going to produce the voltage drop between this point and this point, because this wire assume that is thick rod, the whole resistance will may be few milli ohms.

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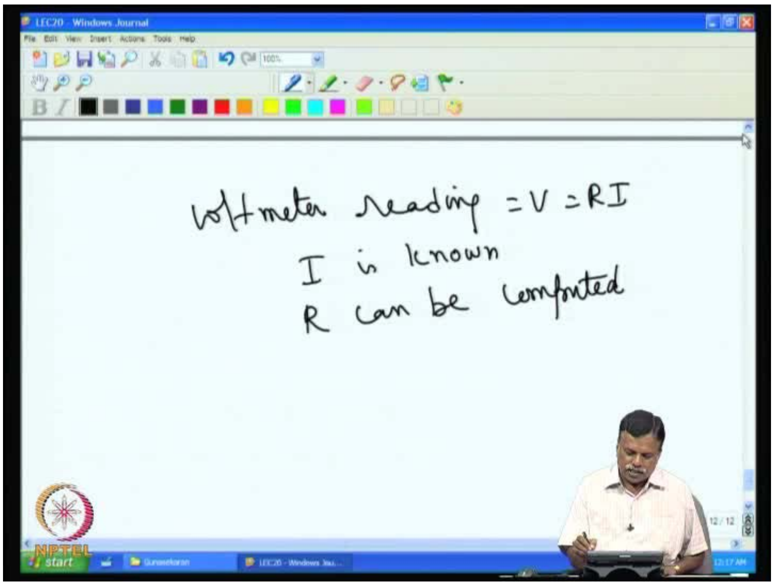

Then whatever current that is flowing, we will produce the voltage drop between these two points that voltage is read by the voltmeter. Now, the voltage at this point would be R into I. So, the voltage is here R into I. So, if I know the volt meter reading that is R into I, so, the volt meter reading is equal to, reading is equal to V that is equal to R into I. Since I is known, R can be computed.

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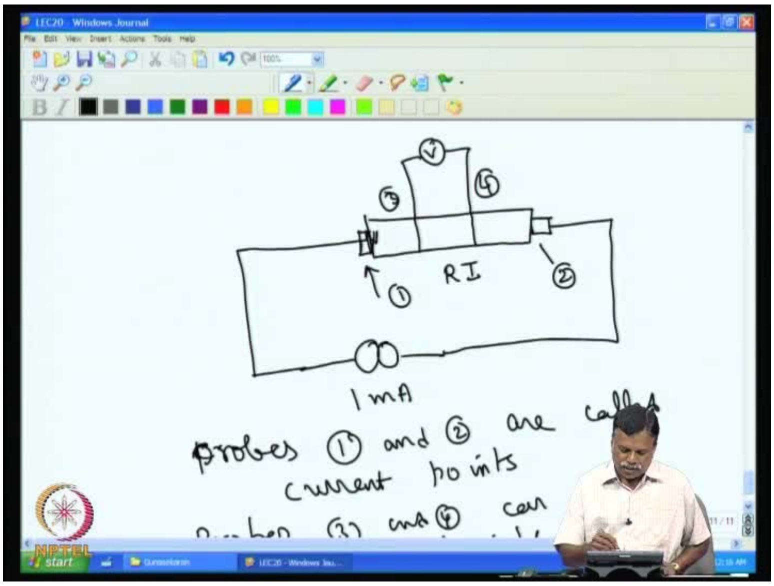

Now, that is the, would the, measurement, they, it is fine. Whether the question is why there is the this method is accurate, and then, it is, the contact resistance is not as problem, because, if you look at the circuit, the voltage that it is coming here only depends on the resistance between these two points, and this resistance and this resistance whatever is added because of the contact, that does in matter, because whatever may be the resistance, the current remain going to be constant only. Whether it is a constant current source, the current is always adjusted to 1 milli ampere. So, this resistance or this resistance has no effect on the measurement.

Now, there can be contact resistances here and here, that also has no effect on the measurement, because the volt meter has very high impedance, the resistance of the voltmeter so high for the resistant measurement. So, there will be a contact resistance at this point and this point. The contact resistance is compared to the volt meter resistance are very small, so, the, there is no error in voltage measurement also. Of course, the error of the volt meter that will be there, but the connection, this connection, this connection, for this a contact resistance, small contact resist is here, small contact resistance here. That actually does not matter, because that contact resistance much smaller compare to the volt meter resistance, because of that, there is no error at this contact that is no error at this contact, so, the measurement is accurate. You will able to make good measurement, even if the resistance is few micro ohms or few milliohms.

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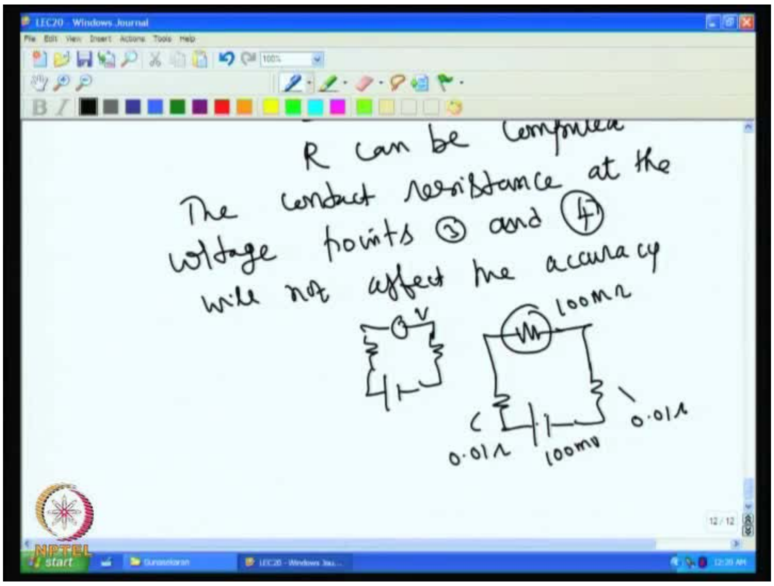

So, the contact resistance at the voltage probe does not matter. So, volt, were reading is a R can be computed. The contact resistance at the voltage points 3 and 4 will not affect the, will not affect the accuracy. This is because, if you the equivalent circuit of the voltage measuring circuit, it looks like, this is the voltage source with two contact resistance connected to the volt meter.

So, if you look at this, contact resistance and the volt meter, so, if the value is, if I plot where draw the thing, it is like this, the contact resistance is may be few milliohms, or few, may 0.1 volt, even 0.01 ohms and this is 0.01 ohms contact resistance, and the volt meter resistance if you see, you know, equivalent circuit of the voltmeter resistance, that will be 100 mega ohm that kind of resistance, because volt meter has very high, a, resistance.

Now, if you see, this is the voltage that is supposed to be measured. Assume this voltage 100 millivolt, this is the voltage drop that is generated across the two ends of the resistance that is, the, this voltage.

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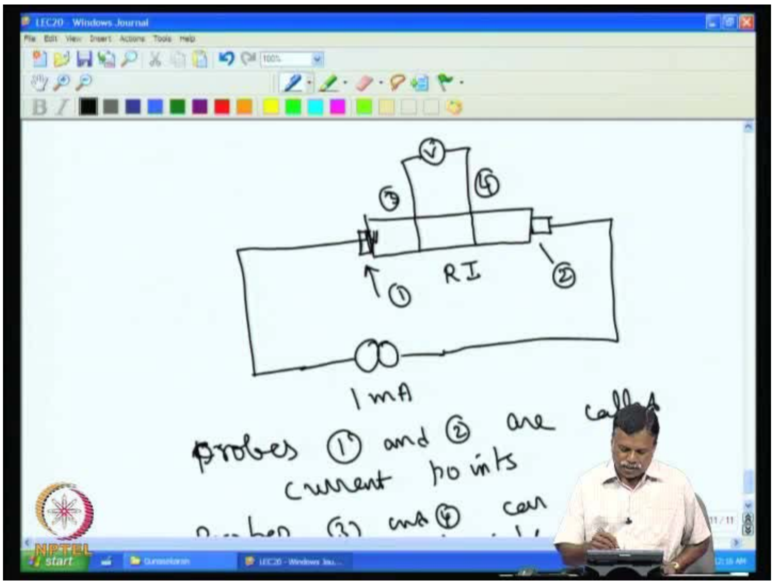

This voltage to be, a, measured. So, the contact resistance here, that is, may be 10 milliohm, 10 milliohm, and this is may be 100 milliohm. Now, the, if you see the error, the error in this circuit is 0.01 no naught now compare to 100 mega ohm is a very small. So, all 100 millivolt whatever is here, appears here, and the error due to 0.01 ohm is almost negligible. If you compute and see, that makes no difference.

So, because of this, this 4 probe method is accurate. Of course, if you have compare with the bridge technique, this is not no one accurate. Only thing is, if it the resistance is very low value, then the 4 probe method is good, because the contact resistance of the wire resistance, all this errors have gone. The error due to this current and the error due to the volt meter, that is will remains there. That error can be avoided only in this bridge technique, not any other technique. So, the other error, for lower resistance, the 4 probe method is good; provided at one takes care of this error due to this current, and the error due to the volt meter which is normally not possible. So, you will have accuracy much less than the bridge technique only.

However, for lower resistance, there is no other go other than using this 4 probe method. So, for all low resistance measurement, 4 probe techniques is used.

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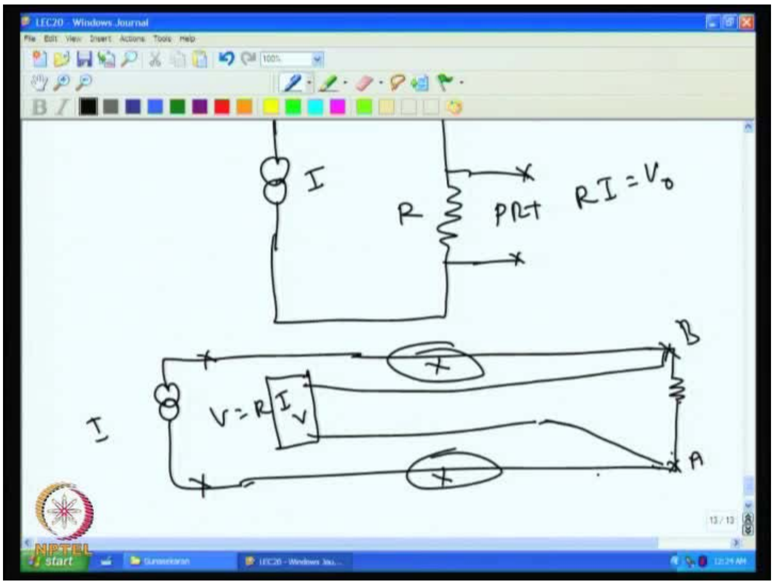

Now, let us see, if I extend this technique, for example, for pattern resistance thermometer which comes in the middle range, what is that I can do? Now, what I can do is the same constant current source I can put here; I can connect pattern resistance thermometer is PRT, then voltage across this, you will give me the PRT resistance, and the corresponding temperature, if this a current source I and it is R, that is the R into I is the voltage output that comes across this.

So, we get the voltage across this which is actually proportional to the resistance value. In this case also one can use 4 probe method, for example, pattern resistance thermometer, in real life, it is to look like this; you have a current source coming from, you know, instrument and the patterns thermometer may be at long distance, may be inside the oven who is temperature to be measured. So, we have put a long wire, and then, connect the patterns thermometer here.

Now, if I measure the volt meter reading, you know, the voltage across this is nothing but voltage across this. So, if I see the voltage across this that should give V R into I if this is the I, but actually, this long, if the resistance of the wire is long, then this resistance and then this wire resistance that matters slots. So, the actual, the tool reading is at this point, at the tool reading is, say at this two point A and B.

So, the tool reading is at this one that means, if I want measure, I should take this 2-wire, and then, put a measuring circuit here. So, this should have I impedance, these measuring units should have I, like a voltmeter is having I impedance. Then the wire, this wire remains is not a problem, so, you will get a tool reading of this resistance. Then this wire resistance, this and this will not contribute for the error. So, this is also 4 probe method, because you have 1 2 3 4 probes are connected and this gives you error without this wire resistance. This is how the patterns thermometer used to make a measurement.

Now, if we look at the current sources, you have different current sources that used. We will see how what are the different current source that is available which one is suited we can see quickly.

Now, one follow me that whether this technique can it be used for high resistance, this medium range of resistance, this technique works well; low resistance, very low resistance also this technique works, alright.

Medium range, even we can also use a bridge, the balancing is not a issue, but if it is I value resistance, for example, if it is 100 mega ohms resistance, then this technique is normally not favored because of the following reasons. For example, the (( )) if have constant current source.

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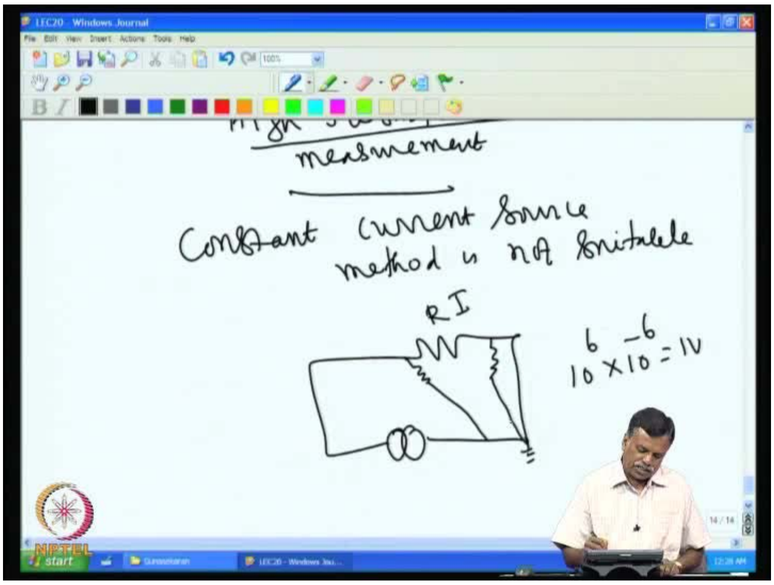

So, high resistance measurement: mega ohm, 10 mega ohm, or 100 mega ohm resistance, high resistance measurement. For this, constant current source method is not suitable, it is not required. This is because we have constant current source mainly eliminates the connecting resistance and the contact resistance and so on, there are very small. So, if I measuring the 1 mega ohm resistance, and if the contact resistance and the connecting a wire resistance are few milliohm, the error that going to come in 100 mega ohm going to a very small, so, the contact resistance is not a issue. So, for high resistance measurement, contact the constant current source method is a not suitable, that is one issue. Then, if I use the constant current source, what is the problem that we will face?

For example, if I is the constant current source for very high resistance measurement, so, the voltage that developed here is R into I. If the resistance is very high, then I set only very small current. Current of micro ampere 1 mega ohm resistance if I take, 10 power 6 into current is 1 micro amps, then you will get 1 volt.

So, since the resistance is if it is 100 mega ohm, then if I keep 1 micro ampere, I need to 100 volt, that means I should make a constant current source here, this one, which have a 100 volt capacity. So, it is not possible to get that kind of voltage rating in the normal current sources. So, you have problem, soon you will find. If you want limit with few volts, then I have to only reduce the current I. The constant current that I am fixing that is to be reduced, then only it is to be possible.

So, constant current source method is not suitable because one is that we have to keep low current, and then, that even if you achieve that, this resistance you will have a leakage. For example, this source will have a ground voltage at one point, one point. Now, there will be leakage from the wire, and all other things, there will be a leakage from this point to ground. Similarly, there will be a leakage from this point to ground.

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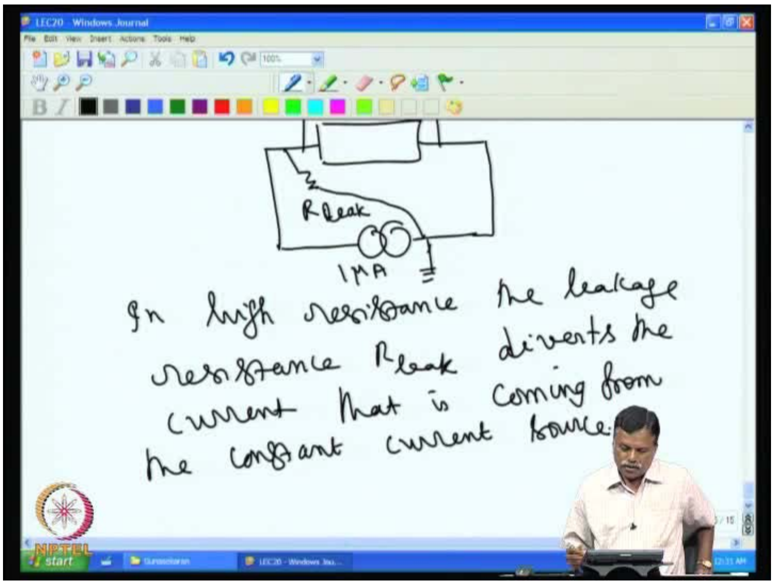

For example, if there is a leakage resistance from 1 resistance, for example, if I want try to measure voltage across 1 resistance like this, then I put this, if it is a, assume is a high resistance, very high resistance, then I put a constant current source. So, the constant current source consume of the circuit which will see now. That is one end is ground, assume that is this end, and then, I connected this.

So, why, we are trying to measure the voltage across this to get the field, you know, to get the value of this. For then, there will be a leakage resistance, the wire will have it is one leakage and leakage current (( )) flowing like this, and this leakage also, you know, if you measuring 100 mega ohm, the leakage resistance also may be the 100 mega ohm. So, what happens is, if am sending 1 micro ampere current here, that 1 micro ampere current, part of them will be lost here to go through this, and whatever current that is flows here is not 1 micro ampere, that will be less than 1 micro ampere, less by the current that is flowing through this. The current that flowing through this is a loss, and that is actually not flowing through this.

So, the leakage resistance makes that this current I, current through the sample is not the, so, the current through the sample is not equal to the set current of the current meter because of this leakage resistance. So, we called it is R leakage, so, R leakage I write.

So, because of the leakage current in the R leakage, the current flowing through this is not the set current, at means the voltage measure not going to be accurate. So, in high resistance, the leakage resistance, in high resistance, leakage resistance R leak diverts the current that is coming from constant current source.

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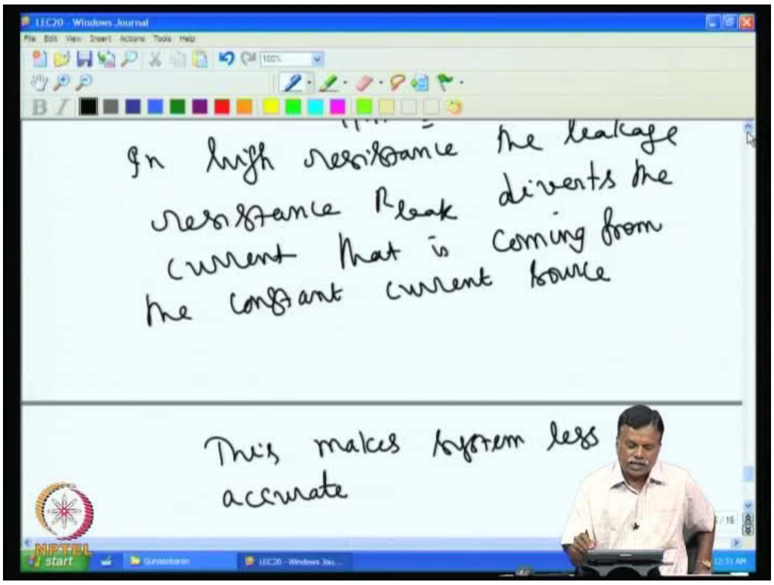

This makes the measurement less accurate. This makes the system, this problem was not there with the resistance is high mainly because, if the resistance is, this problem is not there, when the resistance, when low resistance measurement.

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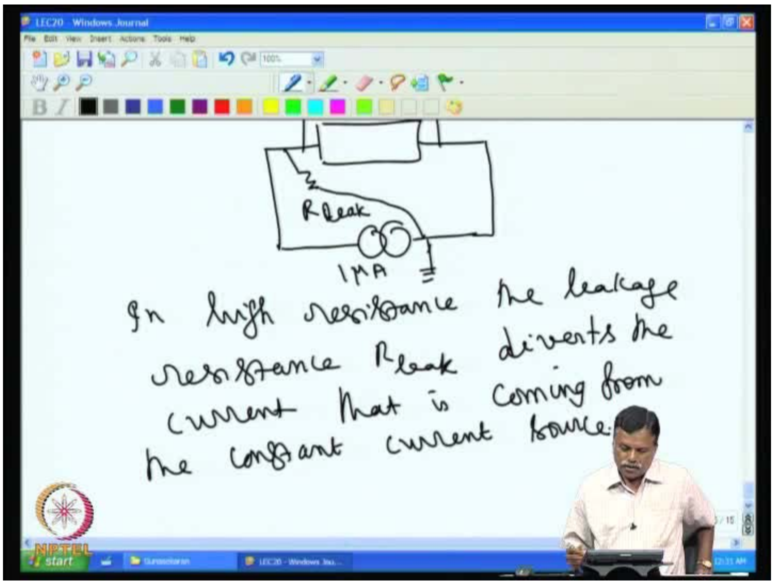

This is because the low resistance is our actual current, constant current source, whatever current we are sending from the constant of source will be high, and this resistances is small, you know, the, at, when the resistance is low, then we can keep large current here and make this current also very small. So, this is, this current will be negligible, and the leakage will not give much error in the case of low resistance; this problem comes only in the high resistance.

So, we, that means what is that technique that we have to use for measuring the value of the high resistance. When we had seen for making measurement with, for low resistance, we can use the 4 probe method, and then, fundamental frequency has also we can use the 4 probe, intermediate resistance will also we can use the 4 probe method, but 4 probe method cannot be used for high resistance measurement because of the leakage current.

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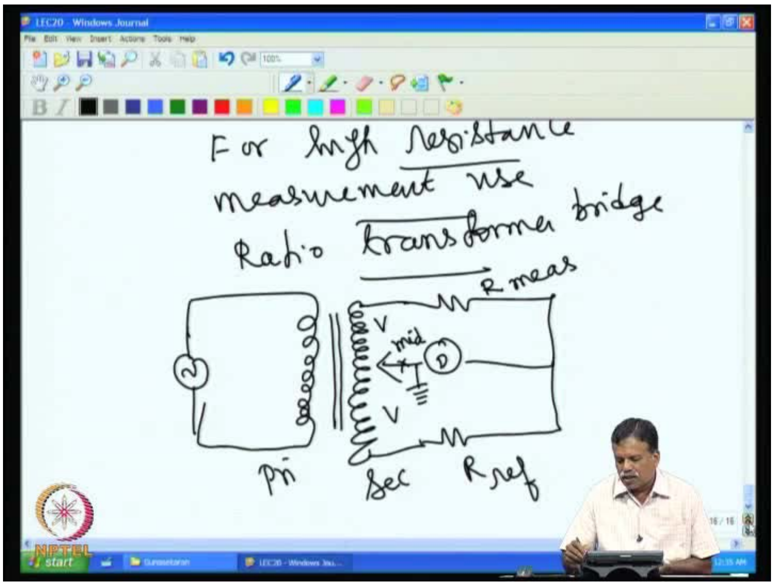

Now, for high resistance measurement, one can use the so called ratio transformer bridge. For high resistance measurement, use ratio Transformer Bridge. Now, what is this technique? how this avoids the error due to the leakage resistance? So, ratio transformer bridge looks like this: you have a AC source, that is connected to the transformer primary, then it has secondary like this, and we have a tap secondary, you know, it has tap (( )) high mu core, very high mu core it is the one. Then, I will put a, for example, I put a deductor here, then I put one resistance, then another resistance here, and then, I connect this to ground. This is the ratio transformer bridge; this is the resistance high resistance which is to be measure is measured; and this R reference; this is a fixed reference resistance, and that is to be fitted here, and this is the resistance which is to be measure that is to be connected here.

So, we had to measure the resistance R accurately using this, and this technique is very popular and it measures the resistance high resistance also accurately. Now, first thing is that this is a transformer; we are connected primary to the AC source. So, you will have induced voltage in this secondary, whatever voltage you have, suppose if it is 1:1, then whatever voltage is put, that voltage will appear across this.

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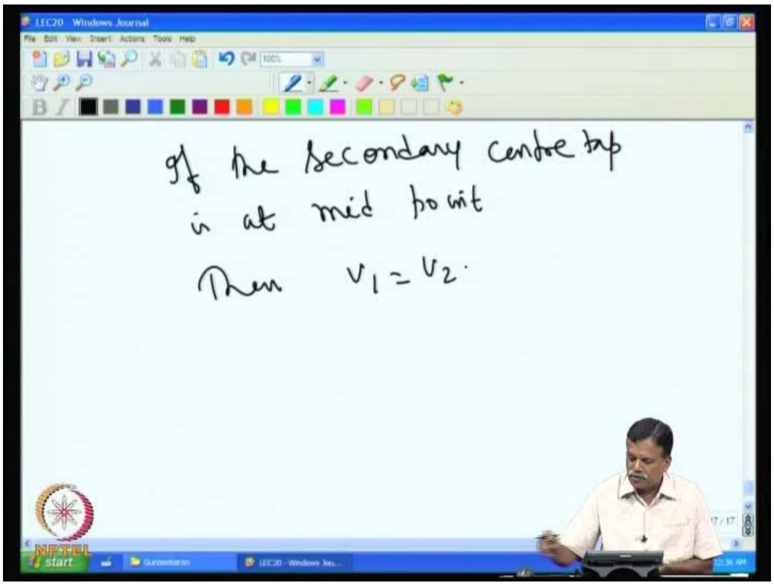

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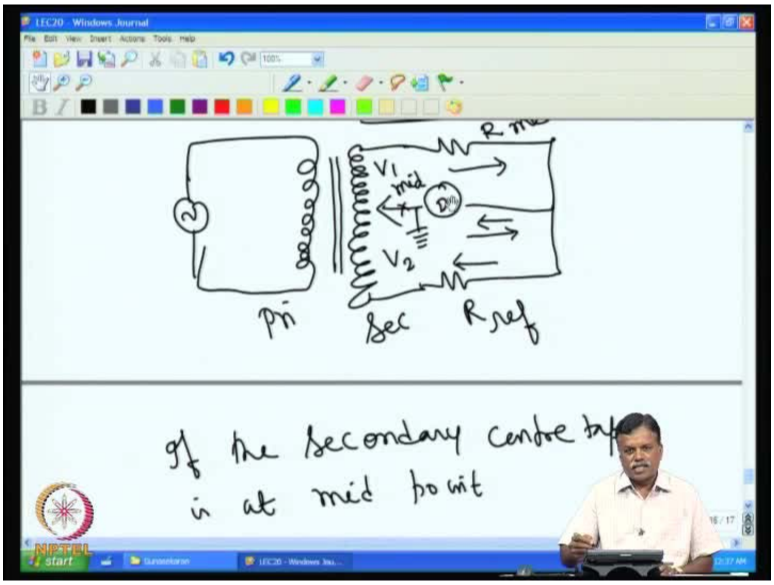

So, if I take this, for example, this is a primary, and secondary. Now, for simplicity assume, then this is at the midpoint, then we know induced voltage here is V and here is V. So, the, both voltages are equal, so, that means the first would be that if the center tap, if the secondary center tap is, tap is, at midpoint, then V 1 equal to V 2, that is this is V 1, say V 1 and this V 2, so, these 2 voltages, this voltage and this voltage are equal. So, if these two voltages are equal, and then, we know that this voltage and this voltage are only (( )) out of phase, that means this will send of current like this, and then, this will send a opposite current, and this current will come like this. So, current in this and this are opposing, that this current in this will be like this, and current in this will be like this.

So (( )) round the current due to this would be in one direction, if you look at here, in this path detector, one current goes this direction and another current this come like this directions.

If these two currents are equal, for example, if I keep it them of middle, in middle, then V 1 of equal to V 2, assume, I put this this value equal to this value. Then these two current also will be equal, so, the current that is going here, you will be, then current that is can be here will be equal. The net result would be the current flowing through the detector would be 0 because this current and this current equal to this current, so, the net current flowing through the detector would be 0, that means if this two resistance are equal, and if this 2 (( )) if it is the midpoint, if it is the midpoint, automatically this voltage will be equal to this voltage, then you will get a 0.

So, in that case, then I know that, I had adjust, this is at the midpoint, so, the bridge is (( )) so it is, so, in 0. I can take this resistance value is equal to this resistance. If it is not equal, then one can adjust the sender to others; one can move this to balance the bridge. Normally what is done is the unknown value is put here and known reference value is put here, and the center tap is adjusted to get a 0. So, if I adjust 0, then ratio of V 1 and V 2 give you the resistance ratio. So, this, we will discuss more in the next class, and there also see how this avoids the leakage resistance problem to make the measurement accurate. Thank you.