Electronics

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Module No. # 01
p-n Diode
Lecture No. # 04
Diode Applications

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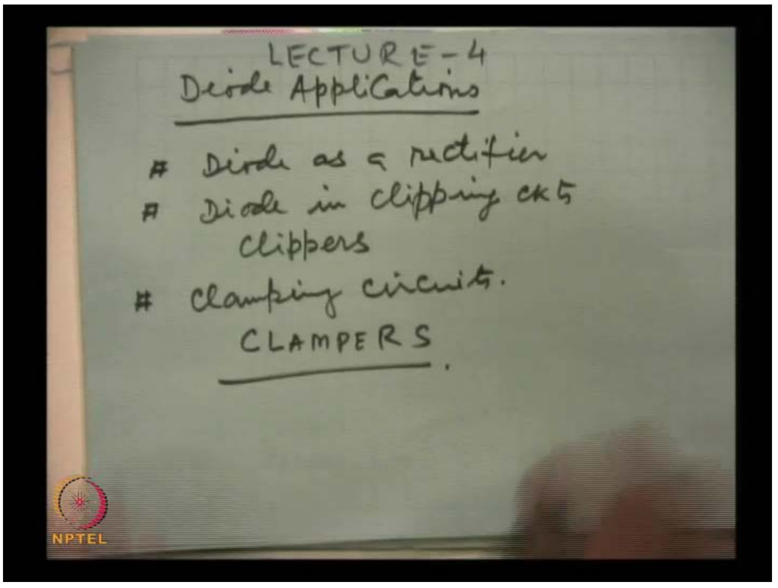

Now, we will take some applications of diode in a circuit. Basically, there are three or four uses for the normal p-n junction diode. The one is diode as a rectifier, diode in clipping circuits, which are known as clippers and diode in clamping circuits which are known as clampers. So rectifiers, clippers and clampers, these are the three basic uses of a diode and we will talk about them one by one.

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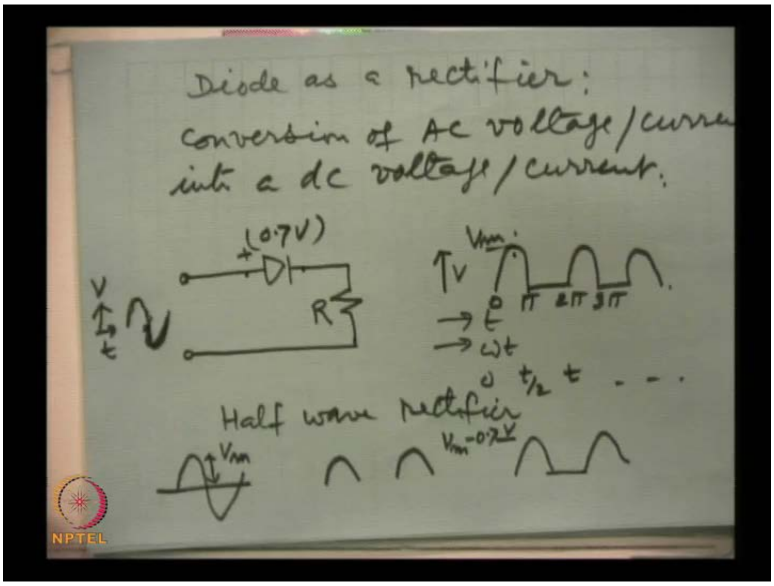

First we take diode as a rectifier.

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Let us see, how the diode act as a rectifier; let us consider a simple circuit. We apply an AC signal here; this is the voltage axis and this is the time axis, so this is the AC signal which we are applying here. And what will happen? This positive cycle, the positive part of the input signal that will forward bias the junction that means by forward bias again I remind that this terminal, the anode has to be at higher potential than this terminal, which is cathode.

So, this will be forward biased by the half cycle. If we consider the diode as ideal then the current will flow and the output will give a voltage here. So, when it conducts there will be a current and there will be a voltage drop. In the in this part in the negative half of the input cycle this will become a reverse bias diode. And if we can see that it ideally then the resistance is infinite, so there will be a break in the circuit and the current will be 0 in the circuit and hence the voltage e drop will be 0.

So, under this condition the output waveform this is the voltage, this will be like this like that; this is time or many times be what actually omega t in terms of angle. So, this is 0 pi 2 pi 3 pi and so on or in terms of time this point will be 0 here t by 2 and here it will be t and so on. This is the output; this is that means the output is not pure DC but, it is pulsated kind of a voltage which will be rise from 0 to a certain value then drop to 0 again for half period it will remain 0 again it will rise, this is called half wave rectification. Half wave rectifier obviously because out of this complete wave in the output it is only the half that is why it is called half wave rectifier.

Now if we consider this as a ideal; then if the peak value of this voltage is V m then this peak value will also be V m. if we take the practical diode characteristics then out of this V m there will be 0.7 volts drop across this and remaining one will be here in that case the peak value will be V m minus 0.07 volts, so this is the half wave rectification.

Rectification is a very important property; there is a no electronic circuit which does not require the DC voltages for biasing electronic device, as when we study a bi polar transistor which is simply called v, j, t or transistor when we require DC voltages to bias the junctions. If we are using field effect transistors then we again require DC voltages to bias the f, e, t. So, every electronic instrument requires a DC voltage and DC voltage of course, can be provided by batteries. But we know they are really expensive, bulky so unless there is a portable instrument, portable circuits then they will use the DC. They will not require any further rectification. But most of the devices like home what we use music systems, transistors, cassette recorders, tape recorders, television or computer they all require a DC source and this is through and the power we supply is for males.

So, we have to use a rectifier and before that we have to use a step down transformer, because these circuits will be actually rectifying a smaller voltages say from 5 volts to 30 or 50 volts. So, this is half wave rectification not of much practical use, because it will have a very high portion of repel. Repel is what is the fraction of AC by the total DC; so there is a small portion a large portion of AC also here so this half wave rectifier is not of much practical value.

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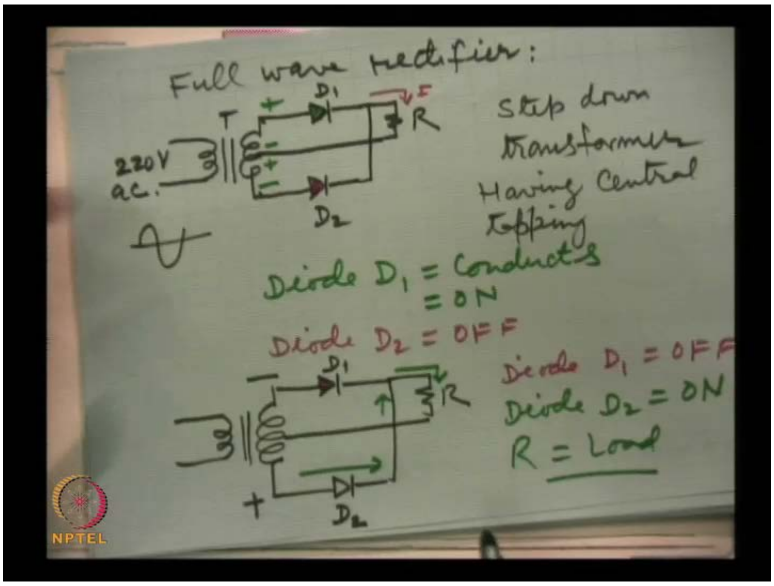

If we use two diodes, then we get what we called a full wave rectifier.

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Full wave rectifier with makes use of two diodes here,

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This is a step down transformer for which the primary is connected 220 volts ac; and how much we have to bring down these this voltage that depends what how much we want to use in many devices. For example, 5 volts is required or 10, 30, 40, 50 volts, so we will use a appropriate transformer with central tipping. This is special transformer which is having central tapping. That means there are three connections in the on the secondary side. These two which are normally there in a every transformer what here there is a third terminal the central connection from the half of the terms on this side upper side and half are there on the lower side, so this is the transformer which is made use in this full wave rectifier circuit.

Now for when this, Let us see what happens in the upper half of the input signal this is the plus terminal, minus, plus, minus. Therefore, diode D will be conducting, while diode D2 will be off; so D1 conducts is on diode D1 conducts or as it is called this is on diode and this is off, D2 diode D 2 is off it does not conduct. So, this will the current will flow this is a very high resistance so this will ignore this path and it will go the current will flow like this; in the upper when this changes that means we talk about this lower half then the connections will be like this.

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Now this will be minus opposite of this, in this case this diode D1 will be off and it will offer very high resistance ideally infinite. So, we can take the circuit is discontinuous here, but D2 will be forward bias and this will be on. Therefore, current will flow this way this is infinite resistance will evolved will not see this diode and current will flow this way; that means for the whole cycle the current flows in the same direction in the load R is the load. Load can be any device like tape recorder. For example, and so then this will be the resistance where input impedance of the device that will act as a load.

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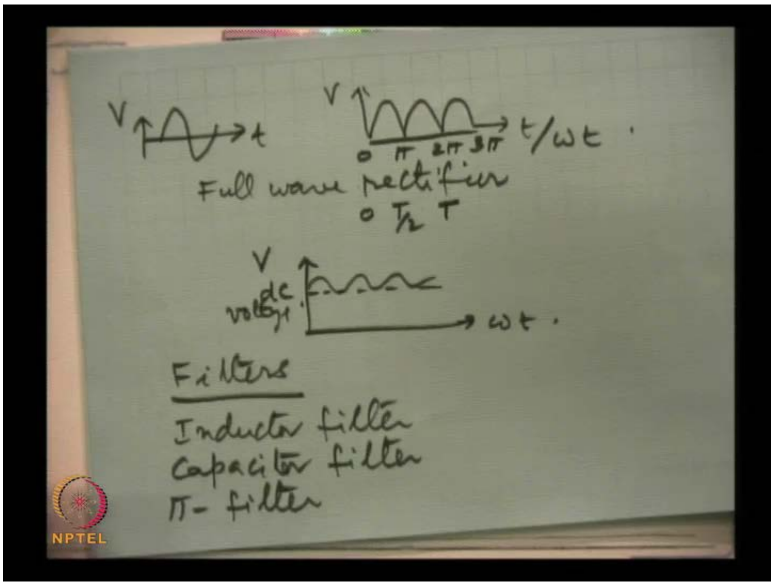

So, what will be the output wave form, when this is the input for this input the output will be now and so on? This will be the output for obvious 0 this is called a full wave rectifier a full wave rectifier and this is 0, pi, 2 pi, 3 pi if this is omega t and if it is time then this is 0 this is T by 2 this is the period T and so on. So, this is full wave rectifier that means both halfs are converted into a kind of DC. DC means that current flows in one direction, but actually this is full wave rectifier is still the output is not very smooth. This voltage wave this can be actually seen as continue a DC part and a AC part. Here, this is the AC part and there was a DC part, this is the equivalent voltage as a function of omega t and there is a DC part, here DC voltage. And the ratio of this ac by DC is known as the extent of rectification and there is a ripple factor.

So, there is a ripple factor so this is the ripple factor so there is still a ripple and in many applications this will be acceptable, because it will be a cheap circuit very economical. Just use of two diodes and that makes with a transformer centrally trapped transformer that makes what is known as full wave rectifier. But in many application in fact in most of the applications this ripple is not acceptable, for that we use filters, there are several kind of filters like inductor acts as a filter, capacitor acts as a filter and the combination of the two the most widely used filter circuit is what is called pi filter. I very briefly talk about these filters and then we will because this is not the part of the p-n Diode actually but, since we are talking of the circuits.

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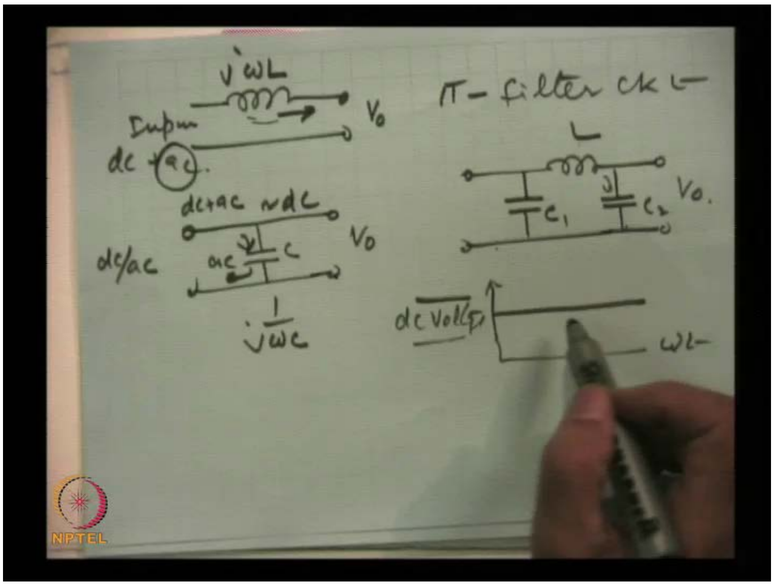

So, I very briefly talk, the inductor filter inductor is used, here this is the rectified output is connected as the input here, this contains DC plus AC now here this is V out output this inductor you know that its impedance for ac is omega L omega is the frequency and L is the inductance and for DC that means the DC resistance of the call is very small and AC here will be very finite in fact large resistance will be offered by the inductor therefore, their more DC will pass to the output while ac will be prevented by this inductor and there will be a AC voltage drop across this that is the ac power is drastically reduced in the output and the that has taken care by the inductor.

Similarly, so remember that inductor filter is used in series and similarly, we can use a capacitor in shunt connection here is the V0 and this is again the same DC and AC that means that rectified output is given as the input to this filter circuit. Now the impedance of this capacitor is that width j omega c so for AC. This will act as a very low impedance path and AC, here it is DC plus AC while AC will find path here and this will be prevented from going to the load. So, this is a much better much smoother output wave form available to the load, when these two are combined that is the best rectifier and which is known as pi rectifier, pi filter which is like this that makes use of one inductor in two capacitors.

Here the input from the output of the rectified circuit and here we get V0, C1, C2 and L so first the AC find a path here it is filtered, then AC is obstructed by this inductor again and whatever remains that goes the AC part goes here so here we get almost a very smooth DC. This is omega t and we get very smooth DC voltage. So, this is DC voltage most widely used a circuit filter circuit is pi filter to get a smooth DC which is required in most of the applications of an in electronic circuits. Now this was full wave rectifier which made use of a central tapped transformer. Central tapped transformer that create sometimes problem sometimes a central connection is taken out, many times it is not exactly symmetrical in the center so there are problems is there a way to get rid of this centrally conduct centrally tapped a transformer in the use of full wave rectifier the answer is yes, and we make use what is known as bridge rectifier.

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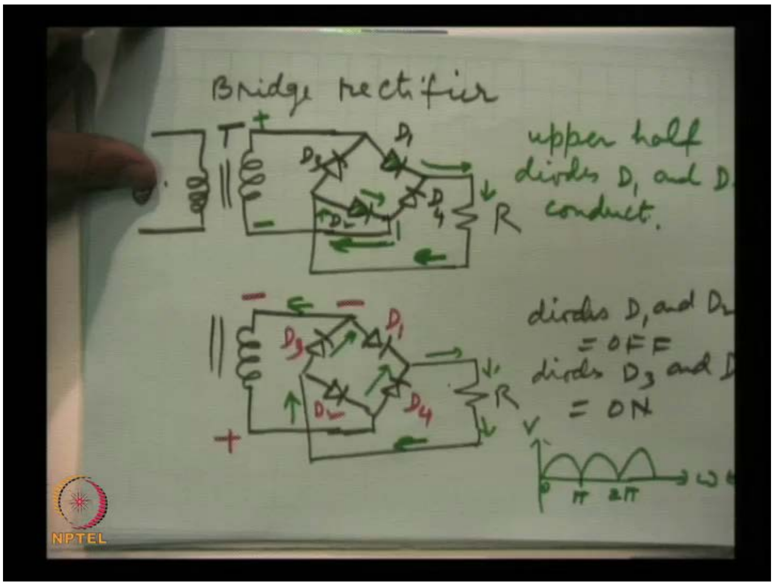

Bridge rectifier is also a full wave rectifier, but it as we will see I draw the circuit it makes use of four diodes and a transformer without central tapping this is the circuit. This is the transformer and there is no central tapping here, but there are four diodes D1, D2, D3 and D4 and the now this is AC through this transformer we get a smaller voltage according to our requirement, but that is still a AC as you know the transformer is steps down the magnitude of the voltage. But still it gives a AC output so for this signal first we take what will happen in the upper half, this will be positive this will be negative.

Now in this case two diodes will conduct this becomes forward biased and this terminal is connected to negative one in the same thing; that means this side is still at higher potential then this so this also becomes forward bias. So, for the upper half upper half diodes D1 and D2 conduct so the current will flow like this from here goes here and so on. So, this is the way the current continues here again out this will be the total path and when this voltage for the lower half the polarities will be like this.

Now for this lower half this will this diode will conduct D3 and D4 this is now minus and this is minus this is plus so this will be reverse bias D1 and D2 they will be half diodes D1 and D2 will be half; while this negative will forward bias this diode D3 and this positive will forward bias diode D4. So, diodes D3 and D4 they are on they conduct and current goes like this so this is the path current will take for the upper half positive half this two diodes will conduct they will be half and for lower half. This two diodes will conduct and this will be this two will be conducting these two will be half. So, current flows always in one direction through the load and the output has in the full wave rectifier here also the output will be containing both and so on.

So, this is again a pulsating DC which will require the filter circuit which we just so this output is connected to the filter here and output of the filter will be very much disseat. This is much better it has compare to full wave rectifier, by the way this circuit is full wave rectifier this is a full wave rectifier and it is called a full wave rectifier. That means full wave rectifier circuit makes use of two diodes D1 and D2 and this centrally tapped transformer, while this is also full wave rectifier but, popularly to distinguish between the two this is always called a bridge rectifier.

So, remember that bridge rectifier is also a full wave rectifier but to distinguish between the two this is called bridge rectifier. This is much better as compared to the centrally tapped transformer full wave circuit and basically at two biggest uses or the other advantages.

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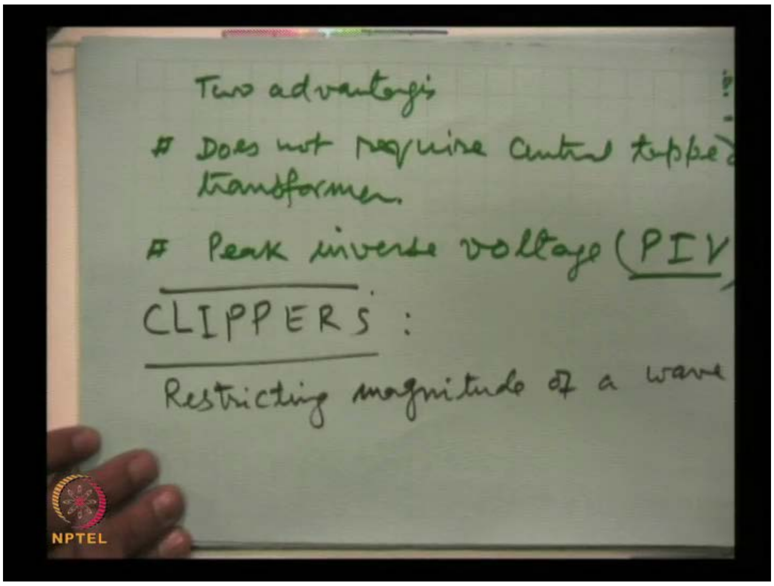

Two advantages two advantages will this has this bridge rectifier number one is does not require central tapped transformer, second thing is what we called peak inverse voltage. Peak inverse voltage P I V that means the diode is subjected to the maximum reverse voltage during the cycle that is known as peak inverse voltage. And there is a limit and we will find that peak inverse voltage in this case for example, when this diode is not conducting the available output is V0 but, the total voltage will be dropped across the non conducting diode. So, P I V in this case is double of that available voltage.

If we get a 5 volts here when peak inverse voltage in a full wave rectifier will be 10 volts the diodes which have higher value of P I V they are more expensive. So, but in bridge rectifier we will see that this is P I V and this is much lower, first thing is whatever voltage we are getting say V0 and this two non conducting diodes. we share the reverse voltage so in this case half will drop across this, half of the that drop here so the P I V in this case is much smaller this will be V 0 by 2 which is a much better factor as compared to the full wave rectifier. So, these are the two basic advantages of using a bridge rectifier. So, bridge rectifier actually is the one which is most widely used and mostly widely used filter circuit is a pi filter circuit which makes use of one and inductor and two capacitors so that makes use that completes our this rectification process and the use of diodes in rectifiers and remember these two advantages are very big advantages.

Then the next circuit application is in clippers. Clippers many times in the electronic design systems we require circuits to restrict the amplitude of a signal. That means we want to chap of we want to cut the upper portions of the voltage go under sub certain reference voltage, these are known as clippers. Clippers are used in restricting the magnitude of a wave and for that diodes are used.

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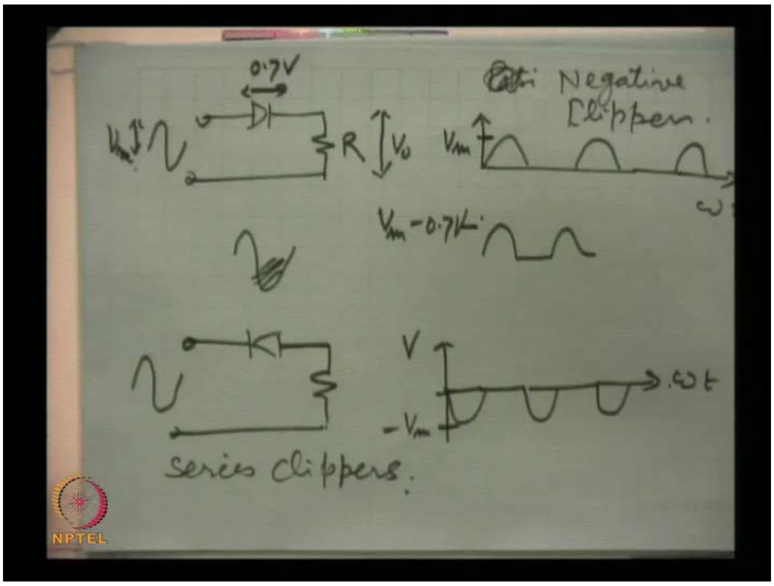

So, let us look at the circuit, here we are feeding AC signal with the peak value V m and this is the load, now this will chap of the lower portion completely that means this upper half will forward bias the diode current will flow and we will get a voltage across the load and this will be V 0. In the lower half the minus plus polarity will be there this diode will be reverse bias this will be air pin circuit low current will flow and the output will be 0. So, the output will contain actually this is almost this is the half wave rectifier. Where from the input wave this lower half’s had been clipped completely removed and this voltage.

If we consider this ideal diode ideal characteristic then this will be same as the peak value will be V m and if we consider a practical diode then 0.7 volts will drop here and then the peak value this will be equal to V m minus 0.7 volts. Similarly, we can reverse it and we will have this is negative clippers and if we change the direction of the diode and we feed here AC signal, then this positive reverse bias this diode and in that case the output will be like this, these are actually series clippers there are parallel clippers as well as you see to this circuit.

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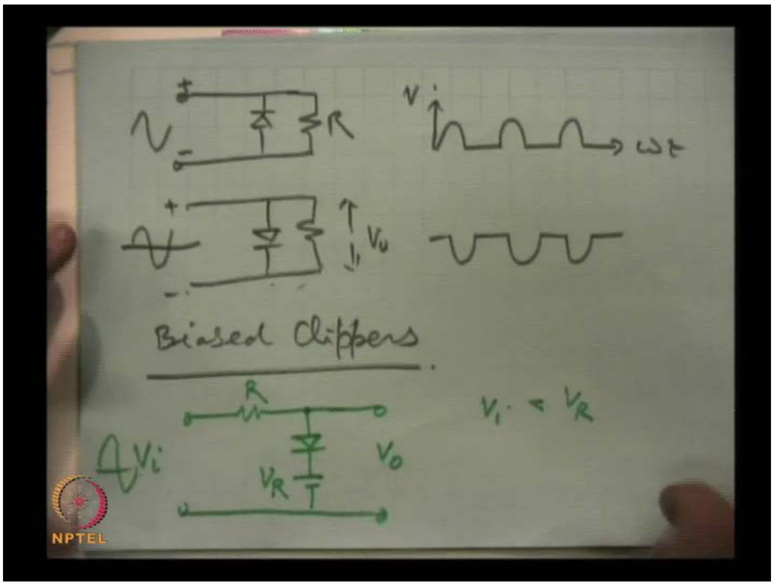

They are very widely used this is R now for the upper half this will be plus, this will be minus and the diode will be reverse bias it will not conduct and the output will be so it will not conduct and the current will flow this is infinite resistance. So, this is almost as if not present in the circuit and this wave shape will appear here. If we reverse the direction of the diode then of course, this will be the case the upper half will give this polarity, it will be conducting means almost 0 resistance two resistance remember this thing it is important two resistances in parallel one high resistance in one almost 0. Resistance the effective resistance will be 0 so if the resistance is 0 there will not be any voltage here V out for the upper half will be 0 but, lower half this will be reverse bias as if it is not there in the circuit and then that will appear

So, in that case the output wave shape of this coil will be there so these are non clipping circuits. Now these clipping circuits we were clipping one portion completely, but this is not always the case we can use biased clippers. Biased cilppers in which we can choose that which portions we can we can we want to clip here this is look at this case this circuit a resistance a diode with this polarity the battery a reference voltage is applied VR. we get the output here this is the input is provided here with some voltage Vi now because of this reference voltage this will not conduct un less the voltage here becomes in the access of Vi for all voltages less than VR that means when Vi. Vi is varying when V i is less than V R then this will be reverse bias and we can analyze we can draw the equivalent circuit for this and analyze that circuit.

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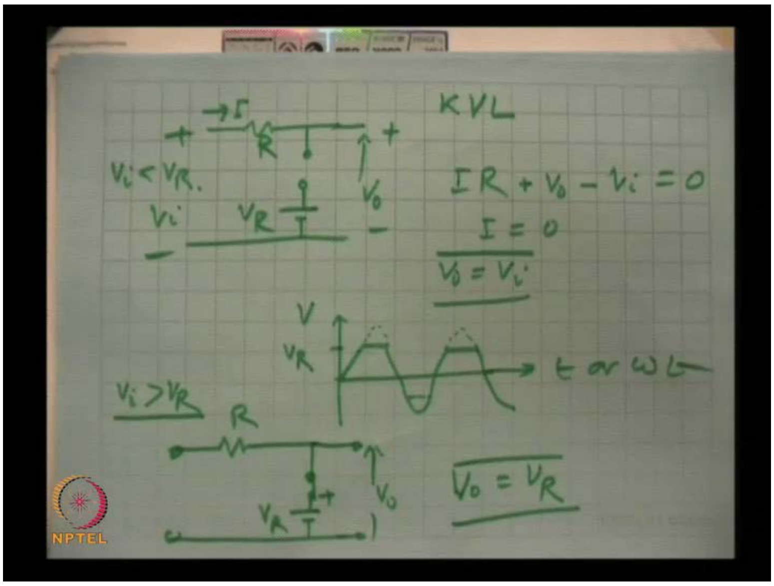

And we will find this equivalent circuit is this because this diode is reverse bias. So, that will be shown almost infinite resistance we can take out infinite resistance and then this reference VR this is Vi is less than VR. Let us, analyze this by Kirchaff voltage law summation of voltages in a loop let us assume that current I flows through this circuit here is a V0 this is Vi then we can write the summation equation, this is the voltage drop across this resistance and when it is V0 this is plus, minus and this is plus, minus again apply for this loop minus Vi equal to 0 and since new current is flowing.

So, I is 0 and hence V0 is Vi, that means for what we will be the wave shape? wave shape will be this, where this is voltage axis this is time or omega t and this is VR we can show VR as we wish we want to limit at 2 volts, then this reference voltage has to be 2 volts we want to restrict it at 4 volt then this has to be at 4 volts so this will be the wave shape and this portion have been clipped for the other wave it will conduct, because all are the this is in a reverse bias and the super imposition of this negative signal here will make it more negative for negative voltage so that means as if this is not there so then this is simple circuit and we will get that the output will be for will be 0.

Now here we took in the in this case where this will be clipped off we can see that the equivalent circuit will be this for any voltage Vi greater than VR this diode will be forward bias diode will be forward bias. So, this is almost over short so this is shorted here and this is the reference voltage and this is VR plus V0 and in this case V0, this is shorted so this will be restricted V out will be equal to VR this is what we have shown here. That output is clipped at VR. I repeat and you understand this again that this is the diode which is forward biased for all voltages in access of VR that the own diode has almost 0 resistance so this is ideally we have shorted it and then what you will absorb here you will absorb here VR.

So, this voltage is this part is clipped and we have this wave if we wish we can use this biased clippers in symmetric so that this portion is also clipped for that we have to use two diodes and both are biased and this is this circuit.

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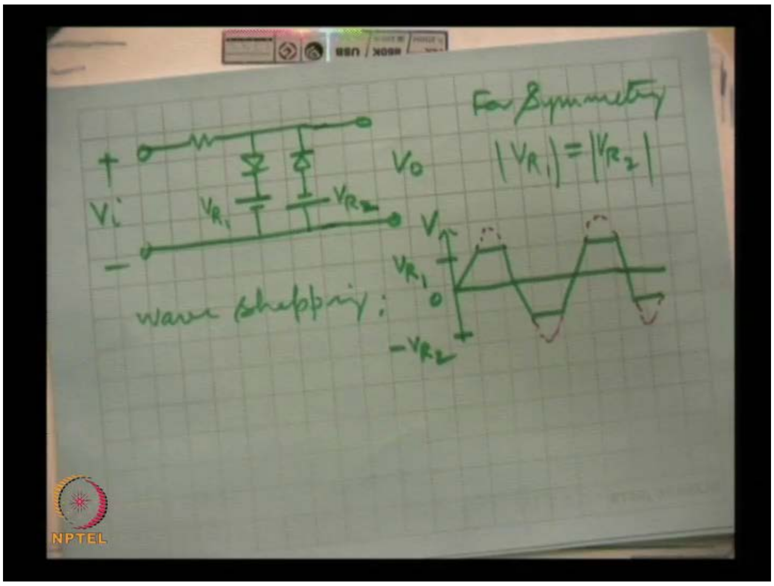

This is VR1, V R2 look at the polarity in the direction of the diodes and here we get the output, here we connect the signal Vi. If we want symmetric wave shape then V R1 for symmetry VR1 has to be equal to VR, VR1 is equal to the magnitude of VR2. And in this case the output wave shape for the symmetric rows, it will be this is voltage 0 this is VR1 this is minus VR2 and under this condition both will be identical and we can here this portion has been clipped off this portions have been clipped off. So, we can restrict the magnitude of the wave this is the topic which is covered in wave shape and as I said earlier and this clippers find by wide application briefly I talk about clampers what is the purpose of the clamper.

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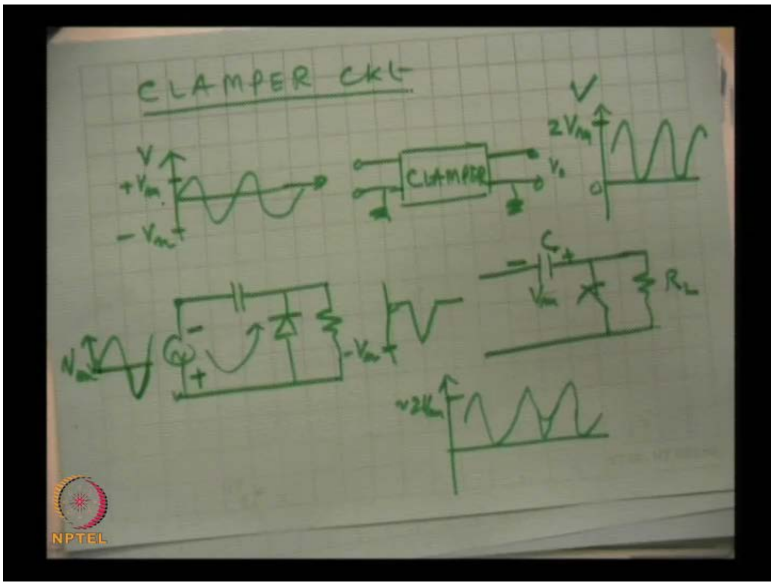

Let us see here, clamper circuit first let us look at the principle of clamper, that if there is a wave like this where this is voltage, this is time access and this is plus V m this is minus V m if this passed this is applied to the clamper. This is the clamper then here this is ground volt terminal this is normally grounded we get the output here, then we can change the DC level. So, the output here we will get like this, ideally we will get where this is voltage access this will be equal to 2V m that means we have added almost a DC level for to this signal to shift the reference so this is 0 and this is 2V m so this is a clamped wave.

So, this is the clamping action very widely used in circuits wherever we want to shift the DC level of a varying wave. And one circuit I take that here this makes use of a capacitor a diode and here is the load and here we apply a AC wave like this. Now what will happen of the lower half this will act as a short so the current will flow, and if we have here a voltage V m in for the lower half this is V m minus V m this will charge the capacitor and this capacitor this polarity of this minus plus we are talking what happens in this lower half, this will forward bias the diode and the capacitor is charged this is short diode and this is load 0 resistance with it will appear 0 resistance but, the current will flow here and this will be charged with this polarity.

And at the positive half this will act as a battery now almost as a battery and for the upper half, this V m plus this is having peak value of V m the two are and at the output we will get a wave shape a wave like that is better drawn this is almost equal to 2V m and this wave we have shifted the level of a the wave very widely used clamper circuits. So this way we talked about some of the applications of diode in a circuit and these are basically three most widely used applications, one is rectifier rectifier circuits are required in every electronic device in most widely used circuit is the bridge rectifier with 5 filters if we want to reduce the cost of filter then often a shunting capacitor is used and that is capaciting capacitor filter is used.

And then we talk of a clipping in clamping circuits which are used for the wave shaping purposes and we can cut symmetrically a wave, we can restrict the upper magnitude in so that is there and in clampers we can change the DC level we can add DC in either way if we reverse the role of capacitor in diode then it can be done in the other way also, these are clampers. So, this was the unit we finish the first unit and that is a on p n junction we talked about the physics and the physical processes involved in the junction formation and then through potential energy the diagram we discussed how the currents will flow in the diode is forward biased in when it is reverse bias.

And then we talked about the properties associated that associated with the junction the contact potential very important and we derived an expression for that then without variation of depletion width and we also talked about the junction capacitings, capacitances there are two capacitances in forward bias, there is a in the reverse bias the transition capacitance in the forward bias there is a defusing capacitance. But in forward bias the effects of the diode are dominated by the current flow while transition capacitance place a important role, when the diode is reverse biased and then we talked about these other circuits so that completes our unit one p-n Diode .