BASIC ELECTRONICS
PROF. T.S. NATARAJAN
DEPT OF PHYSICS
IIT MADRAS

LECTURE-1
INTRODUCTION TO BASIC ELECTRONICS

Hello everybody! We are now going to start a course on basics electronics. It is essentially a laboratory course. We are living in an age of information technology. Electronics is at the very foundation of information and computer age which we are living now presently.

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The giant strides that we have made in the areas of communications and computers are possible only because of the great successes that we have achieved in the field of electronics. It is some times unbelievable how many electronics gadgets that we carry theses days in our person for example digital wrist watch, calculator, cell phone, digital diary or a PDA, digital camera or a video camera etc.

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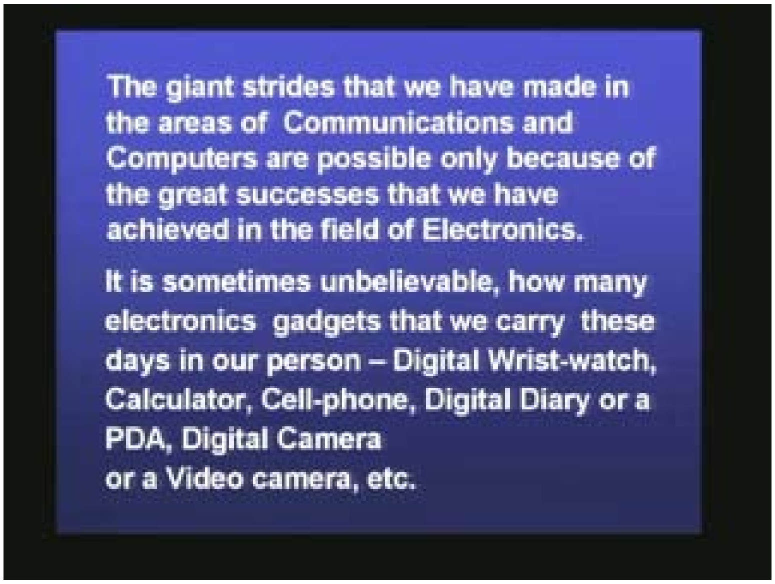

The different types of electronic equipments that have invaded our offices and homes theses days are also mind boggling. Many things we use at home, offices are remote controlled. For example television, air conditioners, audio equipment, telephone, we use a cordless for example.

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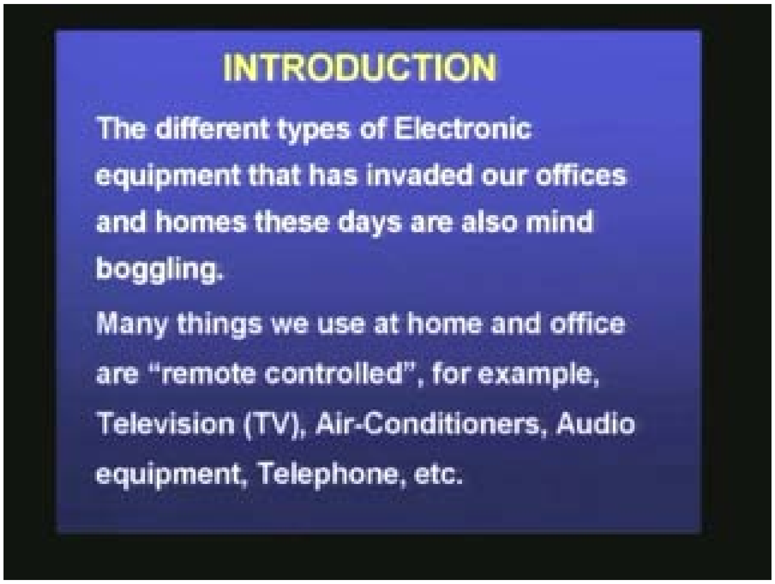

It is almost close to magic how even a small child now-a-days can switch channels or increase or decrease the volume of sound in a TV at home by just clicking on a few buttons at the comfort of a sofa away from the television apparently without any physical wiring or connection.

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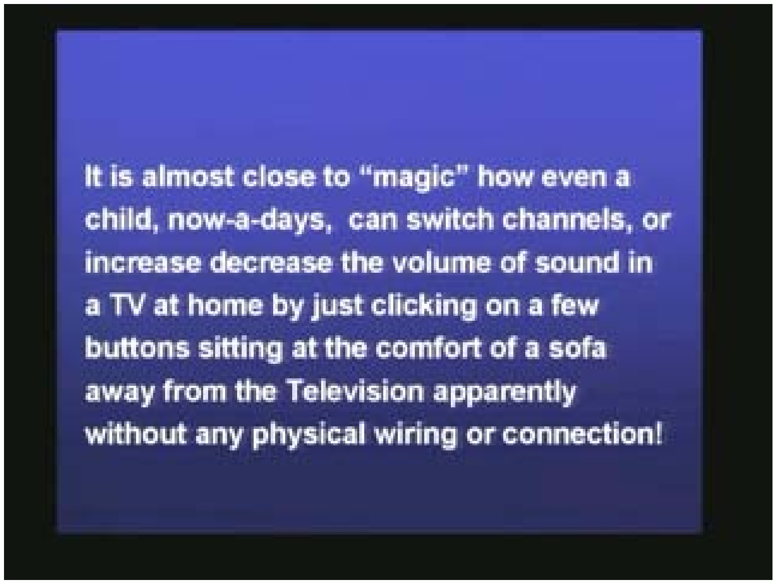

Again we are astonished how we are able to talk to our near and dear living several thousands of kilometers away from wherever we are at home, office, on the road in a car or in a class room by just clicking on a few numbers on our palm sized cellular phones. Electronics has thus made deep impact in several vital areas such as health care, medical diagnosis and treatment, air and space travels and automobile. In short the technological developments of several countries of the globe are directly related to their strengths in electronic design, manufacture products and services related to electronics.

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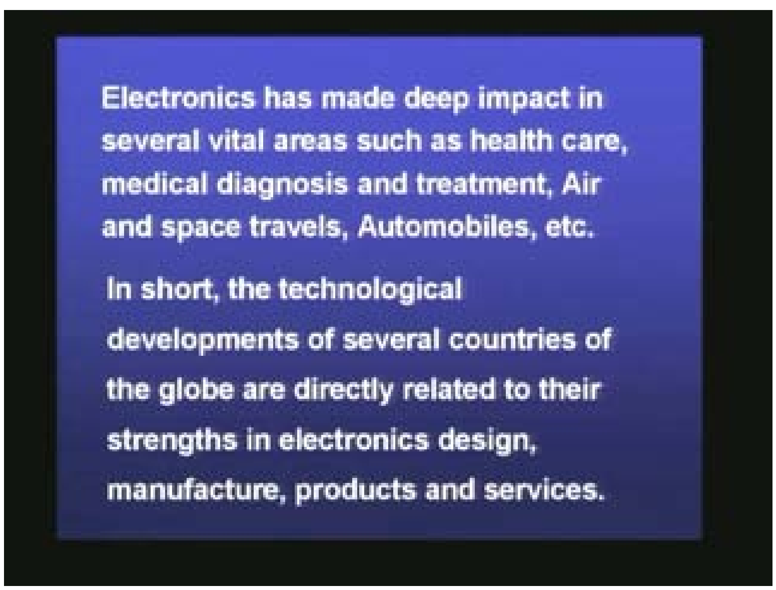

It appears as though that we have to add inevitably an “E” to the three “R’s” that we normally specify to declare a man and woman literate. That is the three R’s are reading, writing and arithmetic. Needless to add that the E I was referring to here means

“Electronics”. So apart from reading, writing and arithmetic one should also have basic knowledge of E, or electronics. Thus electronics has become surely a basic science and it is no more an applied science.

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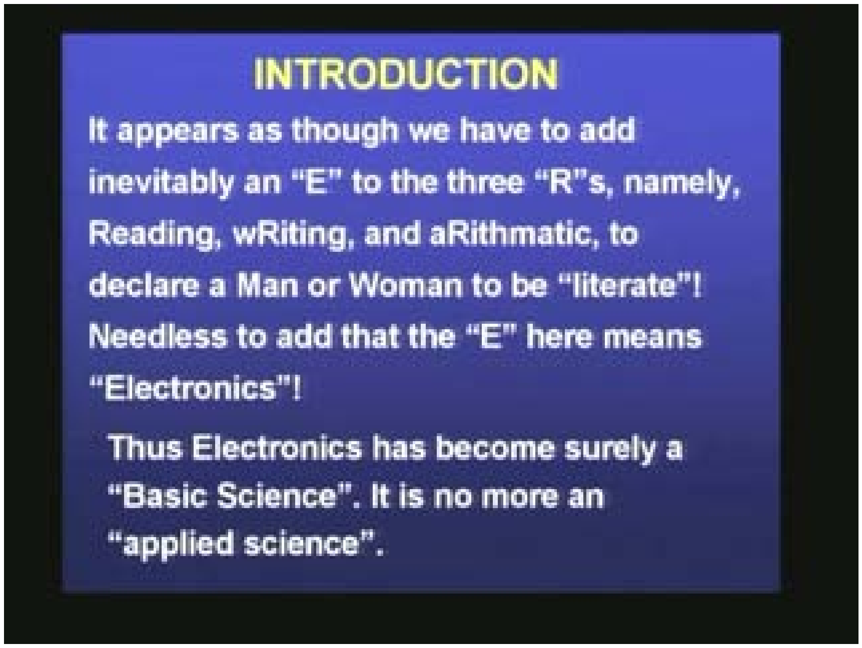

Just as we teach physics, chemistry, biology and mathematics in our schools it is time we start teaching our children at school electronics as a separate subject by itself. This brings us face to face an important question how to teach the basic concepts of such an important subject like electronics in a most efficient and effective manor. If one wants to gain a good grip and understanding of electronics he or she should build circuits and test them independently.

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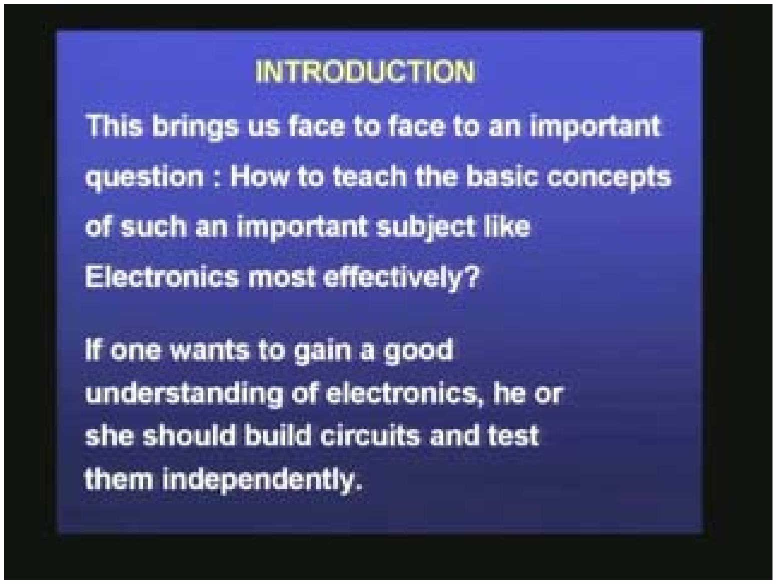

For this one should acquire a practical knowledge of the characteristics of different devices and in constructing the various circuits let as try to learn such skills by the proven scheme of "learning by doing".

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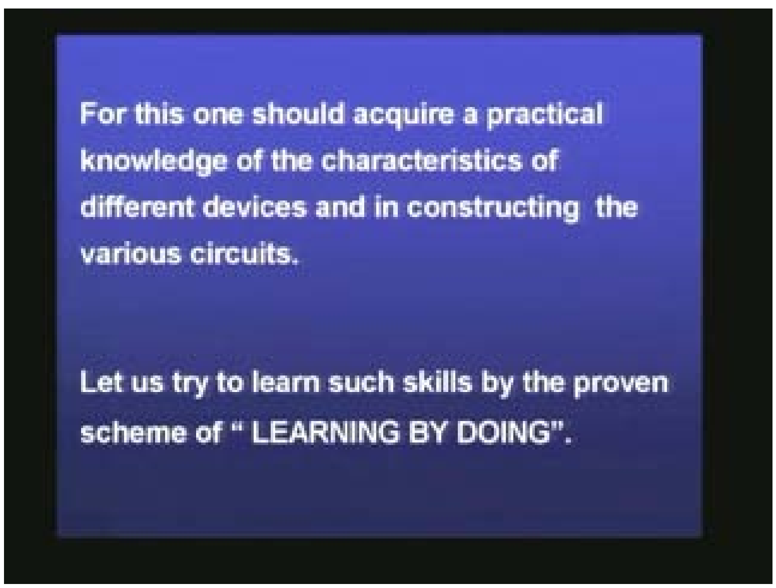

What is this? An old Chinese proverb says I read – I forget; I see-I remember; I do-I understand.

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So if you need to understand and apply whatever knowledge you acquire then it has to be by the method of doing rather than reading or seeing. There is only way to learn to do anything; that is just do it. That is the way we all have learnt as a child even to talk, to walk, to ride a cycle or whatever.

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Many arts and special skills like dancing, singing, swimming and martial arts are all learnt by going to an expert or a teacher who makes us learn by doing rather than by listening to lectures or reading books. But why "learning by doing" is so important? It is very simple. The reason is while doing we are given an opportunity to fail. So failures are very important in the learning process. Nobody wants fail and if one fails, one starts wondering as to what went wrong. Thus at the point of failure there is a profound learning taking place. That is why people say failures are stepping stones to success.

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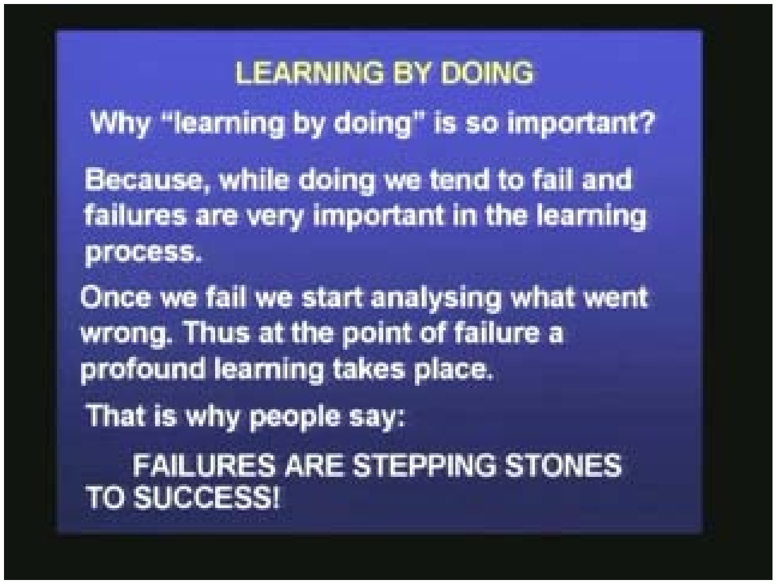

Before we go into the subject of electronics it will be nice to look at some of the historical background of electronics. I will just mention to you few landmarks in the history of electronics. The invention of vacuum tubes or the thermionic valve brought in the age of electronics long time back. Many new and exciting applications were found for theses devices. Many great names like Edison, Marconi, Ambrose Fleming, De Forest, etc., are associated with electronics.

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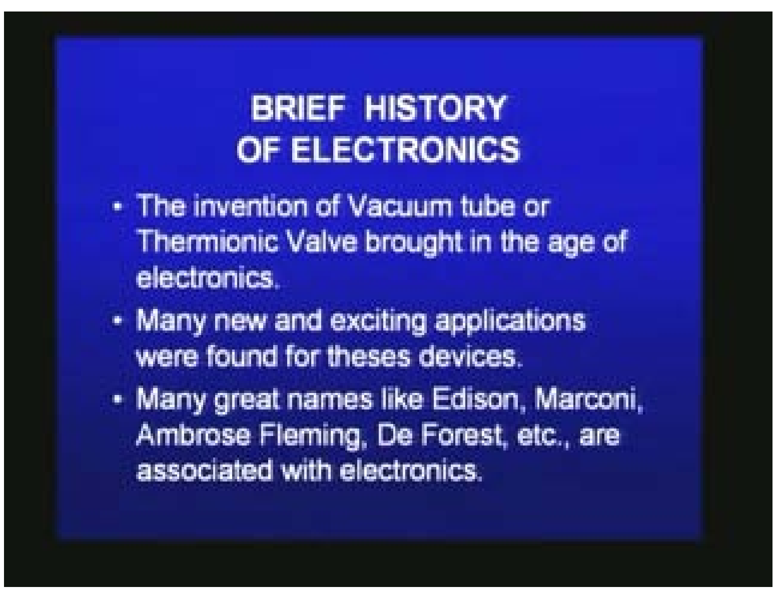

As a mater of fact the transition from the diode to the triode which has got three electrodes was brought about by engineer suggestion by deforest. He suggested that we can introduce a third electrode in the vacuum tube diode to make it into a triode and that really brought about a major change and development in the area of electronics. You can see some examples of vacuum tube on the screen.

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These are different types of vacuum tube used in those days for amplification purposes and things like that. You can see they have a filament, which is a thermionic filament. When I pass a current through that thermionic electrons are develop which are collected by an electrode, called the plate and you have another electrode the third electrode which is the control grid which is in between these two electrodes and any voltage impinched on them will alter the flow of electrons between the two main electrodes- the cathode and the anode. So that is responsible for the amplification and such things. After the war in 1948, the transistors were invented in the Bell laboratories in the USA by the three great people Bardeen, Bratain and Shockely and that brought in much greater miniaturization and applications in the area of radio electronics and things like that.

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On the screen you can see some of the examples of transistors, different types of transistor are shown in the photographs and the major development in electronics came up with the introduction of integrated circuits. This invention is one of the major developments in the area of electronics.

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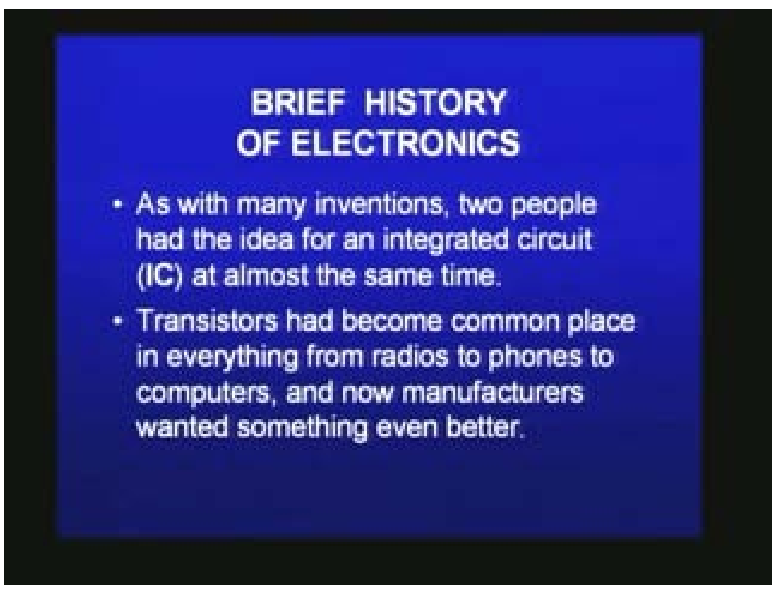

Here transistor have become already common place in everything from radios to phones to computer and therefore the manufactures wanted some thing even better, some thing which is much smaller and much more powerful. Two people are associated with invention of integrated circuits. They are Jack Kilby of Texas instruments and Robert Noyce of Fairchild semiconductors and Jack Kilby were awarded the noble prize in 2000 for his development of integrated circuit.

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Robert Noyce was no more at that time and therefore Jack Kilby alone was given for the partial development of the integrated circuit ideas.

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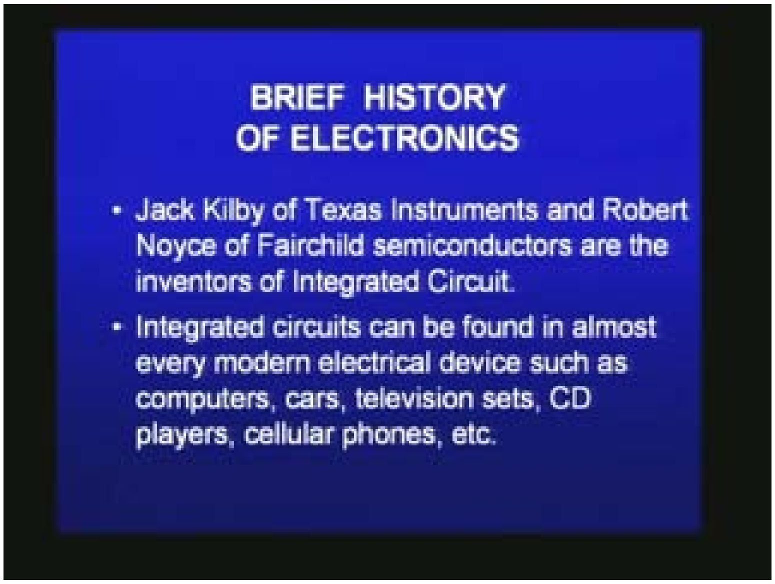

Integrated circuits can be now found in almost every modern electrical device such as computers, cars, television sets, CD players, cellular phones, etc. I will show you some photographs of that. The basic idea here is the semiconductors are used for preparing the transistors. But other devices like the resistors and capacitors have to be independently made by discrete methods. It was the idea of Jack Kilby and Noyce whether the same semiconductors can be used to also prepare diodes, resistors and capacitors.

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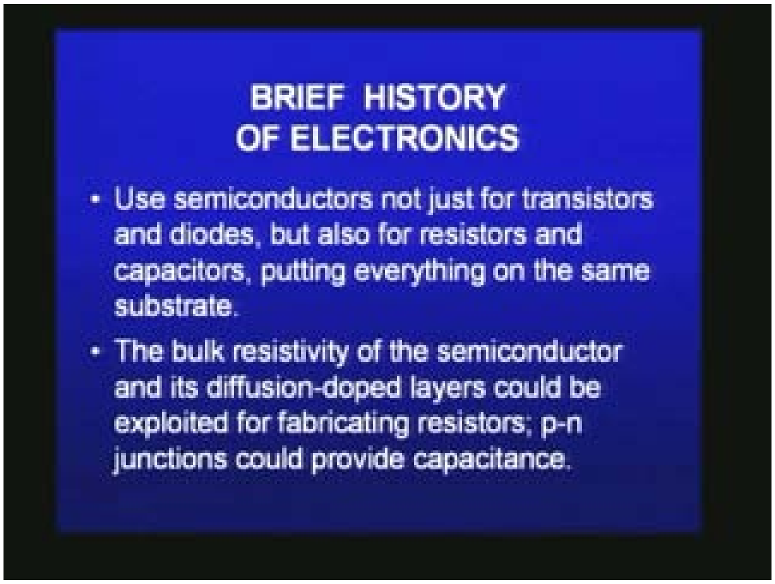

Resistors can easily be developed by doping the semiconductor suitably and the capacitors can be developed by using a p-n junction diode in a reverse bios mode and therefore diodes can be made; resistors can be made; capacitors can be made out of semiconductor therefore Jack Kilby and others started to make the whole circuit, which involves different devices, completely using semiconductors. That is how the whole idea of integrated circuits came. You integrate the different components like transistors, diodes, resistors and capacitors all made of basic semiconductor material on the same substrate. The bulk resistivity of the semiconductor and its diffusion doped layers could be exploited for fabricating resistors, p-n junctions, diode, etc., and that I already mentioned. So this is one of the fast integrated circuit idea which was implemented by Jack Kilby in his lab.

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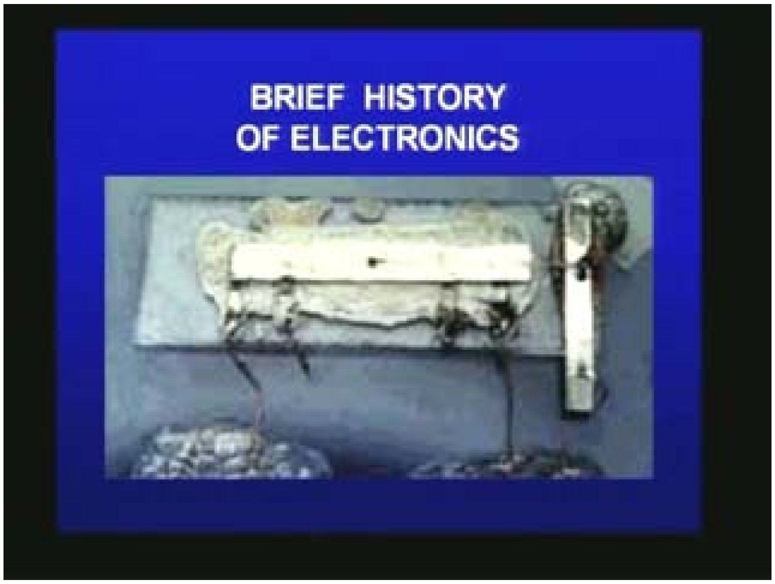

You can see that it is very crude and it has got no resemblance to the modern, well refined, design of integrated circuit which I will show you in the next graph.

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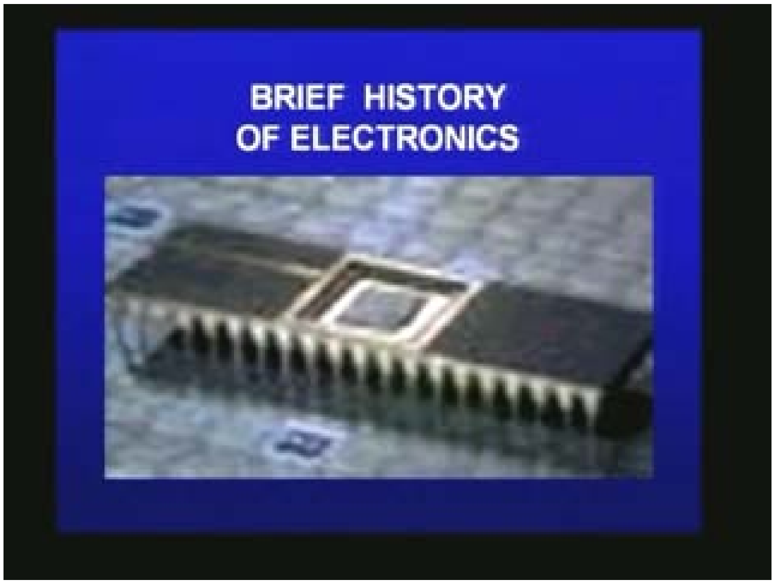

One of the integrated circuits with its memory chip is shown here and the other picture here shows different integrated circuits. They have different packages. In all of these you can see enormous number of transistors being prepared side by side and few of resistors and very few capacitors and no inductances at all.

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So integrated circuits are characterized by very many numbers of transistors, few resistors, very few capacitors and almost no inductances. Therefore the whole idea of integrated circuits completely modified the concept of circuit design. Instead of going for the distribution of various devices, in olden days circuits will have more of resistors, capacitors, etc., and less number of active devices like transistors but with the introduction of integrated circuits the situation reversed. That is we have more number of active devices like transistors, etc and less number of resistors, capacitors and things like that. So this is generally the background of the brief history of the electronics. Now I will move over to the table to show you some real transistors, vacuum tubes and integrated circuits.

Here you can see the vacuum tubes. This is a vacuum tube which is used for power electronics. You have number of pins; you will have a base into which these pins will go and the corresponding voltages will be applied.

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These are characterized by very high voltages of the order of 200-300 volts and you require a separate power supply for energizing the filament and therefore you require large number of power supplies and they will dissipate enormous amount of energy and therefore you will find that they have to be cool if large big circuit are built with vacuum tube diodes and triodes you require very efficient cooling system. Whereas when you come to the transistors, these are semiconductor transistors. You can see this is smallest one; very small three terminal device just as you have triode where you have plate, control grid and cathode, here you have three electrodes – emitter, the collector and the base. Here again you have a slightly bigger one; this is for higher current or higher power. This one is much higher power and this one very large power of several watts. I will just perhaps take it out and show it you. You have two terminals only here. They correspond to the emitter and base and the casing becomes by itself one of the other electrodes which is the collector which takes the brunt of current in any given circuit. So these are transistors of different type, all made of semiconductors.

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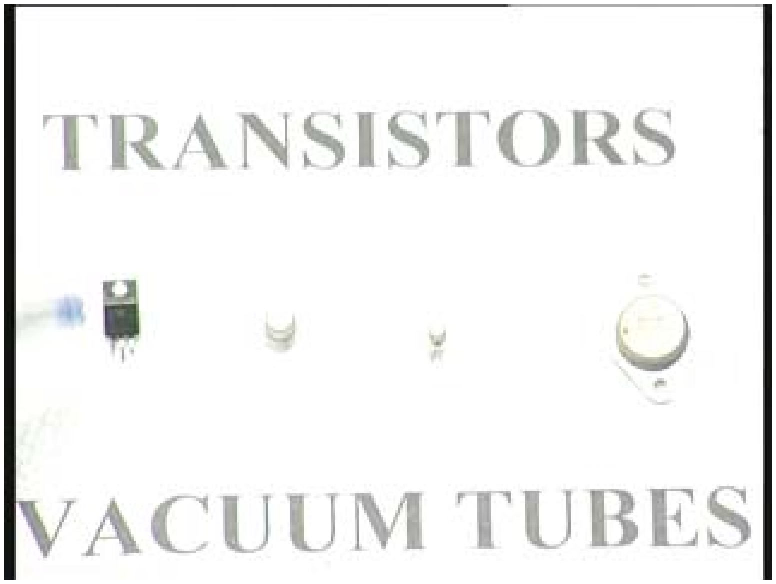

Then we come to the integrated circuits. You have here a very tiny one which has got eight pins on either side. These are called dual in line package and you have much larger one slightly larger one which has got fourteen or sixteen pins on either side; eight on either side or seven on either side. This one is the much larger integrated circuit which has got about forty pins; twenty on one side and twenty on the other. So these are integrated circuits which have got several transistors.

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For example this will have easily about twenty transistors; this will be much larger and this will have thousands of transistors inside and the actual semiconductors will be some where very small, few millimeter squared and to make them easy to handle they are put on bigger package with number of pins so that they can be connected into a real circuit outside.

So these three are the modern integrated circuits. The latest integrated circuits in the computer that you see will have much larger number of pins of the order of 396, 400 and things like that and some of resistors, capacitors also have to be used along with these for building different circuits which have come in; something very similar to intergraded circuits and are called surface mountable devices. So along with these things the miniaturization is complete. Therefore you have enormous number of applications coming out of them including the things that you know of like the cell phone and things like that. They have enormous number of very tiny circuits built with several integrated circuit and several small devices like transistors, capacitors, resistors, etc all found in one. They are all wired on one single printed circuit board; the circuit board itself will be printed with the all the wiring pattern and the whole thing in modern times is all automated and therefore large number of such things can be manufactured very quickly and very efficiently and these devices they also increase in the order of efficiency and performance. The vacuum tubes are not all that good because they have enormous amount of heat generated. These are good but these are much better. Here the transistors are very close to each other and therefore the performance and reliability is enormously improved in these integrated circuits

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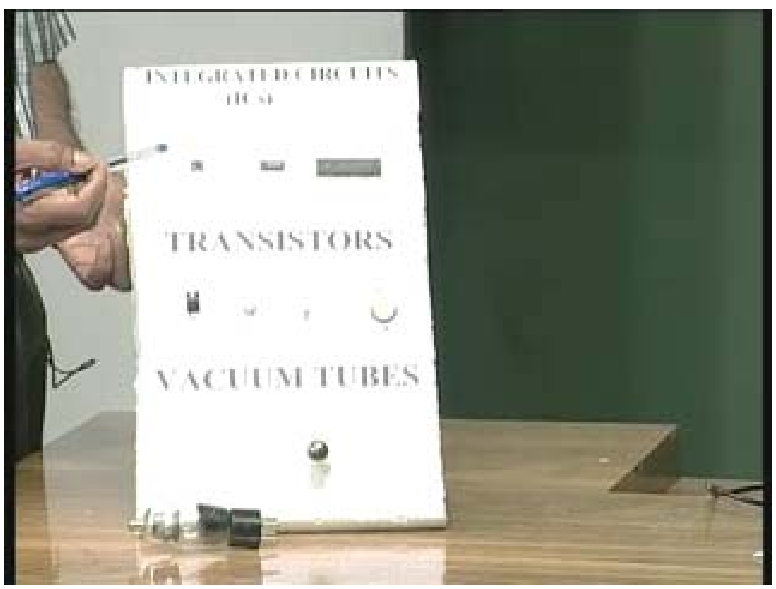

Now let us see what we will discuss in this course on basic electronics. We have components and devices which go into the building of circuits; we have measuring instruments like different types and we also have circuits to learn. For example if we take the components and devices you can classify them basically into two; one is called passive component devices. The examples of passive components are resistors, capacitors, diodes, inductors, etc. If you look at active components there are transistors, operational amplifiers, etc. The passive components cannot amplify; they will only attenuate. If a signal or voltage or current is given to them there will only be reductions if at all after passing through this component. Therefore they are called passive. Whereas if you take the active components like transistors or op amp, there can be an enhancement of the voltage or current or whatever and therefore they are called active components.

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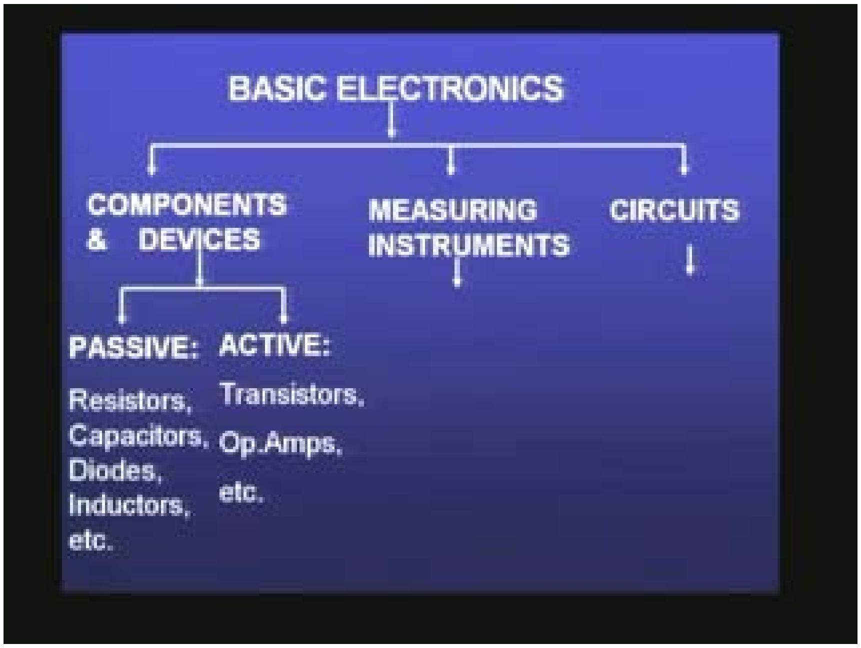

Now if we look at measuring instruments one has to know something about the digital multimeters. Most of them are digital multimeters. There are a very few occasions when you come across analog multimeters. Power supply is very essential for the powering the different circuit for working; voltage sources and current sources, oscilloscopes for observing the different wave forms and function generators which are basically to generate different kinds of wave forms or signals. When you come to the circuit, you find different types of circuit like rectifiers, amplifiers, oscillators, filters and so many different types of circuits.

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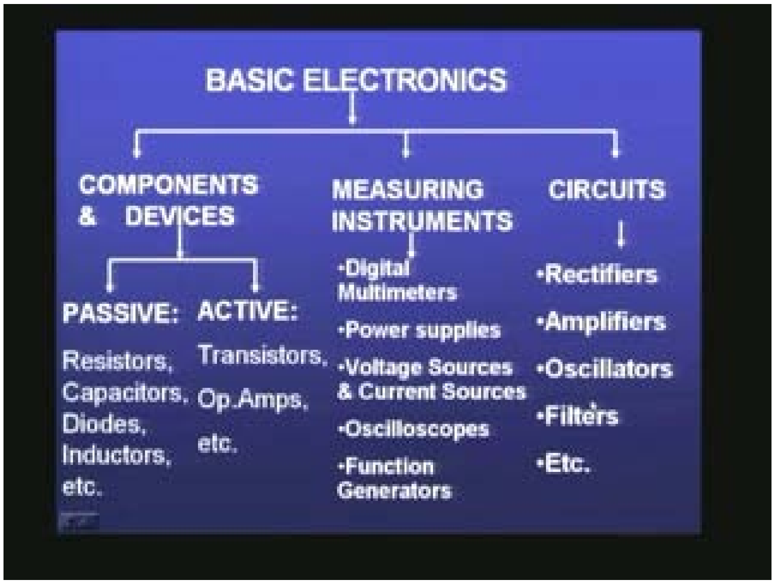

What is the prerequisite of this course? The basics prerequisite we assume for this is that you have a general understanding of the principles of electricity and magnetism. That is all that is required to know from your side. Once you know that we will be able to build on that foundation the whole subject of basic electronics with a practical ….. We will attempt here to learn the basic principles of electronics by the scheme outlined namely "learning by doing".

So what I am going to do is I will try to explain the principles of operation of the various devices, the measuring instruments and the circuits that was outlined a little ago. I will also then demonstrate the working principles by actually performing that part of the theory which we learnt by actually going over to a laboratory table and performing those experiments on a bread board side by side. This I believe will enable you to get greater confidence in the principles and working of electronic devices and circuits and therefore at a later time you will be able to build different circuits on your own and learn from them. Before we proceed further it is important to understand how and where the different circuits will be built and tested.

We will use what is known as a breadboard for constructing the different circuits and for testing. This is very useful here as we do not have to solder the different components while we build the circuit. The normal scheme is to take those components and solder them together on what is known as a group board by soldering them. By soldering, I mean you will use lead and then use a soldering iron which is hot iron and then join the different components into various configurations of the circuit. If we do such soldering then you can imagine the components will have to be cut into different sizes to match the circuit. Once you solder, the components may get spoiled. We may not be able to use the components again later on, where as in breadboard it is very convenient because we are not going to solder the components; you are going to just insert the components or the leads of the components into small tiny wholes which I will show you in a moment and therefore you do not have to solder and the components need not be cut. So the resistors and the various components can be used repeatedly for different circuits. Let us now see how we can use the breadboard. What is the basic principle of the breadboard?

I have shown on the screen a typical breadboard which will be used for building the different circuits. Many of you I am sure are familiar with this type of breadboard perhaps.

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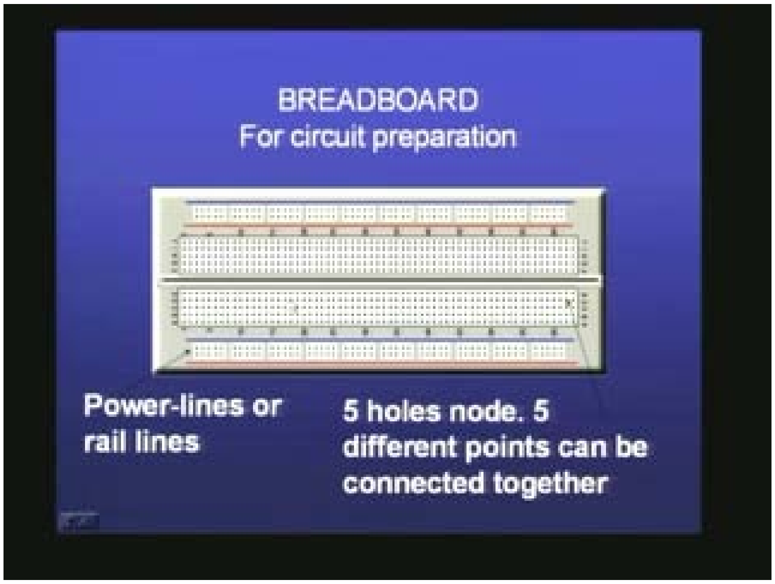

You can see that a breadboard is a plastic board with number of holes on it. There is a pattern of holes. For example you can see vertically there are five holes marked A, B, C, D, E on the screen on side and then F, G, H, I, J on the other side. So you have a whole row of such holes on either side with a small cavity in the center and then you also see on either side, top and bottom between the red and the blue lines a whole range of holes which are running parallel to the length of the rectangle. These lines which are running at the extreme ends between the two blue and red lines are called power lines or rail lines. They are generally used for connecting the power supply lines for the various circuits. The other holes which are marked A, B, C, D, E, etc., are basically five holes in a node. They all correspond to one single node. Most of the times when you build circuit, you find you require many points to be connected together. Here we have five holes. That means five different components or wires can be connected together to one single point. That is what we mean by the five holes node here.

How is it done? For knowing this let us look at the figure that we have on the screen where you can see for example below that holes in the breadboard that I showed, you have a set of clips, metal clips in the form shown in Figure a. This is basically a metal clip which has got very narrow hole at the point where I show and when you insert a component, for example here in Figure b a resistor is shown, and when I insert the resistor inside the clip, the clip expands a little bit and grips the lead of the resistor at this point.

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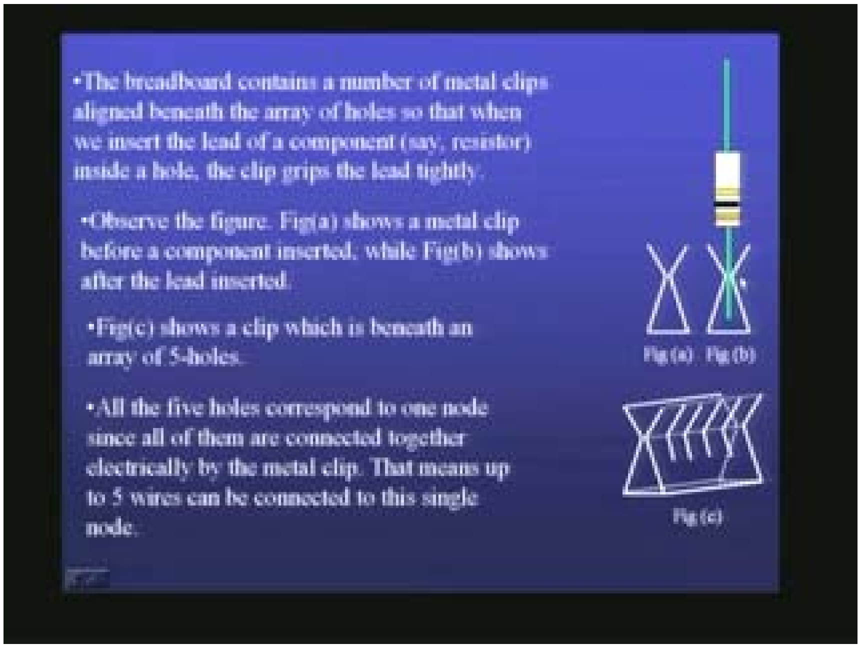

So that is how the connection to resistance is made at these two points and this clip is actually very long as it is shown in Figure c which will actually align below the five holes that we saw on the breadboard. So by connecting different components through different holes corresponding to the one set of five holes you would find, you will be all inter connecting them because all of them have got individual clips below them which are all connected by a single metal frame. Let us look in some greater detail the scheme of things on a breadboard. This is actually a cut screen cut view of the breadboard.

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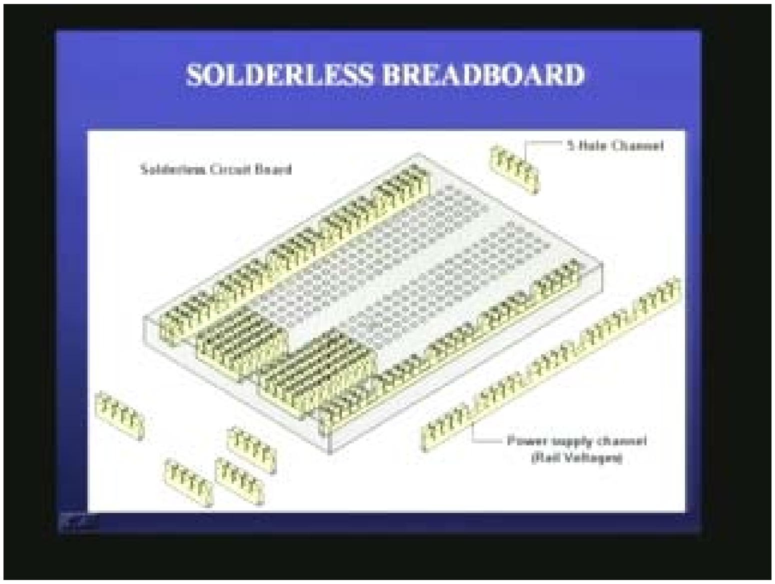

You can see the five clips one, two, three, four, five which will come under these five holes A, B, C, D, E and you also see on the sides which I called the power supply channel or the rail voltage channel you would see there is one single metal clip running all the way down for the entire length and these holes therefore will provide one connection for the power supply. So for example if I connect this hole or this clip to the + 5 volts of a power supply and on this side I connect it to the ground or the minus terminal then you can see that I can get the 5 volts and the ground from any other points along the length for wiring to my circuit which is going to be formed between these two rows of five holes each on either side. I hope you get the picture.

Now how do we check? I mentioned all those things. But unless we check that the pattern of wiring or connections provided below the breadboard is the way I just mentioned to you, we will not to be able to understand the building of different circuits. So we have to try and measure or find out whether connectivity is there in the breadboard as mentioned by me few minutes ago. How do we check that? For that we have to simply use what is knows as a digital multimeter, the DMM and a couple of wires. You insert, for example, two wires in which the insulations are removed and insert the metal wires into two of the holes between which you want to check whether there is connectivity or not.

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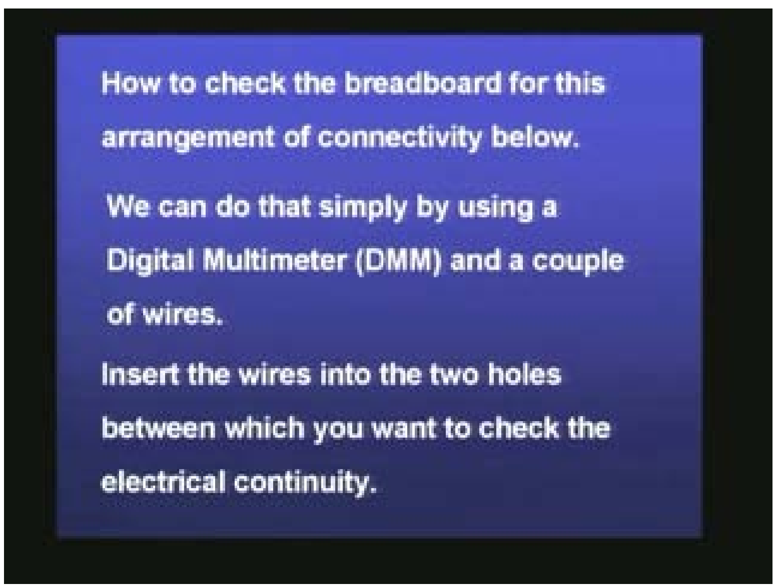

That is electrical continuity; that is what we call. Now choose the resistance mode of the multimeter. So what you are doing is measuring the resistance between the two wires you have inserted into the breadboard. If the resistance shown is zero that means there is no breakage in the circuit; there is continuity or there is connection below these two wires and if the digital multimeter in the resistance mode reads infinite resistance that corresponds to open that means the two points are not electrically connected or they are open or disconnected as we call.

Let us look at a typical image of a multimeter.

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You can see on the screen a multimeter. So a multimeter basically measures. It is multimeter because it measures different things. It can measure for example voltage, AC voltage or DC voltage in different ranges, resistances in different ranges, currents-AC and DC currents as well as it can measure continuity as I was just mentioning to you.

You have a dial with a knob which when it is kept in the position corresponding to off the digital multimeter is off; when I switch it on by rotating the dial to different ranges either voltage on this side, here they are different voltage ranges, or you have an AC voltage range on this side; you have current range on this side and you have resistance over here this is for diode testing and this is for continuity testing.

You have three holes here. One is for voltage, resistance and currents. The other one is a common terminal. This digital multimeter can also be used to measure DC currents of high value corresponding to ten amperes and for that we use this hole for the probe to be connected. So this is the general structure of a normal digital multimeter. You have a display here which could be a liquid crystal display or light emitting diode, LED display. Then it will be some what red or green in color and LCD will be dull and perhaps you have seen some of these multimeters in the laboratory. There are some digital multimeters you will come across where apart from these like the voltages, currents and resistances, you can also measure frequency of the input AC or the capacitors or the characteristics of transistors, the ‘h’ parameter of the transistor.

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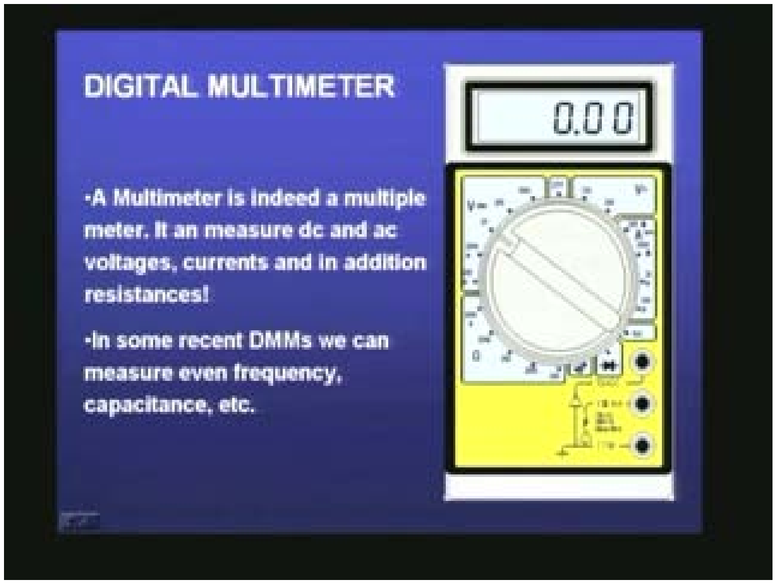

So you can have different types of multimeters which are capable of measuring different types of things. Apart from multimeter you also have a power supply which is very essential for performing experiments in electronics. Every circuit requires electrical power so the power supply will provide the necessary electrical energy. The power supply also can have different outputs. What we are going to use for our experiments during this course will have three different types of power supply all in one box. For example there is going to be 0 – 30 volts variable DC voltage source. That means I can vary the voltage output from a range from 0 volts to 30 volts and this can provide a maximum of one ampere and there is a display, digital display which will measure the voltage that is being set by using couple of knobs on the panel.

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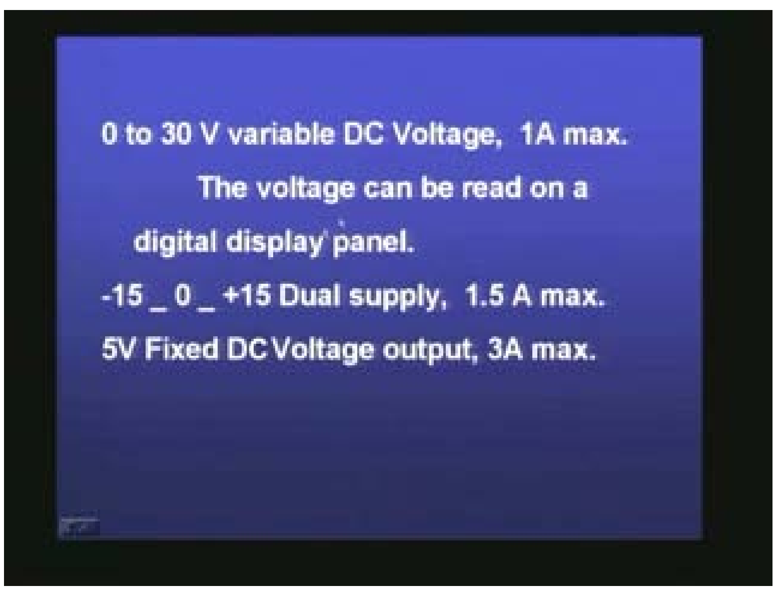

You also have another power supply which can provide -15, 0, + 15. This is called a dual supply. It has got two supplies in one. You can have both minus as well as plus outputs in the same power supply and therefore its called a dual supply and the maximum current that I can draw from this dual supply is 1.5 amperes.

The third power supply which is also built into the same casing is a fixed DC voltage with a value of 5 volts. You cannot vary it. It is constant 5 volts but it can provide you much higher current of up to 3 amperes. The dual supply -15, 0, + 15 is also almost a fixed dual supply with very fine adjustments possible by a very small range from 15 volts may be around 13 or 14 volts.

So this is what we have for performing the different experiments in the lab. You have a breadboard, you have a digital multimeter which can be used to measure different quantities like voltages, currents and resistances and you have a power supply which can be used to apply different types of voltages. The 0 to 30 volts power supply is generally used for a situation where you would like to change the voltages applied to different circuits whereas the dual supply that is -15, 0, + 15 supply will be used most of the time for circuits which we use, for example, operational amplifiers. Most of the operational amplifiers require a dual supply. That means with reference to a common point which is a 0 or a ground you will have both polarities of outputs both +15 and -15 and so the dual supply will be used for powering operational amplifier circuits.

The five volts fixed DC voltage output that I talked about is usually used for performing experiments with digital devices and digital circuits. Now let me quickly go over to the working table and show you the breadboard and I will also try to show you how multimeter can be used in resistance mode to detect the connectivity between different points in the breadboard as I explained to you and then I will also show you the power supply which we will be used for the rest of the course and that power supply as I already mentioned to you has got three built in power supplies; independent built in power supplies, one with the variable voltage 0 to 30 volts. Another is a dual supply +15, -15 and 0. Last one is 0 to 5 volts for performing digital experiments. Now I quickly move over to the other table.

You can see I have a breadboard here and that breadboard is mounted here in a slanting position for better view and you have here a digital multimeter with LCD display and you have the dial which I showed some time ago and presently dial is in the off position.. So if I want to switch on the digital multimeter I just have to click on the knob to the next position. For example here you see there is a symbol which shows a loudspeaker. On the other side we have the ohm symbol. That means this is for resistance measurement here and this is a loudspeaker which shows that it will give a sound when it has continuity or when resistance is zero. For example I have the two knobs here. Red one is at volts, ohm etc. The other one is a common ground. Now I am going to take two wire parts and touch them together. If I touch them together you can see there is a sound coming from here. That is why the loudspeaker symbol is shown here. That means there is zero resistance in the circuit because I have not connected any thing. When I take them out there is very large infinite resistance do to the air dielectric. Therefore it shows a blinking display here.

That shows it is infinite resistance. If I connect them together there is a sound which shows there is continuity in the circuit. Now this is the way I am going to test the breadboard as I mentioned. For example I am inserting one of the wires in one of the holes at the bottom. So immediately when I push the wire, the clip expands and receives the connecting wire and when I connect the next wire in one of the other holes for example here I have put in F and J. Now you can see the multimeter is giving a sound. That shows the resistance between J and F is zero. There is continuity which is what we saw because there is one single metal clip which is aligned parallel to the five holes that we see here.

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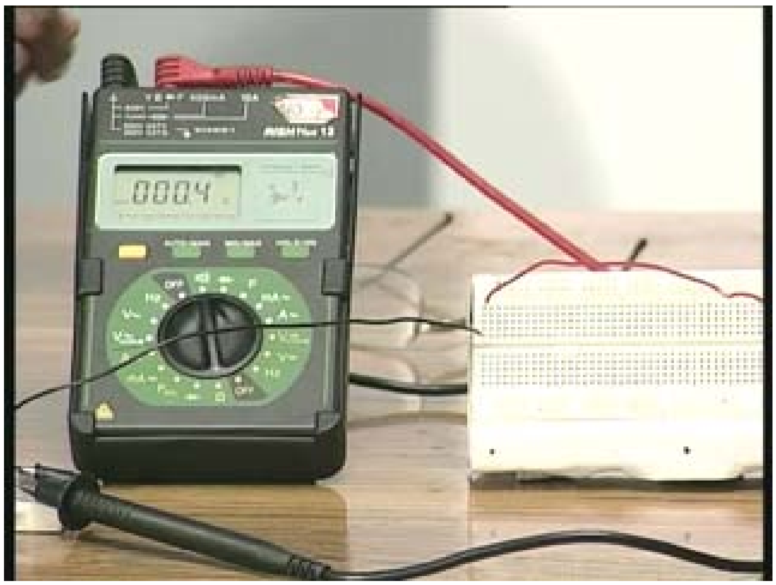

Now if I put this into the next column of holes, now I have done that, one of the wires I retained in the same place; another wire I connected to the next column of holes. Immediately you find that the display is blinking and there is no sound. Because the display is blinking and there is no sound that shows this is infinite resistance; that means there is no connectivity or there is no continuity between these two. That means all these five holes are independently together but the neighbouring ones are separated by infinite resistance.

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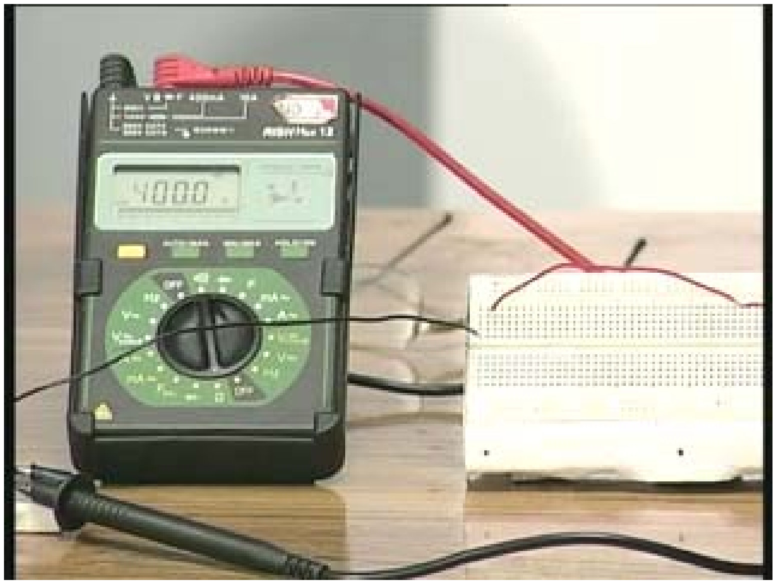

So they can be used for building different types of circuits. I also mentioned that the two rows that you see on the top here and at the bottom here they are meant for power supply lines and also I mentioned that all of them in a given row are all connected together completely from this end to this end. That we can now verify. For that I put one of the leads to the first hole on the top and the other wire I am going to connect anywhere in between. Now you can see that these two wires are on the same row and the sound is coming. That means there is continuity.

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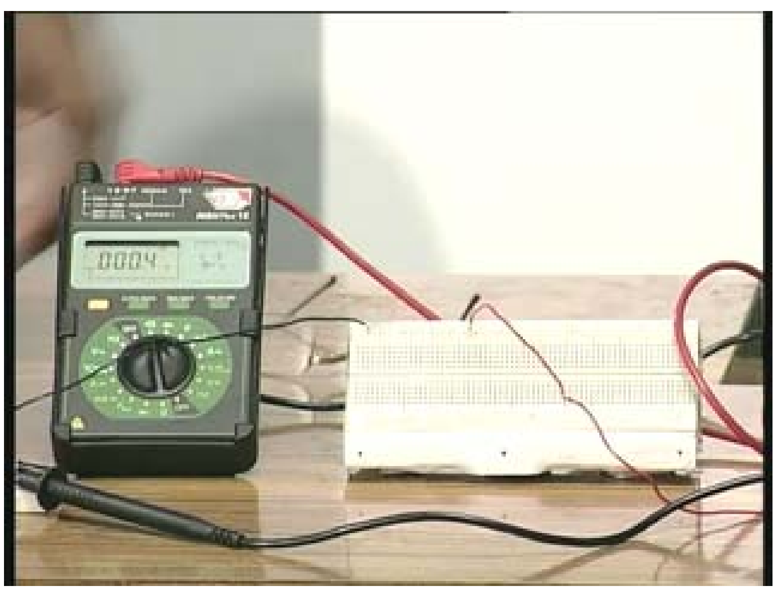

So wherever I put it, I remove it and put it near the end again you see there is sound coming; wherever I put that means the entire row is one single connection. If I put the same wire in the next row just below that, you would find there is no sound and the display is blinking.

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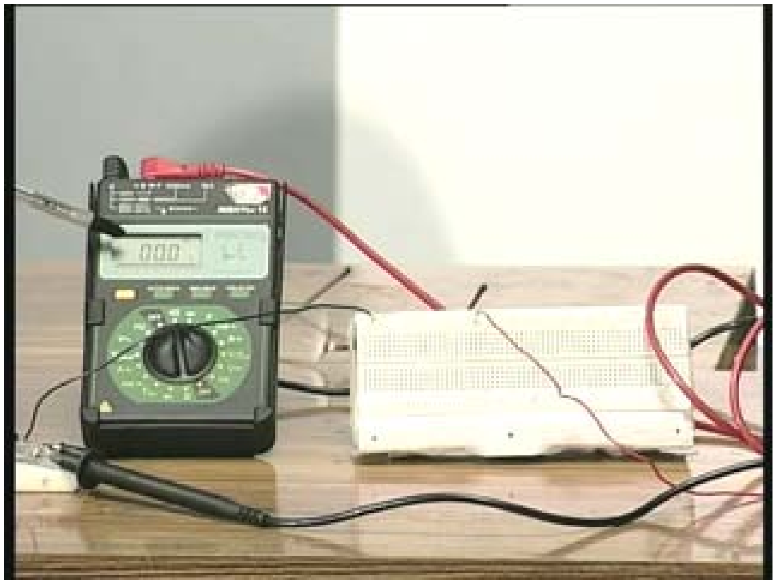

That shows there is no continuity between the first row and the second row at the top. A very similar exercise will tell you the situation is identical with reference to the bottom row also. There are two rows at the bottom; there are two rows at the top which are normally used for powering the power supply lines in a given circuit. So this is about breadboard. Once you know about the breadboard, it becomes very easy for you to construct different circuits.

Now let us quickly move on to the power supply. I will switch this power supply on and you can see in the power supply there are three knobs here. This is red in color, green and black. This corresponds to plus; this corresponds to minus and if you see the display here it is 0 to 30 volts and the maximum of two amperes.

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There are two knobs here; there are two knobs here. You can see that by varying these knobs I can vary the voltage here. The voltage is read here and this is for fine control.

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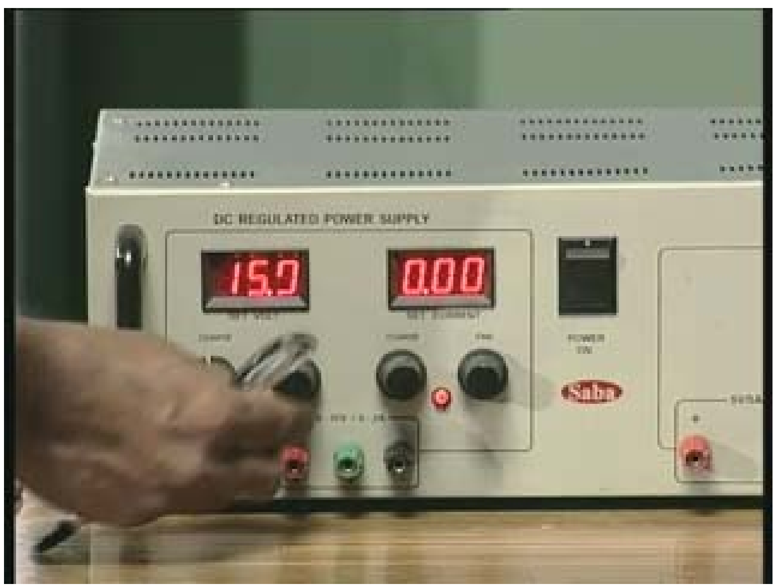

The voltage here can be changed very slowly by using the second knob which is called fine control. This is coarse control which is used for varying the voltage by larger extent and similarly you have two more knobs here and there is a display here which is for measuring the current. So I can change the current limits; that means what is the maximum current I can apply using this power supply. I can limit it by using this knob and I can increase by using these two knobs. Again you have the coarse control and the fine control for the current. So this forms the first block of power supply that I mentioned to you 0 to 30 volts with the maximum of two amperes and then if you come to the other side, you have here red and black knobs which is marked five volts, five amperes for this is generally used for digital circuit and at the end you have three knobs once again.

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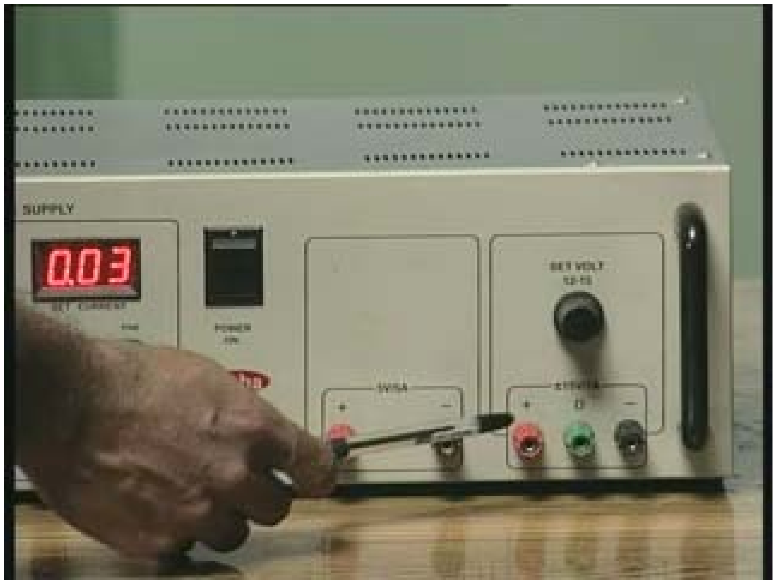

The plus, the zero and the minus corresponding to red, green and black and this is basically the dual supply that I mentioned to you about +15, 0, -15 and the range can be slightly modified by using this knob from 12 volts to 15 volts both sides. That means if I change the knob, the voltage can be +12, 0, -12 or +15, 0, -15. One single knob will vary the output on both sides so that is what we have here.

So having got the multimeter, now let us try and see whether we can measure the voltages from the multimeter. So I will remove the clips and I have the simple test probes and I will change the knob position here so that I can measure the DC volts. So I move over to the DC volts. I press this knob because this is in yellow. I should press yellow button because I want to measure now the DC volts as shown here.

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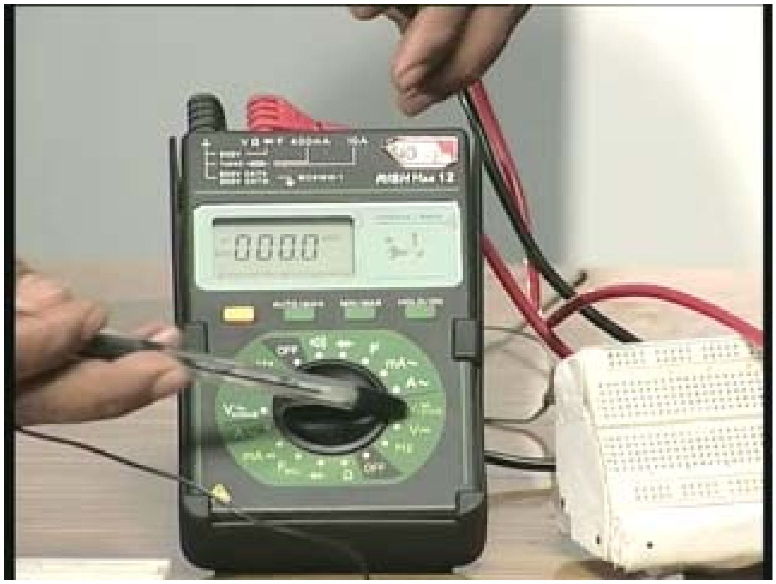

So now I have selected the DC volts measurement using the multimeter and I have the two probes. I am going to connect it to the two outputs; the black and the red and this display shows it is around 15 volts and you can see the display on the multimeter is also close to 15 volts.

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So if I now change the fine control or the coarse control, you can see the voltage is changed. For example now it is around 8 volts.

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Both here as well as in the multimeter. So this is the voltmeter, voltage source, which can go up to nearly 30 volts. Now I take it out and connect it to second power supply which is five volts, five amperes power supply and the moment I connect it this display does not correspond to this output. This is a fixed voltage output and therefore the display there you can see is showing 5 volts constant; that can not be varied.

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This is generally used for performing digital experiments. In the last one you have three knobs. I can take it out and connect red to the red and black to the green because this is 0, this is +15 and so you can see output voltage on the multimeter is +15 volts right. Now I take the red wire and connect it to the black knob on the other side. I have not disturbed the black probe of the multimeter which is still with the green. Now you can see that the voltage measured is -15 volts.

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That voltage, as I already mentioned to you, can also be varied by using this knob. You can see that when I change the knob, the voltage in the multimeter is changing. So when I change the knob here the corresponding voltage in the multimeter will also change. So now it reads something close to 12 volts. So you have here two voltage supplies with a common terminal which is here the green. The red one gives the positive voltage and the black one gives the negative voltage and therefore this is a dual supply. You might perhaps ask me why do we have a green knob here which I did not use with reference to the first power supply. So I will try to do once more. I connect one of the knobs to the red and the other black probe to the black and you can see the voltage is 22 volts here and that means the power supply output is only between the black and red terminals. Then why do we have the green? If you look at the green at the bottom you would see there is a symbol corresponding to ground, earth which is shown here. I hope you can see that.

So this is used to make this power supply either positive power supply or negative power supply. For example if I take a wire and connect the green to the black then it becomes 0 to whatever voltage that I get. For example this is 22 volts, it will become a +22 volts power supply this becomes a 0. If I connect both of them together by a small wire I can either take from green or red it becomes a ground or common terminal and this is the output which goes up to 22 volts.

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Now if I want a negative voltage then what I do is I connect the wire between the green and the red. Then this positive end is grounded. What I have is an output from the black which is -22 with reference to the common which is now shifted to the plus terminal and therefore with reference to the plus terminal this will be 22 and therefore when it is 0 by connecting them together this become -22 with reference. So this is actually a floating power supply between plus and minus. By connecting to ground either the plus or the minus I can get a positive supply or a negative supply. So that is about the power supply. What we have seen we have got multimeter; we have got a breadboard and we have got a power supply and perhaps we may need some more instruments for performing some of the experiments that we will be discussing about.

In summary therefore what we have seen, we have seen the importance of electronics, how one has to have some basic understanding of electronics, the various components, devices, the various measuring instruments and the circuits. Then we also saw why learning by doing is the best way to learn any subject, especially subjects like electronics which is an applied subject. We also saw the plan of course with reference to different topics that will be covered. For example the basic devices and components, the measuring instruments like the multimeter, oscilloscope, power supply, function generator, etc and also the different circuits like rectifiers, the amplifiers, the filters, oscillators, etc. We also saw that it will be better to build the circuit using what is known as a breadboard.

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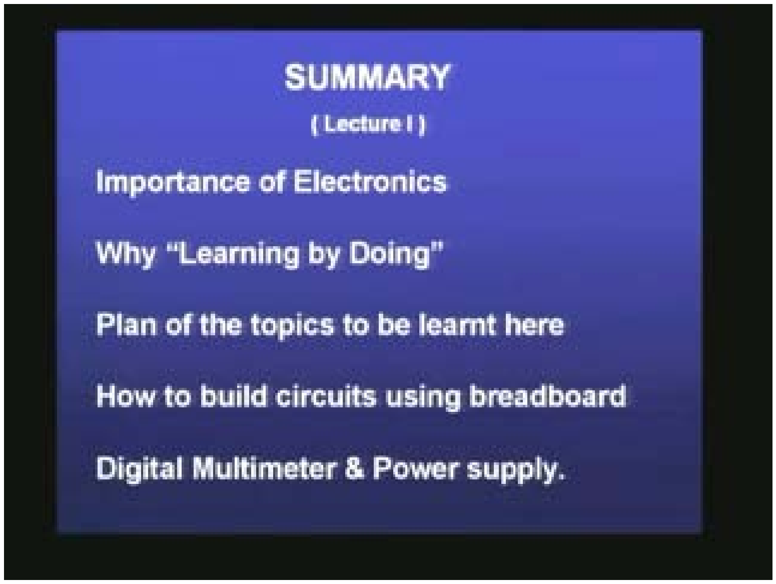

We saw how a breadboard is constructed, its parts, how it is able to receive the different components without having to solder them together and we also saw how a digital multimeter and a power supply can be used for building the different circuits and components.

We also simultaneously saw by actually using the multimeter and measuring the various points on the breadboard and then it was seen that the breadboard has got a very special type of connectivity between the various sockets which can be used for building different circuits. We also saw the power supply with three different output voltages starting from a single variable supply and a dual supply and a digital power supply with 5 volts output and we also measured some of the voltages using the multimeter and we just got basic understanding of the various instruments and devices. Now what are we going to look at during our next lecture? In the next lecture we will be looking in some detail about some of the components that we will come across while building the different circuits namely resistors and capacitors, their properties, their color codes; there are different types of resistors and capacitors and then how the different combination of resistors and capacitors behave in different situations in a circuit.

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All these things will be discussed during the next lecture. Thank you.