Industrial Instrumentation
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Lecture - 7
Thermistor

Welcome to the lesson 7 of Industrial Instrumentation. In this lesson, basically we will discuss the thermistor. As you know, thermistor is a temperature sensitive device, I mean if you increase the temperature, its resistance decreases and by using this property, mainly it is used as the temperature sensor, but it has many other applications in electronic circuits that we will discuss one by one.

Now, contents of this lesson.

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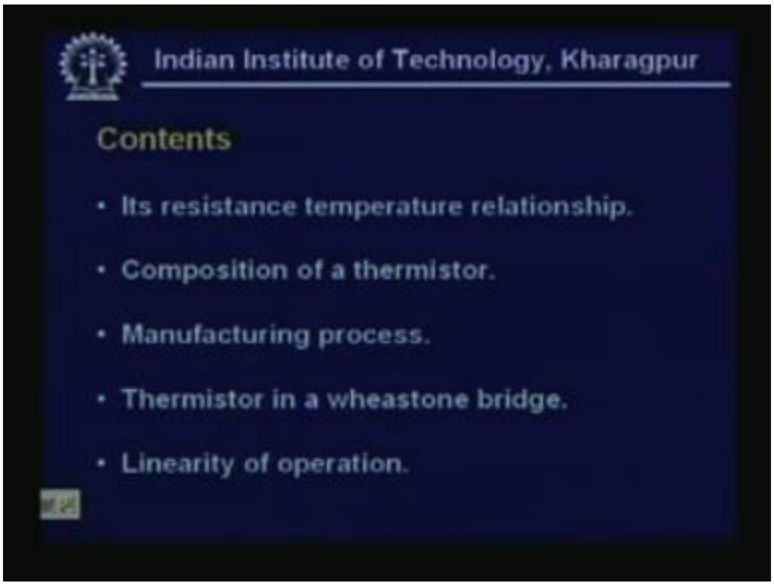

Its resistance temperature relationship or characteristics, composition of a thermistor, because it is a semiconductor material, so you have to look at what are the compositions and how it is made? Manufacturing process, how actually a thermistor is made and thermistor in a Wheatstone bridge. This is very important. We will show that Wheatstone bridge is used to take an unbalanced voltage which is calibrated in terms of temperature and its linearity of operation.

We will also see the thermistor in a potentiometer circuit. Either you can use it in a Wheatstone bridge or in a potentiometer circuit; we will see both. We will analyze both and what is the linearity of operation? Thermistor is very non linear sensor; we will look at all these things.

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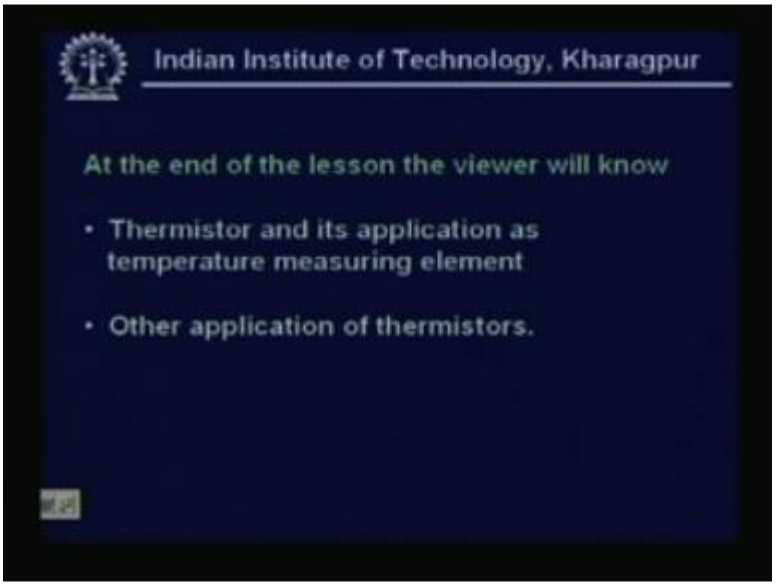

At the end of this lesson, the viewer will know thermistor, its, all its characteristics. It is used in the, how it is used in the electronics circuit, what are the signal conditioning circuitry associated with the thermistor along with its application as a temperature measuring element. This is the main application, but we will touch some of the applications, even though it is not within the perview of the industrial instrumentation like in the power supply circuits, in a Wien bridge oscillator circuits, there are some uses of thermistors in those applications also, as I said other application of thermistors.

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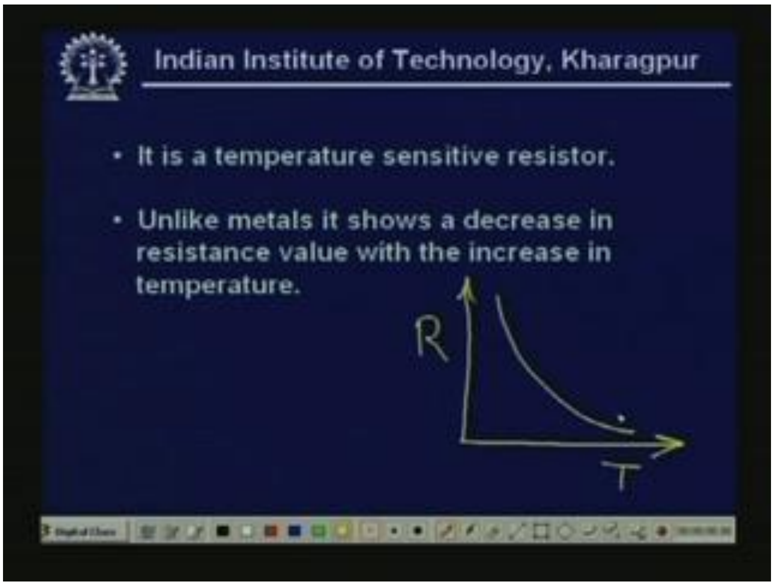

Now thermistor, it is a temperature sensitive resistor. As you know the, all the resistors are temperature sensitive. If we increase the, normally if we increase the temperature, resistance increases. However, unlike metals, it shows a decrease in resistance value with the increase in temperature. This is a unique feature which we have in thermistor, which no other, I mean resistors have this type of property. This is inverse, I mean its, its resistance is not increasing with the increase of temperature; resistance decreases with increase of temperature; rather I should, I mean if I draw it, it will look, the characteristics will look like, like this. You see that, suppose if I draw here, temperature here and resistance here, the relationship is exponential like this one, clear? This is the temperature versus resistance relationship of a thermistor.

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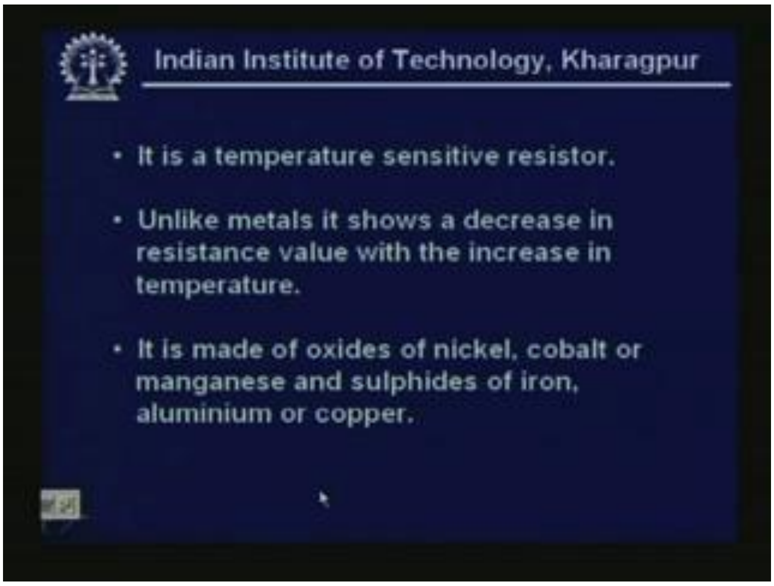

It is made of oxides of nickel, cobalt or manganese and sulphides of iron, aluminium or copper.

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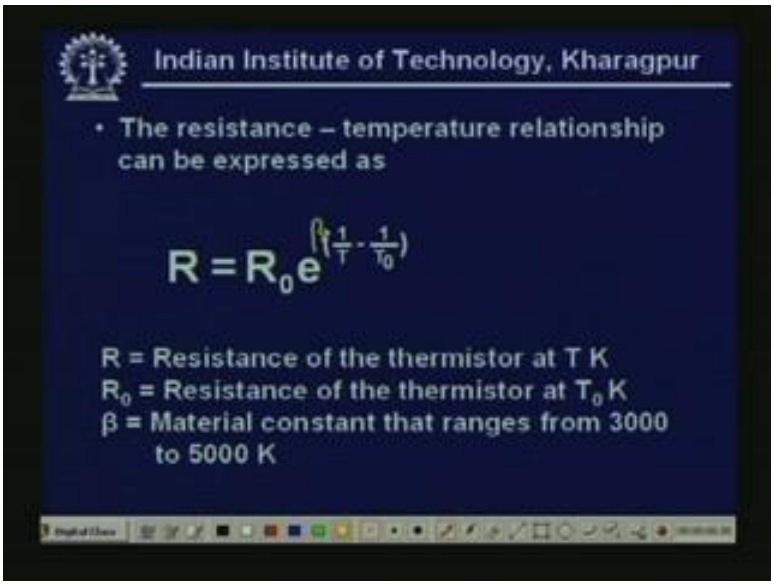

The resistance temperature relationship can be expressed as R equal to R naught exponential to the power 1 by T minus 1 by T naught. What are those legends? R equal to the resistance of the thermistor at T Kelvin, R zero is the resistance of the thermistor at T naught Kelvin and beta is the material constant that ranges from 3000 to 5000 Kelvin. In fact actually, I am sorry, there is a mistake, so it will be beta multiplied by this; the beta multiplied 1 by T minus 1 by T naught.

This is the thermistor, because this is unit less quantity that should be, so beta is a material constant that ranges from 3000 to 5000 Kelvin. Now, one thing is very interesting. You see that as the value of beta, always we desire that the value of beta, it is not very difficult to find the value of beta, because I can measure the temperature, I can measure the resistance at two known temperatures. So, obviously I, from that I can find the value of beta. Now as the beta is higher, always people prefer beta to be, beta should be higher.

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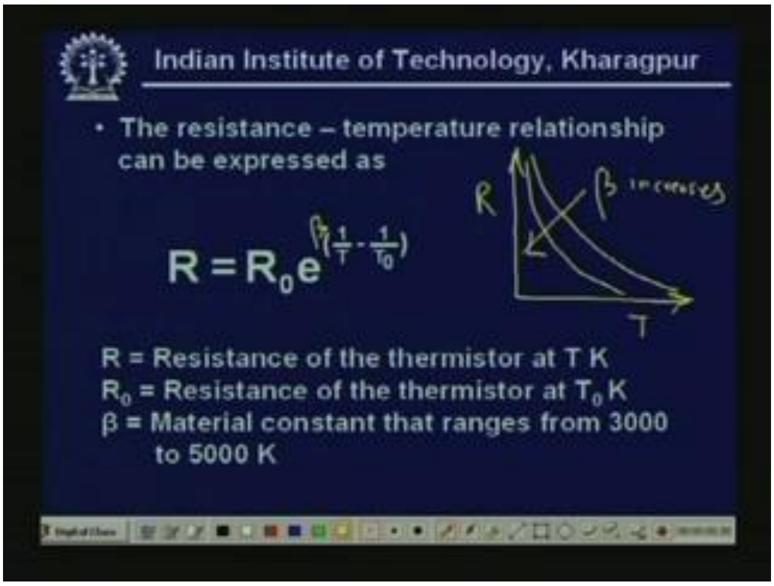

The reason is that if the beta is higher, we will see that if the beta is higher, the relationship will be sharper and sharper and beta increases in this direction, beta increases in this direction. As we can see, if the beta increases, sensitivity that means this temperature versus resistance relationship, sensitivity of the thermistor also increases. That means for the same rise of temperature, I will get higher decrease of resistance. So, that is always an advantage for making any instrument that the instrument should be more and more sensitive, clear? I should go back, as I told you this should be, beta should be multiplied, right?

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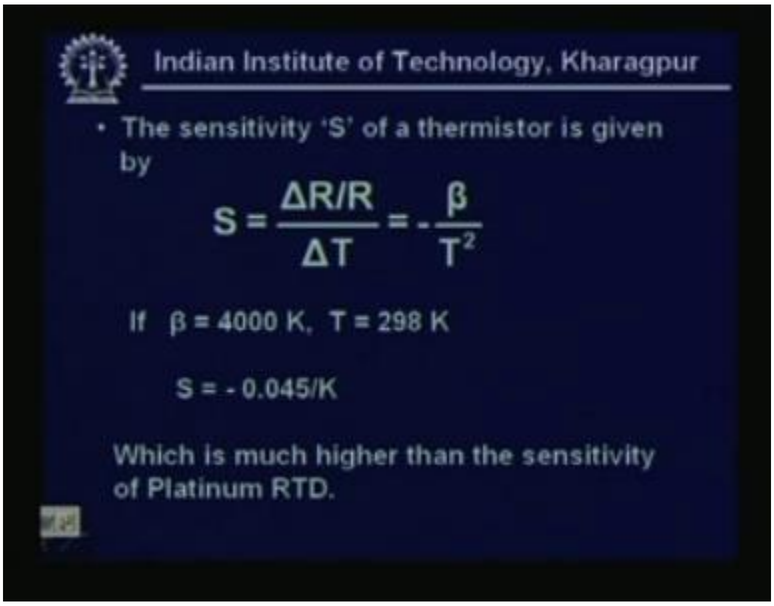

The sensitivity S of a thermistor is given by S is equal to delta R by R by delta T. If you can derive, then I will get minus beta by T square. If beta, for an example if beta is equal to 4000 Kelvin and T is 298 Kelvin, S, we will find the S, the value of the S to be equal to minus 0.045 per Kelvin and this is much higher than the sensitivity of Platinum RTD. Platinum RTD is not that this sensitive, because both are resistance, resistive sensors.

As you know, RTD means basically resistance temperature detector and I mean, if you look at the sensitivity of the RTD, it is much higher. So, it helps to measure the very small difference of temperature.

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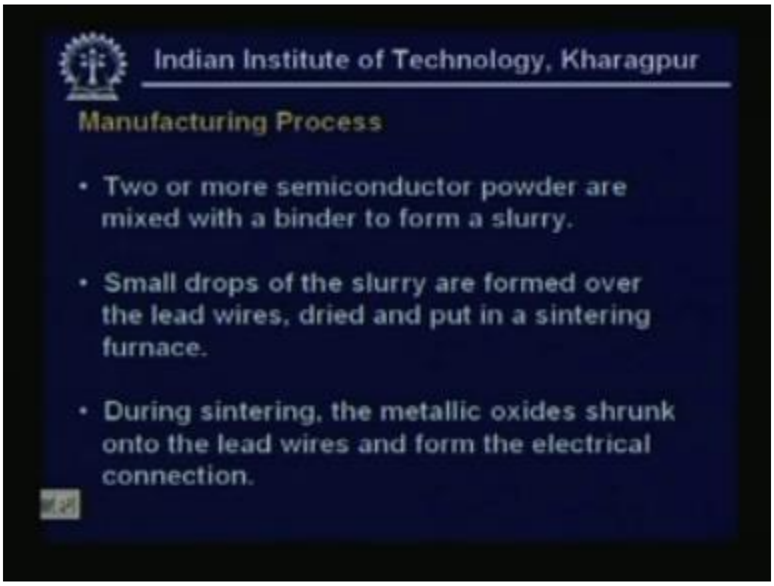

Now, manufacturing process if you will look at, two or more semiconductor powder are mixed with a binder to form a slurry. Small drops of the slurry are formed over the lead wires, dried and put in a sintering furnace. During sintering, the metallic oxides shrunk onto the lead wires and form the electrical connection.

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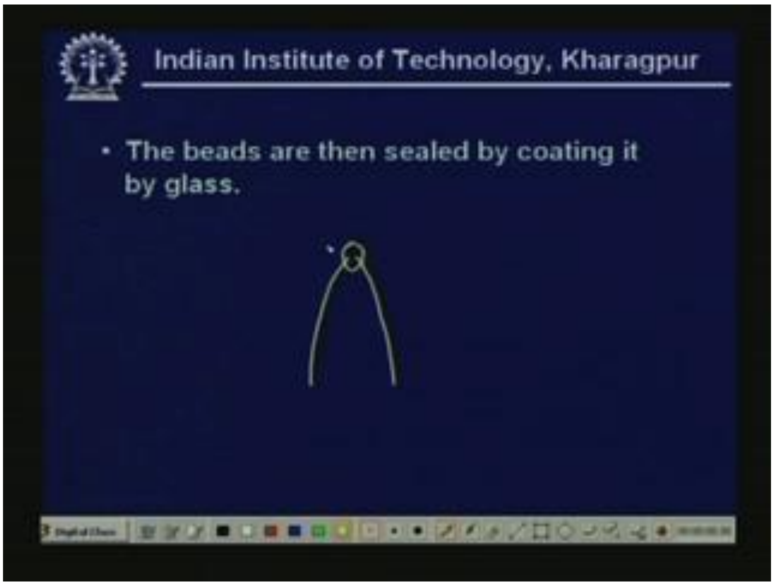

The beads are then sealed by coating it by glass. It looks like this, actually. So, two wires we will take. I should, I will draw it here. I should draw it here, so two wires are there. It is coming out, so the slurries are dropped on this one. Now, you put in a centering furnace, so I will get a bead like this one, right? So, what will happen? So, this will, sorry, this again I will draw it here. Let me erase first, so I can, so the slurries are dropped on this one. So, it is put on a sintering furnace. Now, if you put in a sintering furnace, what will happen? You know it will, it will shrink and this shrinking process will make a very good electrical connections. Now, please note that the thermistor are very sensitive to the, since it is semiconductors device, it is sensitive to moisture also. So, there should be some protection, so that it will not deteriorate with the moisture. Performance totally deteriorates with the moisture, right?

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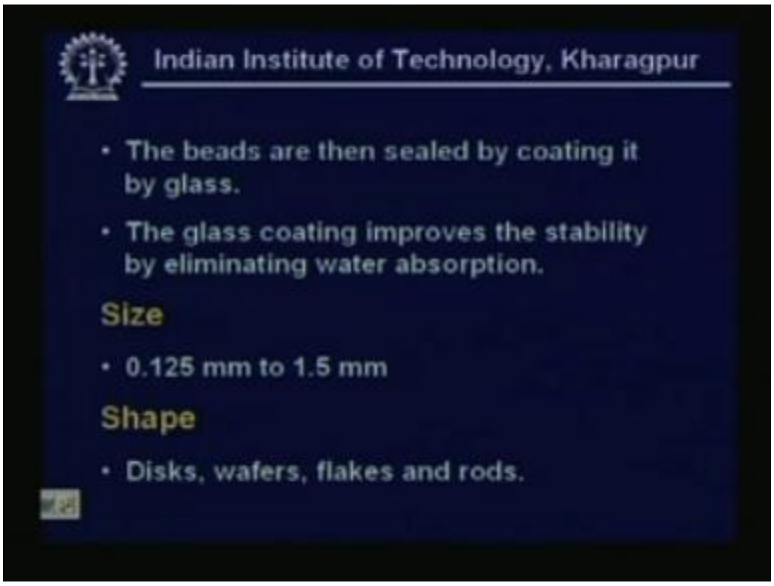

The glass coating improves the stability by eliminating the water absorption. So, obviously if we make a glass coating, so water cannot be absorbed there. Typical size of a thermistor, it is 0.125 millimeter to 1.5 millimeter. As usual we compare the three basic temperature sensors - one is thermocouple, then RTD, then thermistor. We will find that the thermistor has the smallest size, I mean some of the size is so small, it is sometimes very difficult to even to look at the naked eye. It can be made so small.

Now, making this small and there are that, there are two advantages of making such a small size. Even though we have to put on a glass coating and all those things, first of all its time constant of the thermistor is very, very small. If you compare to thermocouple and RTD, the time constant of the thermistor is very, very small that is the great advantage and making in this small size also will allow you to measure the temperature in a very, I mean in a narrow location, very small location, where there no other sensor can go inside, right?

Shape, it has various shape. It can be available in disks, wafers, flakes as well as in rods. These are the different shapes of the thermistor.

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Resistance of the thermistor may vary from few ohms to several kilo ohms. Usually, I mean as you know, the thermistor, one application as I told you that we will find it has, in electronic circuits also, we use it. Now, resistance of the thermistor may vary from the few ohms to several kilo ohms. Now, one thing you should be very careful about the minimum resistance, because the, as the temperature increases its resistance drops, its resistance falls. So, it should not fall in such a way that it will make a, either it will draw a huge current from the voltage source, from battery that means prevention of short circuit should be there and also it should not load the subsequent instrument, because if you have the very low resistance, obviously there is a chance of loading the subsequent, I mean the signal conditioning circuit that is to be also avoided.

Other semiconductor, conductor temperature sensors include the carbon resistors, silicon and germanium. These are the some other, I mean sensors, even though which are not much in use.

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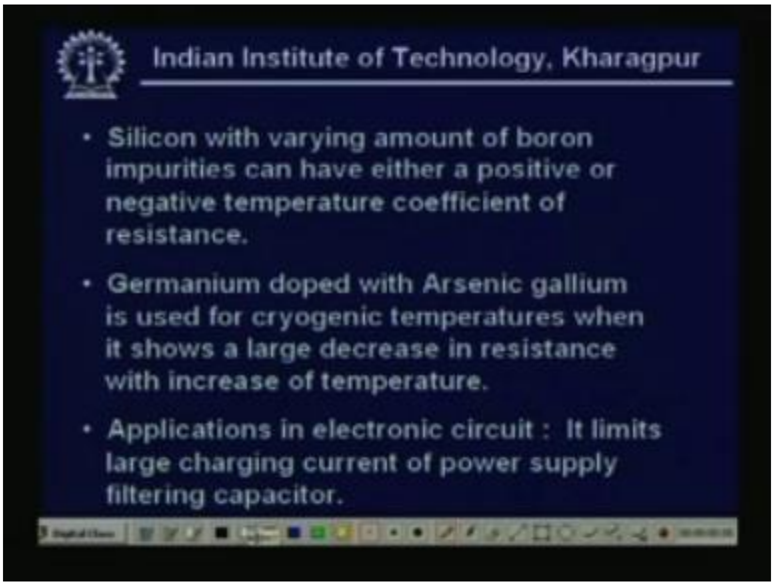

Now, silicon with varying amount of boron impurities can have either a positive or negative temperature coefficient of resistance. So, you can have either positive thermistor or a negative thermistor. We are not interested to have a positive temperature coefficient, because we have many other sensors. But we need negative temperature coefficient that also with a very high sensitivity, which is available in th case of thermistor.

Now, germanium doped with arsenic, gallium is used for cryogenic temperatures, when it shows a large decrease in resistance with increase of temperature. Because this you know, cryogenic instrumentation is one of the very important instrument, instrumentation especially in the measurement of temperature of the liquid helium and all those things. We will find that in such a case of, because many a times it is necessary to measure all these super conducting circuitry and all these things, we have to measure the temperature. So, the cryogenic temperature measurement is, is again another challenge. So, in that type of situations, I can apply the thermistor and it is germanium doped with arsenic, gallium and it is used for cryogenic temperatures, where it shows the large decrease in resistance with increase of temperature and applications in electronic circuits.

It limits the large charging current of power supply filtering capacitor that we will show later on at the end of the lesson that how it can be controlled. This, it has also application of stabilizing the Wien bridge oscillator circuit. It is also used for stabilizing our, I mean …. point stability of the, our analog amplifier circuits, I mean transistor amplifier circuits. So, all these applications we should show later on.

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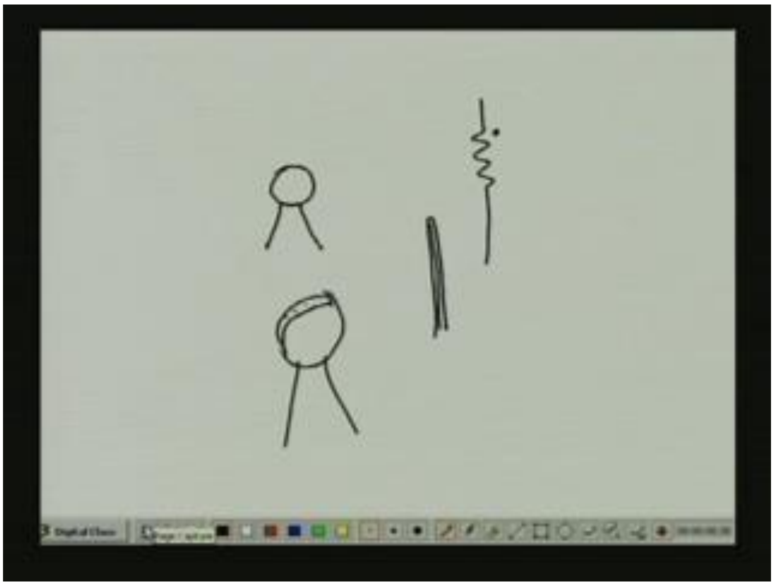

Now, please note that the, in the case of thermistor, if I take a white page, the, it is actually available; those are, because there are two types. Its resistance is drawn like this one and in electronic circuit when they are using, we are using, making a dot like this one. This is the case of thermistors, I mean dots, which is used in an electronic circuit. In that type of the cases, it is available in the form like this one, disk like, so two wires are coming out and it is colour coded. That means it happens, you see that it looks like this.

So, colour code is put here, so that people will know the, what is the, at the room temperatures or at some calibrated, particular calibrated temperature what should be the resistance of the thermistor, right? Resistance is not very constant, as you know that, because it is sensitive. Even though in the case of, suppose the carbon resistors when you buy a, when you buy a carbon resistor there is a colour code on the carbon resistor. So, obviously that colour code, I mean that value depends, I mean value actually refer to some particular room temperatures. Whereas, in the case of thermistor, the temperature is very important, because it is varying a large; it will vary a large at the increase of temperature. So, colour code is there; whereas, in the case of thermistor switch it is used in as a sensor, you will find it is like this one on a glass. So, it is glass coating, so they put the thermistor there, right and wire is coming out, right?

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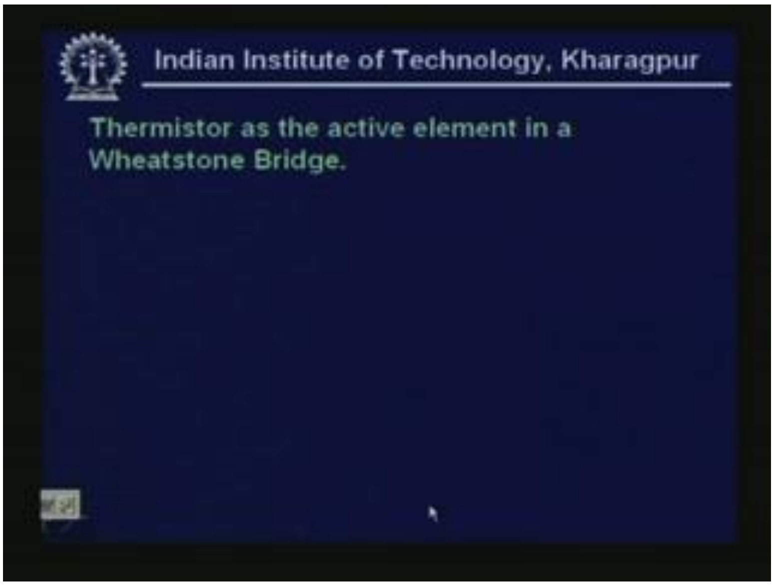

If I go back, now thermistor can be used as an active element in a Wheatstone bridge, because you know, it is a resistance change. Ultimately the, if I want to measure at any temperature, so what will happen that you have to calibrate the output voltage in terms of temperature, if we use the bridge as an unbalanced, I mean if you use bridge in unbalanced condition. So, I have to make the, that unbalanced voltage should be calibrated in terms of temperature. That is actually done in the case of, if we use it as a temperature measuring device.

There are various, I mean, I mean you can use a voltage to frequency converter and frequency can be calibrated in terms of temperature. There are various …. people tried with so many alternative. They have tried also with a thermistor as a frequency changing elements of the circuits. Otherwise, as you know, very standard features that unbalanced voltage of the Wheastone bridge can be given to a v to f converter, so that the frequency will be directly calibrated, can be directly calibrated, which can be measured by some frequency measuring devices and that can be calibrated in terms of some frequency measuring circuits that frequency can be calibrated in terms of temperature; that is also possible.

By all these means, actually people are doing all these different, I mean methods with just to increase the resolution to increase the sensitivity, eventhough it is a quite sensitive device. But in some situations, where the fraction of the temperature change of measurement is important, in that case you have to think of that about change of frequency with the increase of temperatures and all those things.

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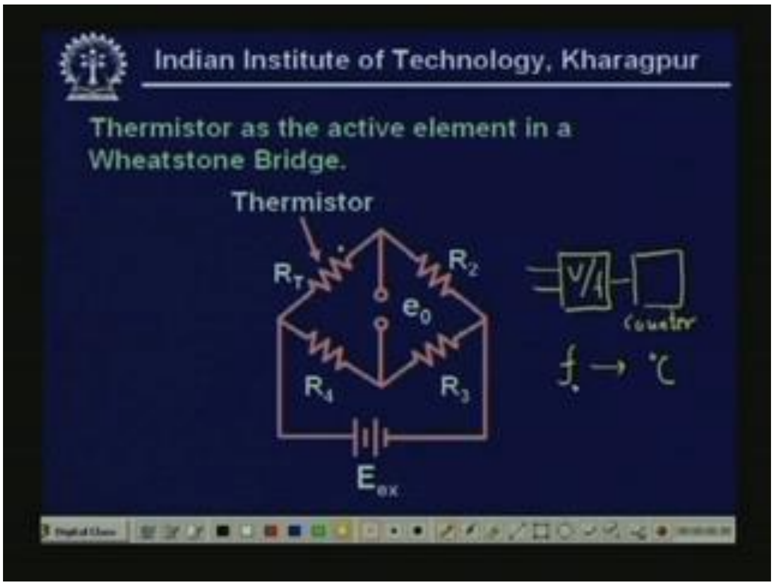

Now, this is a Wheatstone bridge, we have seen and you can see this one. You see, here these are thermistors, so I can put a dot here. If I choose a yellow pen, so I can put a dot here. So, it is thermistor. R's are just simple carbon resistors. These are bridge excitations, E subscript ex and this is our output voltage. Now, if the, initially the bridge is balanced, then what will happen? Suppose all the R T, R 2, R 3, R 4, all are same, all are same, then bridge will obviously be balanced at room temperature, suppose.

Now suppose there is a temperature change in R T, so obviously the resistance value of the R T will change. So, if the resistance value of the R T decreases, I will get an unbalanced voltage. Previously unbalanced voltage is zero, now we get some unbalanced voltage. That unbalanced voltage can be calibrated in terms of resistance change and that resistance change, unbalanced voltage also further can be calibrated in terms of temperature. This unbalanced voltage, I can feed to a, this voltage I can feed to a v to f converter and this, a frequency measuring circuit, a counter or frequency measuring circuit, right?

What it will do? So, it will simply do, it will measure the frequency and the frequency will be calibrated in terms of temperature degree centigrade. The advantage of this type of thing is, as I told you earlier, the resolution; sensitivity also can be increased, because I have the signal conditioning circuitry, where I can make all this, all these type of manipulation, so that I will get the frequency change more sensitive.

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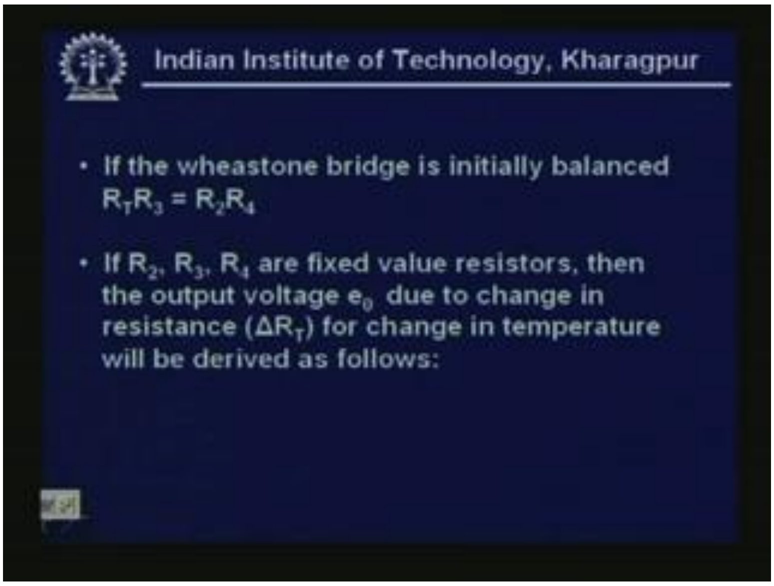

Now, if the Wheatstone bridge is initially balanced, we assume that the Wheastone bridge is initially balanced, even not, not necessarily that the, all the resistance will be equal. If this condition is valid that R T into R 3 equal to R T into R 4, then what will happen is, you can see if R 2, R 3, R 4 are fixed value resistors, then the output voltage e naught due to change in resistance delta R T for change in temperature will be derived as follows.

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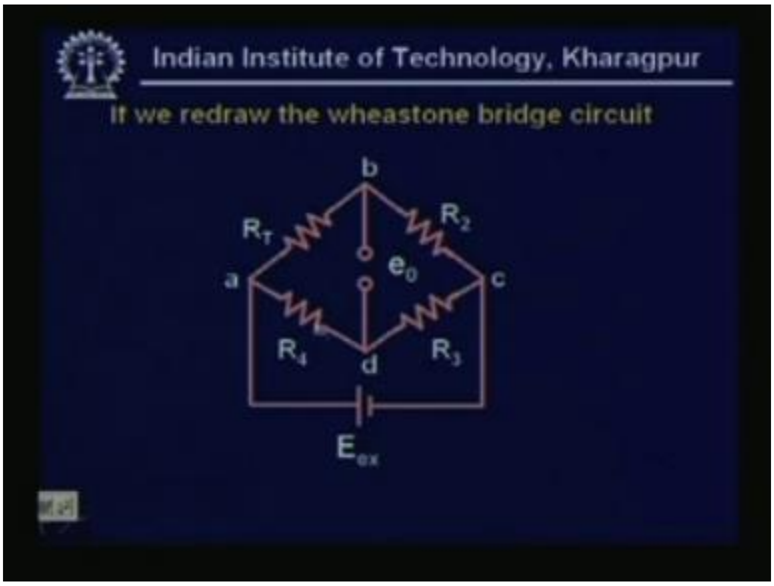

If we redraw, let us redraw the Wheatstone bridge again. So, we will find, so we have redrawn the circuits, we have labeled something a b c d. We have taken in, I mean clockwise direction. This is R T thermistor, then R 2 carbon resistors, R 3 fixed resistors. So, I should rather say that these resistors, R 2, R 3, R 4 is temperature independent. That means if the temperature varies, this resistance, it is, their resistance does not change, fine. We can accept that thing.

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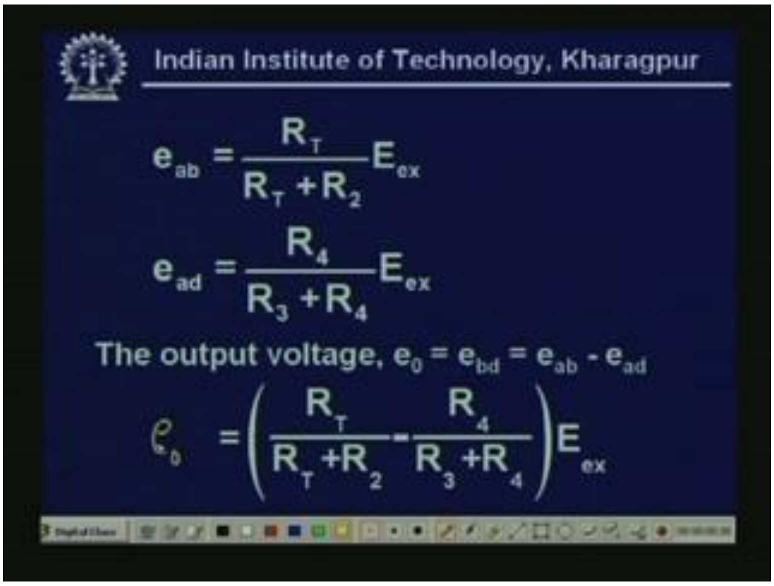

Now, e ab you can simply see that it will be equal to R T upon R T plus R 2 multiplied by E ex, because this is our excitation, isn't it? This is our excitation voltage. Then, e ad will be equal to R 4 upon R 3 plus R 4 multiplied by E ex, where ex is the excitation, right? Now, the output voltage e naught equal to e bd equal to e ab minus e ad equal to R T upon R T plus R 2 minus R 4 upon R 3 plus R 4 multiplied by E ex, right?

So, again this is now, so this is our e naught. So, this is our e naught equal to this voltage, fine, no problem.

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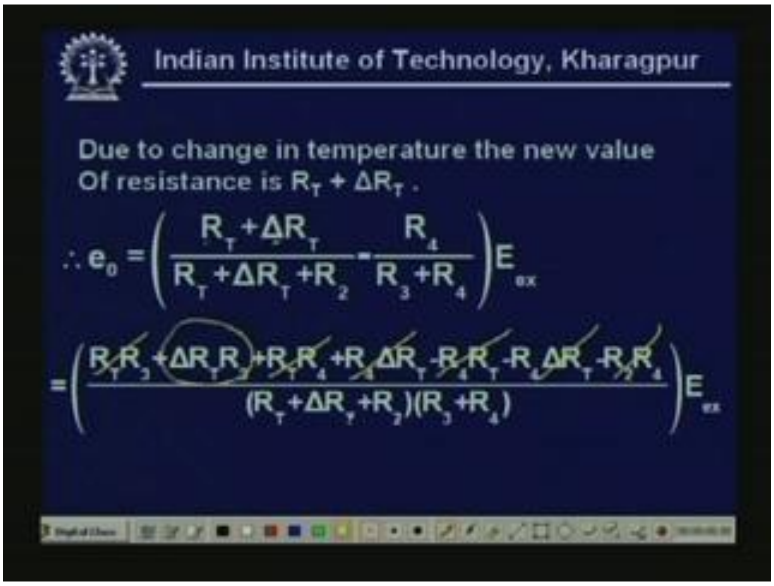

Due to change in temperature, the new value of the resistance is R T. It is no more R T, so it is R T plus delta R T; whether delta will be positive, negative that I am not thinking, that we will discuss later on. There is a change and we said that the R T plus it is delta R T. If it is there, then you see that I can write that e naught, the new value of R T, let me take this one, R T plus delta R T, because it is a new value of R T. What is this new value? This is due to temperature change. R T is replaced by R T plus delta R T in these equations.

So, R T plus delta R T R 2 R 4 upon R 3 plus R 4 multiplied by the excitation E ex. If I make all these cross multiplications, I will get, in the denominator I will get the R T plus delta R T R 2 R 3 plus R 4. Numerator I will get R T R 3 plus delta R T R 3 plus R T R 4 plus R 4 delta R T minus R 4 R T minus R 4 delta R T minus R 2 R 4. Now, interestingly you see that what will happen that here these will cancel out, obviously. If I take out, it will be easier. You see that this and this will cancel out, R T, R T R 4, this and this will cancel out, isn't it?

Then, R 4 delta R T and R 4 delta R T also will cancel out. Now, R T R 3 according to the conditions, this and this will cancel out, is not it? So, if I look at, so what will remain? It will remain delta R T into R 3. So, this is the only factor which will remain. In the numerator R 1 R T plus delta R T plus R 2 multiplied by R 3 plus R 4, right?

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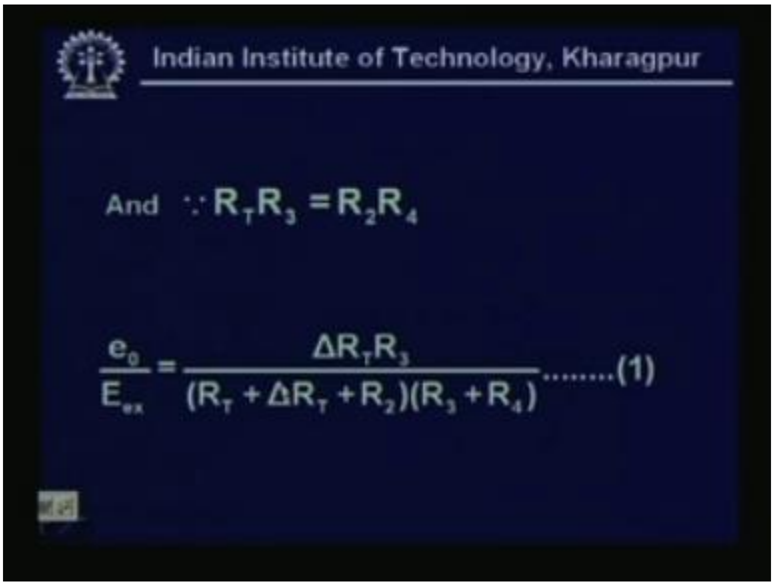

Because the condition is R T R 3 equal to R 2 R 4 that is the reason the first term and the last term was canceled out. So, ultimately I will get the expressions e naught upon excitation E ex will be delta R T into R 3 R T plus delta R T plus R 2 the whole multiplied by R 3 plus R 4.

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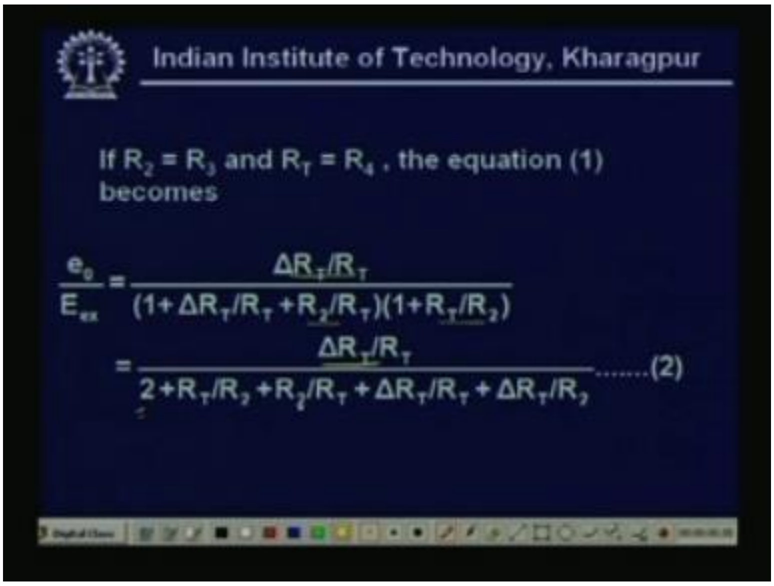

Now, assume that the, if R 2 equal to R 3 and R T equal to R 4, the equation 1 becomes, you see R T delta R T by R T the, I mean upon 1 plus delta R T by R T plus R 2 by R T 1 plus R T by R 2. If you just, in the numerator it will remain same; it will remain same in the numerator. So, in the denominator you can multiply a 2 will come, because you see here this R 2 R T and R T R 2 if we multiply, we will get another one. So, this will make 2, then R T plus by R 2 R 2 by R T plus delta R T by R T plus delta R T by R 2. This is equation number 2, right?

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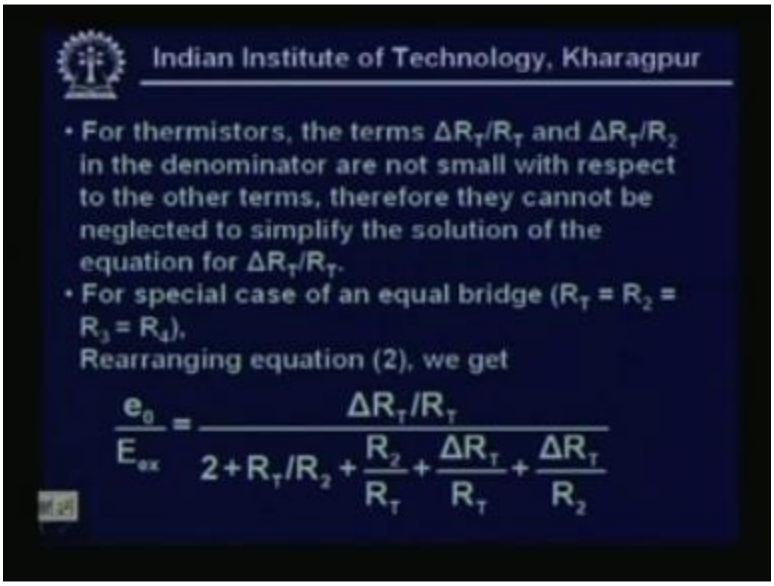

So, finally I will get an equation. For the thermistors you see, the interesting term is that in the, in the last equation, equation number 2 that the terms delta R T by R T and delta R T by R 2 in the denominator are not small enough with respect to the other terms. Therefore, they cannot be neglected to simplify the solution of the equation for delta R T by R T. For special case of an equal bridge R T equal to R 2 equal to R 3 equal to R 4, rearranging equation 2 we get, e naught by E ex equal to delta R T by R T upon 2 plus R T by R 2 R 2 by R T plus delta R T by R T delta R T by R 2.

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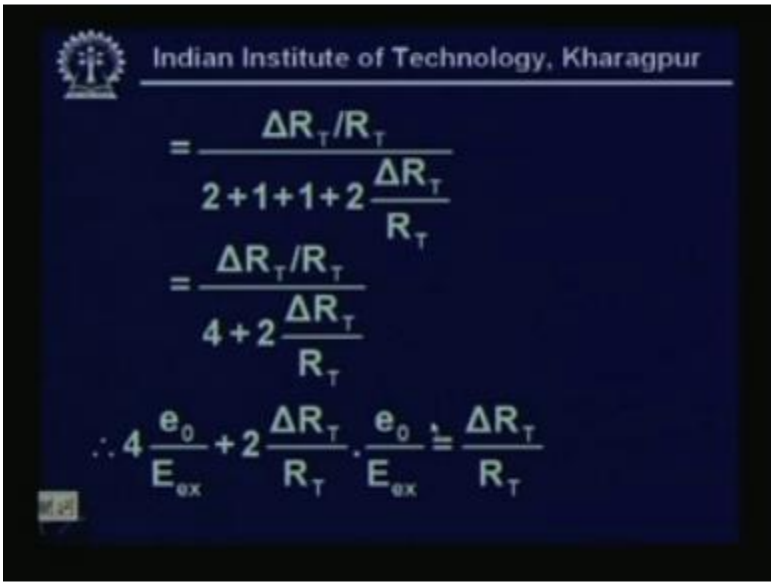

If you do these things, so ultimately I will get, because if the R T equal to R 2, we have assumed already, so I will get an expression, we have assumed that the R 2 equal to R 3 and R T equal to R 4. So, I will get an expression which looks like, we have assumed R 2 R T R 2 R 3 R 4 are same, so I will get an expression like this one. So, this will lead to delta R T by R T 4 plus 2 multiplied by delta R T by R T, right? So, if I make a little arithmetic manipulation, so this will be actually, this will be minus sign; we have, minus sign should be there, 4 e naught by E ex 2 delta R T by R T minus e naught by E ex is equal to delta R T by R T, right?

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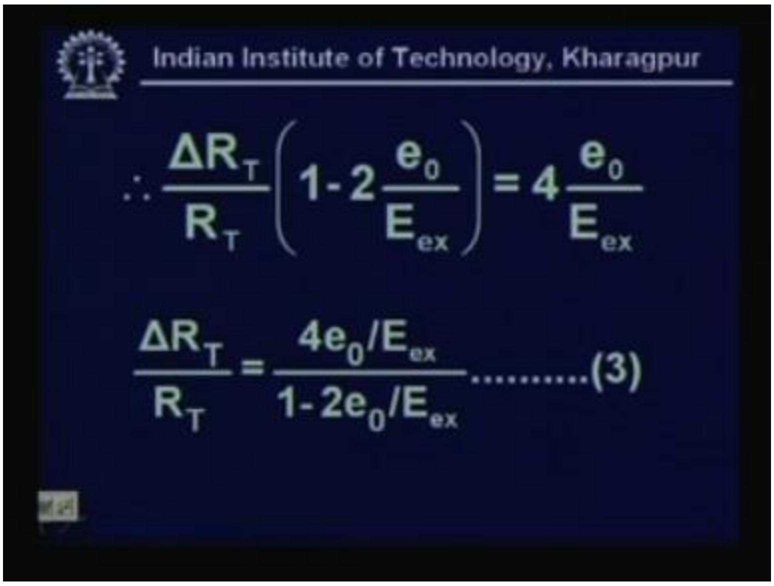

So, delta R T by R T 1 minus 2 e naught by E ex equal to 4 e naught by E ex. So, delta R T by R T equal to 4 e naught by E ex 1 minus 2 e naught by E ex, equation 3.

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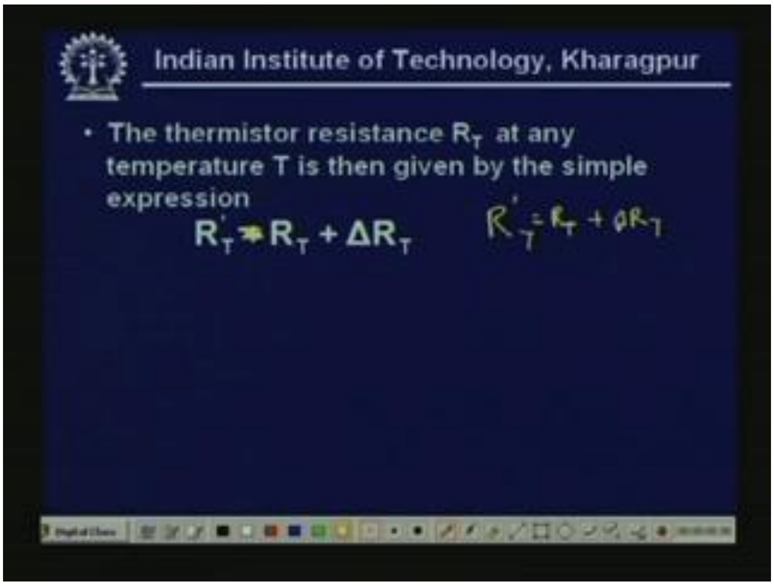

Now, the thermistor resistance R T at any temperature T is then given by the simple expression. Actually this is wrong, mistyped, so this will be equal, right? This will be equal sign that means R T dash equal to R T plus delta R T, right?

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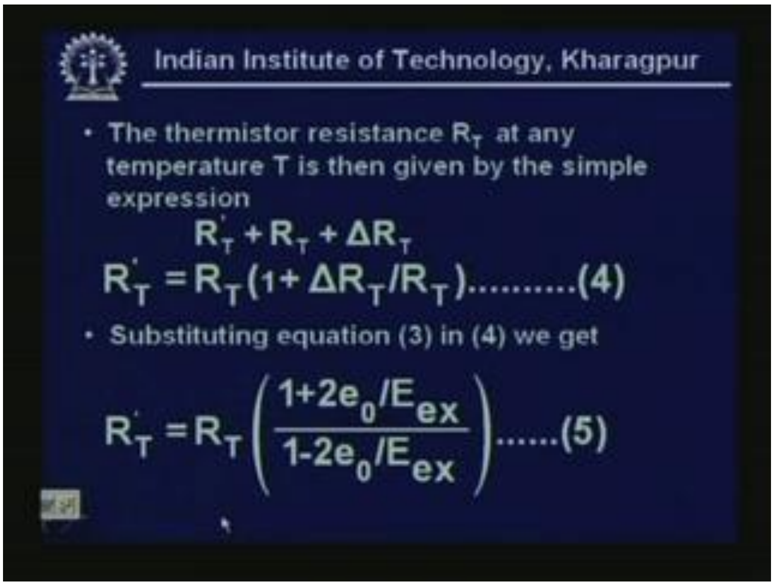

So, I can write that if I take R T common, so R T 1 plus delta R T by R T, so this is equation number 4. Substituting equation 3 and equation 4, we get R T dash equal to R T 1 plus 2 e naught by E ex 1 minus 2 e naught by E ex. This is equation number 5, right?

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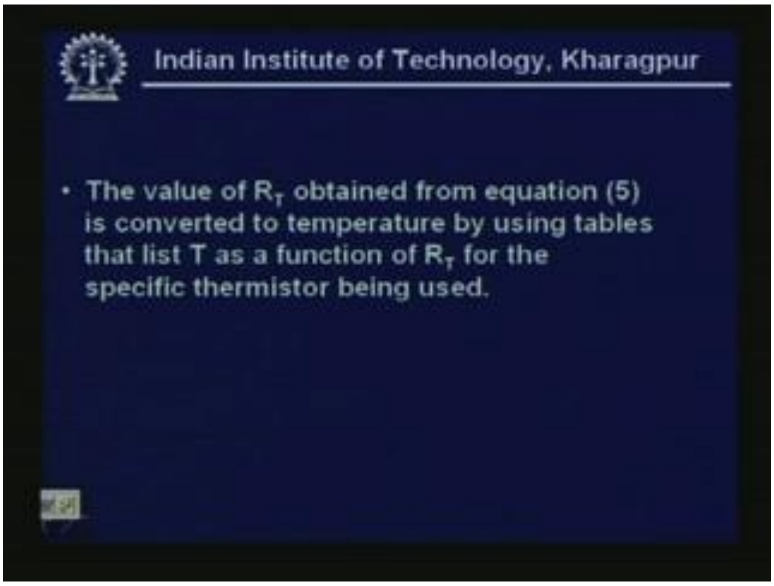

The value of R T obtained from the equation 5 is converted to a temperature by using tables that list T as a function of R T for the specific thermistor being used, right? So, we will get a table. So, we can find it; we can make a calibrator and as you know, ROM and you can make calibrated ROM for also this type of purpose. So, if the, ROM, the advantages is those linearity problem, nonlinearity problem can be easily eliminated in the case of thermistor.

Even though it is an excellent device, very sensitive, very small in size, I mean you can, it can, it can be used for the dynamic temperature measurement, everything is there, but the problem is that non linearity. Even though thermocouple is also nonlinear, but the advantage of thermocouple, for a short range you can consider as a linear sensor. I am sorry.

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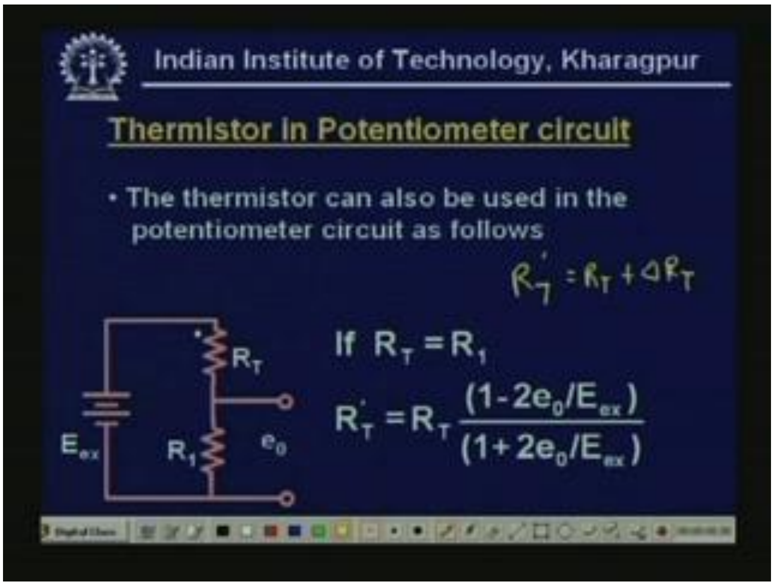

Now, thermistor also can be used in a potentiometer circuit, right? You see, there are various potentiometer circuits; also used in the potentiometer circuits as follows. You see, this is one of the thermistors which is used in the potentiometer circuit, right and you see here that this, this should be the sign. So, this is the thermistor R T and R 1. In this case if R T equal to R 1, so R T dash will be equal to R T. That means change resistance, where R T dash, as I told you earlier, equal to R T plus delta R T. R T dash equal to R T 1 minus 2 e naught by E ex excitation upon 1 plus 2 e naught by E ex.

Now, interestingly one common question arises. What will happen if I flip it? That means if I put R T here and R 1 here that means the circuit, if the circuit looks like this, then what will happen?

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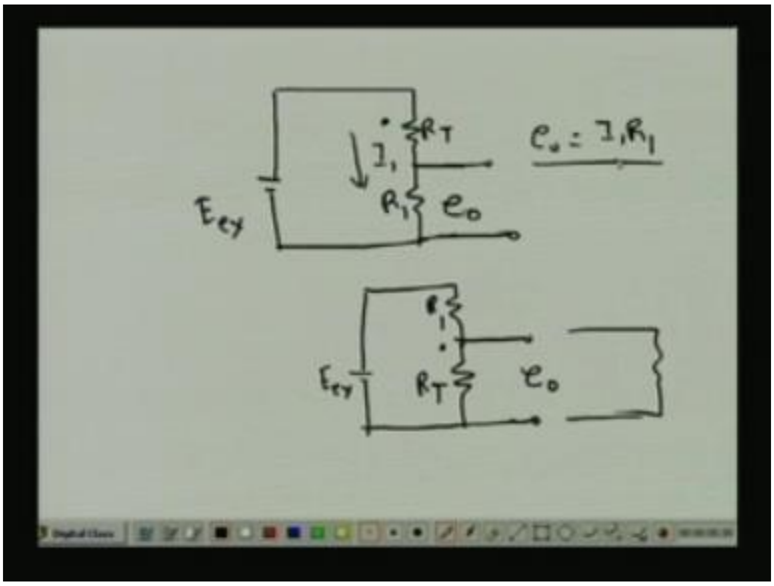

If I take a white page that means suppose I have an excitation, let me take, first erase this one. That means if I take a, that means actually our circuit, we got that like this one, is not it? Thermistor here, R T we have connected here. This is excitation E ex. I am connecting this output voltage, this is R 1, right? Instead, what will happen if I make the circuit like this one? R 1, I will put the thermistor here. You remember in the previous, some, some time back we have discussed the instrumentation engineers must consider the loading effect of the, of the thermistor in case of temperature. Why it is not used? You see, like this one, is not it, here.

Now, what will happen if the temperature rises? If the temperature rises, you see the, the thing will happen, this resistance will fall and fall, right? So, the impedance of this resistance, of the impedance from looking from this side will be different, right? In some cases it will be, some value in some other cases, so it will make the problem in a subsequent signal conditioning circuit. Then, if we have a signal conditioning circuitry here, so that will, designing that type of circuitry will be different.

Whereas, if you make the circuit like this one, you see the, I will get a, some impedance R 1 always same, right? So, that is the reason instead of connecting like that I put a thermistor here, so this circuit should not be used. So, you should use this circuit. So, what will happen if the temperature changes? This resistance will fall and we will get more current through this resistance, which is in series and I will take the output voltage.

So, obviously output voltage also will increase, because if the current is I, I 1 suppose, so I will take the current e naught equal to I 1 by R 1. If R 1 increases, R 1 decreases obviously, sorry, the I 1 increases because if the resistance falls, if the resistance falls obviously I 1 will increase. This value will be, I mean value of the voltage will increase. So, as the temperature increases, the e naught will increase, right because this current will increase, because this has fallen down, right?

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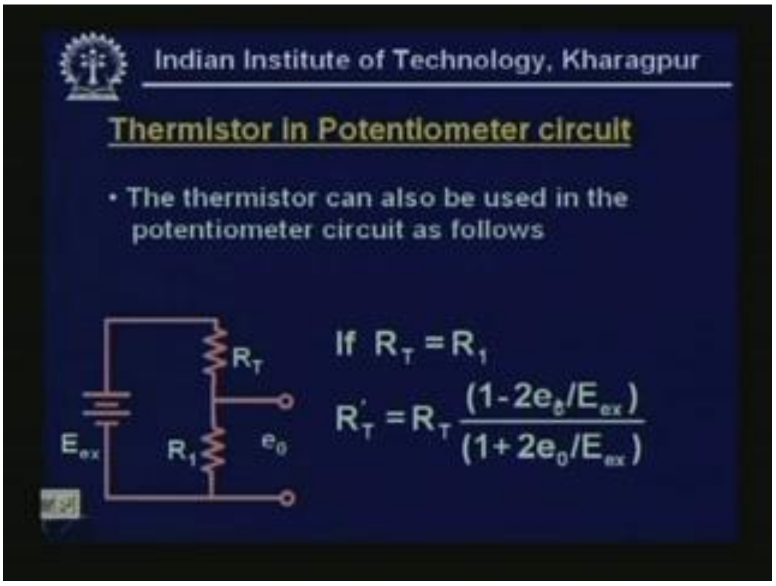

So, that is the reason we have got the expression R T dash equal to R T 1 minus 2e naught upon E ex excitation upon 1 plus 2 e naught by E ex, right? This is one of the circuits.

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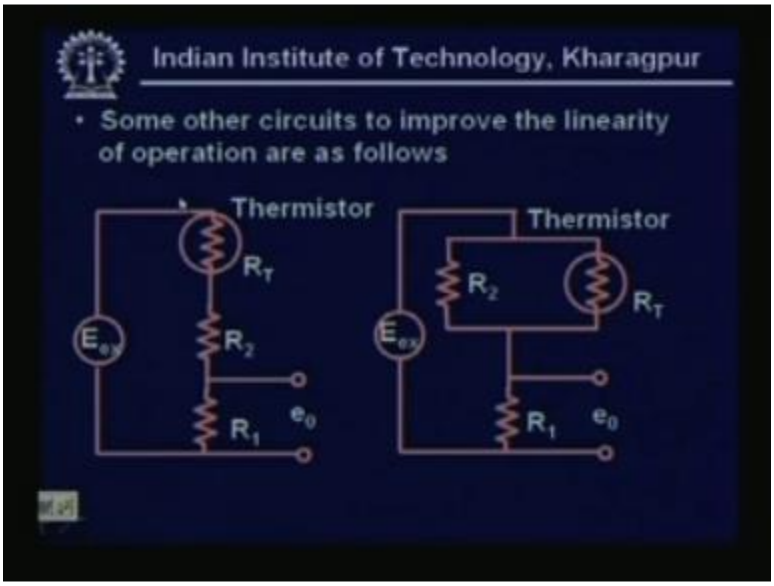

Some other circuits to improve the linearity of operation are as follows. You see, some of the circuits we have shown. These various circuits to influence the impedance, output impedance and all those things, these are the circuits; we will see. So, this is the thermistor here. Instead they have put a circle; instead of putting a dot, they have put a circle like this one and this is another circuit. So far, the thermistor as we increase the temperatures I mean sensing devices, we have seen that, we can also prove analytically that whether you use it in a bridge or in a potentiometer, its sensitivity, resolution does not, I mean vary much. It does not vary at all.

But, however we will find that if I, if we use a sensor like this one, I mean if we use a, suppose a circuit like this one, I will get always some advantages. I will show you what is the advantages?

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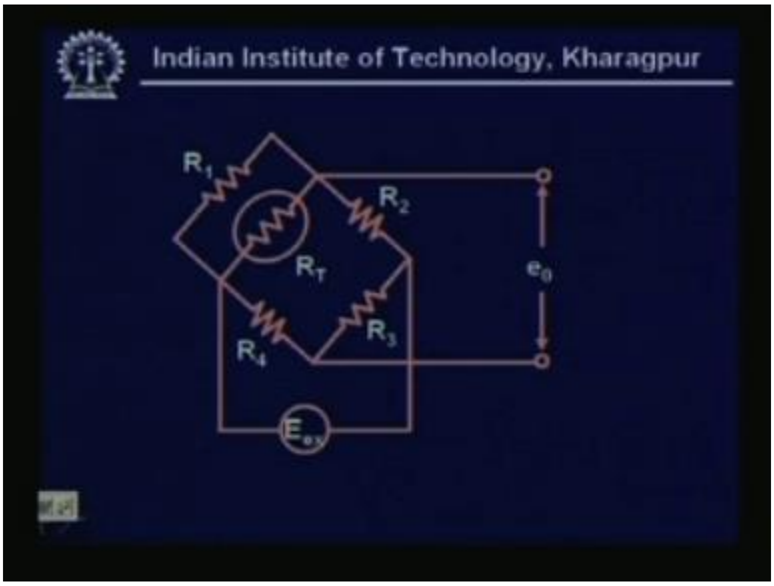

This is another circuit of the thermistor, which is used in a bridge circuit. You will see here, there is typical reason why we have connected a resistance in parallel with the thermistor. Now, as I told you, thermistor is a nonlinear device. So, linearity is a great problem with the thermistor, so what they are doing? They always, there is a common thumb rule that you use a resistance in parallel with the thermistor, right? So, what will happen you see?

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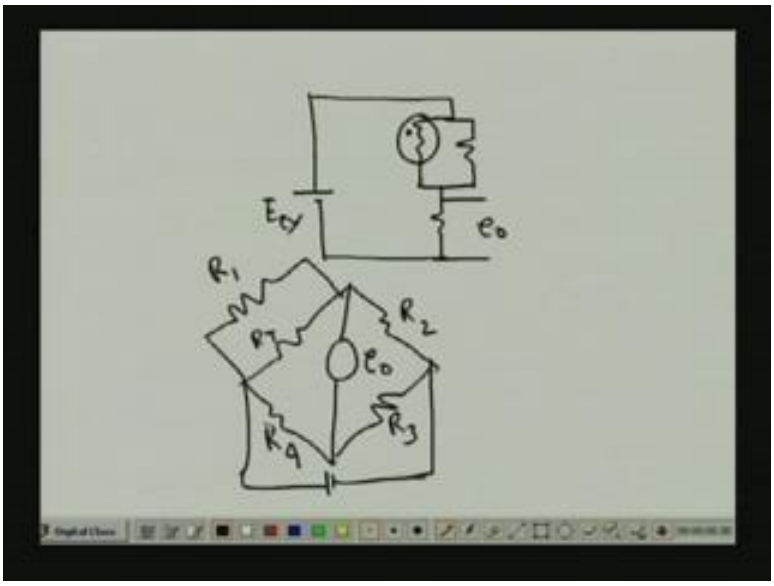

So, I have a thermistor. Any circuit, we have seen two circuits; so, one is a circuit like this one, right? So, this is a thermistor and like this one we have seen, right? I can take the output voltage from this position or we have seen a bridge circuit, excuse me. So, we put a bridge, we put the resistors here, right? So, this is R T. So, I put a resistor in parallel and this is R 2, R 3, R 4, clear?

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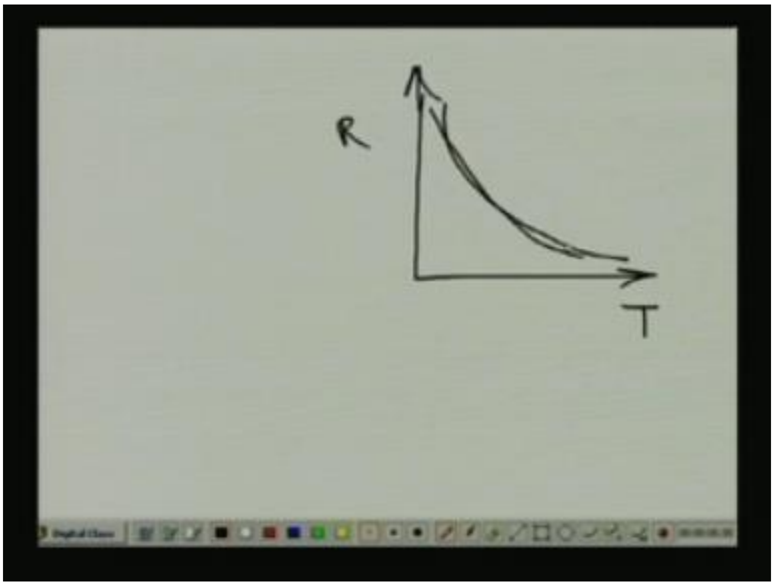

Now, any resistance, if I take a new page, whenever you are connecting a resistance to a thermistor, you know what will ………, you know what will happen to its characteristics? Suppose I have a characteristics like this one, temperature versus resistance characteristics of a thermistor, it looks like this, depends on the value of beta, how sharp it will come down. As I told you in the beginning that the higher the value of beta more sharper and sharper will be the fall that more and more will be the sensitivity of the thermistor; all of us want that the sensitivity should be more.

Now, if you connect the resistor in parallel with the thermistor, you will lose first of all sensitivity and if you lose the sensitivity, it will look like this one. You see, it will look like this. For some small range, I can use the thermistor almost as a linear device, if I use a thermistor and with the resistance in parallel. So, it won’t be fully linear. It is not possible, because it is already a nonlinear device. So, it is exponential fall, but if you use a resistance in parallel, for a small range it will become linear. So, by sacrificing the sensitivity I am making the circuit or thermistor linear.

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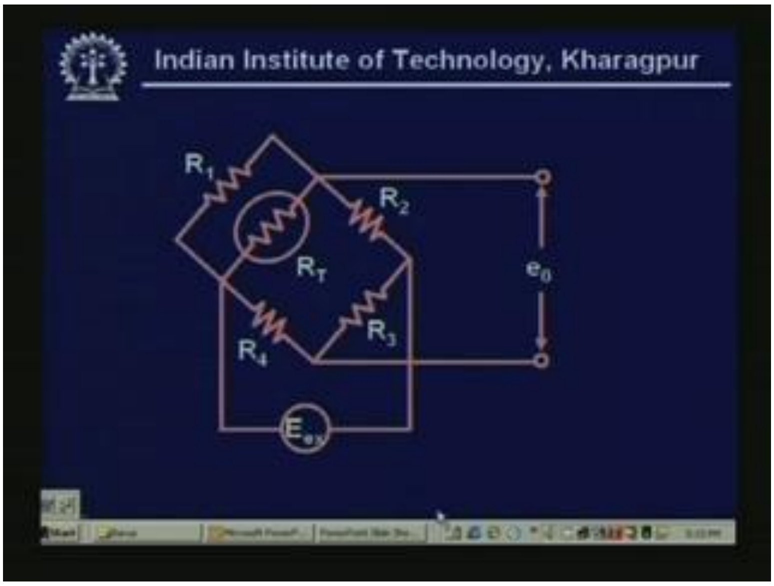

This is my circuit, as we discussed.

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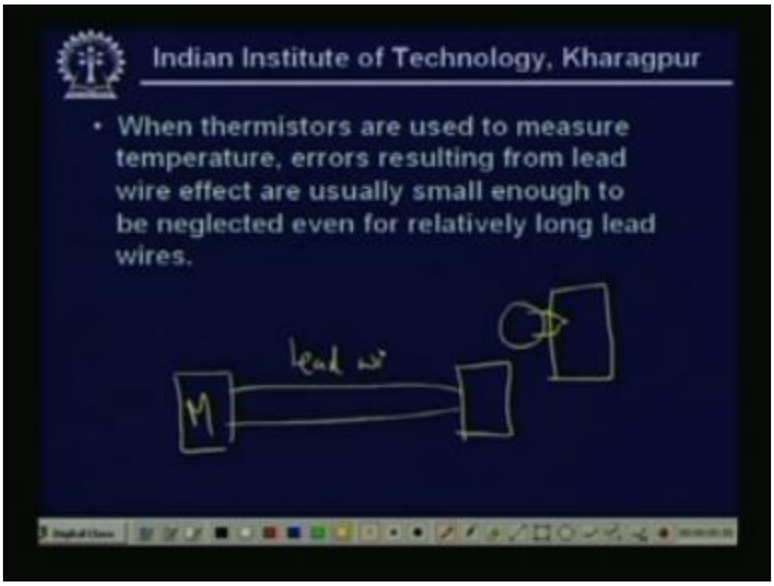

Now, when the, when thermistors are used to measure the temperature, the errors resulting from the lead wires effect are usually small enough to be neglected even for relatively long lead wires. Now, this is the typical problem of any temperature sensitive devices. When you are making a temperature sensitive sensor, temperature sensitive sensor, these are the typical problems, because the, I mean resistance of the lead wires, because you see that you cannot, I mean put, suppose I have a, you cannot put like this one.

That means suppose I have a, what I am saying is, suppose I have a, suppose I have a furnace here, you, you cannot put, a thermistor might be inside; you cannot put the, I mean you cannot put inside that very near to this meter. So, you have to take out. Suppose if I have a furnace here, so you have to take out the wires and might be here we have the meter. Here we have the sensors. Suppose these sensors are inside, so this is the lead wires. It can be few meters also, right? It can be few meters also. All temperature measuring, whether it is a thermocouple, thermistor and I mean or RTD, it does not matter. So, this lead wire creates the problem.

Now, actually lead wire is not very critical in the case of, in the case of thermistor, because of the reason that the thermistor resistance value is quite high compared to the lead wire resistance, because there are many problems. Suppose there is a temperature change along the lead wire, so obviously I mean the total resistance, because if you look at the meter, meter from this side, what it will see? It will see that the total resistance, it will not care, it will not, it will not see only the lead, only the thermistor resistance, it will also look at the lead wire resistance plus thermistor resistance. So, the lead wire temperature variation is very important in instrumentation, right? So, it is not important in the case of thermistor, because of its typical value. Its value is high, but it is very important in the case of the, in case of RTD. We will see that in the later, I mean lesson, right and even though for a, I am sorry …

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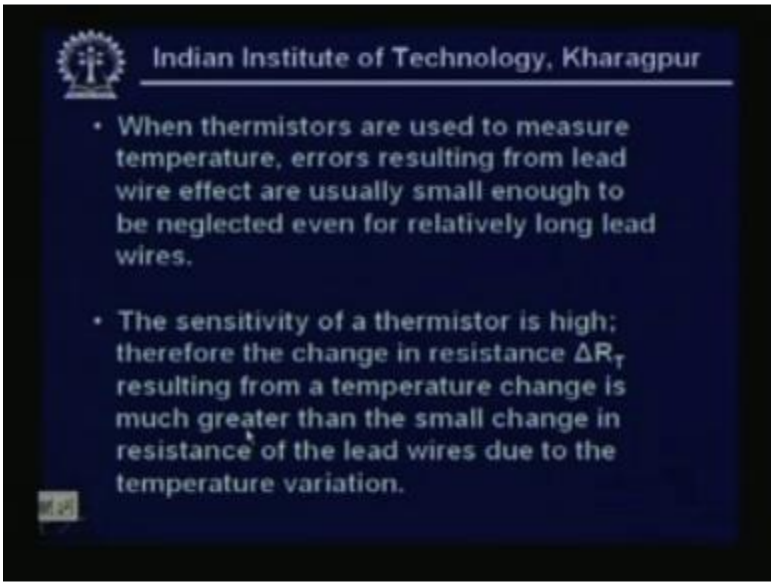

So, we will see that when the thermistors are used to measure the temperature, errors resulting from lead wire effect are usually small enough to be neglected, even for relatively long lead wires, can be few meters also like this. The sensitivity of a thermistor is high. Therefore, the change in resistance delta R T resulting from a temperature change is much greater than the small change in resistance of the lead wires due to the temperature variation. This is very important, right? That is the reason we can have a long lead wire in the case of thermistor.

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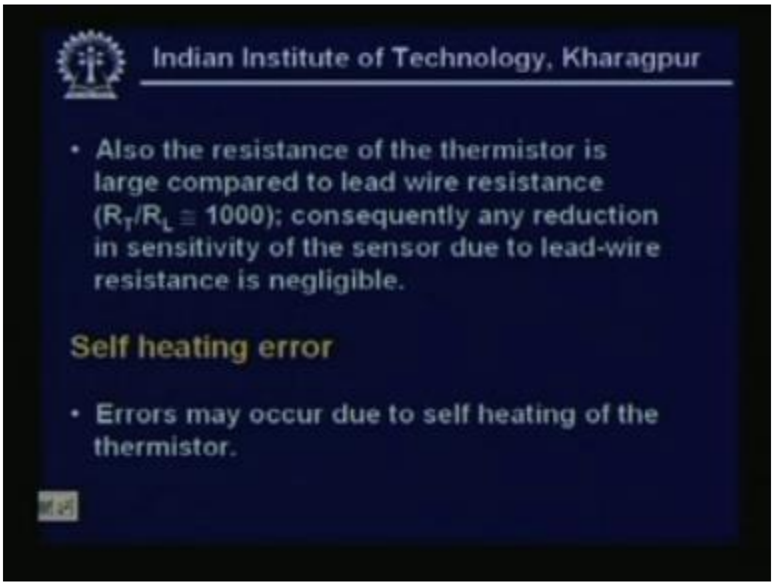

Also the resistance of the thermistor is large compared to lead wire resistance. We have already, I discussed these things. It can be, it typically can be R T by R L can be 1000. Consequently, any reduction in sensitivity of the sensor due to lead wire resistance is negligible, right? Now, there is another problem with the thermistor. It is called the self heating error. Any resistance devices whenever you are using, the self heating error, it is, it is common to both the thermistor as well as RTD, right? This cannot be avoided.

This is the, I mean physical phenomena. You can avoid the lead wire problem, but you cannot avoid, I mean the self heating error. Errors may occur due to the self heating of the thermistor.

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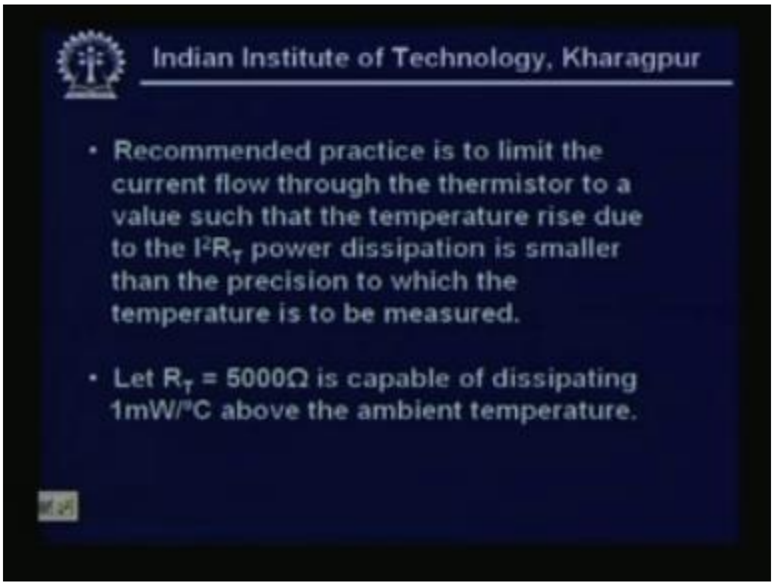

Recommended practice is to limit the current flow through the thermistor to a value such that the temperature rise due to the I square R T power dissipation is smaller than the precision to which the temperature is to be measured. So, actually the precision will tell you how much current you will pass through the thermistor, right? So, sensitivity and precision if you look at very careful that is going side by side. So, let us look at, now suppose that R T that means resistance of the thermistor is 5 kilo ohm is capable of dissipating a power of 1 milliwatt per degree centigrade above the ambient temperature, right?

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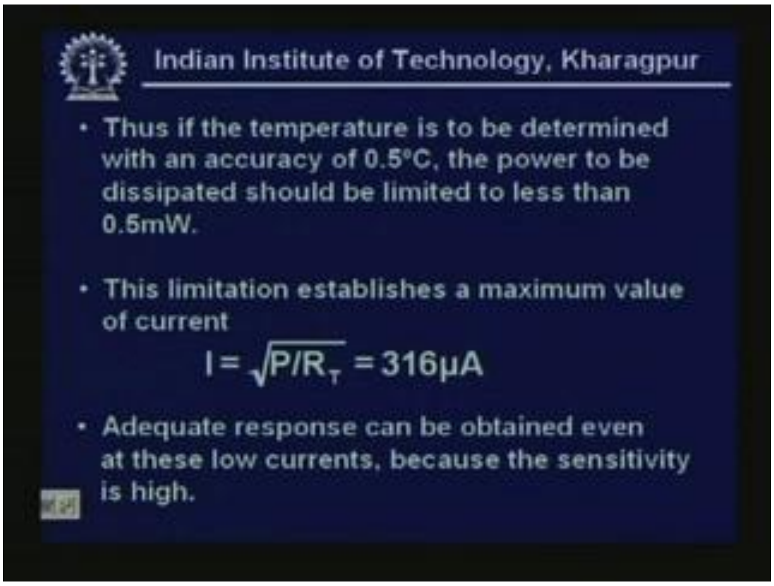

So, thus if the temperature is to be determined with an accuracy of 0.5 degree centigrade, the power to be dissipated should be limited to less than 0.5 milliwatt, right? This limitation establishes a maximum value of the current. What is that maximum value, we will show this. So, you see that the maximum value of current which will pass through the thermistor can be P by R T equal to 316 micro ohm, micro ampere.

This will actually lead you to choose your bridge excitation or the potentiometer value of the, I mean value of the potentiometer excitation or the value of the Wheatstone bridge excitation, right because you can calculate how much the maximum current will be allowed and accordingly … But please remember, if you do that thing, obviously you will lose the overall sensitivity of the system, because your output voltage also will be getting reduced, is not it? We are not measuring that resistance there; we are measuring the output voltage. So, output voltage will be reduced. So, adequate response can be obtained even at these low currents, because the sensitivity is high. So, sensitivity is high, I can make the adequate response, but this is a typical problem that sensitivity.

That is the advantage because, but obviously what will happen if you reduce, if you I mean think of this limitation, obviously you have to sacrifice some amount of sensitivity. That is quite obvious that you cannot avoid and I am sorry, it is not thank you, I mean, let me go and look at some of the circuits for which thermistor is used. As you know, the Wien bridge circuit, it is a typical circuit, it looks like this.

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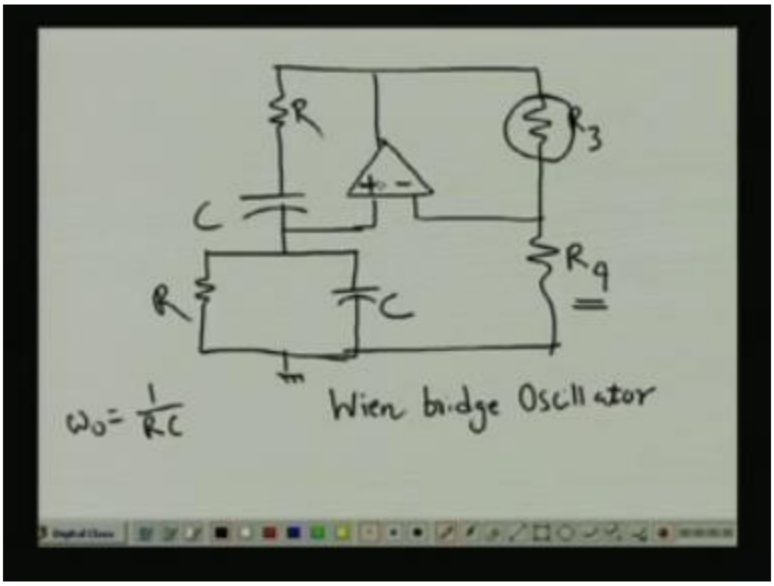

You see, the Wien bridge circuit looks like this, very familiar. It is a standard, I mean circuit for making commercial oscillators. So, basically Wien bridge oscillators, now there is R 3, R 4, like this one. So, these two voltages are coming to the, an op amp. I will show you some of the other applications of the thermistor. This is the Wien bridge oscillator circuit, right? This is Wien bridge oscillator. Now, see that always we, we will try to make the, the gain of this amplifier very high. To, to oscillate we will always make this gain of the amplifier quite high.

Now, there are some resistances. Suppose this is R, this should be R. If it is C, this should be also C. There is no doubt about that thing and the frequency of oscillation is omega naught will be equal to 1 by R C, right? Now, there are two resistances, you see, R 3 and R 4. Now, I will not go into details of this Wien bridge oscillator, but you see that in the, for stability of the system the gain should not be that high that it should saturate the amplifier. It should not be that low also that the, your oscillation may not start.

So, what they do commercially? They use either, previously they used R 4 as a tungsten filament, because as you know, the tungsten filament and its resistance depends on the temperature. So, as the current, as the time goes on, its resistance increases or you can use R 3 as a thermistor. If you use R 3 as a thermistor, what will happen? As the time goes by, the current will start to pass through this one and its resistance value will decrease. So, that will control the amount of feedback you are giving to this oscillator. Now, so instead of tungsten filament, I can use this thermistor for making temperature, for making the stabilization of the Wien bridge oscillator. This is one application.

In other application, as you know that we make usually that our power supply, is not it? So, typically power supply looks like this.

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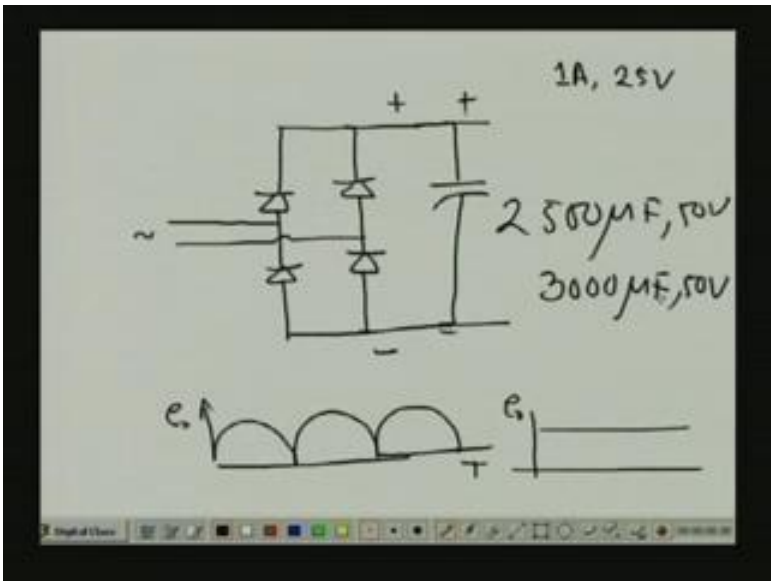

All instrument needs the power supply, right? So, I am giving a supply here, right? This is our AC supply. After stepping down and all this, this is the ……. I am getting a DC here, positive this side, negative this side. This is AC this side. Now, any full rectification as we know that, you see that our, it is not a DC, it is a ….. So, I must smoothen it, because the pure DC should have a, suppose this is the time and this is the amplitude, so this is the battery voltage e. So, it should be like this one, right?

Now, what they do commercially? They put a capacitor, a large value of capacitors, right? Now, even for a, suppose 1 ampere power supply, 1 ampere, suppose 25 volt power supply, so this is around, suppose 2500 micro Farad or 3000 micro Farad, this is a typical value for the power supply. Now, according to the voltage, whatever the voltage, across the voltage, suppose if it is plus minus 25 volt power supply, I will …… a 50 volt power supply like this one, right? Now, the problem arises. You see that when you switch on, now what will happen here? You see, if I look at, now what will happen?

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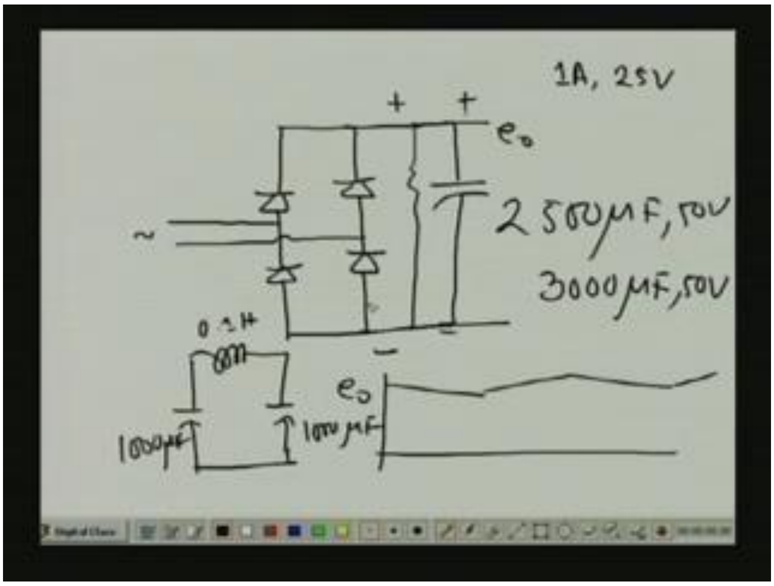

You see the, now my output voltage, suppose this is output voltage, right output voltage will look like a slight fall, then again it will rise like that one, light fall, …, because before the capacitor fully discharges, I mean charges, again it will fall like this one, the output voltage. Charging and discharging of the capacitor, it will look like this one, almost steady DC voltage. The best filter for this power line filter is a pi section filter that means you use a, like this one, right? But, L is not, no more used, because L has lot of problems, associated problems, magnetic field and it is costly, it is bulky. So, to avoid that, people use the simple capacitor, so higher and higher value. So, in this case, suppose if we use a 1000 micro Farad capacitor, 1000 micro Farad capacitor, then we should have one, suppose this is a .1 or Henry or like this one, so this will give you very good, but this is not used. We use it in very high value of the capacitor 2500 micro Farad or 3000 micro Farad capacitor value.

Now, in this case, you know what will happen? You see that that initially when you switch on the system, when you switch on the system, you will find there is a large current is necessary to charge this capacitor, because you cannot connect the capacitor like this one. There should be some leading resistors and all these things here, available in resistors. So, this is always necessary, because otherwise the capacitor will fully charge, right? So, what the people do you know, because what will happen that if I charge this, I mean capacitor with large current, because if it is totally, I mean discharge capacitors, it needs a large current.

Then, what will happen? This, there will be a large surge current to the diode, so diode will burn out, right? To limit this, what we have to do, what we can do actually? We can put a small value of thermistor in this position, right?

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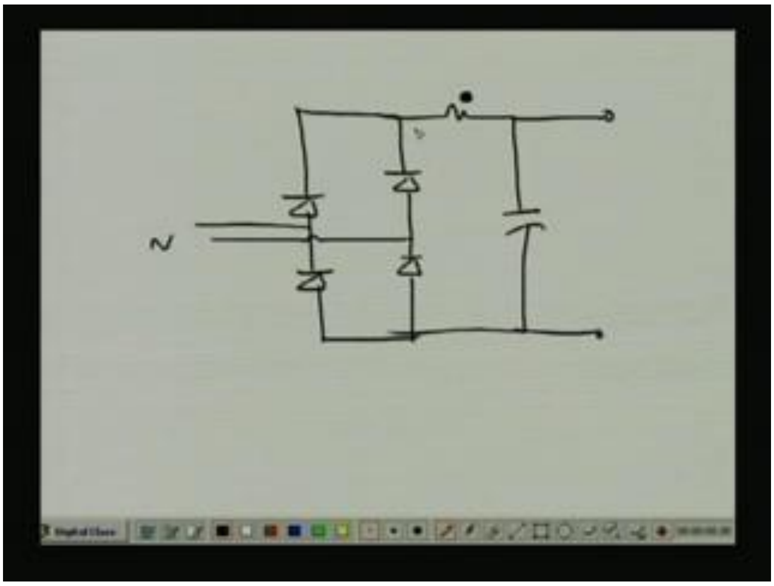

If I take a new page, if I take a new page, it will look like this one. So, I will put diode as before. So, put a, now put a capacitor there, small value of the thermistor, I mean AC. Now, initially what they do? You see it will, it will offer high resistance, this thermistor and capacitor will charge and capacitor will slowly charge, because at this time what will happen that the, since it is high resistance it will not charge fully. Then, after sometime what will happen?

You see that as the time goes on, this, its resistance is, as the temperature …., because the current will pass, there will be a self heating. So, what will happen to this resistance? Its value decreases. That I want actually, because this is a wastage, this is a loss of power; this will never be utilized. So, the efficiency of power supply will be deteriorated just to protect four diodes. Because in semiconductor device you can say, sir, I will use some fuse here. A semiconductor device is to be protected by another semiconductor device, please note that, right? So, you cannot do that thing. So, I have to use, if I use this one, so it will offer a large resistance. So, slowly it will start to charge and as the time goes on, this temperature, resistance will increase, resistance will decrease, sorry, temperature.

As the current passes resistance will decrease, because the temperature is rising and I will get full. The loss within this thermistor also will be reduced, because there is no utility of, because this is the total loss, because this voltage will be … So, this is the typical circuit also used in smps also, because in smps also you know the switch mode power supply or regulated power supply and all that, for giving the power to all the chips also they do not, they need some power supply even though there is a switch mode supply. But, for that reason they use a small series regulator. So, in those series regulator, I have a diode rectifier like this one and it will utilize the thermistor.

Thermistor is also used in electronic circuits also for, I mean for stabilization. You know, the …. point stability is very important in the devices. Now, once you switch on, especially the circuit where there is a feedback, there is a chance of oscillation. So, what they do? They purposefully put a thermistor there and this will limit the current and this is a typical circuit I can show you.

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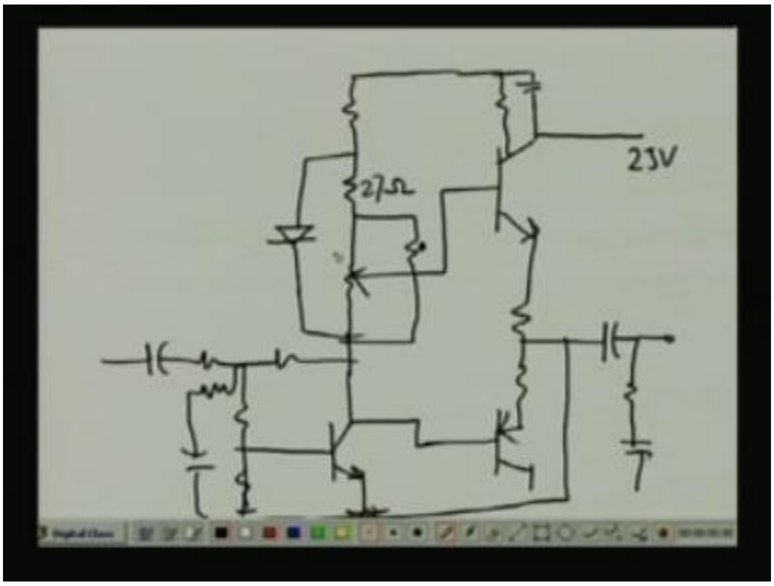

You see here I have a, you see there is a current is going. There is a push pull circuit, which is utilized for, for making amplifiers, right? I am taking a load from this position and output, so I am giving a power supply of 25 volt here suppose. Now, what they do actually? So, I have subsequent circuits like this one. So, there is a DC circuit, DC circuit. So, this circuit is coming here, this circuit is coming, coming to the collector like this one, like this one. See, this is used as a thermistor, right? So, this can be do like this one. So, this is some resistance, we can come here also through a capacitor. So, this 25 volt can be connected here. So, in fact this 25 volt should come here. 25 volt, sorry 25 volt should come here. So, this signal, this is a typical amplifier, so where the signal will come here in this, from this direction, it will go down there.

Now, see the reason for there is also here, connection here. The reason for this type of circuits is that, this is …. point stability, right? I need a stability of the thermistor. This is another application of the thermistors in the electronic circuits, right? See, it will make the …. point stability, because due to the resistance and all those thing it may happen that it will go out. So to, because this is the feedback there, so actually there is a feedback, so it should go like this one and it should go. So initially, so if that, it may go to the oscillator region, so to stabilize this thing, so we will use the thermistor and this ends the lesson 7 of Industrial Instrumentation.