BASIC ELECTRONICS
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LECTURE-7
APPLICATION OF DIODES

Hello everybody! In this lecture we will discuss some more aspects of semiconductor diodes. You may recall in the previous lecture we discussed about the semiconductor diode, different types of diodes like the rectifier diodes, light emitting diodes, photo diodes, Varactor diodes, etc and then we also saw how the light emitting diode, LEDS can be used for display purposes by using the seven segment display system. We also discussed that in the previous lecture. Diodes are generally specified in data sheets by their maximum forward current ratings and the peak inverse voltage and continuous power rating. These are the three important specifications of a diode. That is how much maximum current I can have under forward bias condition and then under reverse bias condition what is the maximum voltage I can apply across the diode without the diode going into the break down region and lastly what is the power rating of the diode?

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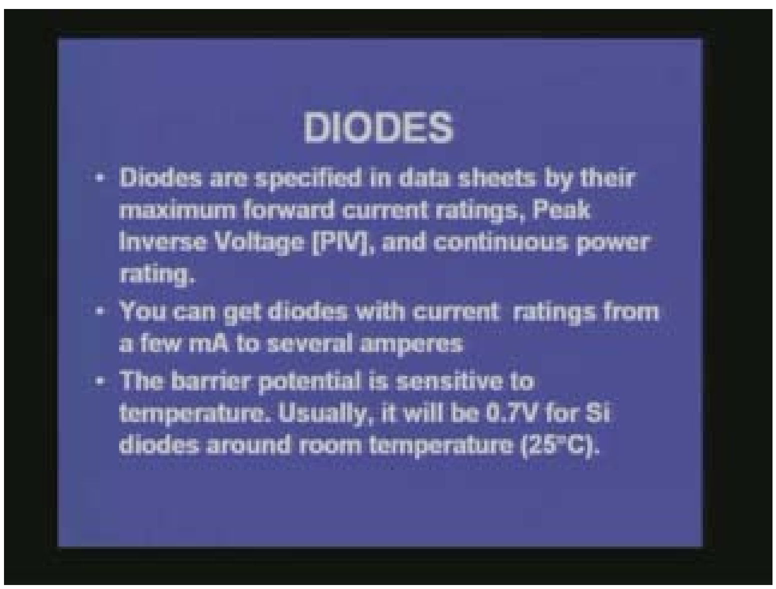

These are three important parameters that we normally obtain from a data sheet of semiconductor diode. Usually the manufacturers will specify all these information in their data sheets. We can also get diodes which have got current rating from few milliamperes to several amperes. You may recall when I showed the diodes, some diodes were very big like nut and bolt and they are actually meant for very high currents. There are also diodes which are very tiny, small. You would have seen last time and they are generally meant for small currents of the order of few milliamperes. The barrier potential for a Silicon diode for example is about 0.7V or 700millivolts. For Germanium it is about 0.1 to 0.2V.

This barrier potential is also very sensitive to temperature. Whenever we use a semiconductor diode we should be conscious about this fact that they are very, very sensitive to temperature. So the barrier potential is usually 0.7V at around 25 degrees centigrade which is about room temperature. If you go beyond room temperature or when you go below room temperature the 0.7 can change. How will it change? That is normally expressed, as you can see on the screen, as variation of the potential across the diode with the temperature which is called delta V by delta T. That is the change in the barrier potential with the change in temperature is given approximately as -2 millivolts per degree centigrade.

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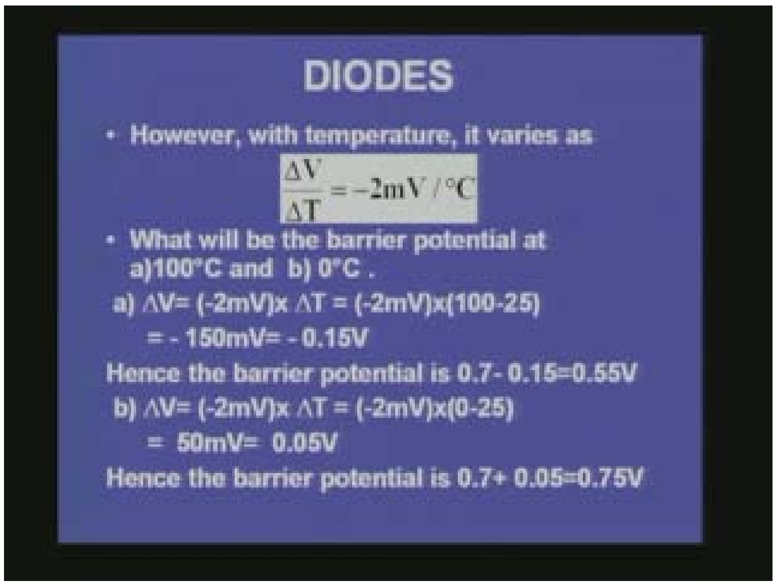

That is it will vary by two millivolts for every change in one degree of temperature. Let us just quickly find out what will be the barrier potential at two different temperatures for example 100 degree centigrade and zero degree centigrade which we are very familiar with. You can see on the screen if I take the first case of 100 degree centigrade you know delta V by delta T is -2 millivoltage per centigrade. I want to know the delta V for change in temperature which is between 100 degree and 25 degree. -2 millivolts into delta T gives me the delta V. That delta T in this case is -2 millivolts into 100 -25 because I want up to hundred degree centigrade and the normal temperature specification is 25 degree centigrade. Therefore100-25 is about 75 and 75 into 2 is 150. So you will have -150 milli volts or if you express it in volts, it is -0.15V. So this amount of voltage will be the change in the 0.7 that you think of. Hence the barrier potential will become 0.7- 0.15 which is equal to 0.55. Therefore at room temperature 25 degree centigrade, the voltage across the diode when it is forward biased will be around 0.7 approximately but under the same condition if I increase the temperature to 100 degree centigrade it will not be 0.7 but it will be only 0.55 volts at 100 degrees centigrade.

Similarly let us work it out for the second temperature which is zero degree centigrade. Because I am going in the opposite direction from 25 degrees delta V is -2 millivolts into delta T. Here delta T is 0-25 and therefore another minus here coming in. When you multiply, it is about +50 millivolts which is equal to 0.05V. The voltage of the barrier will vary by +0.05 when I go down to temperature from 25 degree centigrade to room temperature. Therefore the barrier potential in this case will be 0.7+0.05 which is equal to 0.75V. When I go down in the temperature the barrier potential will increase when I go up in temperature the barrier potential will decrease. As a mater of fact this is made use of to measure temperature. That means a diode can be used as a temperature sensor. A sensor is something which will show a change when there is a change in temperature or change in pressure whatever you want. In this case the barrier potential shows a change whenever there is change in temperature. Therefore the diode with forward bias condition can be used as a temperature sensor for measurement of temperature because we have a very clear behavior. As a mater of fact it is linear. The temperature variation is linear over very large range of temperature from about 300Kelvin to about even 40 degree Kelvin for a silicon diode. Therefore in low temperature laboratory you would find semiconductor silicon diodes are used as temperature sensor for measurement of temperature. This is one of the very important applications of a diode.

We always consider about ideal devices. What will be the ideal nature of a diode? If I take an ideal diode how should it behave? What should be its V_I characteristics, voltage current characteristics? I have shown on the screen the ideal case. You know the behavior of the diode in an ideal condition. When I forward bias it should conduct completely, when I reverse bias it should not conduct completely. It should become an insulator. That is the ideal characteristics of a diode. In the first circuit there is a voltage source, there is a resistance, there is a current meter and there is a diode here which is now forward bias and because I assume ideal condition I take forward bias diode is fully conducting and therefore I just replaced the diode with a short here.

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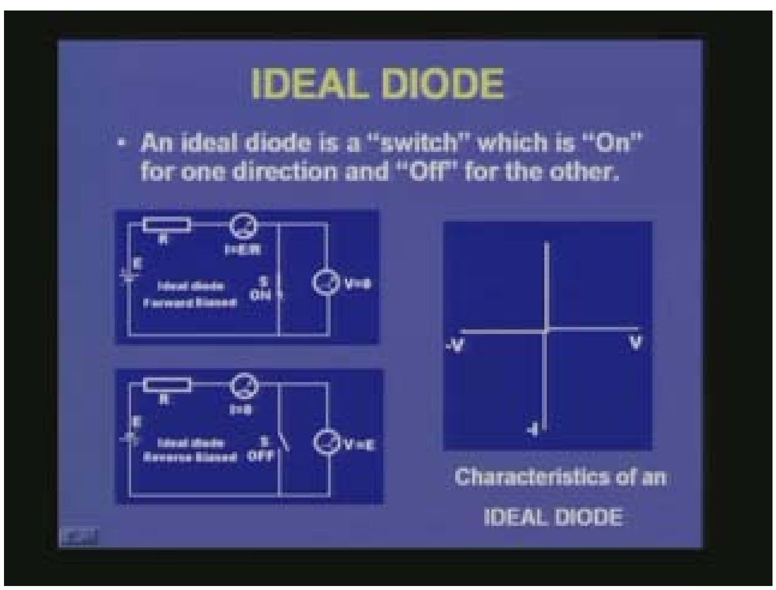

If I replace it with a short it is zero resistance and if it is zero resistance you can see the voltage across the switch will be zero. So the voltage across the diode is zero when the diode is a ideal switch and it is on in the forward bias condition and the current will be decided only by this R because that is the only the resistance in the circuit. So I is equal to E by R. The current meter here will show you a current which is equal to E by R and there is no voltage across the diode and you get zero volts across the diode. This thick line corresponds to diode when it is forward biased there is no voltage across it and the current can be decided by the external resistance only and that is why it keeps on going. If I increase the voltage current only increases. Nothing happens to the voltage across the diode.

If I look at the reverse biased diode then you can see the diode which is acting as an ideal switch is now off because in reverse bias the diode offers high resistance. In ideal situation it offers infinite resistance. Therefore it is an off switch. When the switch is off whatever be the voltage I apply that will come across the switch because there is no current flow and therefore there is no drop across the resistors and the entire voltage E will appear across the diode now and therefore this voltmeter will read V and this current because it is zero will read zero. That means the voltage will increase as I increase the input voltage but the current is zero. Therefore the characteristics of the ideal diode under reverse bias condition should be along the negative X-axis, negative voltage axis. This thick line here shows the reverse bias characteristics of an ideal diode. The forward bias is a straight line parallel to the Y-axis along the Y-axis and for the reverse bias the characteristic is along the negative V axis. There is no current and this is the ideal characteristics of an ideal diode. But we never have ideal diode. We all know for example this is not going like that. There is a …… 0.7V after that only it increases and it is not straight line here. When the current increases it will go along the slope, with a finite slope and therefore these are non-ideal situations of a normal diode which is what we normally encounter in all our circuits. Similarly under reverse bias direction the current is not absolute zero. You know there will always be some intrinsic conductivity which is again sensitive to temperature and therefore you will have very small, finite current which is of the order of micro amperes or nano amperes which will be flowing here and it will not be perfectly zero in the non-ideal diodes. This is what we should remember. I have also shown you the different approximations that you can have for a normal diode. An ideal diode is like a switch, I already mentioned to you and the characteristics is something parallel to the Y-axis along the Y-axis when it is forward biased and along the negative X-axis when it is reverse biased. But this is not the way we get in a forward bias condition because you get some voltage which is the potential across the barrier which I call here V_0 and therefore if I now introduce a DC battery corresponding to the 0.7V for example in the case of silicon then I can assume the normal diode as the first approximation as a voltage source of about 0.7V connected in series to an ideal diode. When I do that you find what actually happens is when I forward bias this vertical line which is going along the Y-axis will be shifted by a value corresponding to V_0 and therefore I will get a vertical line here.

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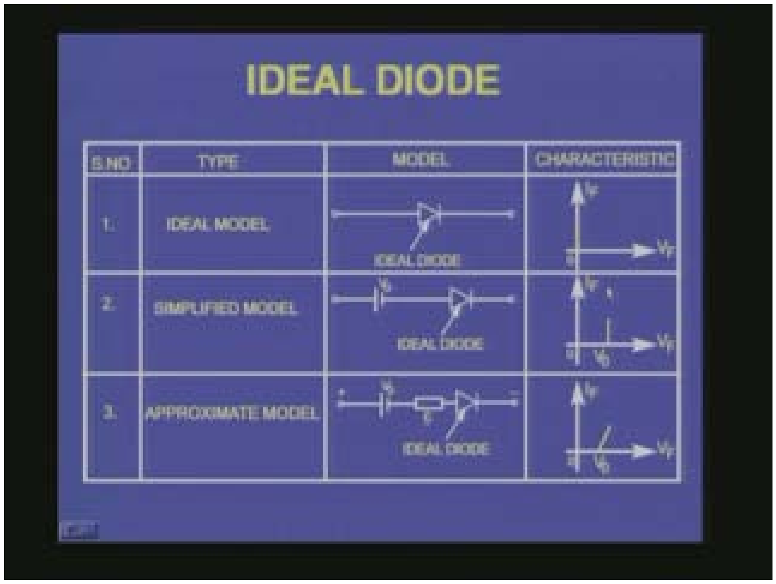

That will be the characteristics of the diode under forward bias condition with first approximation where I take into account the potential across the barrier alone. But we also should perhaps take it account the resistance associated with the diode when it is forward biased due to the bulk resistance and therefore I must include another resistance if I want to make it more closer to the actual diode that we have and therefore in the next approximation I have introduced a resistor here which is called R_f and R_f is the forward resistance of the diode and I have the voltage which is corresponding to the barrier voltage V_0 and have a resistor which is corresponding to the bulk resistance of diode in the forward condition and this is the ideal diode. All these three in series can almost approximately resemble the actual diode that we normally come across.

You will find that characteristic is like this and in a real case it will just be slowly curling toward this end and it will be coming to the zero and this is the second approximation of the diode. These are very useful when we make use of the diode. You should always remember there is around 0.7V across the diode. It is not as though when it is forward biased it is fully conducting when it is reverse biased it is fully off. It is not like that. We will come across this aspect as we discuss about some of the applications of the diode.

We come to the applications. One of the very important primary applications of a semiconductor diode is as a rectifier and this is being made use of in several ….. electronic devices that you come across in daily life. Because most of the devices like transistor receiver or DVD player or television require a DC voltage of a finite value. Most of the time we require the DC voltage of about 6V or 12V as the case may be. But at home and office whenever you want the voltage or when you want the device to be operated you immediately put it into mains plug 220V AC and now I am saying we require only 6V or 12V DC. How do you understand this? The point is when I put the plug there is actually a circuit inside the device, a transistor radio or DVD, where this AC volts which is coming to our homes and office is converted. Alternative voltage AC mains 220V will be converted into suitable DC of 12V or 15V as the case may be. In every one of the those devices or equipments you will always have a power supply circuit which basically makes use of a diode as a rectifier to convert AC into suitable level of DC. This is one of the very important applications of diode.

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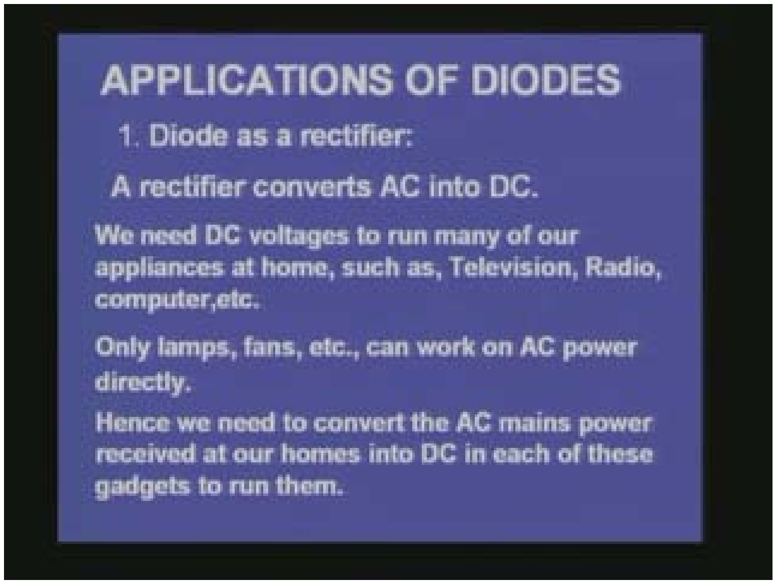

If you have devices like lamp and fans you can still have mains directly. In the case of a lamp or bulb or in the case of the fan you will just use 220V as such. You do not have to convert them into DC. In all other devices, most of the devices we have to use AC and convert it into a suitable DC and then only make use of them in our circuit. Because most of the circuits make use of DC for powering. If that is the case you may start wondering and I am sure many of you would be having this doubt why on earth we are having AC mains come to our house? Why not have DC directly? If you want 6V let us have the plug coming to our house having an output voltage of 6V or 12V as the case may be. The reason is very profound. It is very important because at the source by using a dynamo when I want to generate electricity in a hydel project or any atomic power plant it is very easy to generate a DC or an AC by a slight modification of the dynamo. You know the difference between an AC dynamo and DC dynamo is not very complex. We can always make them either as DC or as AC. However from the power plant or from the source where the electricity is generated to the place where it is being used like our houses and other offices the distances involved can be several kilometers. If you want to take electrical energy from the source where it is generated to the place where it is to be used for example in houses and offices you have to run long wires for several kilometers. The wires are either copper or aluminum wires which has got very good conductivity, they are very good conductors but still if you consider them over several kilometers then you can imagine that they will have finite resistance of the order of few hundred ohms for several kilometer. Therefore when you have large resistances when I apply a voltage across that you know there is going to be heating. I square R. That heat is actually energy loss. Apart from that there will be voltage drop across the resistor. So when you look at the user end the voltages will be degenerated. It will come as less voltage. It will not be able to drive some of the appliances we will connect them to. Therefore transferring AC or DC over long distances is full of losses and therefore one has to take care to make the losses as minimum as possible. One way to do that is when you transmit them in an alternating mode, AC mode you can step them up by using simple device which I already explained in some of the earlier lectures by using what is know as a transformer. A transformer transforms one AC input into another value of the AC input depending upon the number of turns; ratio of the number of turns on the primary and the number of turns on the secondary. The ratio will decide the output voltage for the AC. You have step up and step down transformers. You can design them. When I step up for example 220V, usually they step up to 22,000 V and 44,000V. When you increase them to very high tension and very high value of voltages the total energy is constant. When I increase the voltage, the corresponding current will have to be very, very small. So at 44,000 and 22,000V the current involved will be very, very small. So when I send them over long distances through conductors, several kilometer, losses which are more proportional to I square R, you know energy loss is I square R, that I square is now going to be very, very small because the current that we are now talking about are very, very small. Therefore losses will be minimized. Therefore there is no other option for us but to send voltages from the power plants to user end only by alternating voltages. Near our houses we will again have transformers which will transform them back to 220V or whatever convenient level and 50 hertz and that is what is given to us in our houses and offices. So transmission of AC is the most effective and efficient wave of transmitting electrical energy to different places, distributing it to different places. But we require for our electronic appliances DC voltages only and therefore we have to convert the alternating voltage available at our houses and offices into DC voltages of required value and therefore we require rectifiers. So how do we do that?

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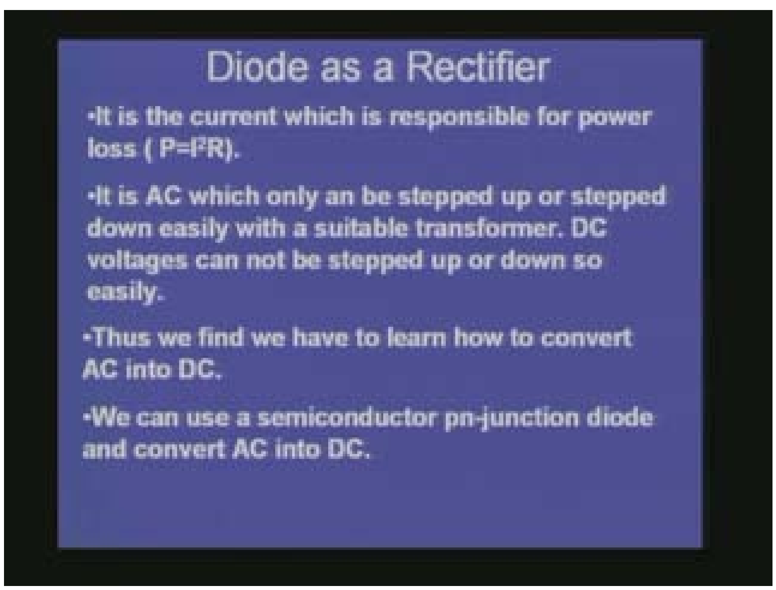

How can we use a semiconductor diode for converting AC into DC? Before that, let us recapitulate some concepts regarding alternating current and voltages. I am sure many of you are already familiar with them. I will just briefly explain to you. For example on the screen you can see there is a sinewave. This is sinusoidal wave. It is a continuous wave. It keeps on going. I have shown only one period of the sinewave along the time axis and the voltage which is going to the maximum. This is the zero point and there is a maximum here. This voltage is called the peak voltage.

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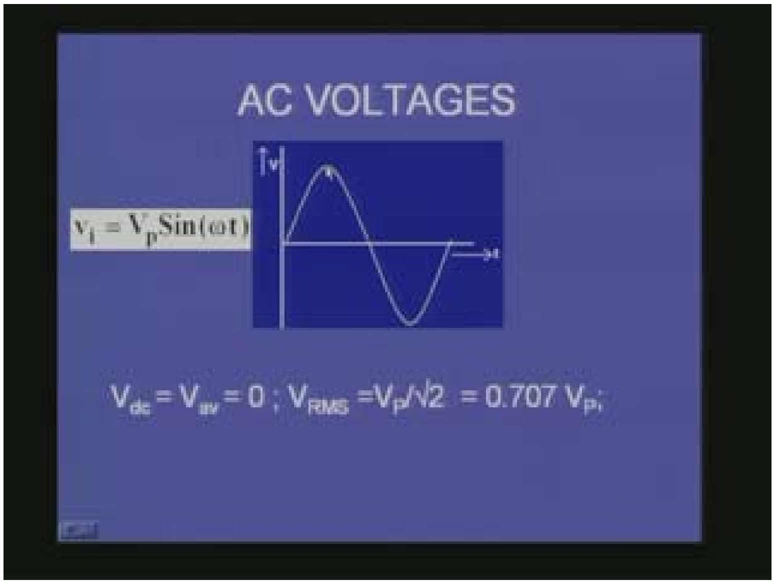

This is the peak voltage on the forward condition and this is the peak voltage on the negative cycle and therefore V_I at any instant is given V_PSin(Omega t). V_P is the peak voltage, maximum amplitude and Sin omega t shows depending upon time t, the omega is angular frequency depending upon the time t you would find the amplitude can be different. Here the amplitude is only this much. At a later time it is much higher. At the maximum value it is Vp when SinOmega t is one and similarly it keeps decreasing. The voltage is alternating between $+V_P$ and $-V_P$ in a sinusoidal wave. This is what we get at our house as 220V mains.

What is the DC component of this? If I now connect this output to a DC voltmeter you know what we will get? We will get a zero because you find the excursions are both on the positive side and the negative side and the average of this over a cycle is zero. Therefore V_{dc} which is basically $V_{average}$ is zero in the case of an alternating voltage. But we should have some idea as to how much is the voltage we have. That is obtained by looking at another value which is called V_{RMS}. What is V_{RMS}? Root mean square voltage. That is what we do is we square the sinewave. When you square the wave, the negative also will become positive and you have to sum it over one period and divide by the period. Then you will get an average over one cycle and take the square root that becomes root mean square. Root means square root; mean means average over a period; S means square. You actually square and take the mean for one period, take the square root. That will give me the effective DC voltge which I should apply, which will produce the same effect as my AC voltage that I apply. That is idea behind V_{RMS} and it is given by V_P by root two. When you do that for a sinewave V_{RMS} is equal to V_P by root two. These things you would have done as exercise in your earlier courses and which in numerical values is equal to 0.707 times V_P where 0.707 is actually the value of one by root two.

With this background let us look at diode. In the first circuit here I have an AC input, V_{IN} and I put a diode and a resistor. Now I apply an input sinewave. What will happen? You can immediately imagine what will happen? During the positive cycle the diode will be forward biased and across the load R_L you will get the full cycle of the positive excursion of sinewave but during the negative half cycle, the diode this end will become negative, this end will be positive and therefore the diode will be reverse bias and ideally it should not conduct and therefore nothing will happen. No current will come and therefore current will be zero and the voltage therefore will be zero. That is what is shown by the gap here on the output. Again when the next positive cycle comes, again the diode will conduct you get the positive excursion.

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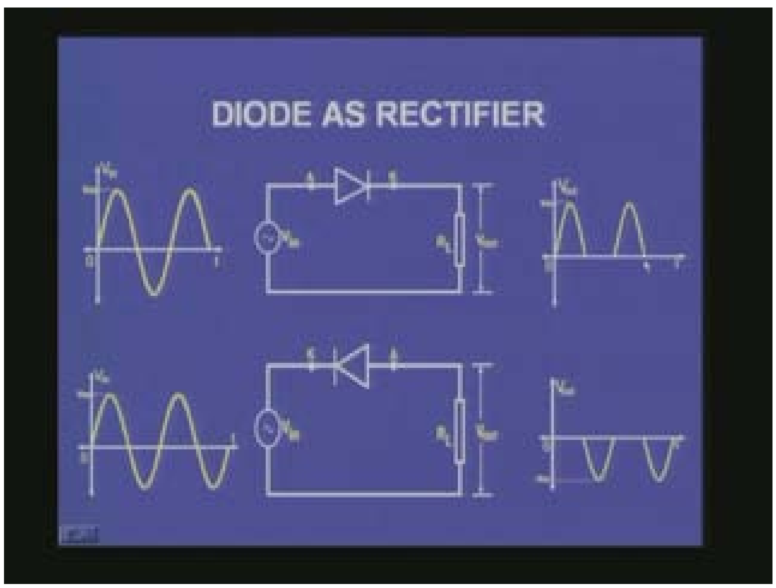

When I give a full sinewave, continuous sinewave input of a diode, at the output if I measure across the load you will get only one half cycle; each of the positive half cycle of the sinewave only coming at the output. This is called half wave rectification. Half of the wave is rectified. But you should remember there is no negative excursion here. Therefore it is the unidirectional voltage. The voltage is in only one direction; zero to positive V_P; maximum can be V_P but some times it can be less than V_P and some other place it can be even zero because during the negative half cycle you get only zero only. This is half rectification.

If I just interchange the diode in the opposite sense, invert the diode the same thing will happens with reference to the negative cycle. During the positive cycle the diode will be reverse biased; during the negative cycle the diode will be forward biased. You can immediately see and therefore the output will have only the negative excursions of the sin input and this is also called half wave rectification but it is the other half.

I have tried to use a transformer here. I have put a transformer so that 220V mains can be reduced to some tolerable value for example 6V or 12V and then the diode is put. You can see the half wave rectified output.

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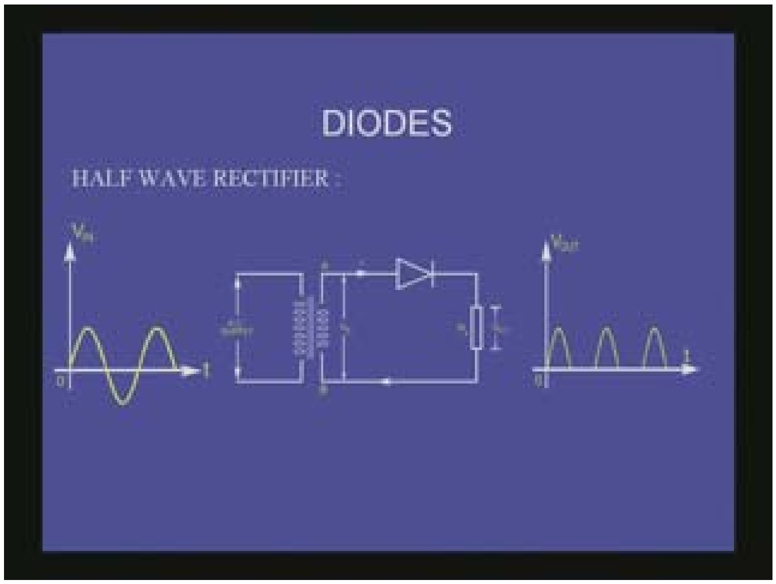

I have already converted the AC into DC in some sets. It is not constant. It is varying. If I connect a voltmeter what I get will be an average voltage. So for an half wave rectification the average of the half cycle will be V_P by pi and one by pi is 0.318 and the V_{dc} equivalent DC voltage of the half wave rectified output will be about 0.3 times the peak voltage. It is very, very small; 0.3 times only 30% of the voltge is available as the DC voltage.

I have taken a simple example. If I use a transformer 20:1 that means 20:1 is the turns ratio; at the input side it is 20 and at the output side it is 1. With the 220V RMS they should be decreased by the same ratio 20:1 and the frequency is 50Hz. Secondary output will be 220 divided by 20 because it will be reduced by 20 times and that will be 11V RMS. That is what I will get at the output. What will be the peak voltage in that case? Peak voltage is multiplied by root two. Therefore it is equivalent to dividing by 0.707 which is 15.5. Therefore from the RMS value when you go to the peak value it will be more than RMS value. It is 15.5V when I have a RMS of 11V and the V_{dc} is 0.318 times 15.5 V_P and that corresponds to about 4.99V only. The peak voltage is 15.5 but what you get as an average dc is only 4.9V. You are loosing enormously there.

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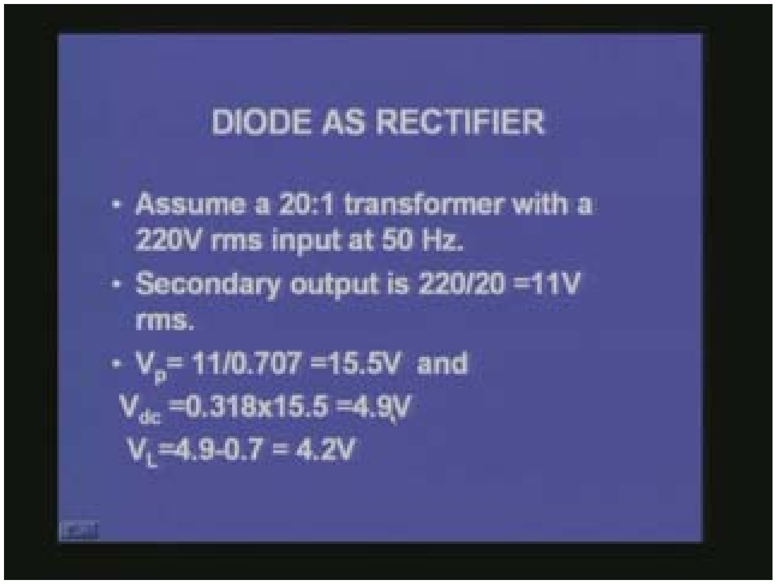

If you come across the load we should remember across the load, voltage is not just 4.9 but less the 0.7V which was taken away by the diode when it is forward biased and 4.9-0.7 is 4.2V. This will be the voltage that I will get at the output of the half wave rectifier.

Let me move on to a full wave rectifier. If one diode can rectify one half of the wave then you can imagine immediately that if I cleverly use two diodes may be I will be able to get both the half cycles on the same side. The trick that we play is to use a transformer with a center tab. What do you mean by the center tab? When you wind the secondary of the transformer, if I have 200 turns, at the center of turns i.e., after hundred terms I will take extra one lead from the coil and then continue to turn another 100 turns. So you will have equal number of turns on either side of the center tab and when I apply an input voltage to a primary with reference to the center tab, the two ends of the secondary can be in opposite face. If I take this as my reference zero then this will be plus with reference to zero for one half cycle and this will be at that time minus.

During the next half cycle this end, B end will become plus and the A end will be become minus. So you can have the polarity changed, plus and minus, with reference to the center and therefore this can be used cleverly to make a full wave rectifier by using two diodes. That is what is shown in the figure here. You have one diode connected to one end 'A' of the secondary and the other end is connected to another diode and both of them are connected together and the load is connected between that point and the center tab. If you do that when the positive excursions are coming this end will become positive and this diode will conduct and you will get a positive half cycle corresponding to the diode D_1 conducting. That is what is shown here. When the excursion is negative at the input then correspondingly the secondary voltage will also go negative at the A but at the B it will now be positive because they are 108 degrees out of face A and B. Because it is now positive this diode will start conducting during that negative cycle and therefore the output will still come in the same direction across the load. The direction of the current will be the same and therefore the voltage due to D_2 will be again positive and it will be as show in the figure. For each of the half cycle, each of the two diodes will work alternately to conduct and you get a full wave rectifier. That means you have converted the entire AC into a unidirectional DC voltage.

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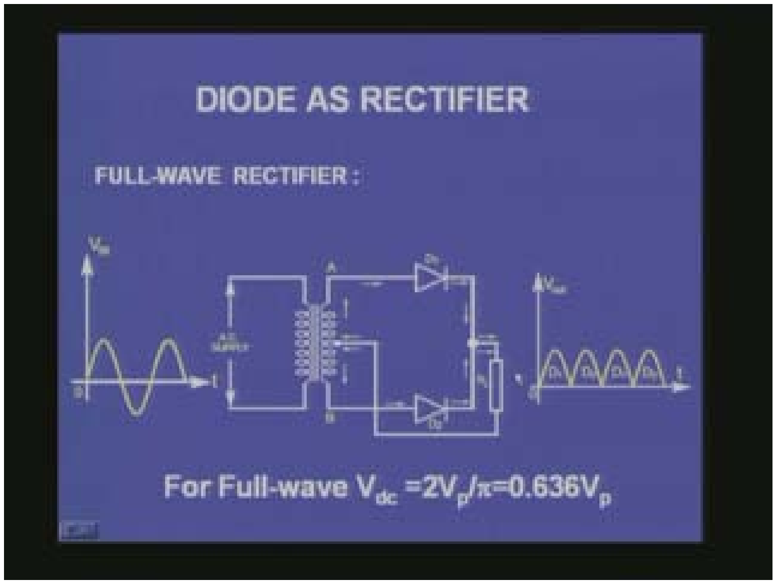

When you do that if you take the average it was V_P by pi for the half wave rectifier and for the full wave rectifier which as got two such things coming together you will have $2V_P$ by pi; two times you should get and that corresponds to two times 0.3186 that is equal to 0.636 times the peak voltage. The DC average of a full wave rectifier has now doubled. It is twice the value that you got for the previous case and if I take the same example of 20:1 transformer with a 220V RMS input with 50Hz, the secondary output will continue to be 11V with center tab there and the 11V by 0.707 which is the peak voltge is 15.5 which is also the value we got the previous time.

But now V_{dc} is 0.636 times 15.5. Therefore it is 9.8. That means it has doubled from the previous value and V_L will be 9.8-0.7 where the 0.7 is the forward voltage across the diode and therefore it comes around 9.1V. You can see when I use a full wave rectifier I am able to get much higher DC voltage than I have got for the half wave rectifier. This helps us make a better power supply, DC power supply, unidirectional power supply.

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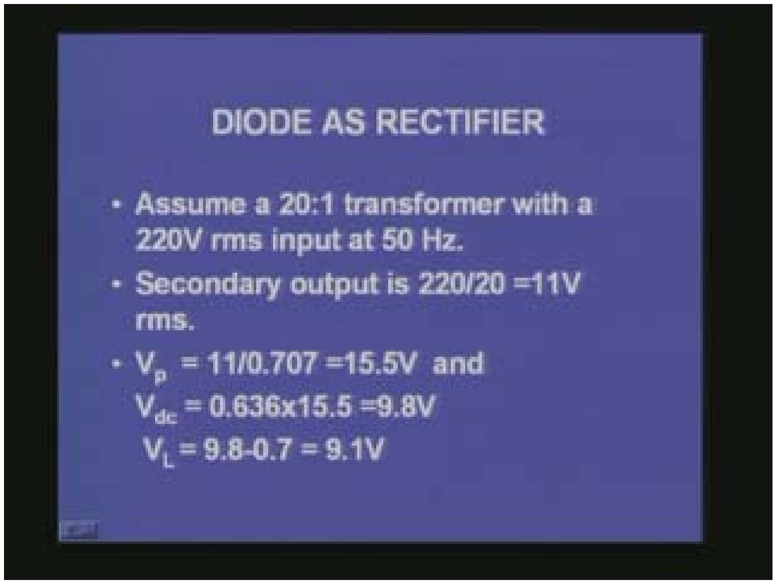

So this is a full wave rectifier. I …… to show a full wave rectifier.

Let me move on to the third type of rectifier which is called bridge rectifier. In this you can see I am going to use not two diodes but four diodes. As you can see on the screen I have four diodes D_1, D_2, D_3 and D_4. They are connected in the form of a bridge and you have the input sign wave coming in through the primary and the secondary voltage will be some what smaller in value for example 6V volts or 12V and that is connected to this type of Wheatstone bridge type of connection. But you must very careful with reference to the orientation of the diode. The diodes will have to be connected exactly in this form. Then only it will work correctly. If you invert any of the diode it will not work properly.

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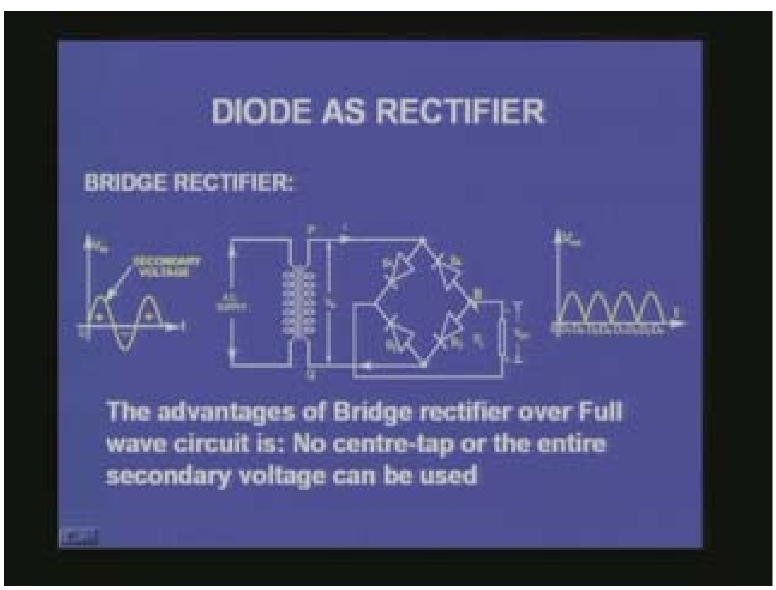

The input is given to two ends of the Wheatstone's network and output is taken from the other two opposite ends. You can see the output voltage here will again be a full wave rectifier. It is very similar to the full wave rectifier that we saw earlier. Only difference is in that case is I used only two diodes and I used the center tab transformer. Whereas in this case there is no center tab and there are four diodes which are being used. But effective output is full wave rectified output and that means it is again 0.636 times peak voltage. That is what I will get.

If I take the same example of 20:1 transformer and calculate in this case the peak voltage will continue to be 15.5V.

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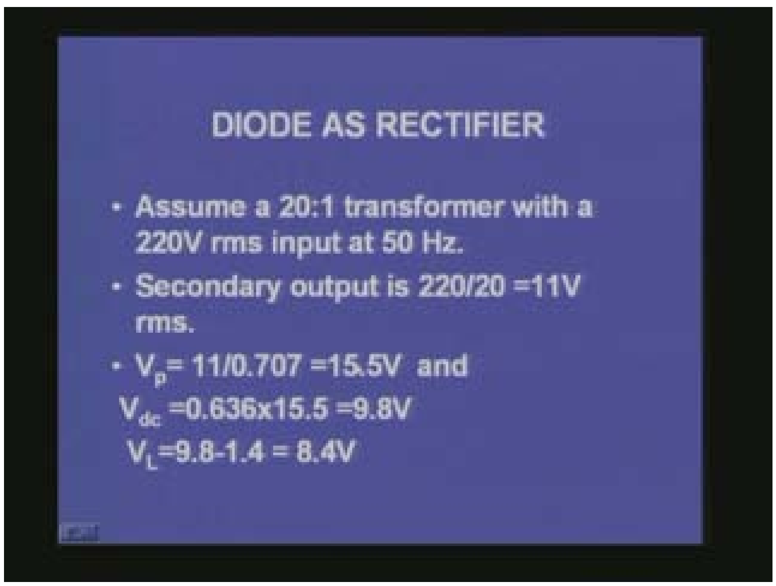

But when I use 0.636 times V_P because it is a full wave rectifier, I should multiply 0.636 by 15.5 that corresponds to 9.8 which is also the same as the case that we had in the previous situation and the load voltage we have to very careful. Why? What is happening here is when I connect the transformer and connect it to the mains when this P end is positive you will find the current will flow in this direction and then it will go in this direction. That means this diode will be forward biased and this diode also will be forward biased and therefore there are two diodes which are forward biased for one half wave. For the other half similarly these two diodes will be forward biased. In the case of the full bridge rectifier I should not subtract 0.7V as I did in the previous case but 1.4V because there are two diodes coming in series for each of the half cycle and therefore 9.8-1.4 is 8.4V only across the load. Some voltage is lost during the rectification due to the voltage drop across the diodes and what I get across the load will be 0.7V less than what I would normally get in the case of the a pure full wave rectifier with the center tab transformer. Now I will compare the three different types of rectifiers that we discussed.

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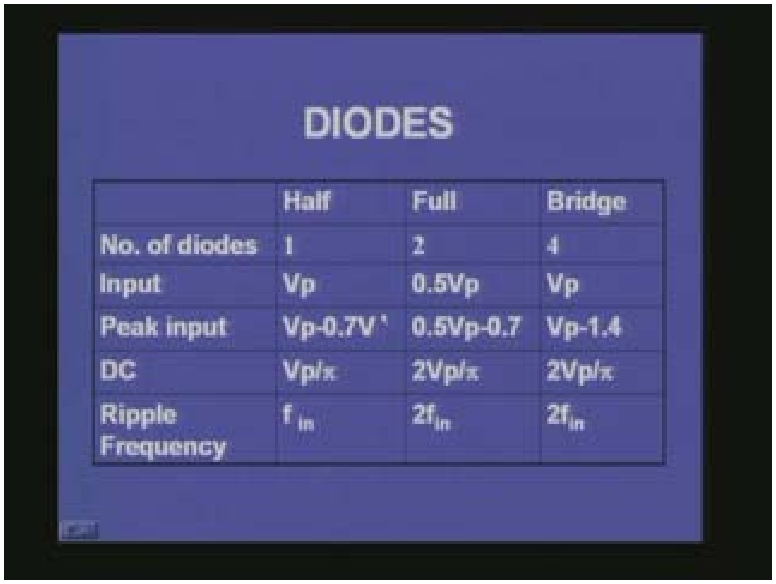
DIODES

	Half	Full	Bridge
No. of diodes	1	2	4
Input	Vp	0.5Vp	Vp
Peak input	Vp-0.7V	0.5Vp-0.7	Vp-1.4
DC	Vp/π	2Vp/π	2Vp/π
Ripple Frequency	f_{in}	$2f_{in}$	$2f_{in}$

If take the half wave, full wave and bridge you can see the number of diodes used in half wave is only one diode; in the case of full wave I used two diodes and in the case of bridge rectifier I used four diodes. The input is V_P in the first case, half wave. In the full wave because I use the center tab transformer it is only 0.5 times V_P and in the case of bridge rectifier there is no center tab therefore it is a full V_P and the peak input is V_P-0.7 in the half wave rectifier. In the full wave rectifier it is 0.5 times V_P minus 0.7 and in the case of bridge rectifier V_P minus 1.4V. Similarly if I look at the DC voltage in the half wave rectifier it is Vp by pi and in the full wave rectifier it is two times Vp by pi because it is two half waves which are coming together and in the bridge rectifier also it is two times Vp by pi.

The most important point with reference to frequency is in the case of half wave you are having only one wave coming for every full wave and therefore the frequency does not change in the half wave rectifier. But if you come to the full wave you find the both the halves are coming and the frequency will be correspondingly double. I do not know whether you see that. Perhaps I will go back here and show you the figure. If you see on the figure the full wave rectifier you can see this is corresponding to one half wave, this is corresponding to the other half wave and this for next cycle. So in one cycle you have two humps, maximum Vp and another Vp and therefore if I look at this as a variation you can see the frequency of the variation is now twice. For every one cycle there are two humps which are coming and therefore the frequency of the alternating component in these will be twice the frequency of the applied and therefore if I apply 50Hz I will have 100Hz for a full wave rectifier. It is true both in the case of full wave rectifier and in the case of bridge rectifier which is also another form of full way rectifier. These are the important points that we should always remember with reference to rectifier.

I have shown here actually what we require? What we require is we want to generate a DC voltage from the AC mains. That means ultimately I must have the voltage for example V_1 which is constant with reference to time. This is what we want ultimately. When I want to energize any of my equipment or device I require a constant DC voltage.

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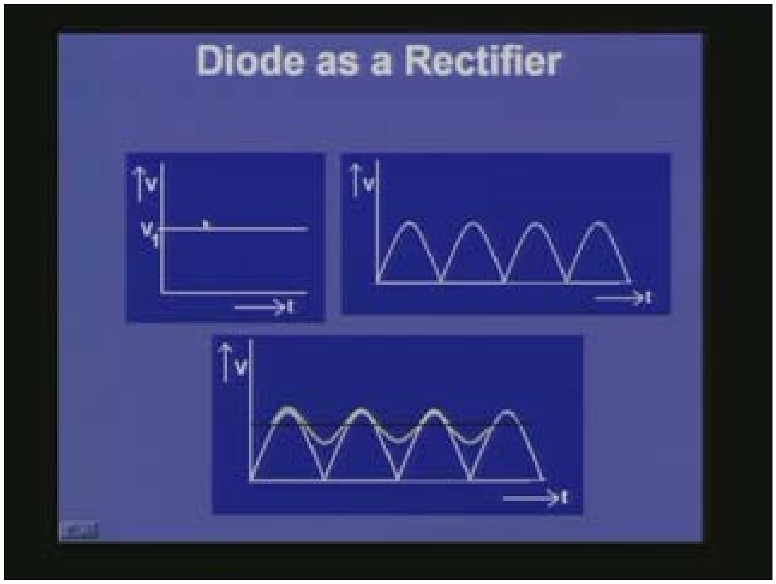

That is what a battery or dry cells which we use normally in some of the devices provide. They provide a constant 1.5 or 6V as the case may be. In the same wave using the AC mains if I convert using diode as rectifier I must also get a similar constant DC voltage. But we have seen when you do a full bridge rectifier or full wave rectifier I get a wave form which is continuously changing. It is not constant. The value of voltage is continuously changing like this and that means I can always consider this as an average DC which is about 0.6 times the Vp plus a small AC component which is due to this humps that we get which has got a frequency which is twice the applied frequency which in this case is 100Hz.

You can see this output which I now get in a full wave rectifier has got two components. One is a constant DC and the other is a ripple voltage which is an AC component superposed on the DC and that is what I have shown in the figure. If you want to achieve this constant DC voltge situation, you must some how get rid of this AC component. You must filter the AC component and retain only the DC component. There are number of filters available and one of the very simple schemes is to use a capacitor. You know the basic behaviour of the capacitor is that it blocks DC and it will pass AC. If I put the capacitor in the way I have shown on the circuit across the load then what will happen? Whenever I get rectified output the AC component will be passed through the capacitors whereas the DC component will not be passed and what I have will be pure DC. Some of the AC component would have gone through the capacitors.

That is what is shown in the graphs by the side. This is the input which is going to a peak value and what I will get after I put my capacitor is like this. That means if the capacitor is charged to the full peak value and then when the voltage drops at the input, the capacitor cannot discharge because it has got a resistor here. It can discharge only at a steady rate depending upon the R_C time constant of the capacitor and the load.

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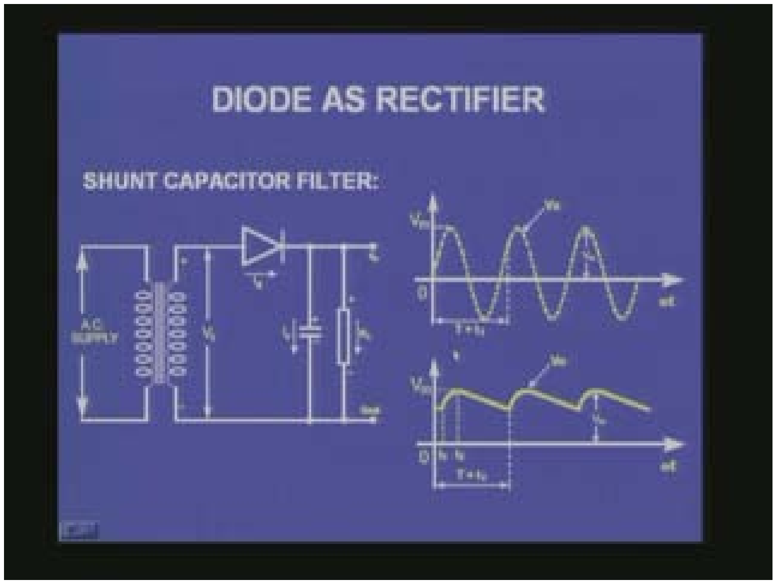

That will make the discharge very, very slow and it slowly discharges and before it comes to zero, the next positive pulse will come and it will again take the voltage across the capacitor to peak and this reduction in the AC component can be very easily seen here and the AC component or the ripple component of the output will become very, very small the moment I use a capacitor. Depending upon the value of the capacitor you can make this DC much closer to the value that I wanted, constant value. If I use a very large capacitor I will get almost very low ripple and therefore it will be a reasonably constant DC output. If I use the small capacitor only small amount of ripple component will be removed and you still have some ripple component which is larger in the output. This is for the half wave.

What will happen if I go for the full wave case? You will find in the case of full wave it will be much better because the average itself is very high and therefore the voltage across the diode can never go below the average DC and therefore you will have much smaller ripple content. How do we calculate the ripple factor or the peak voltage of the ripple? The peak to peak ripple voltage for a capacitor input filter is given by V_R is equal to one I by fC. I is the DC current, load current, f is the frequency and C is the capacitance that I have used. I by fC gives me peak ripple voltage with some approximation and we will be in a position to calculate what is the peak to peak ripple voltage in the case of a simple shunt capacitor filter. There are different configurations of the filter. You can have a pi section filter; you can have LC filters with inductances and you can have pi section LC filters. There are different varieties; but because we are handling very low voltages a simple capacitor filter will itself be very, very good and useful. In this case I have got a load current. I assume a load current of 20 milliamperes and the frequency is 100Hz for a full wave rectifier and if I assume 500 microfarad capacitor then the V peak to peak ripple will be 20 milliamperes, I/f which is 100 Hz, c which is 500 microfarad and this when you calculate it will be around 0.4 voltage peak to peak.

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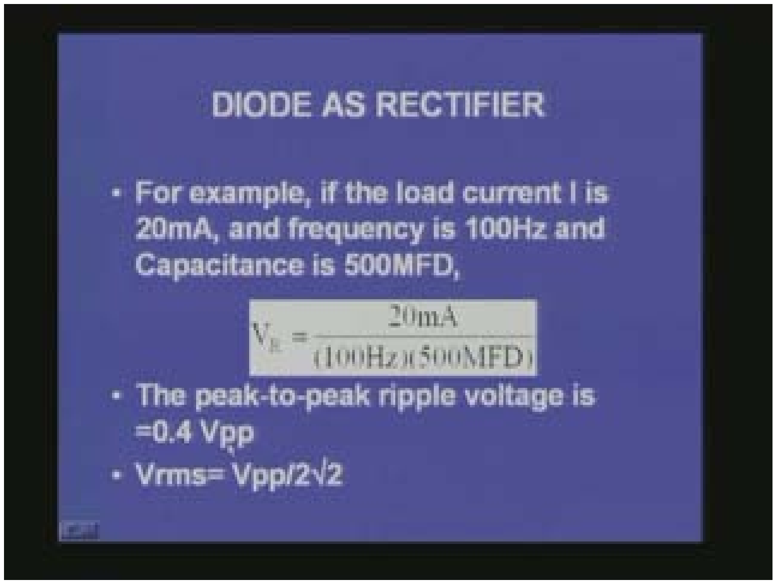

The peak voltage will be 0.2, half of this and V_{RMS} of the peak ripple will be V peak to peak by two root two. The two comes because we are attaining the peak to peak voltage. What we actually require is the peak voltage and therefore there is a division by two and the root two comes because you want the RMS. Vp by root two is the RMS. Vp is V_{PP} by two and therefore you have V_{PP} by two root two here. This will be a very, very small value of the order of few millivolts and we have almost converted alternating voltage into a reasonably constant DC voltage with very small ripple component.

Let me show you some of this in the experiment and I will show you a half wave rectifier, a full wave rectifier with the center tab transformer and full wave rectifier with the bridge rectifier and then I will also show you with capacitor input how the ripple component is reduced to a very low value. I have a transformer with the two leads coming here. I will connect that to the output of oscilloscope. You can see the output of the transformer is a full wave sinusoidal wave.

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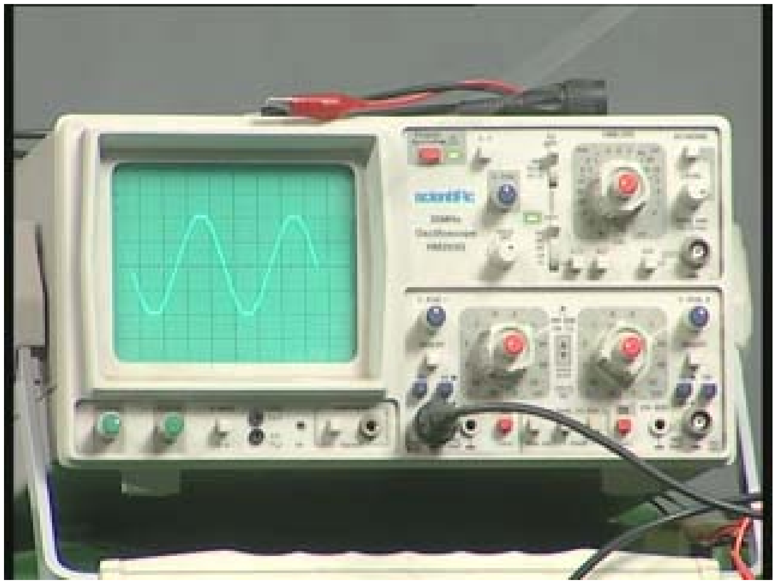

Now I take that input and connect it to a simple half wave rectifier. You can see there is a diode here; there is a resistor here and one end of the transformer is connected here; the other end of the transformer is connected at the diode and the voltage across the resistor which is a load resistor is now connected to the oscilloscope. One end of the resistor is connected to one end of the oscilloscope; the other end is connected to the ground and you can see the output is half wave rectified.

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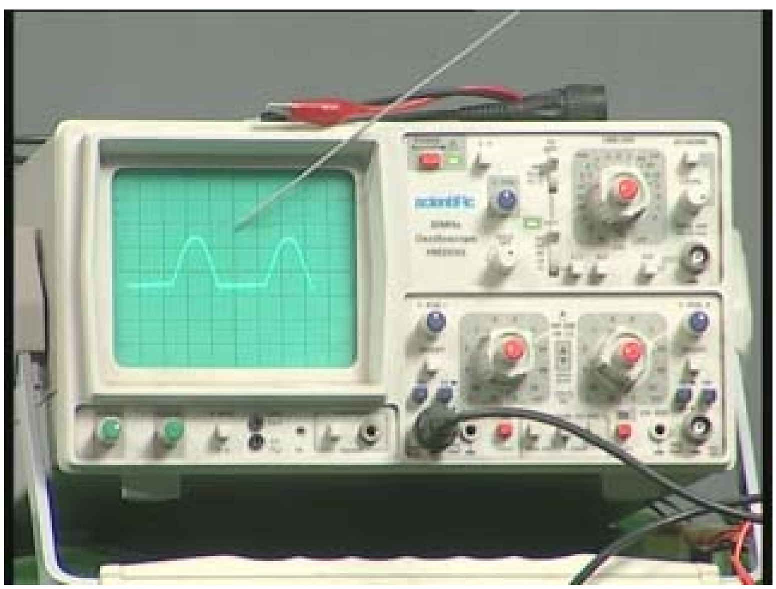

The output is half wave rectified because I have used one diode. This is what we already saw. The next circuit I have here is a full wave rectifier. You have got two diodes and the resistor is connected. Now I should take the transformer with the center tab and connect it to the two ends. I will just do that now. I have connected one end of the transformer here;

the other end of the transformer at this point and the center tab is the yellow wire which is connected to the ground and I measure the output voltage using the oscilloscope.

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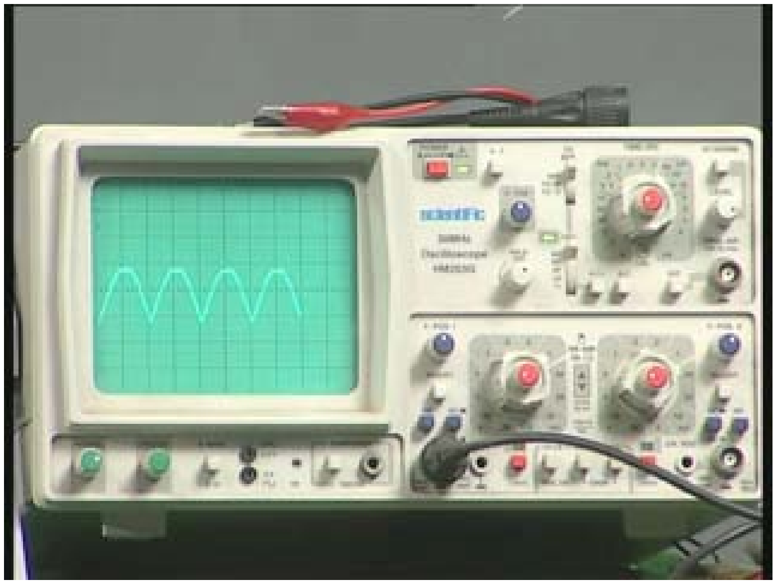

You can see the full wave rectifier output here when I have two diodes and the center tab transformer. The next experiment I will use the bridge rectifier. You can see the circuit is already wired here with the output connected to the oscilloscope and now I connect the transformer. I have connected one end of the transformer to this end; the other yellow end to the bottom and I have taken the voltage across the resistor. You can see again there is the full wave rectified output here, both the half cycles.

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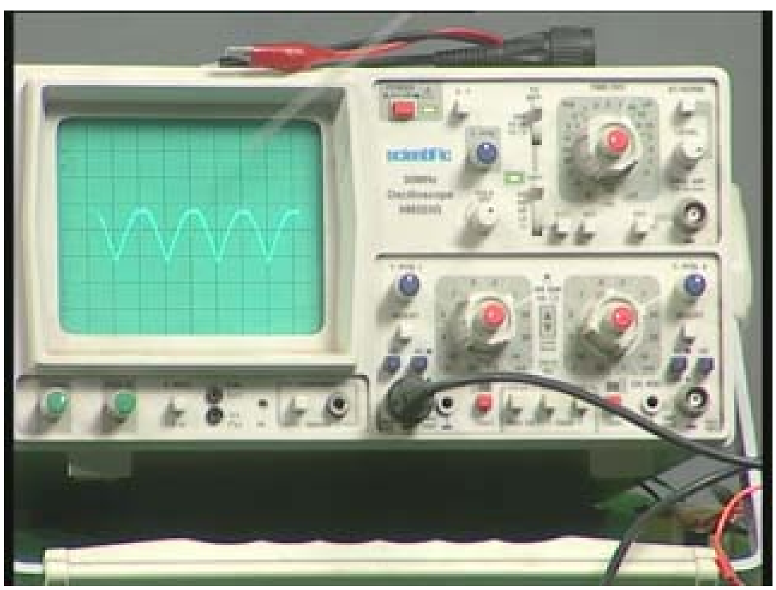

This is corresponding to one pair of the diode; this is corresponding to the other pair of diode. This is again full wave rectified output.

I will show you the same experiment using light emitting diodes. Here I have the bridge formed with four light emitting diodes and at the output also I have connected a diode and this is an oscillator. I will switch on the oscillator. I have switched on the oscillator and kept it square wave. This is square wave and at very low frequency, 1Hz. This is again a bridge rectifier except that instead of normal diode, I am using light emitting diodes here and the output is also connected to the diode. Because it is a light emitting diode, whenever they conduct they show the color whether it is green or blue. I have used two red corresponding to one part of the bridge and two green LEDs for the other part. For the output I have connected one red LED. You can see these two LEDs are glowing for some time and these two LEDs are glowing for other times. This is for one half cycle; this is for the other half cycle. But all the same this diode is always on. That means for both orientation this current is always in the same direction. The load current is the same; but these two pairs of diodes will conduct alternatively to make the output continuously come through the load. This is exactly the full wave rectification but with the bridge rectification shown with light emitting diodes.

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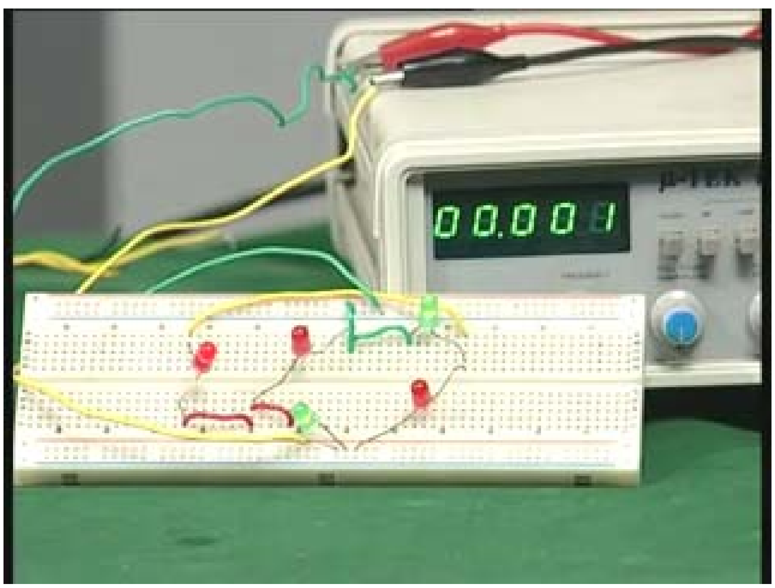

Before I conclude I will show you the rectification with the capacitor filter. I will show you only one circuit. I have the same bridge rectifier with the two ends of the transformer connected to the bridge and the output along with the resistor I have connected a capacitor of about 100 microfarad.

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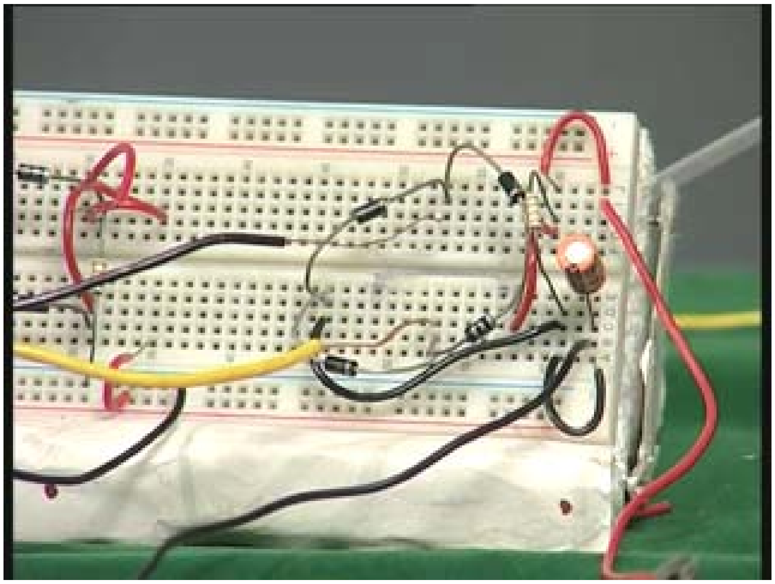

The output is connected to the oscilloscope. You can see here the charging and discharging of the capacitor corresponding to every pulse.

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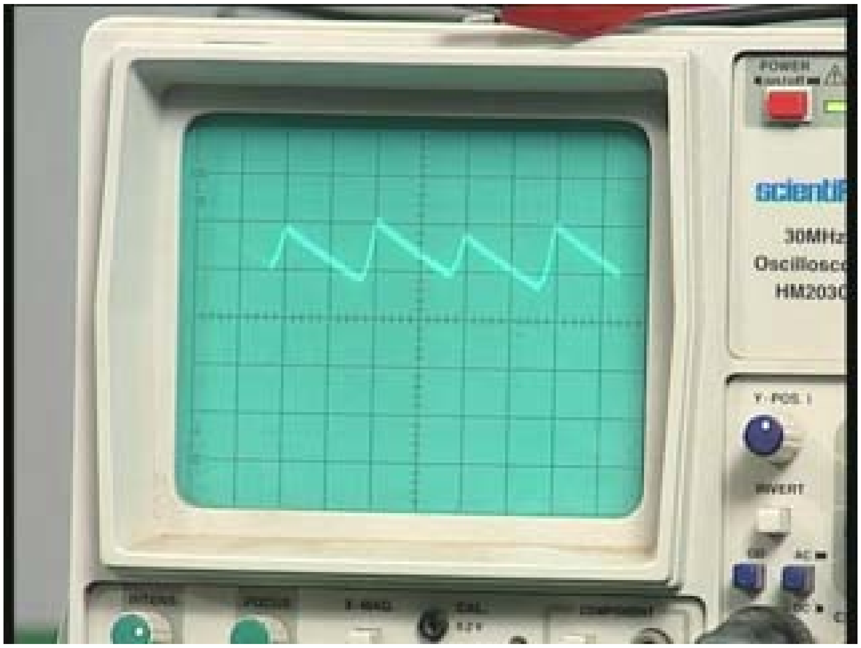

You can see it is charging and then slowly it is discharging and then again the next pulse comes; charging and discharging. This is what I showed you in the figure when I talked about it and if you look at the dial the voltage will very, very small. The ripple content after I filter this peak to peak voltage is going to be very, very small. It is approximately of the order of 0.1V for division. It is about 0.1V. That means 100 millivolts. So when I have an output of about 15V I have a ripple of only 0.1V and that means the capacitor has connected all the AC down and what comes out is almost a pure DC volts and this is the full wave rectifier with the capacitor filter.

So far what we have seen is how a diode can be used as a rectifier for converting AC voltage into DC voltage. We saw three different circuits; a half wave rectifier which makes use of only one diode and a full wave rectifier which is of two types. One with the center tab transformer you can have two diodes and make the full wave rectifier or also you can use a bridge configuration of the diodes and make use of the full wave rectifier. You do have some AC component in the output which is called a ripple and the ripple can be eliminated by using a shunt capacitor, filter capacitor filter and thereby you would be able to reduce the AC component in the DC output to a very small value of the order of millivolts.

This way you will able to construct a DC power supply from the AC mains voltage. But if you still want constant voltage you have to use what is known as voltage regulators. We will perhaps see some of those circuits at a later time. With that you will be able to get almost ripple free DC voltage at the output and that is what we normally have in many of our equipment and devices. This is a very useful application of the diode. There are other applications of the diode which we will also see especially in wave shaping, clippers and clampers. We will see some of these circuits in the next lecture and we will also see how the diode, the special type of diode called the Zener diode can be used for voltage regulation purposes. The zener diode is used only in the reverse bias direction and that is very useful for regulation application. We will see that in the next lecture. Thank you!