BASIC ELECTRONICS
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LECTURE-2
ELECTRONIC DEVICES -1
RESISTOR, IDEAL SOURCE VOLTAGE
& CAPACITOR

In the last lecture we saw the importance of learning about electronics, method of learning by doing, how it is very useful learning a subject like electronics and a brief history of electronics, about various stages like the vacuum tube, the transistor and integrated circuits. We also saw the plan of the topics to be learnt during this lecture, how to build circuits using breadboard and some ideas about use of digital multimeter and power supply which we would be making use of in doing different experiments in electronics. The plan is to read about three aspects in electronics basically components and devices, the measuring instruments and different circuits. Under components and devices, the passive components like resistors, capacitors, active components like transistor and operational amplifiers, measuring instruments like digital multimeters, power supplies, current sources, oscilloscopes, etc and circuits like rectifiers, amplifiers, oscillators, etc.

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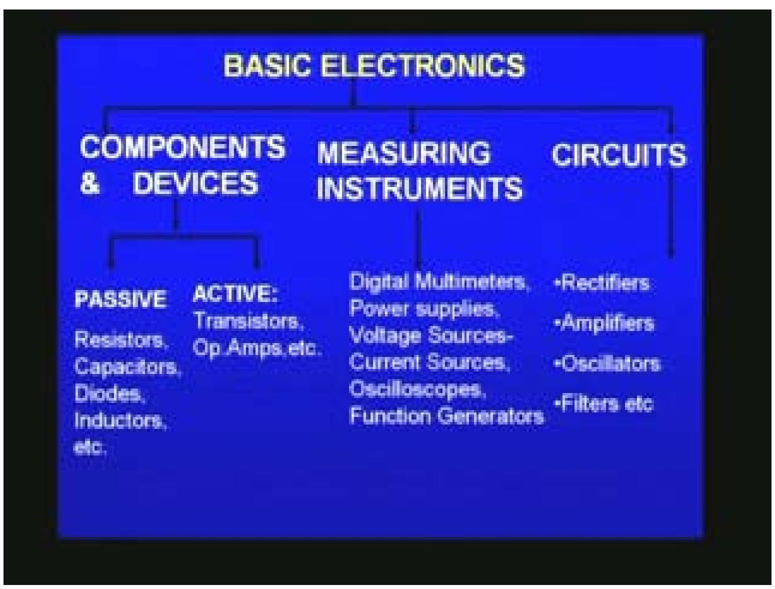

Let us first start with resistors. What are resistors? They oppose the flow of electrons basically or in effect the current.

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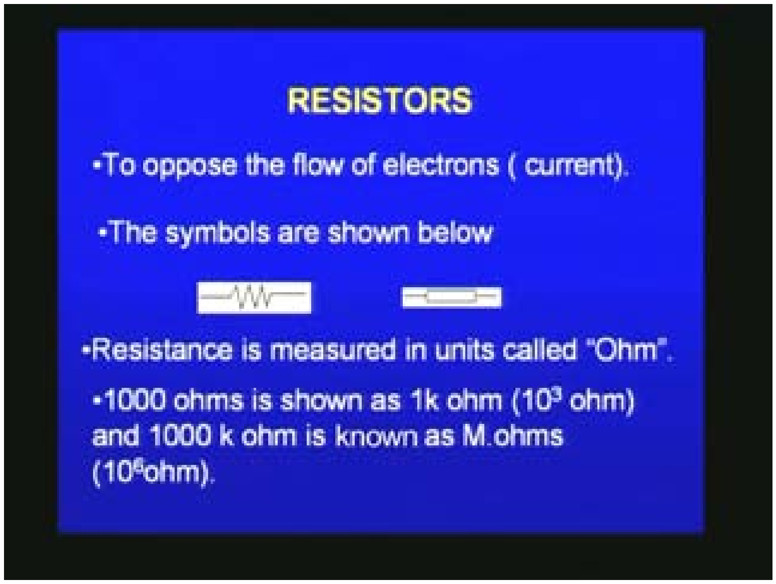

So resistors resist, as the name suggest, the flow of electrons or the current. The symbols of resistors are shown on the screen. Again see there are two types; many people use different type of symbols, any one of them and resistance is generally measured in units called Ohm.1000 ohms is also known as 1K. It is written as one kilo ohm or 1K which is equivalent to ten to the power three ohm or one thousand ohms. Similarly one thousand kilo ohm is also shown as mega ohm which is equivalent to ten power six ohm.

Resistors can be broadly divided into two types. One is fixed resistor and the other is variable resistors.

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Fixed resistors means the value is fixed. It will not change during the use whereas in variable resistors, the value of the resistance can change while being used in different circuits. One of the well known examples of fixed resistors is carbon film resistors.

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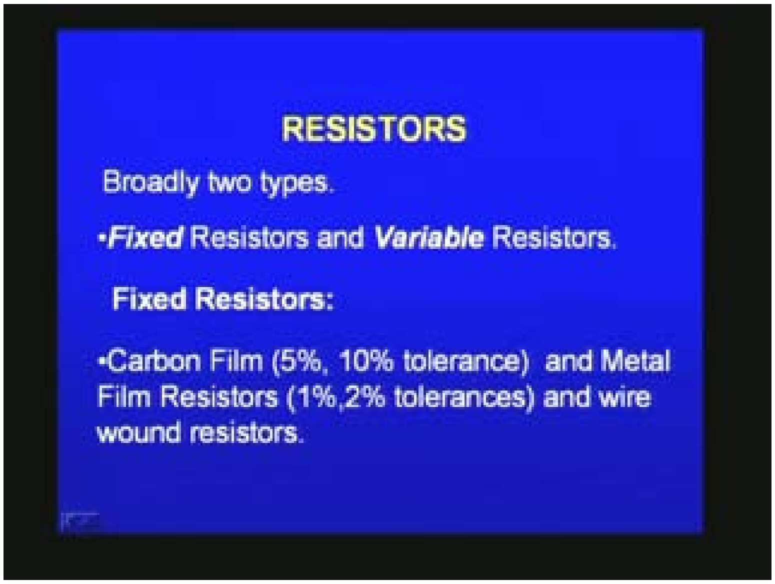

They have about 5 to 10% tolerance mostly. We will explain more about what we mean by tolerance and metal film resistors are also very popular these days. They have better tolerance 1% to 2 % and lastly wire wound resistors where it is the wires which are used of different lengths for generating different value of resistance. Fixed resistor is one as I already mentioned for which the value of the resistance is specified or cannot be varied in general while in use.

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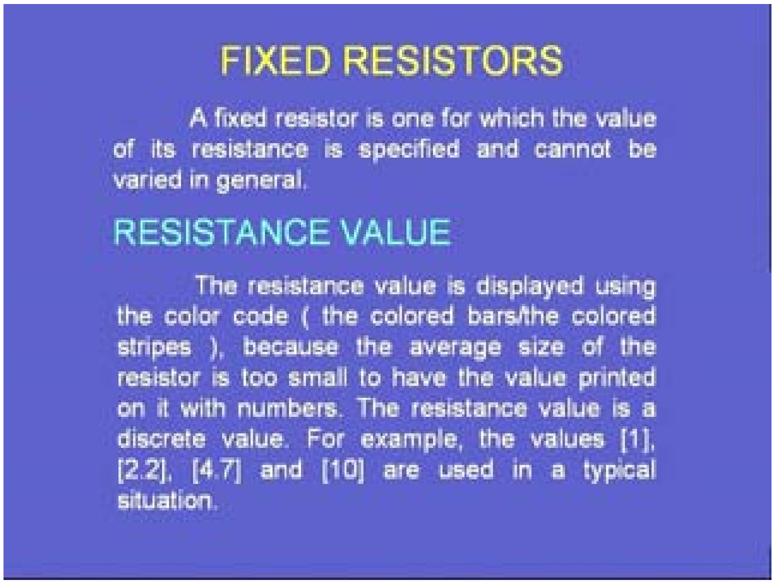

The resistance value is displayed using a colour code or colour bars as the case may be because the average size of the resistor is too small for the actual numbers to be printed on them and therefore the use of different colour codes which are actually rings of colours having different numbers as codes. The resistance value is a discrete value for example you have come across values like one, 2.2, 4.7, 10, etc in a typical situation. I have given an example here of a carbon resistor. You can see there are number of bands of colour all around itself, something like a cylinder. You can see there is a brown here, black, orange, yellow, are the four colour bands that we have here.

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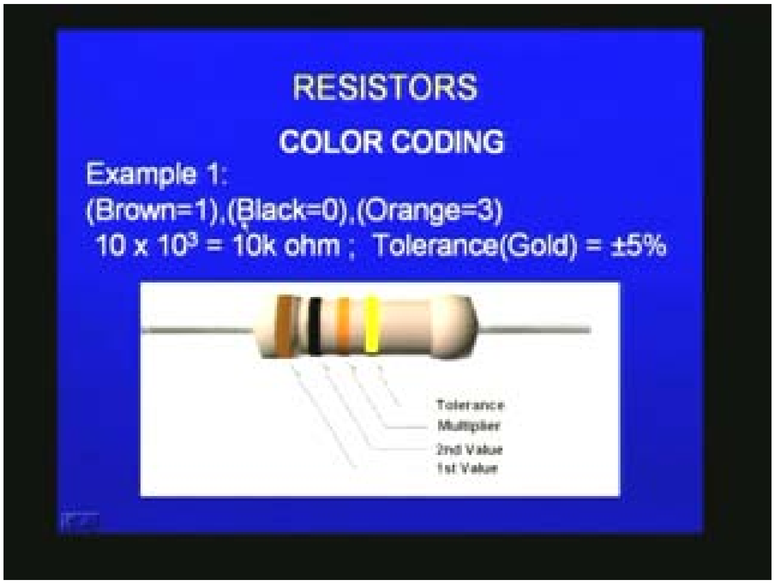

The brown the first ….. corresponds to number one. It is equivalent to the value one; black has value zero; orange has value three and therefore this one zero into ten power three. The third band corresponds to the number of zeroes that we should add or ten to the power three. In this case, ten into ten power three which is equivalent to 10K ohm; ten kilo ohm; ten thousand ohm. The last band the fourth band here is actually the tolerance band. It tells for example how much the fixed value of resistance can vary and the gold strip here corresponds to plus or minus 5 %. So tolerance here is plus or minus 5% and the value of resistor is ten kilo ohm.

Here I have a given a table of all the colour codes for example. Black, brown, red, orange, the colours of the VIBGYOR plus some additional colours like white, etc are all included here and the corresponding value is listed in this column in the table.

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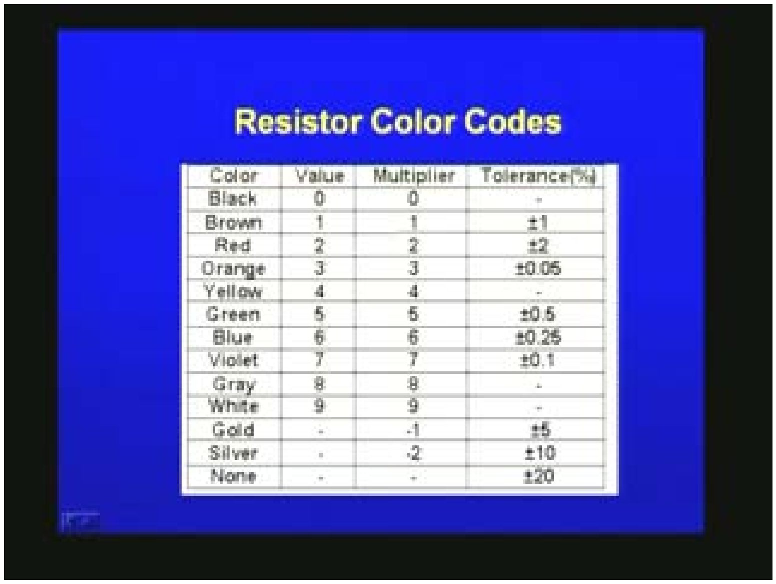

Color	Value	Multiplier	Tolerance(%)
Black	0	0	-
Brown	1	1	±1
Red	2	2	±2
Orange	3	3	±0.05
Yellow	4	4	-
Green	5	5	±0.5
Blue	6	6	±0.25
Violet	7	7	±0.1
Gray	8	8	-
White	9	9	-
Gold	-	-1	±5
Silver	-	-2	±10
None	-	-	±20

Zero, one, two, three, four, five, etc., up to nine and this is the multiplier which is the ten to the power that you normally specify. You can have zero, one, two, three, four etc which is also same as the previous one and the last column shows the tolerance. When you have a brown ring it corresponds to plus or minus 1% or red plus or minus 2 etc. These are the colour plans or tolerance values.

Now I will also show you one other example, a second example, where you can see there is yellow, violet, black, red and brown. This is a five band resistor, the first four bands corresponds to the value and the last band, brown as you can see here corresponds to tolerance which is plus or minus 1% as we also saw in the table. The value of the resistor is obtained by looking at the corresponding code for colours; yellow for example is four, violet is seven, black is zero and so 470 is the value of the resistor and the red is actually power of ten and that is 2; therefore ten power two which gives value 47,000 ohms or 47 K ohms and the tolerance is plus or minus 1%.

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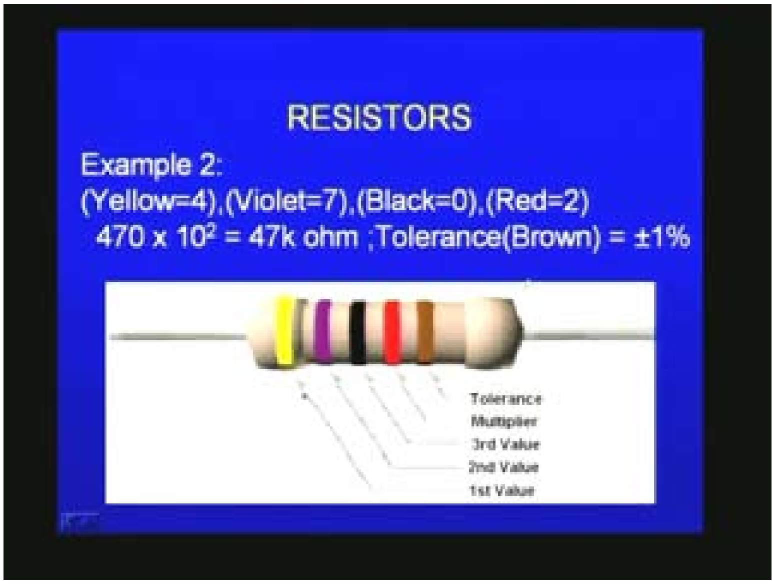

So by knowing this colour code one can easily understand the value of a given resistor and can make use of them in the different circuits.

Now let me explain little more about the tolerance. The tolerance of the resistor is also an important property of the resistor to consider in different applications. For example a 100 ohm resistor with 10% tolerance means that its value can be any fixed value between 90 to 110 ohms; 10% this way or that way to 100 ohms which corresponds to the 90 to 110 ohms. That means if I pick any resistor from a 100 ohm bunch, the bunch of resistors which are marked as 100 ohm, it can have a value any where between 90 ohms or 110 ohms. Similarly a 120 ohms resistor for example with same 10% tolerance can have values anywhere between 108 to 132 which is again 10% either this way or that way of 120 ohms. Thus the upper limit of 110 ohms of the lower value corresponding to the 100 ohms and the lower tolerance limit of 108 ohms of the upper value 120 overlap. That is how the choices of resistances manufactured are decided so that for each resistor value its lower limit and upper limit overlap with the next value of the resistors. That is the reason why you have different number like 47, 33, 22 etc coming into the manufacturing of the resistors. So a resistor with the value between 100 ohms to 120 ohms can be obtained from either of two sets of 100 ohms or 120 ohms.

Most of the times, the value of resistance in the given circuit is not very critical in the performance of the circuit. A small variation in resistance will not bring about any major variation in the performance of electronic circuit most of the time except there are some special cases where you have to have very precise value of resistor introduced. Similarly a resistor value between 120 ohms to 150 ohms can be obtained from either of the two sets of 120 ohms or 150 ohms. So the resistor values for manufacturing under 10% tolerance are chosen such that the upper limit of the lower value and the lower limit of the upper value overlap so that one need not manufacture the intermediate values of resistance.

I will show you the values that are normally manufactured; 10 ohms, 12 ohms, 15 ohms, 18, 22, 27, etc.

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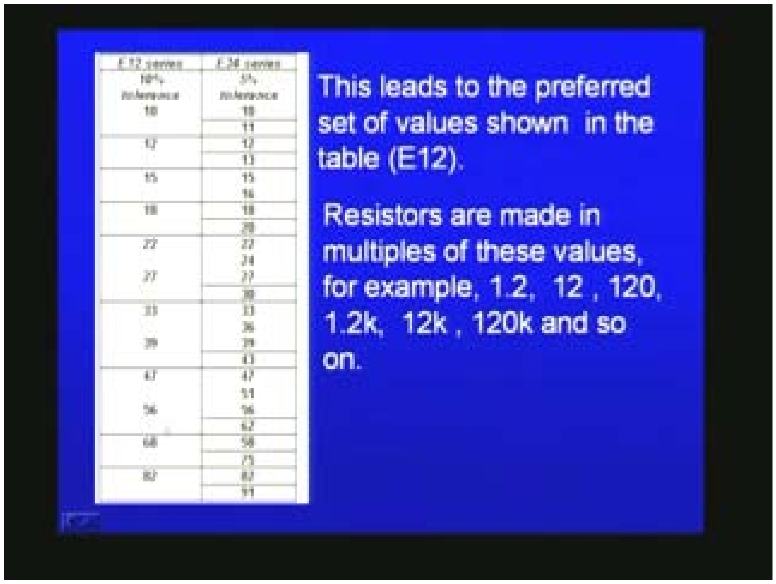

I can add another zero here for example 100 ohms, 120 ohms, 150 ohms are also manufactured; 1000 ohms, 1200 ohms, 1500 ohms etc., are also manufactured. 10 kilo ohms, 12 kilo ohms; all values of resistors in different denomination will be manufactured having values only what is shown in this column of the table if they belong to 10% tolerance value of resistances. If I go to 5% tolerance you can see that overlapping will be limited and therefore I have to introduce more number of values in between so that the intermediate values can obtained from any set of these values of resistors. So a 5% tolerance will be manufactured for more number of preferred values as you can see in this table.

Now let us look at carbon film resistors. This is the most general purpose and very cheap in terms of cost. Usually the tolerance will be around plus or minus 5% and they are manufactured with different power ratings. For example 1/18th of a watt, 1/4th of a watt and 1/2 a watt are frequently used in many electronic circuits. There are many disadvantages of using a carbon film; mainly they tend to be very noisy.

The figure shows some of the example of carbon film resistors. You can see they have different sizes. This one is very small; this is slightly bigger; this is much bigger. This is for example 1/8 watt, this is quarter watt and this is half a watt.

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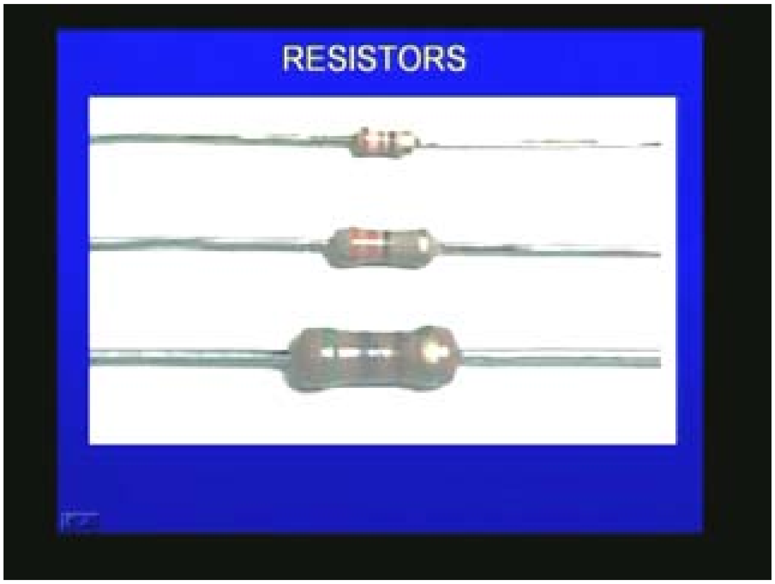

So you do have resistors with higher voltages and the resistor with higher voltages will be bigger in size in general. We will discuss more about what we mean by a higher voltage value.

Then there are other types of resistors; for example metal film resistors which are very, very useful. Metal film resistors are used when you require much closer tolerance, more accurate value. Usually nichrome, which is an alloy of nickel and chromium, is used for the material of the resistors. They are much more accurate than the carbon film resistors. They have about plus or minus 0.05 % tolerance. Here I have given the photographs of metal film resistor.

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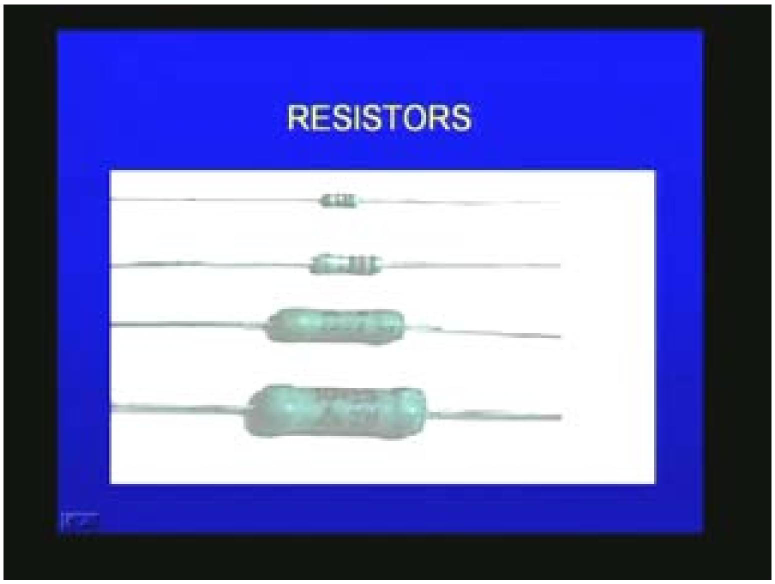

By physical appearance they do not seem to be very different from the carbon film resistors but then in terms of performance, these resistors are much better and as I mentioned in the other case, the different sizes here corresponds to different wattages.

There are other resistors, for example wire wound resistor. The wire wound resistor is basically a long wire of a very specific resistance value which is wound on an insulating …… and then the resistance value can be generated to any precise value. So high wattage resistors, in general are made of thick wire material. Usually wire wound resistors are used for higher wattages. But wire wound resistors cannot be used for high frequency circuits because of the associated inductive values, inductances. These are some of the wire wound resistor.

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This is actually 660 ohms; this you are not able see; should be around 10,00o ohms or some thing like that. They are wound on a ceramic base over which the wires are wound.

The next type of resistor is ceramic resistor. These are again wire wound resistors but cased in a ceramic encasing so that they can have much higher wattage, higher power rating. They have 1 to 2 watts sometimes even 10 watts and 20 watts. You can have wire wound resistors which are encapsulated in ceramic encapsulation. These resistors can become extremely hot because they are meant to be used at very high wattages and therefore one has to take care of these resistors when they are being used. For example this is a ceramic resistor.

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Inside you would see the ….. of wire wound on a ceramic ….. and that is completely enclosed in a ceramic encapsulation.

There are some more resistors which are used in modern circuits. The concentration there is to make them very, very tiny, small and they will almost look like a small integrated circuit, IC. So it is made with many resistors. They are called resistor arrays or network resistor, single in line and they have one resistor or multiple resistors connected or disconnected; different types are there. For example they can be used whenever we use light emitting diodes to control the current through the light emitting diodes. The single in line network resistors or array resistors will be used and the value of the resistor will be generally printed on them.

I have here an example of a single in line resistor and the corresponding arrangements is shown in detail; on the right you can see that. The resistors are all here and they all are connected at one end and the common terminal is provided whereas the other end is available for us to use in different circuits.

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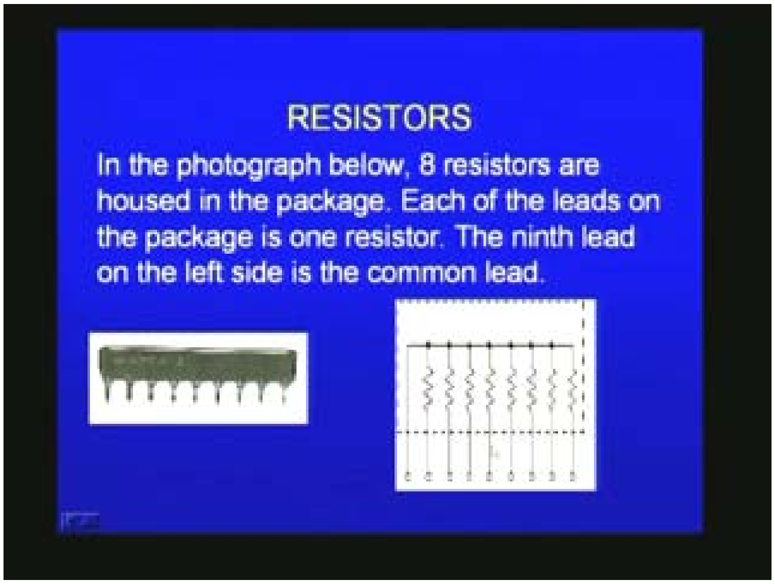

Usually they have nine leads; eight resistors all of them having one common and rest of the eight leads are given here. This is one type. There are also other types. For example 4S resistor network where the 4S indicates that the package contains four resistors.

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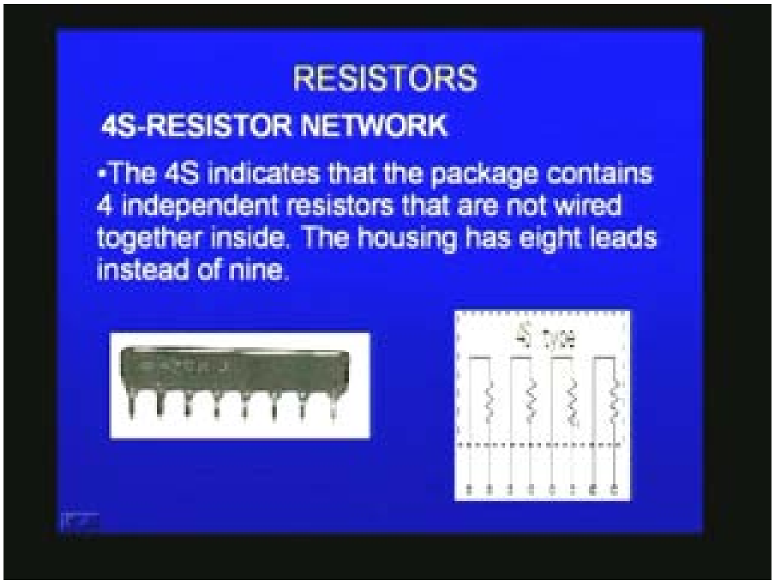

So, each one of the resistor is independently given. Unlike in the previous case you can see there are four independent resistors but all of them encapsulated in one piece. Therefore you can use them in different applications independently. When you want large number of resistors instead of buying independently different resistors, you can buy a single package in which four, five, six independent resistors are provided. This can be used in a compact way in different circuits.

Now we will come to variable resistors. There are two general ways in which variable resistors are used. One is where the value is to be changed during the operation. General example is the volume control in the case of an ordinary radio receiver. The volume control is basically a variable resistor and when you move it or turn it around you would find the volume will increase or decrease depending upon the direction of rotation. There are other semi-fixed resistors that are not meant to be adjusted by the user, by anyone other than a well trained technician. It is usually to adjust the operating condition of a circuit by a technician. So it will not accessible most of the time to the user but it will be inside the circuit. A technician will set it up and then slightly vary to a preferred value that he would like to have and set it at that stage. Nobody will be able to change it beyond that. These are called preset variable resistors. The other one is called potentiometers.

The semi-fixed resistors are used to compensate the inaccuracies of the resistors. You will not be able to get very precise value and then you can use this type of the variable semi-fixed resistor and set it to a fixed value for fine tuning a circuit. The rotation angle of most of the variable resistors will be around 300 degrees. Some variable resistors must be turned many times these are called multi-turn potentiometers, “multi-turn pot” for short. To use the whole range of resistance you have to turn several times. Not just one rotation but may be 10 turns or 20 turns as the case may be. So for example if the value of the resistor is 10,000 ohms, you have to rotate the knob ten times. Then you can see for each rotation the variation in resistance will be rather very small. So the resistance will be very slowly varying. Therefore you can set any precise value appropriately. These are called either potentiometers or trimmer potentiometers or presets.

I have shown here in the picture number of variable resistors.

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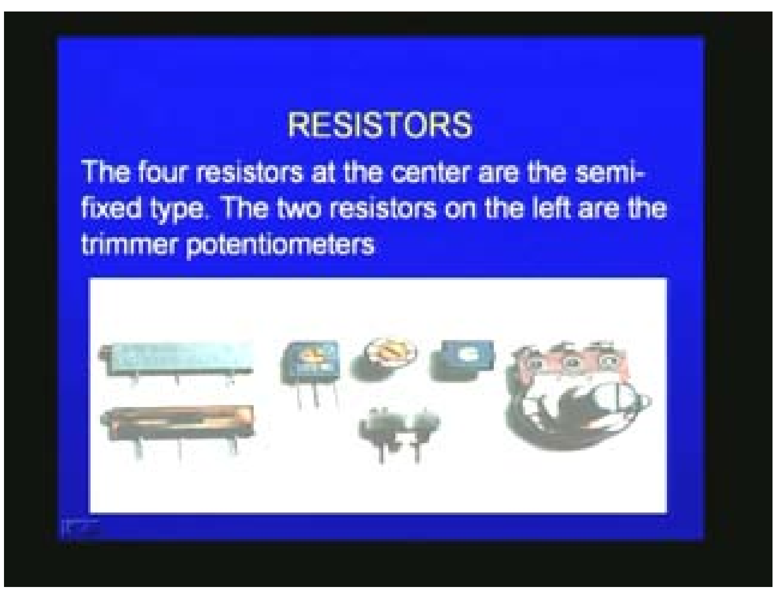

This one is very big variable resistors with the knob here which can be rotated. All the variable resistors will be characterized by three terminals one, two, three and all the four in the center are preset potentiometers or trimming potentiometer. They are used for setting precise value by the technicians that I already mentioned to you. These two at the left end are multi-turn potentiometers. There is a small screw here which can be rotated and depending upon the number of rotations that you give the value of the resistance will change. There are three terminals in all the cases as you can see. But for a variable resistor we will use only two of the terminals. The value between the two will only change. If I choose the extreme ends usually the resistance value will not change. It will be fixed. That can be understood by looking at the construction that I have shown in this picture.

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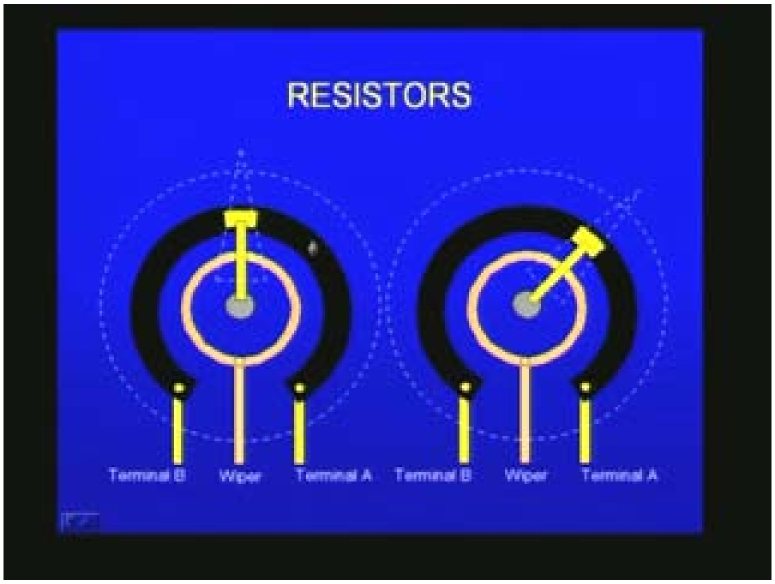

For example there is a terminal A; there is a terminal B. This is the carbon composite or whatever which is used for the resistor material and this center one is actually called a wiper. This wiper can be moved on along the periphery of the resistance value so that if I take between terminal A and the wiper, the value of this only will be included in the circuit. Therefore the resistance will be this much. Whereas in this figure if I use the same center and terminal A it has got much larger portion of the resistance and therefore the value of the resistance will be much higher. This wiper can moved through out by around 300 degrees and there by I can vary the resistance value. Therefore you can understand that the variable resistance will have to be using this wiper and any one of the other two terminals only. Either A or B, not both. So this is about variable resistors.

This graph gives you a change in resistance as we change the rotation angle, clockwise for example. This is the resistance value. There are three different types A, B and C. In the case of B, you find the resistance changes linearly by precise value with rotation angle. This is called a linear potentiometer. Whereas in the curve corresponding to A, initially the resistance varies very slowly and then the resistance varies very fast, with large values.

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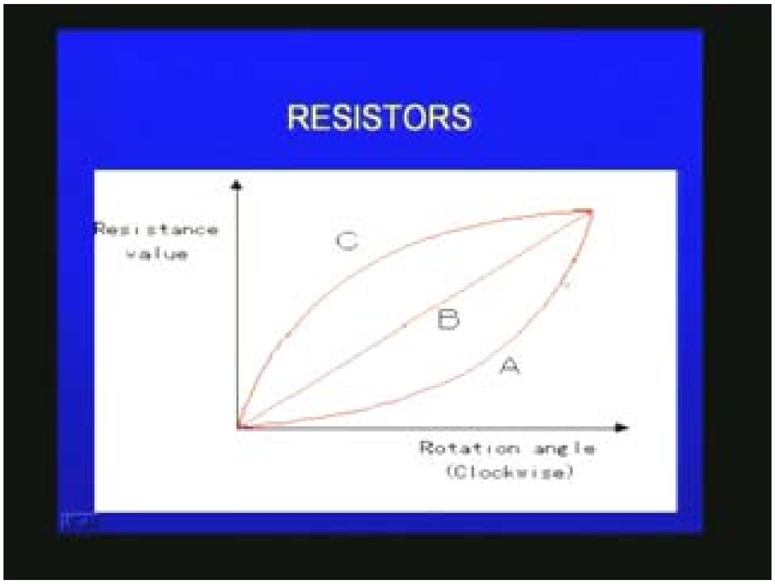

In the case of C, it is other way about. First resistance changes very rapidly by large values and as I come to larger angles we find the resistance changes very slowly. All the three types are there but most of the time we use only A or B in many applications.

Now we will come to a different type of resistor. In resistance there are different types. For example here is one type which is called light dependent resistance or LDR. Some components can change resistance value by changes in the amount of light falling on them. One type is the cadmium sulfide photocell resistors. It is a kind of resistor whose value depends on the amount of light falling on it. When you keep it in darkness its resistance will be very, very large and as more and more light falls on it, the resistance becomes smaller and smaller because it is basically a semiconducting device. I will show you construction of a light dependent resistor.

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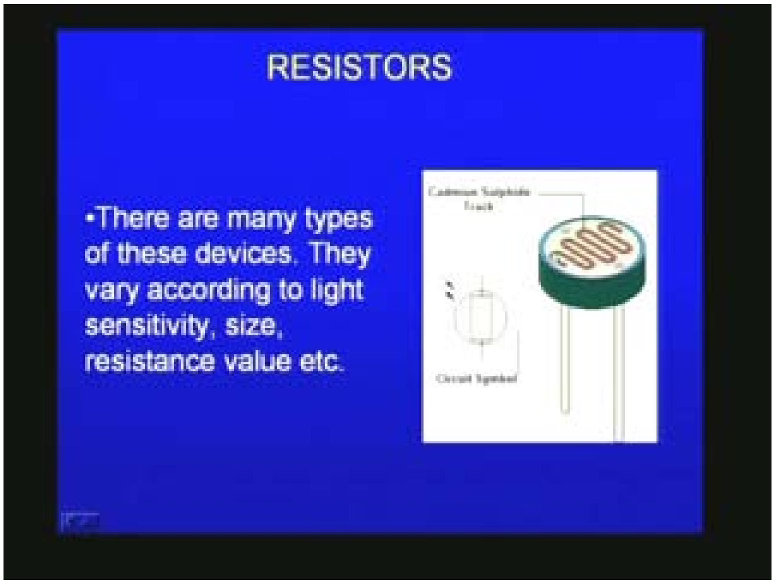

This is the cadmium sulfide portion and you can see a circuit symbol is normal resistor symbol with a circle and external arrows showing light falling on them. The circle shows that they are conditioned by some parameter, in this case the light. This is the circuit symbol.

This is the actual photograph of a LDR; typical case of a LDR is around 8 millimeter in diameter, 4 millimeter in height and it is in the form of a cylinder. When bright light is on it, it will be around two hundred ohms and when in the darkness the resistance can be more than 2 Mega ohms.

Similarly there is another type of variable resistors which is a special type called thermistor. These are thermally sensitive resistors. The LDR's are light sensitive resistors; the thermistor is thermal sensitive resistors. Thermal means temperatures; that means heat sensitive resistors. Therefore they can be used for measurement of temperature. The resistance value of the thermistor changes according to temperature and therefore they are used as temperature sensor. There are in generally two types of thermistors; one is called negative temperature coefficient and the other is called positive temperature coefficient or PTC. The NTC shows that when the temperature increases, the resistance decreases; that is corresponding to the NTC. The positive temperature coefficient means when the temperatures increases the resistance increases also. So there are two different types and they can be used for temperature sensing.

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This is a figure of a thermistor with the two leads and its resistance will be dependent on temperature as I already mentioned to you and approximately equations representing a thermistor can be seen on the screen. R, the resistance at any given temperature will be equal to R zero exponential some constant beta times 1/T – 1/T not where T not is the reference temperature and R not is the resistance of thermistors at the reference temperature T not.

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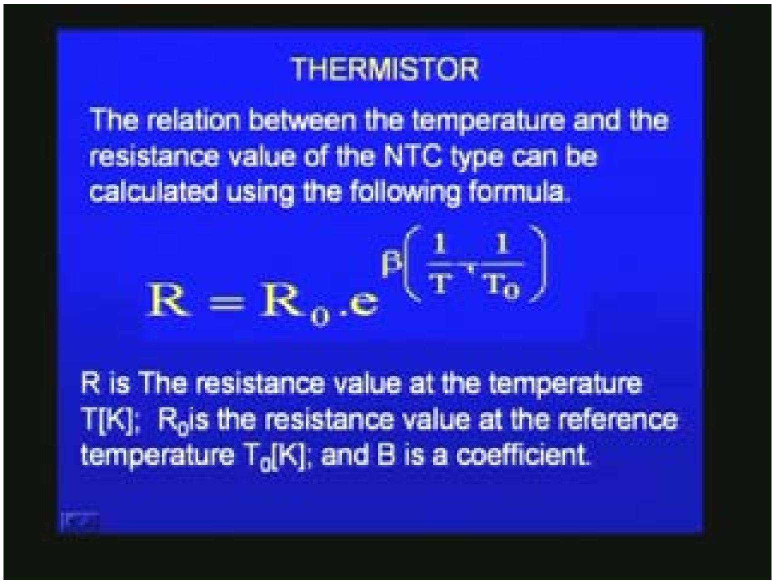

So at any given temperature T the resistance will change according to this exponential relationship and therefore you can see as temperature increases, the resistance will also increase, in this case R depending upon whether it is NTC or PTC.

We have seen different types of resistors like LDR and thermistors. In general resistors are also rated for the power dissipation. For example when the resistors are used in any given circuit due to the current flowing there will be heat generated which is called the joules heat and so for a given current if I keep on increasing the current for a given resistance, the heat generated can become so large that the resistance can be damaged due to the heat generated. Therefore there is a maximum power rating for any given resistor which should not be exceeded in any given circuit. So the maximum power rating specifies the maximum current that we can pass through the resistors. They are specified usually in watts.

The power is calculated using the square of the current, I square R as we all know where R is the resistance value, I is the current. Resistors as I already mentioned to you before comes in different rated values like 1/8 watt, 1/4 of a watt, 1/2 a watt, 1 watt, etc. For example when we power light emitting diodes, usually LED's require just one or two volts to operate. But you may be connecting to a five volts or ten volts power supply. Then you should try to put additional resistors to drop the total ten volts to two or three volts what is required only to be applied across the LED. You will see more of that later. But these resistors when you want to drop down some voltage in a given circuit will have to be carefully worked out on the basis of the power rating that you can think of.

For example I have a twelve volts power supply which is to be used for powering a LED or a given circuit which requires about hundred milliamperes of current. So the circuit requires only five volts. It requires hundred milliamperes maximum current and that means 12 – 5, the extra 7 volts will have to be dropped in some resistance.

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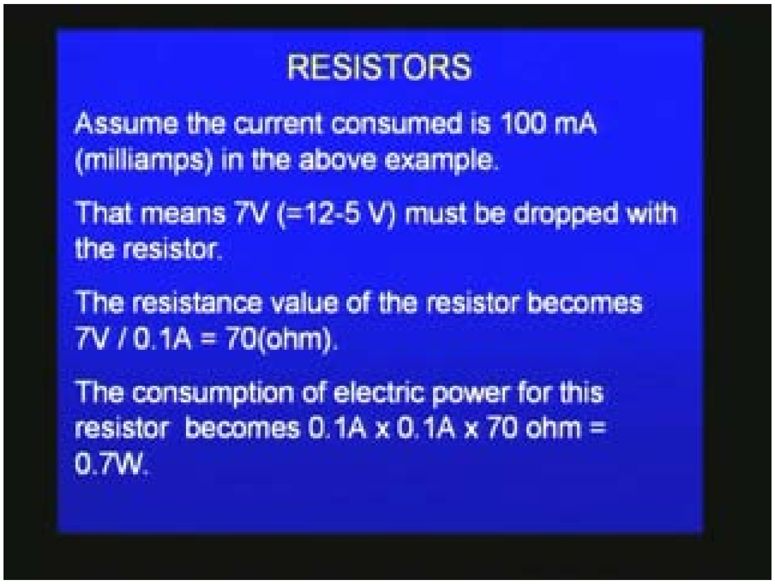

How to calculate the resistance? It can be calculated using voltage by current which will give me the resistance. Therefore seven volts divided by point one ampere or hundred milliamperes is equivalent to point one ampere and that corresponds to 70 ohms here and therefore I must try to use 70 ohms resistor in series with my circuit which requires only five volts when I applied 12 volts power supply. The consumption of electric power will have to be worked out by using I square R formula. In this case point one ampere into point on ampere into seventy ohm which is just about point seven watt. Therefore in general if it is a point seven watt it is better to use about twice the value as the actual safe value of resistance. So if you use one point five or two watt resistor it would be good enough. So the selection of resistors therefore depends upon two factors; one is the tolerance, the other is the power rating. Now I will go to the working table and I will show you some of the real resistors and I will try to measure the value of the resistors and I will also show you light dependent resistors and thermistor.

Here you can see resistors with different wattages. These are actually different wattages. This is about 1/8 of a watt; this is 1/4 watt; this is 1/2 a watt; this is 1 watt; this about 10 watt. This is ceramic resistor that I mentioned to you and apart from that you can see the size is also increasing corresponding to the value. Some of the values are almost same, for example this one is thousand by the colour code; this is also one thousand; I think this is also one thousand. So many of the resistors are of the same value but the size is different because they are used for different higher wattages.

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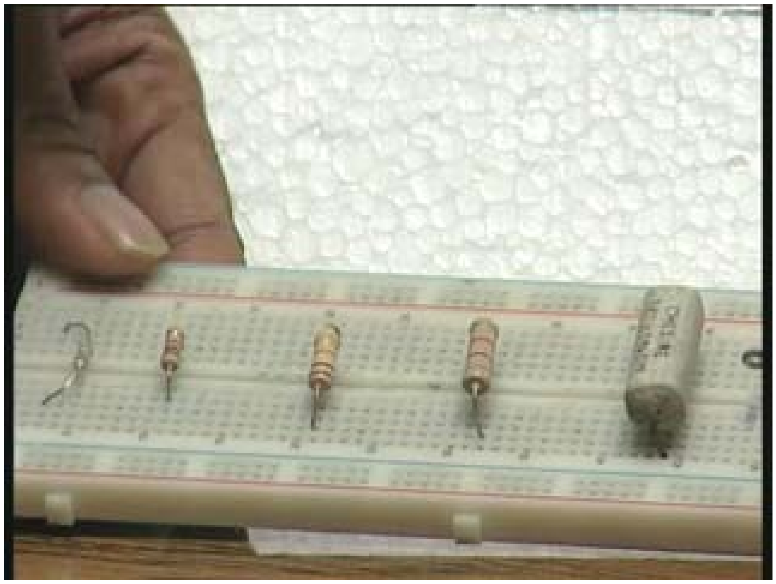

Next I have here for example a potentiometer that I already mentioned to you. I have a knob here which I can turn by which I can vary the value of resistance. So you have three leads here which I have connected here. I can measure the resistance using a multimeter. Here I have number of fixed resistors as I already shown you also. These are actually cheap resistors or single in line resistors.

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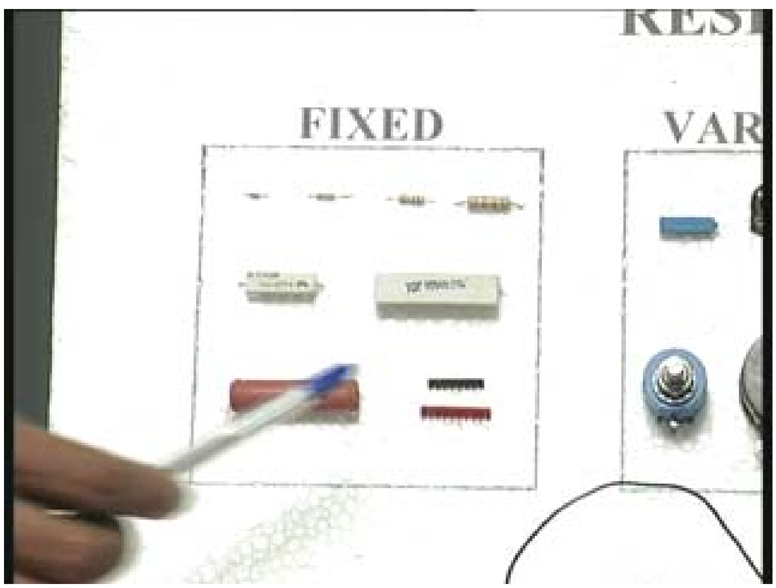

These are different wattages. Here I have number of variable resistors.

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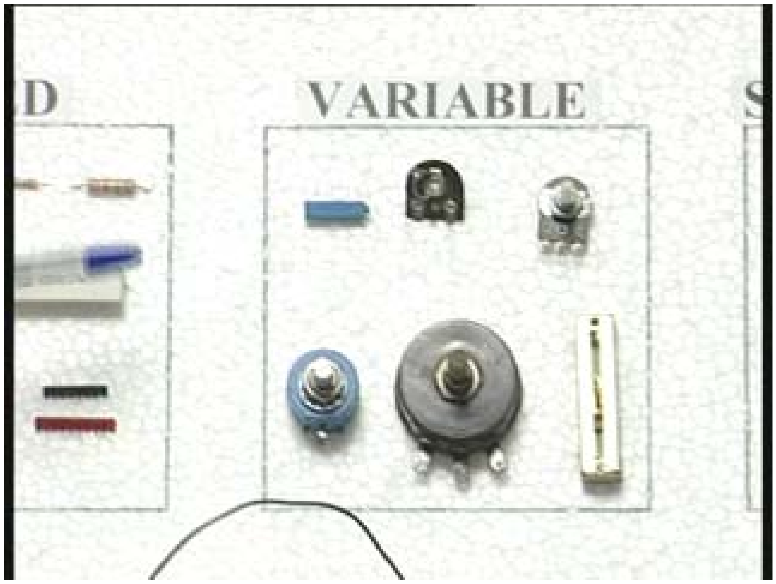

For example this is a trimming resistor. This is again a trim pot. These are variable resistors with carbon. This is a leaner potentiometer. The variation can be changed by moving it along the line and these are variable resistors where rotation angle will decide. This is a multi turn potentiometer; you have to turn this multiple times to vary the resistance. Here I have connected one variable resistor in a breadboard; green one is the center and I have used one of the center and one of the other terminals and I have connected to a multimeter. Now you can see the resistance is around 354 ohms.

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Now I am going to change the value of resistance by changing the knobs and you can see the value of the resistance also changing there. Therefore the value of resistance can be changed by using this type of potentiometer. Next I am going to show you a light dependent resistor. This one is a cadmium sulfide light dependent resistor.

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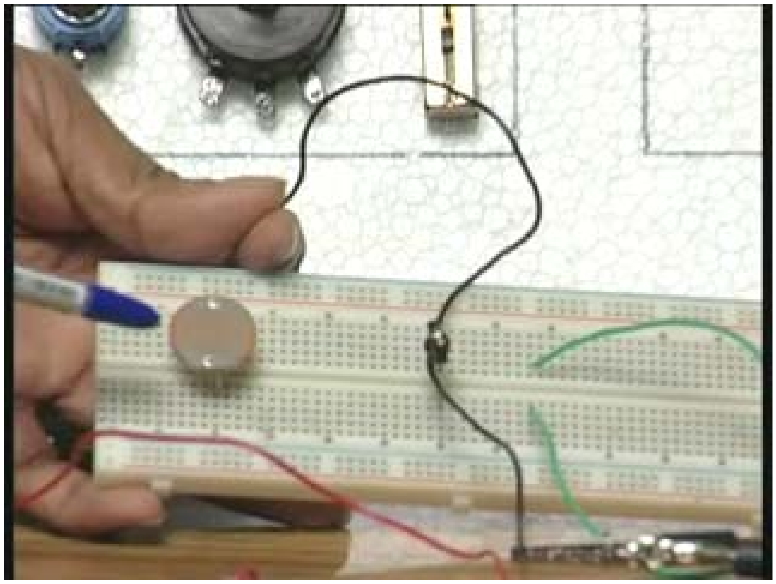

This one is thermistor in which resistance value will depend on temperature. I am going to show you this example by connecting two wires. I am going to change the amount of light falling on it and measure how the resistance is changing with reference to light. You can see that I have connected it to the multimeter. It shows something like four hundred and fifty to five hundred ohms.

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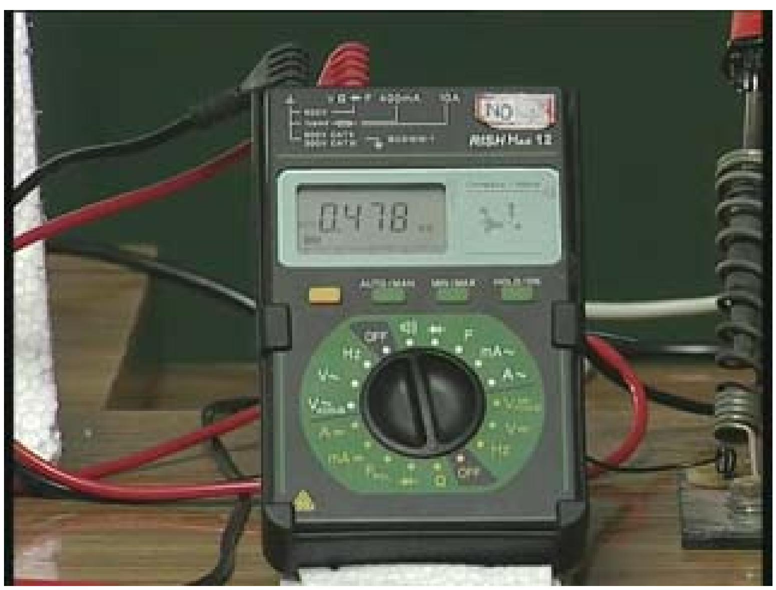

Now I close the light falling on it. Then you can see immediately in the dial, resistance becomes very large; it is around four point some K. If I completely hide it with a very opaque material, the resistance will still go higher. I remove my hand and you can see the resistance again comes down to some few ohms and when I close it goes to very high value of the order of several kilo ohms. Actually when I completely close it will go to very high values equivalent to Mega ohms.

Next I want to try looking at the variation of resistance with temperatures. I have again connected the two ends to the multimeter. It is showing some 12 K ohms right now. I am taking a soldering iron which is very hot and I am going to touch the thermistors. Immediately you see in the display the resistance keeps coming down; 5K, 4K, 3K, 2K, etc.

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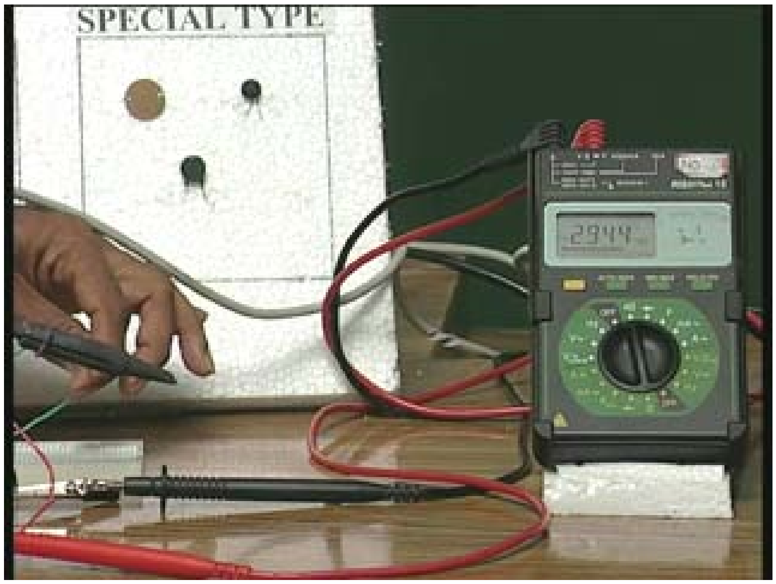

If I remove the heating then you would find then the display slowly climbing up to a original value of about 12 K. Now it is already 4K. It is becoming larger as I cool. As I cool, temperature is falling down and therefore the resistance will increase. So I have shown you here all the different type of resistors; both fixed and variable resistors and special type of resistors like LDR and thermistors.

Now we will go on to a very important law which relates the resistance. For example the voltage, current and resistance are related by a law which is called ‘ohms law’. This is very, very important fundamental law, most of you might already know and what ohms law states that the voltage when I apply across a conductor, the current produced due to the voltage will be proportional to voltage applied. V is proportional to I or V is equal to I into R, where R is the proportionality constant which is called resistance.

So this is true only for a given temperature. We have already seen in every resistor, the temperature changes can change its resistance value. That is called temperature coefficient. That is why it is called NTC and PTC; the negative temperature coefficient and positive temperature coefficient with reference to thermistors. R is the called the resistance and is measured in ohms and usually can be in ohms or kilo ohms or Mega ohms and there are other useful relationships that we get which corresponds to for example V is equal to I into R or R into I and R is equal to V by I.

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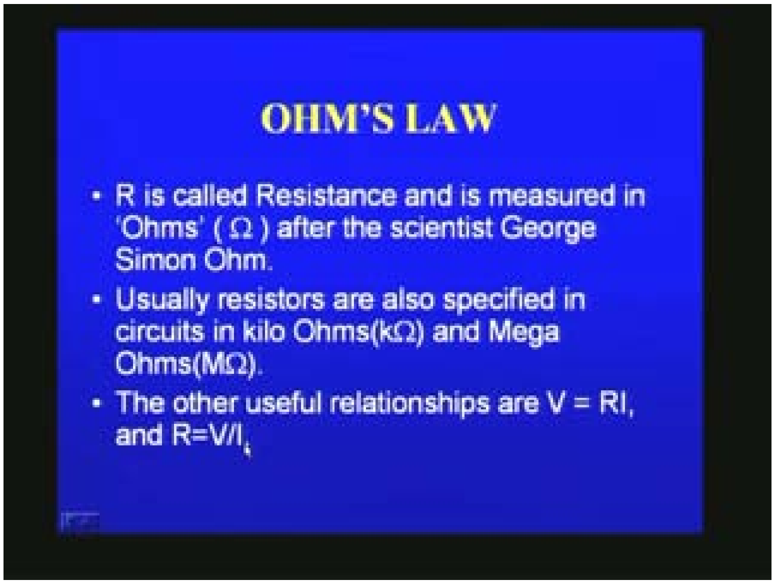

You can see V, I and R are related by three different relations. V is equal to I into R, I is equal to V by R and R is equal to V by I.

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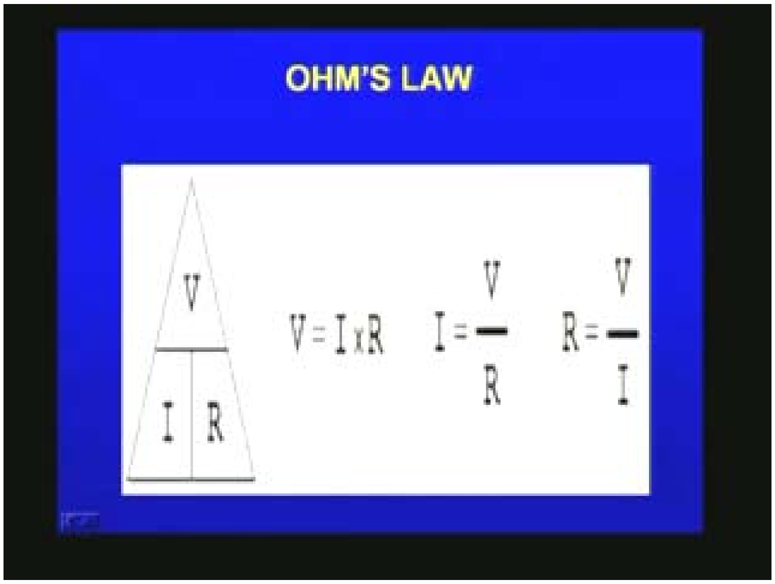

Here I have much bigger plots where I also make use of the power rating P, the current I, the voltage E and resistance R.

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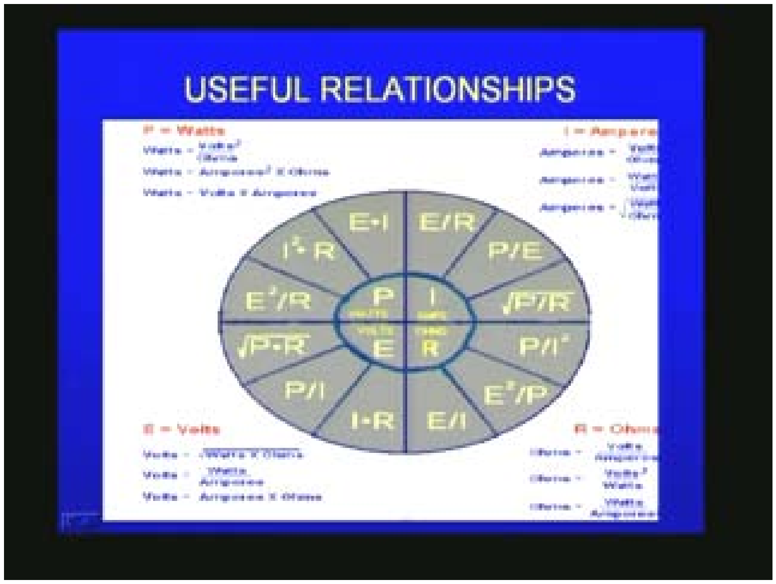

All of them are related by different relationships. Depending upon what you want in a given situation you would be making use of all these relationships.

Now let me quickly explain to you about ohms law. For performing a verifications of ohms law you require battery, you require a current source, current meter and you have voltmeter and a resistance.

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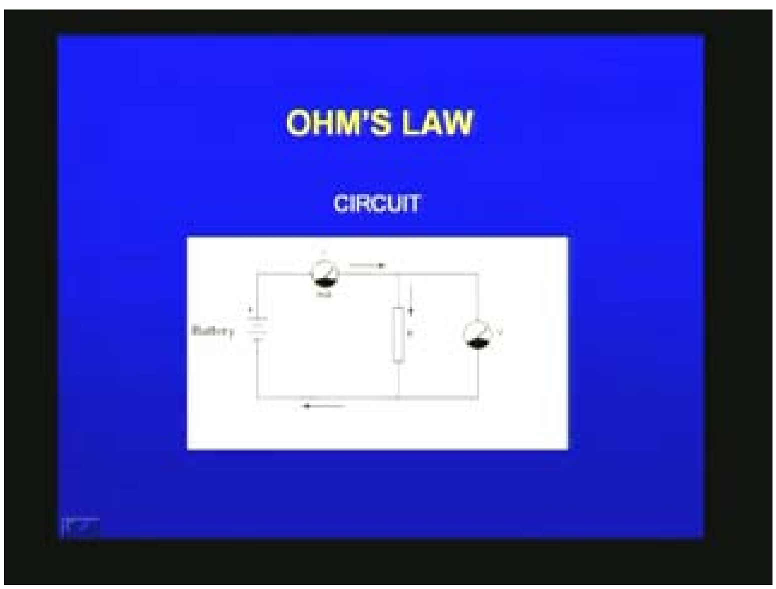

So if you look at the circuit diagram you have a battery, you have a current meter; you have a voltmeter and a resistance. The battery, current meter and resistance are connected in series and voltmeter is connected across the resistance to measure the different voltages.

If I vary the voltage of the battery here you would find the current will increase when I increase the battery and correspondingly you will see the voltage measured across the resistance will also increase. That is what ohms law says. Now we will quickly go on to verify ohms law in an actual case on the table and then we will come back to the rest of the things.

Here I have a circuit. There is a resistance here which is I think around ten kilo ohms and you have the voltmeter. I have an ammeter. I am connecting the ammeter; now I am connecting the voltmeter to the positive end red, negative end to black. So I have connected the voltmeter which is here and the ammeter which is here. I will switch this on and bring it to current and I want DC current. Therefore I will press the yellow. Now this measures DC current. This I should switch it on to measure voltage and I want DC voltage. This is now measuring DC volt. This will measure current. Now I will switch this on and I have connected the battery to the input here. Now let me slowly increase the voltage; so you can see the voltage is around 9 volts and the corresponding current is around 9.5 milliamps. If I reduce the voltage by some 4.4 volts, the current also is around 4.5 milliamperes. Now I again still decrease to around 2 volts, 2.32 and you can see the current also is 2.36.

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Therefore you can see the voltage as I decrease the current is also decreasing; when I increase the voltage the current also increases. Now you can see I am increasing the voltage to around 5.5 or so and the corresponding current also is increasing to 5.5. Therefore a resistance when it is in the circuit, voltage and the current are proportional. Voltage is equal to I.R, the resistance that I have included here. The resistance incidentally is around one kilo ohm.

We have seen ohms law where we have used a very simple circuit using a battery, a current meter, which is actually a multimeter used in current mode and a voltmeter which is again another multimeter used in the voltage mode and I have used one kilo ohms resistance in the circuit and by varying the voltage, the current and the voltage was shown to vary proportionally and the proportionality constant is actually resistance or the circuit. I have tried with one thousand ohms but we can also try the experiment different resistances and we would find that the ohms law is verified. But ohms law is verified only for resistances which are fixed value not for a special resistance that I mentioned. For example light dependent resistors or the thermistor because their resistance also depends on another parameter which is either light or temperature and therefore unless you maintain a constant light intensity in the case of LDR or a constant temperature in the case of thermistor they will not obey normal ohms law.

So one has to precisely set the light intensity or the temperature as the case may be and then only verify for such resistances, special type of resistances. There are also other types of resistances like voltage dependent resistors, VDR as they are called. I did not mention to you; I did not show you; but VDR's are generally used for protection in a circuit. Their resistance depends upon voltage. So when the voltage suddenly increases, their value will adjust itself so that there is no damage done to the circuit. They are used as protective resistors and there are also other resistors called magneto resistors. They are used for measurement of magnetic field. There are plenty of types of resistors which one can study about.

Now let me move on to another important concept. The whole of electronics is to be learnt by going through very precise concepts which are very, very useful in the whole application of electronics. The first concept that I would like you to understand is about the ideal voltage source.

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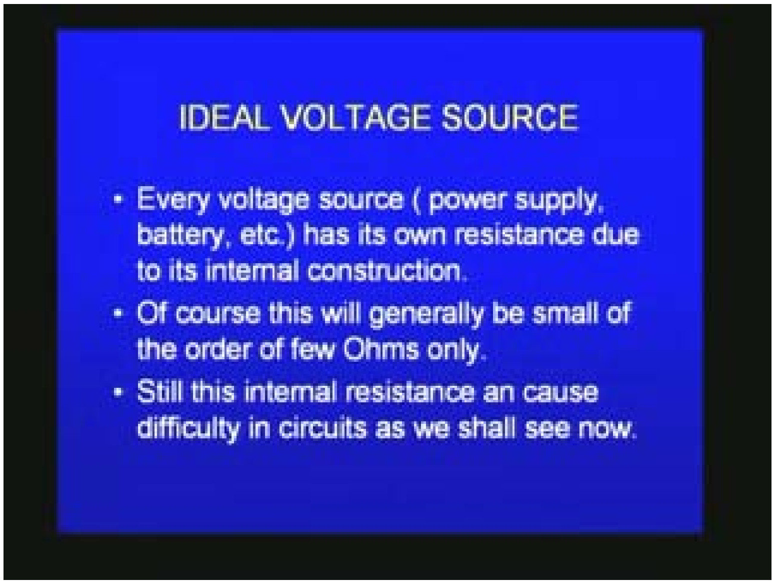

We make use of voltage sources by way of power supply or battery. But we should always recognize that each one of these devices the power supply or the battery will also have a resistance of it own which is called the internal resistance of the devices. So any power supply for that mater will have an internal resistance. The resistance in general will be kept very, very small but there is a finite resistance associated with every voltage source; be it a battery or a power supply as you have seen. So this internal resistance will produce lot of problems unless one take note of it because whenever I apply a voltage source to a set of network of resistors, there will be a current drawn and depending upon the amount of current that is being drawn you would find the voltage drop will be there in the internal resistance of the source and therefore the amount of voltage available for the external circuit will decrease. This is a very important thing that I wanted to explain to you with a simple example. Here you assume 6 volts battery connected to two different types of resistors in two circuits. In one circuit a 6 volts battery is connected to 6 ohms resistor. In another circuit the same battery similar battery is connected to one ohm resistor.

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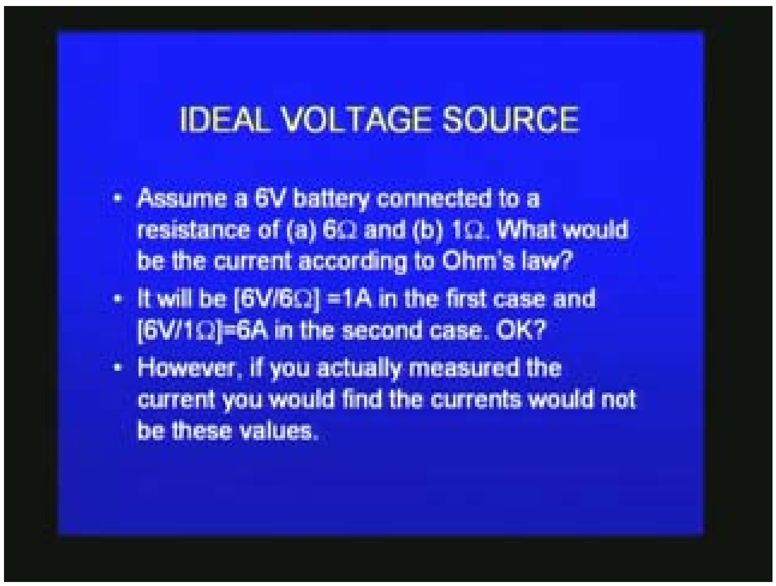

What could you expect the current to be in each case? In the first case for example six volts by six ohms, voltage by resistance gives current, gives me one ampere current as you can see on the screen. In the second case six volts by one ohm, because the resistance there is one ohm, you expect six amperes to be flowing in the circuit. If you actually put a current meter as we have done in the earlier case and measure the current you would find that the current will not be the value that we calculated. I have shown once more the circuit here and the current that you measure will not be the same as what we calculated using simple ohms law for the simple reason that the battery has got its own internal resistance corresponding to one ohm. When I have one ohm along with six ohms the total resistance in the circuit is not six ohms but seven ohms. So six volts by seven ohms is 0.86 amperes. It is not one ampere as we calculated because of the additional one ampere. Similarly six volts by one plus one, one ohm is the external resistance, one ohm is the internal resistance; together they form only three amperes.

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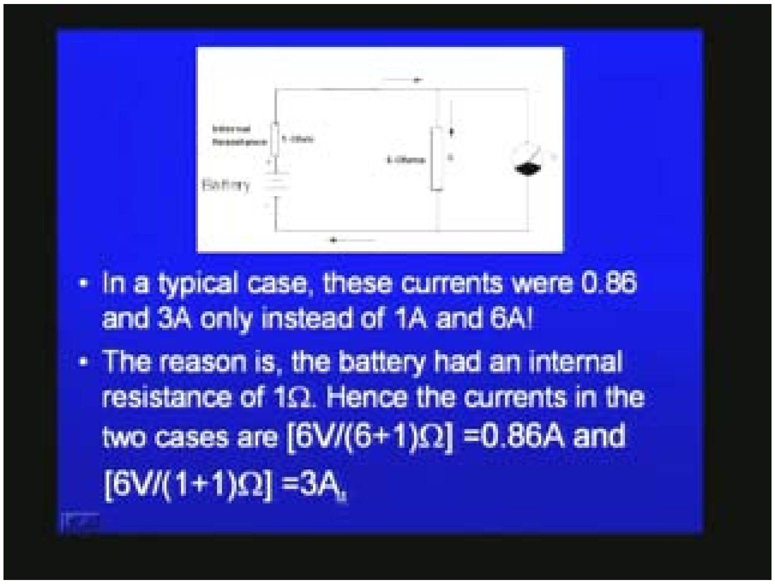

Therefore the actual measured current in the circuit will be either 0.86 amperes or 3 amperes. So what is happening out of the 6 volts in one case, 0.86 is dropped across the internal resistance and you have only 5.14 volts available for the external resistances. In the other case because 3 volts is dropped across the 1 ohm internally, you have only 3 volts available for the resistors that you have connected outside. Therefore you find even though you apply six volts to a battery and you assume you are applying 6 volts, because of the internal resistance the actual voltage applied to the external resistance will defer depending on the actual current that is being used in the circuit or drawn in the circuit.

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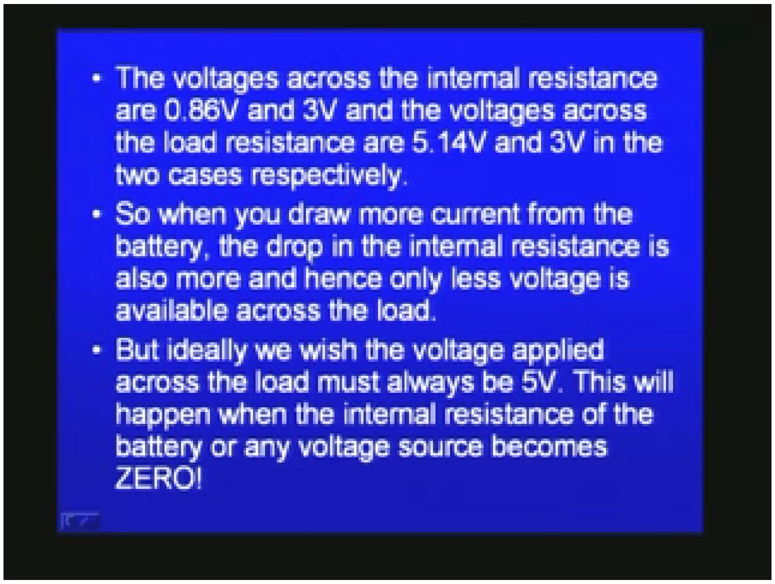

So when you draw more current more voltage will drop across the internal resistance and therefore less voltage only will be available across the load. A load here is external resistors that you connect. But ideally we wish the voltage applied across the load must be equal to the actual voltage of the battery and this will happen only when the internal resistance of the battery or any voltage source becomes zero. Therefore when the internal resistance of a voltage source becomes zero whatever may be the current that you draw by connecting different loads you could find there is no drop in the internal resistance and therefore there is no voltage variation at the load and the load voltage will always remain constant. So ideally we would like to have that situation. That is a situation where the voltage source is characterized by zero internal resistance.

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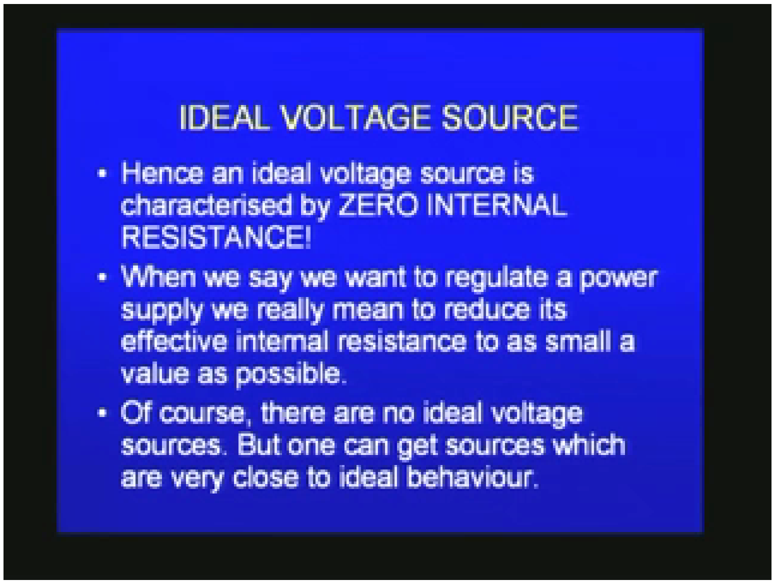

So we would see later on circuits which will regulate an unregulated power supply and unregulated power supply is one who's voltage can change whenever we change the load.

So if you want to regulate that means you want to maintain a constant voltage then you should attempt to introduce devices in the circuit which will make the effective internal resistance zero. When that happens you would find this will become very close to an ideal voltage source. An ideal voltage source is characterized by zero resistance. In reality all voltage sources as I already mentioned to you will have a finite resistance. Even when I regulate the resistance will become smaller and smaller but it can never become zero as we all know and therefore and there are no ideal voltage sources in reality but the resistance of a regulated power supply can be made very small so that for all practical purposes it remains very close to an ideal voltage source.

We have seen different types of resistors in this lecture.

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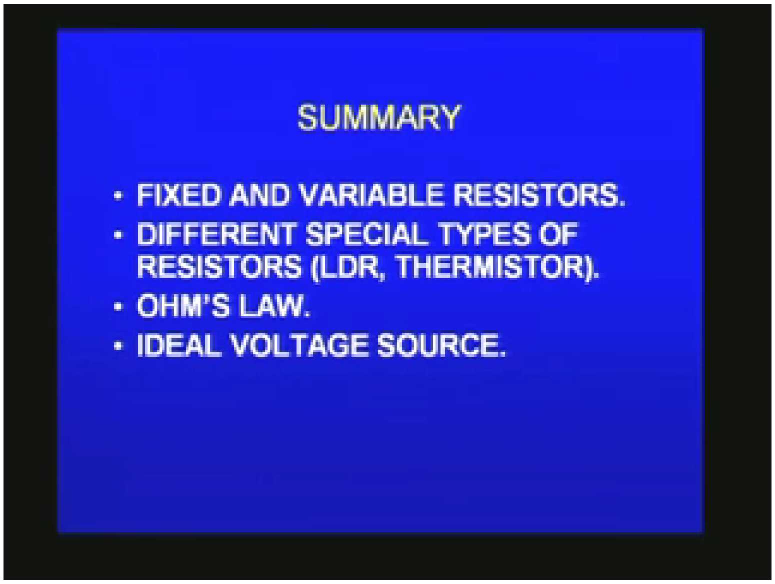

Variable resistors, fixed resistors and different types of fixed resistors like carbon resistors, metal film resistors, wire wound resistors and also we saw the single in line package resistors which are used along with IC's. Now-a-days we also have what are known as chip resistors. They are too small even to show to you. They are very small; you have to use a lens to find out and you will be asking perhaps how they would be soldered. They are soldered very carefully by a tiny soldering iron. There are different techniques for soldering such devices these days but they also exist.

If you look at any modern circuit board you will find they will not have any of the resistors that I showed but they will have more and more of these chip resistors which are very, very tiny in size. We also saw the different special type of resistors like light dependent resistors who's resistance depends upon the amount of light falling on it. They can be used for detection of light, amount of intensity of light or any special applications using light operated switches. Another special type of resistors is the thermistor which is a temperature dependent resistor who's value of resistance depends on temperature. Therefore they can be used as for application in thermometry, application in heat control and temperature control. We also saw one of the very important fundamental laws in electronics making use of these resistors which is ohms law. We also did a simple experiment whereby I showed that voltage is proportional to the current when I have a fixed resistor in the circuit thereby verifying ohms law.

I finally talked to you about an ideal voltage source. An ideal voltage source is characterized by zero resistance and an actual voltage source will have small value of internal resistance. We should always be conscious about this fact that all practical power supplies and voltage sources will have finite though small resistance as part of its internal circuit. Therefore the internal resistance which is very small may have to be taken care of in the application of different circuits.

In the next lecture we will see about current sources. Just as we have voltage sources, we also have current sources which are characterized by constant current; the characteristics of an ideal current source and the effect of the properties of current sources and resistors when combined. For example they can be combined in different ways one way is to combine them in series and another way is to combine them in parallel. So we will also see the effect of connecting resistors in series and in parallel. For example the parallel resistors will divide current, series resistor will divide voltages. That brings us to a very important application of resistors which is as potential dividers.

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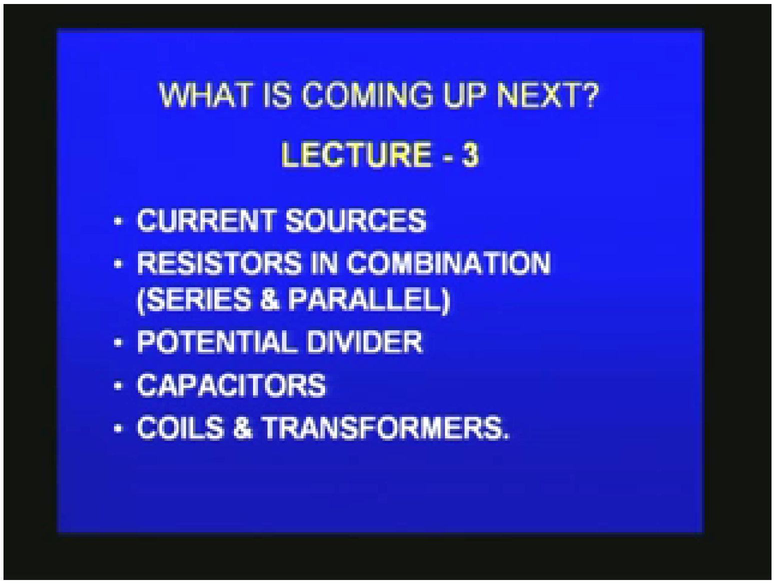

So resistors can be used to obtain or divide given voltages in the appropriate division. Apart from that we will also see some of the other components. One of them is a capacitor. A capacitor is some thing which is used for storing charges and they find very wide applications in different electronic circuits. Capacitors have several applications. There again you get different types of capacitors and different types of special capacitors just as we have different types of resistors, different types of special resistors like LDR's and thermistors, we also have different varieties in capacitors. You have fixed capacitors, and variable capacitors. All of them are very, very useful in electronics in doing different circuits. Apart from that there are other components. Again they all belong to the common category of passive components; coils and transformers. Coils are basically inductances. They are also used in oscillator circuits and in different applications.

Transformers are also very useful for stepping up or stepping down AC voltages and therefore they very useful in making power supply for electronic applications and therefore we will see about inductances or coils and transformer-step up step down. We will briefly see the basic functions of the transformers, the characteristics of transformers and also we will see different types of transformers and coils before we go into the actual application circuits. We will also see later on about the active devices like transistors, field effect transistors, operational amplifiers and then we will also see some other instruments which are being used for electronic applications. Thank you.