Basic Electronics
(Module – 1 Semiconductor Diodes)

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Lecture - 6

Clipping and Clamping Circuits

Today we shall discuss about clipping and clamping circuits which are circuits that are built from diodes and resistors and capacitors together in order to shape certain wave forms. When we do not want the complete waveform or suppose we want to clip one portion of the waveform which is given as input or we want to clamp the DC level of a waveform at certain higher level than what actually is, this clipping and clamping circuits are used. Basically these are the wave shaping circuits which are made from diode and resistors and capacitors generally built into a circuit and this clipping and clamping circuits find applications in many areas of electronics, for example in communication. In control and instrumentation circuits, etc, we some times require some particular or special waveforms not general waveforms like sinusoidal, etc. To build these waveforms both normal and Zener diodes are used. Today we will be discussing about these clipping and clamping circuits which are nothing but wave shaping circuits. So diodes can be used in wave shaping circuits. These either limit or clip portions of a signal or shift the DC voltage level of the signal.

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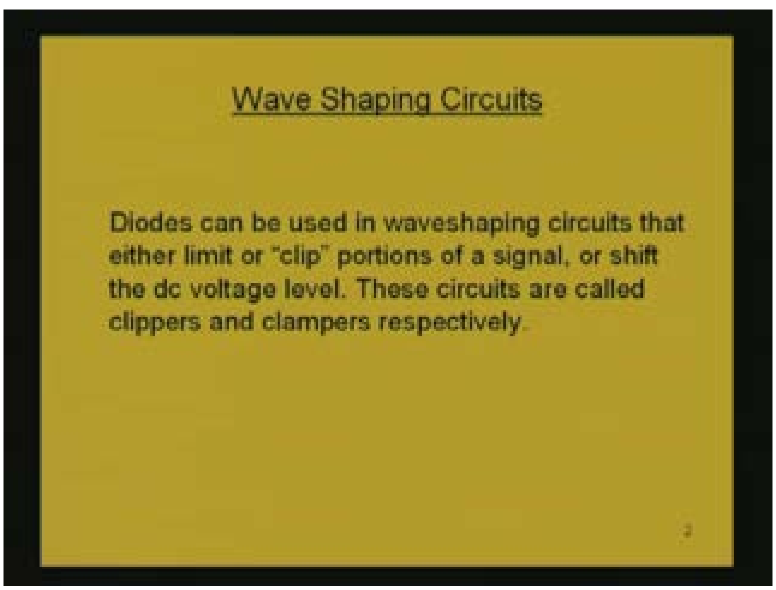

These circuits which clip a portion of the waveform are called clipping circuits and those circuits which clamp the DC level at some other value are called clampers. In order to understand clippers circuit let us first take an example of the clipper circuit using an ideal diode.

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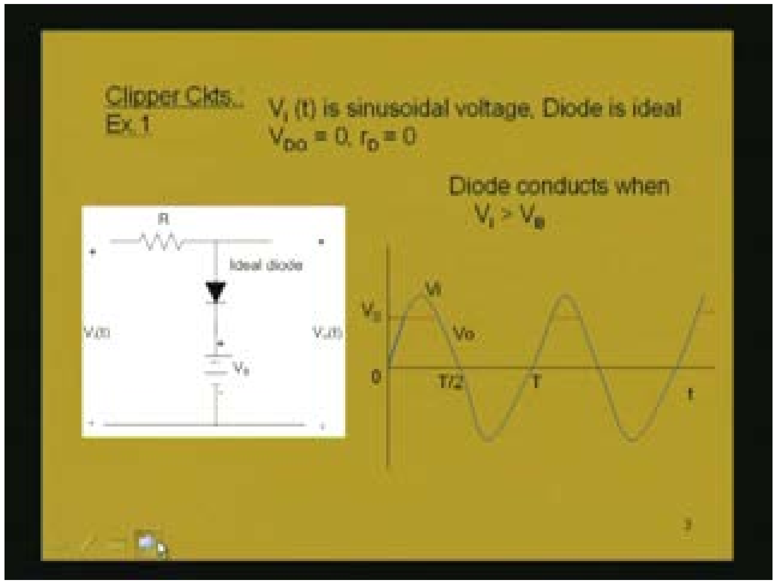

First we will be discussing a clipper using an ideal diode for simplicity and easy understanding. Then we can go for actual diodes. This circuit here is ideal diode having the threshold voltage zero and the diode forward resistance zero. Input which is applied to the circuit is a sinusoidal wave for example. This circuit has a resistance R and this is the diode and at the N side of the diode is connected a battery. Positive terminal is to the N side and this battery has a magnitude of V_B. We have want to find out the voltage waveform at the output which is V0(t). Suppose we want to plot V0(t) and V_i(t), that is given a sinusoidal waveform to the input what will be the output? With these polarities we will be denoting this output signal. This point is higher with respect to this. This is actually ground point.

In this circuit we have to first see when the diode will be conducting. This diode has on the N side a battery which is having the potential V_B. In order to conduct, the voltage at P side must be higher than the voltage at N side. That means V_i(t) magnitude at any point should be higher than V_B so that the diode conducts. V_i is a sinusoidal waveform as shown here. The voltage at any instant will be varying as shown in this plot. Suppose we consider this half cycle. When the V_i rises then till the point V_i is less than V_B; this point is at a lesser potential than this point then this diode will not conduct. That means we have a non-conducting diode for those portion of the input voltage waveform till the point V_i is less then V_B. When V_i is less than V_B this is at a lesser potential than this point. P is at a lower potential than N point. So the diode does not conduct. It is like an open circuit. This part is like an open circuit.

We want to find out the voltage at these two points, this point and this point across which we are finding this voltage. Then these two points are nothing but these two points. Since the current is not conducting, this point and this point are same as this point and this point. There is no conduction of current. So there is no voltage drop. The voltage $V_0(t)$ is equal to $V_i(t)$ for the portion of the input voltage waveform when V_i is less then V_B. The V_i and V_0 will be just coinciding or it will be same voltage V_i and V_0. When V_i is greater than V_B, this P is at higher potential than N because N is connected to V_B and this is now higher than V_B. Now the diode will be conducting. When the diode conducts then what will be the voltage across these two points? That is we want to find out $V_0(t)$. Since we are assuming that the diode is ideal, the diode drop is zero and the resistance of the diode is also zero. This voltage V_0 with this point higher than this point means with these polarities what will be the voltage V_0? V_0 will be equal to V_B. That is shown here. This is V_0 equal to V_B when the diode conducts.

You note that this sinusoidal voltage V_i is varying and from this point downwards V_i is less than V_B. When again V_i is less than V_B, the diode will be off. That diode is non-conducting. There is no current flow. This voltage V_0 (t) will be equal to exactly $V_i(t)$. From this point again till when V_i is greater than V_B up to this point, input and output voltage are same. Again it will be conducting when V_i is greater than V_B. The output voltage V_0 will be equal to this V_B voltage and again this will be continuing like that. You note here that the upper portion of the input voltage is now clipped. We are getting a output voltage V_0 which is like this. This portion is just clipped away from the input voltage. This is a very simple example of a clipper circuit.

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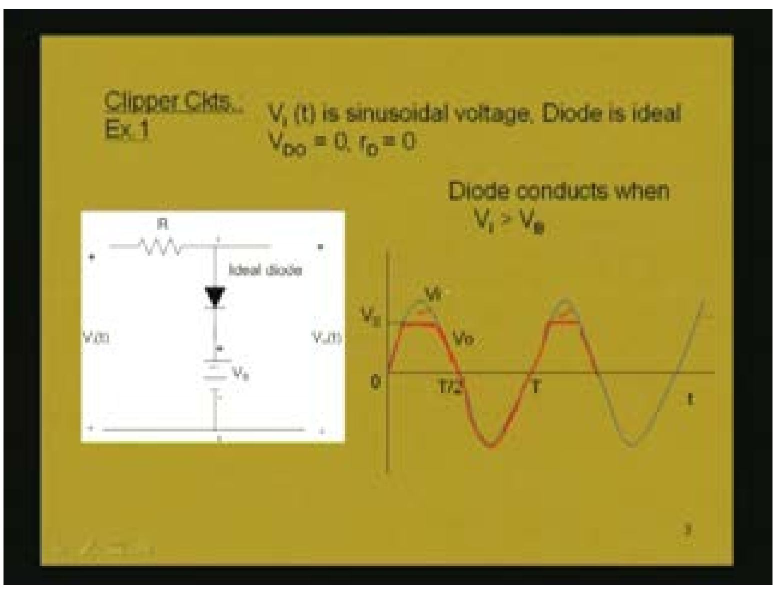

Here you notice that we are still assuming that the diode is ideal without any voltage drop when it conducts and resistance being zero but now we consider the diode having the voltage drop V_{DO}. That means we consider another example where we have a diode which has an equivalent constant voltage drop model. Let us see an example of a clipper circuit using a constant voltage drop model of the diode that means a diode which has V_{DO} equal to say around 0.7 volt for silicon.

In this example here we have this diode which has V_{DO} drop and r_D is ignored again. That is resistance of the diode is very small which we ignored here. That means we will be using the constant voltage drop model for the diode.

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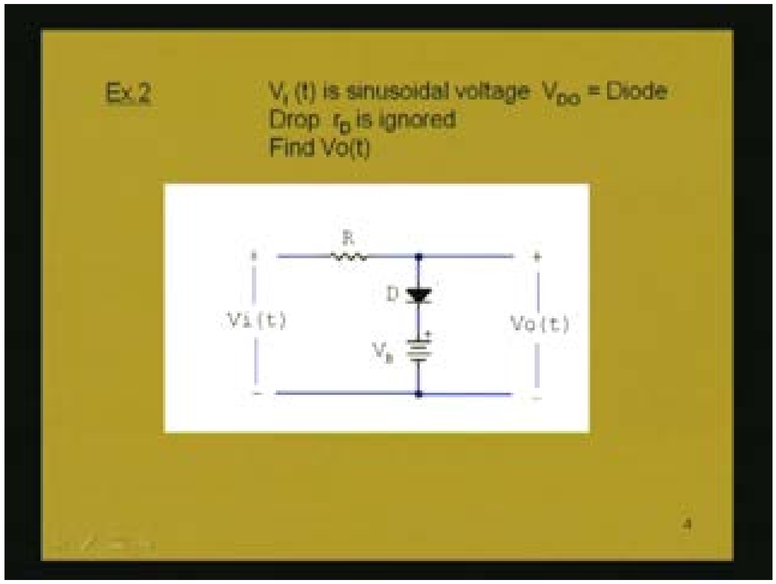

This circuit is having this diode which is connected to a battery V_B. In this example N is connected to positive of V_B. In the same example if we now consider that the diode is not ideal but it has a voltage drop V_{DO} what will be this output voltage V0(t) for the input sinusoidal voltage that is being given and in earlier case also we were using sinusoidal voltage. Now also suppose we give an input sinusoidal voltage, find output voltage for this circuit. The easiest to way to deal with such circuits and to plot the output versus input is to draw the equivalent model for the diode. That will simplify the circuit. Instead of considering this diode and assuming V_{DO} as a diode drop we will be drawing the circuit again with constant voltage model for this diode that is having V_{DO} 0.7 volt or 0.3 volt as the case may be.

Let us generalize it as having V_{DO} as the diode drop and we will draw the circuit using equivalent model for this diode. We draw the equivalent model for this diode and replace it along with an ideal diode. If you remember what is done for equivalent model, what we have done earlier is that when you want to replace the diode by its equivalent model we draw the battery showing the drop V_{DO} along with the ideal diode. Ideal diode is just to show the direction of the conduction of current in the diode. The same circuit we are equivalently drawing again by using this constant voltage drop model V_{DO}. Others are same. V_B is there and this source is there. We are assuming that input voltage is sinusoidal. In this case you find out the condition when the diode will be conducting? That is V_i is sinusoidal. It is varying with time. Up to a peak value it will be increasing then decreasing to the negative peak and it will be continuing. At any instant in order to know the condition for the diode to conduct we must see when this P is at a higher potential than N. We are applying the voltage V_i.

Whenever V_i is higher then what is potential at N point? This potential is V_B+V_{DO}. If you find out the potential at this point with respective to ground what will it be? V_B is already there; again this is the diode drop. So minus plus minus plus it will be in series totalling up to V_B+V_{DO}. The potential at P must be higher than V_B+V_{DO}. When this happens then only the diode will conduct. Whenever V_i is greater than V_B+V_{DO} then the diode will be conducting. When the diode conducts what will be voltage across these two points? This potential being higher than this potential that is the way we are denoting V0(t). Conventionally it is denoted like that. This potential is negative with ground when the diode conducts.

This is ideal diode. That is normally we replace the diode by its ideal diode and battery V_{DO}. The voltage V0(t) when this will be conducting that will be this voltage. With respect to this point what will be the voltage at this point? V_B plus V_{DO}. When the diode conducts the voltage will be constant at V_B+V_{DO} and when V_i is less than V_B+V_{DO} then the diode will not conduct. When the diode is not conducting these two points are like open circuit. There is no current through this or that means these two points are open circuited. The voltage at this point is same as the voltage at this point means output voltage is equal to the input voltage.

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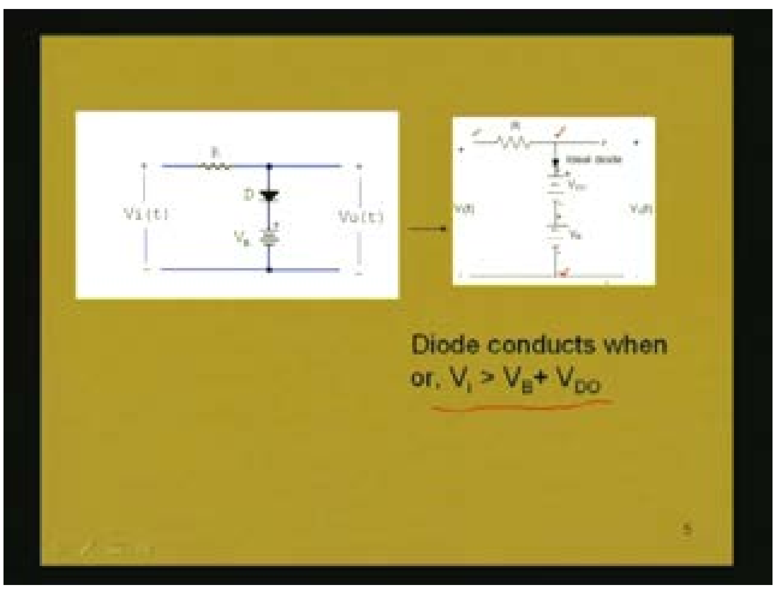

Since there is no voltage drop across this resistance, input and output voltages are same. Now we can draw the input and output voltage waveforms. V_i is the input voltage which is sinusoidal. Suppose it has a peak value of V_m and we want to draw V_O along with this V_i, superimposing on V_i, then we will be getting this, that is denoted by this green line. This is the output voltage V0(t). Till the point when input voltage is less than V_B+V_{DO}, the diode does not conduct. So input and output voltages are same and whenever V_i is greater than V_B+V_{DO} the diode conducts and the voltage V_o will be equal to V_B+V_{DO} we get a constant voltage across the output terminals. So V_o will be V_B+V_{DO}. Then from this point downwards again V_i becomes less than V_B+$V_{DO.}$ We have the diode not conducting.

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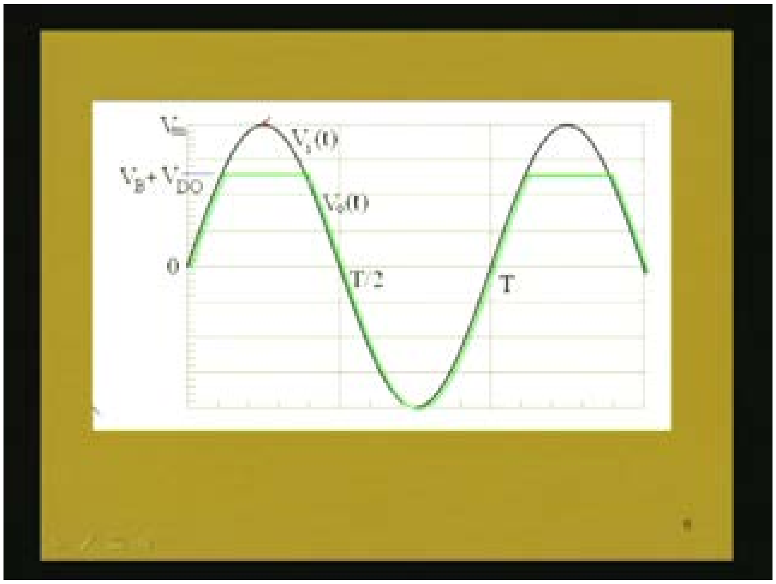

So output voltage and input voltage are exactly equal and this will continue like this. We now see the effect of the V_{DO}. That is the diode drop which was earlier ignored in the first example now we are considering. If you compare these two plots, here it was cut at V_B. That means upper portion from V_B was clipped but because of this diode drop, now the upper portion from V_B+V_{DO} will be clipped. This is typical example of a constant voltage model drop considered for the diode and this is a simple clipping circuit, clips a portion of the waveform, upper portion is clipped. We can design different clipper circuits according to our needs. If we want to clip an upper portion like this at this voltage then we can design the circuit like this or suppose we want to clip both upper and lower portion then also we can design it. We will be now showing some more examples to illustrate different clipper circuits.

Before going to another circuit again consider the same circuit and let us discuss one important characteristic that is transfer characteristics. Transfer characteristic is basically a plot between the output voltage and input voltage. You have to be careful because both the axis are in volts. Input voltage we plot in the x-axis and output voltage in the y-axis. We have to plot V_o versus V_i. That is called a transfer characteristic. For this particular example if we now plot the transfer characteristics from this output waveform versus input waveform we see that till the point input voltage is less than V_B+V_{DO}, output and input voltages are equal. Output and input voltage will be having a linear relationship with a slope like the one which is shown here. Here on this straight line passing through this origin the voltage input and output will be the same and it will be continuing till the point when V_i is greater than V_B+V_{DO}. When V_i is greater than V_B+V_{DO} the voltage is constant at V_B+V_{DO}.

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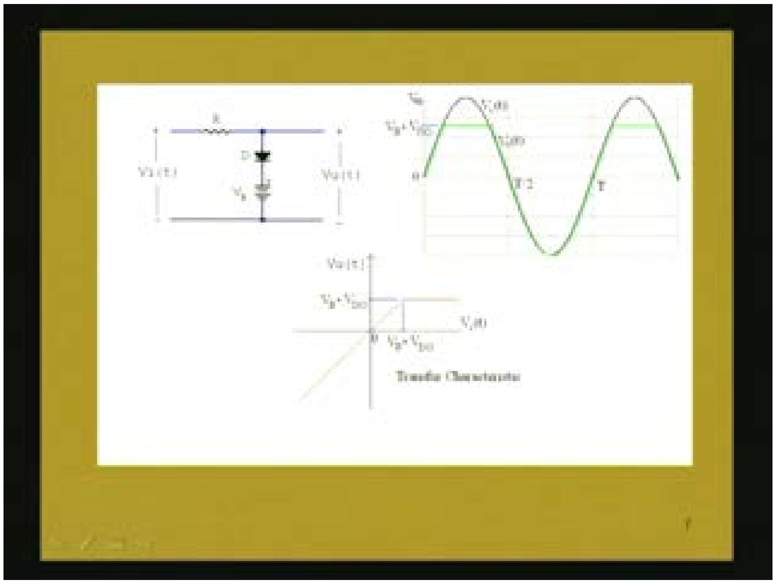

That is why it will be constant and whenever V_i is less than V_B+V_{DO} it will be bearing a linear relation with slope 1. That is shown here by this red line. That is this portion is for the non-conducting portion of the diode. From this point onwards the diode is conducting. Voltage drop is constant at this voltage V_B+V_{DO}. This portion is the non-conducting portion where input and output voltage is same defined by this straight line passing through the origin having slope 1. This is an important characteristic which we can draw from the input and output voltage waveforms. Now let us consider another example.

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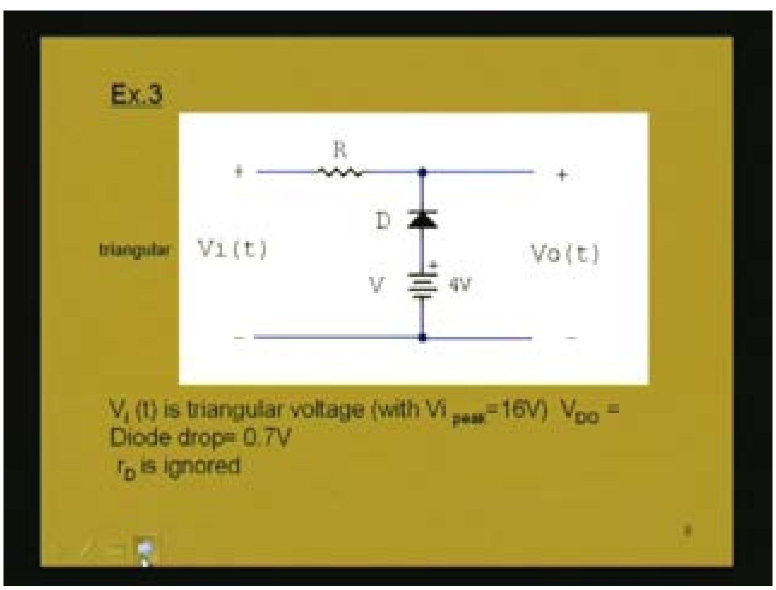

Here you have to note that this 4 volt battery is there which is connected in a such a way to the diode that its positive terminal is connected to P and suppose we are applying a triangular voltage of V_i. Instead of sinusoidal which we have discussed let us now apply a different voltage waveform triangular waveform with the peak value of 16 volt. That is this triangular voltage waveform has a peak magnitude voltage of 16 volt. Here also you have to assume V_{DO} equal to 0.7 volt. That means it is a silicon diode. r_D is again ignored for all practical purposes because we are dealing with resistances which are generally having high value and we can neglect this r_D which is very small that is the forward resistance of the diode.

We now look into the condition for conduction of this diode. We have already seen that this diode is being forward biased by this 4 volt. That is this P is connected to positive. Input voltage is a triangular voltage. When will it conduct? That diode will be conducting when we have this voltage at the point P being higher than the voltage at the point N and you see here N is being applied a voltage and if we consider now this conduction let us first draw the equivalent circuit for this diode as we have done earlier. This diode drop V_{DO} it will be along with this ideal diode which shows the conduction direction and this 4 volt battery is already there. We are applying a triangular voltage waveform.

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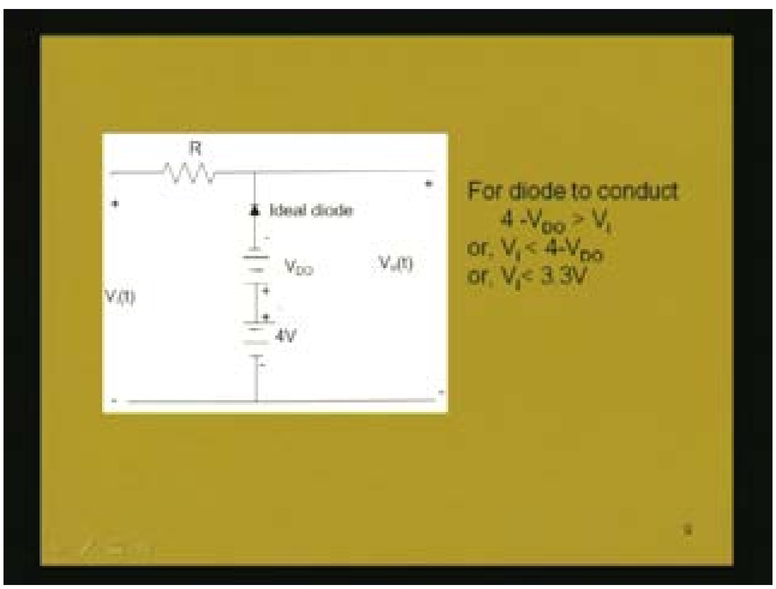

This diode will conduct current when the voltage at this point is higher than the voltage at the N point. What is the potential at this point P of the diode? From this point if we see 4 minus plus that means 4 positive; in the direction it is minus to plus it is positive and this is again plus to minus, its negative. So $4-V_{DO}$; this voltage must be greater than the voltage at the N which is V_i. The condition is $4-V_{DO}$ should be greater than V_i in order that the diode will conduct. We can write in another way that V_i is less than $4-V_{DO}$. Snce we have been told that this V_{DO} is 0.7 volt, 4-0.7 becomes 3.3 volt. That means we get a condition that when the input voltage V_i will be less than 3.3 volt then the diode will be conducting. Whenever it is greater than 3.3 volt then it will be not conducting. The moment it becomes greater than 3.3 volt you can see that this will be reverse biased. So it will be not conducting. We now get output voltage plot versus input voltage plot.

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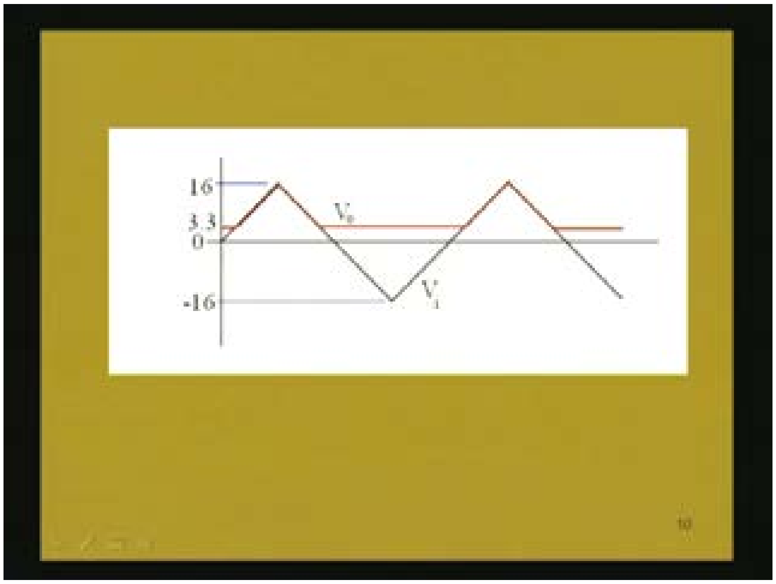

This input voltage is triangular voltage having peak value 16 volt. The output V_o if you draw we have seen that when V_i is less than 3.3 volt it will be conducting. When it conducts what will be this voltage? This voltage is nothing but from this point, 4 volt positive minus 0.7 volt, 3.3 volt. So it will be clipping; the output voltage will be clipped at 3.3 volt when the diode conducts. We get the output voltage as a constant voltage for the conducting part. This will be constant when the input voltage is less than 3.3. That means this is the conducting region and when the input voltage is the greater than 3.3, the diode does not conduct. You can see here when the diode does not conduct the input voltage is greater than 3.3; it will be not conducting and when it does not conduct it is like open circuit. The output voltage and input voltage are equal. We get output voltage and input voltage just overlapping for the reason when diode does not conduct. This will be the output voltage plot that we have drawn with respect to the input voltage. In this case you see that lower portion, this portion is clipped. The lower portion when the voltage is less than 3.3 volt which is this portion is just clipped away. This is another example of a clipper circuit.

Let us take example of another circuit. Here 2 diodes are there. The diodes are connected in such a fashion and 2 batteries V_{B1} and V_{B2} are being connected to these two diodes with these polarities as we see here in the diagram. Let V_i be sinusoidal again. Find what will be the output voltage? With these polarities we are denoting the output voltage. Here also we will be considering a constant voltage model of the diode. That is diode drop is V_{DO} and we have to ignore the forward resistance of the diode r_D.

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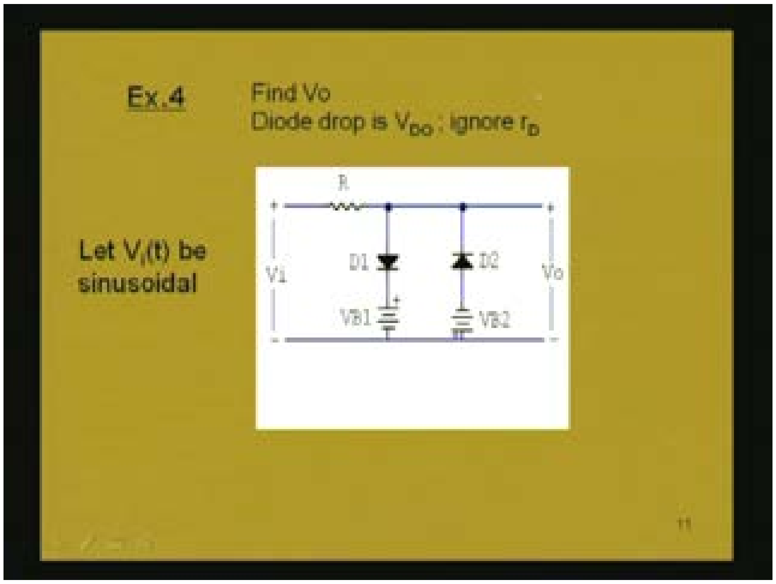

As it is easier to deal with such circuits we replace the diode by its constant voltage drop model. We will be doing that. This circuit we are drawing again by replacing the actual diode by its constant voltage drop model and that is shown here. This diode is D1 and this is diode D_2. Both these diodes actually have same drop V_{DO}. V_{DO} along with the ideal diode with the conventional way of denoting the polarity of the V_{DO}. That is the diode conduction is in this way. V_{DO} will be having positive polarity here, negative polarity here. This is the way of showing the equivalent model with the battery polarities like this.

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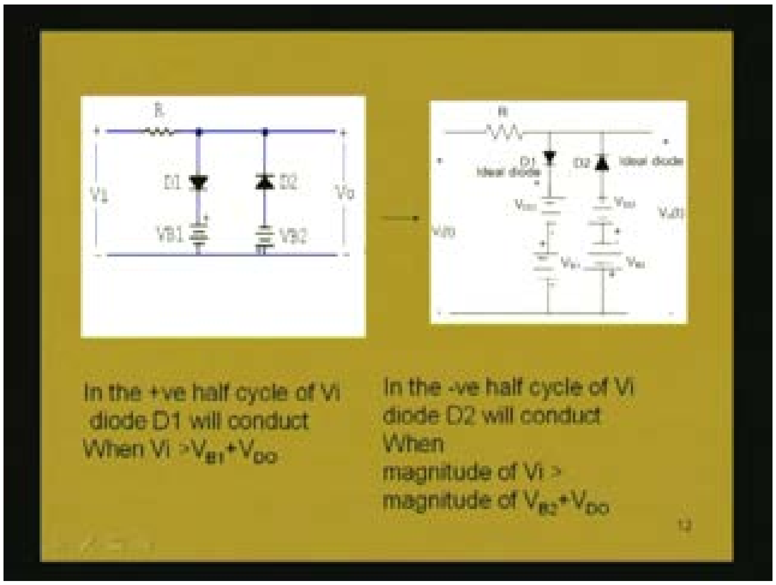

Similarly other diode conduction is in this direction from bottom to top. So the diode drop V_{DO} will be also having the same polarity that is positive here, negative here. This is V_{DO} and the other voltages battery V_{B1} and V_{B2} are as it is we have drawn and these are ideal diodes. We have to find out what is the output voltage for a given sinusoidal voltage $V_i(t)$.

Let us consider a positive half cycle of the input voltage. That is positive half cycle when this point is at a higher positive potential than this point. When it is positive this V_{B1} and V_{B2} are connected in such a fashion that they are already reverse biasing these diodes. That means this V_{B1} which is positive is connected to N, here negative is connected to P. That means both are connected in such a way that both the diodes are already reverse biased. It will be depending now on the polarity and the magnitude of the input voltage when it will be conducting. In order to conduct if we consider a positive half cycle of the input voltage when this point is at the positive potential than this point then it will conduct. Diode D1 will be conducting when this point P is at a higher potential than this point. What is the potential of this point N? It is $V_{B1}+V_{DO}$; minus plus minus plus that is series. 2 batteries are in series with this point negative, this positive. So $V_{B1}+V_{DO}$ is potential here. When V_i is greater than $V_{B1}+V_{DO}$ then this diode D1 will be conducting. But as you can see here this diode D2 will not conduct in that half cycle because here in the positive half cycle of the input voltage this diode is reverse biased and this battery is also connected in such a way that this V_{B2} is reverse biasing. There is no question of conduction of diode D2 in the positive half cycle. In the positive half cycle of the input voltage, when the input voltage is higher than $V_{B1}+V_{DO}$, then the diode D1 will conduct.

In the negative half cycle again if we see the diode D2 will be conducting. This diode will be conducting when this magnitude of V_i is higher than magnitude of $V_{B2}+V_{DO}$ because it is in the negative half. Negative half of the input half cycle will be such that whenever at this point, potential is higher than this potential which is $V_{B2}+V_{DO}$ but with the negative sign because we are considering negative half cycle. That is why it is written here that magnitude of this V_i must be higher than the magnitude of this total voltage in the negative half cycle we are considering and when this diode will be conducting in the positive half cycle with this condition then output voltage will be simply this plus this; $V_{B1}+V_{DO}$. Similarly in the negative half cycle when this diode will be conducting for this condition to be satisfied that V_i is greater than $V_{B2}+V_{DO}$ if we find out this voltage it will be this voltage plus this volt but with a negative sign in the negative half cycle.

We can now draw this output voltage waveform versus input voltage waveform. Input is this black one, V_i and if we now find out and plot the V_o, this is zero starting with this. When input voltage half cycle is positive and input voltage is less than VB1+V_{DO} the diode does not conduct. When the diode does not conduct then this voltage is same as the input voltage. Because there is no conduction of current there is no drop here. These two points and these two points do not have a change in the difference in their potential. So V_o will be equal to V_i for this portion. Whenever V_i is greater than $V_{B1}+V_{DO}$, the diode D1 conducts and the voltage will be equal to $V_{B1}+V_{DO}$. That is why it will be constant. Then again when V_i is less than this voltage, the diode D1 will not conduct and input voltage and output voltage are the same.

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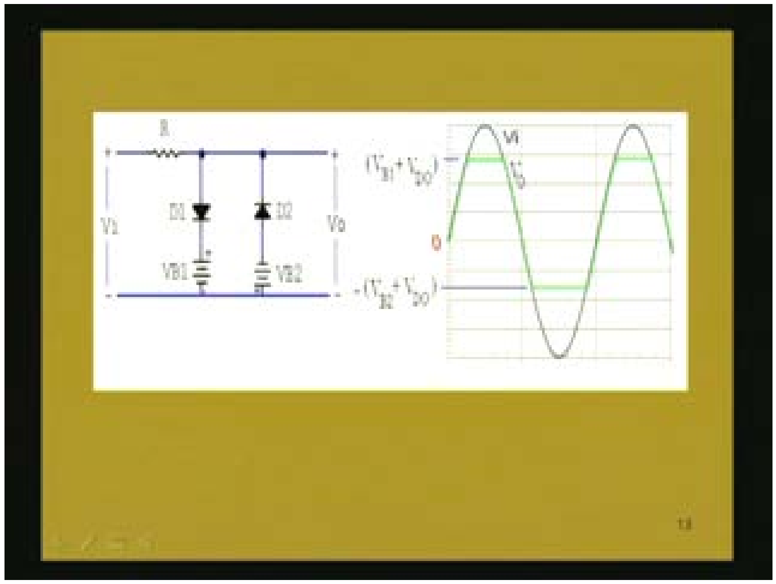

It will be continuing in the negative half cycle when V_i is greater than V_{B2}+V_{DO}. Then this diode D2 will conduct and when D2 conducts the voltage will V_{B2} plus the diode drop in the negative half cycle that is shown by this constant portion. This whole green curve will be showing the plot of the output voltage V_o. We see here an example where both the upper and lower portions of input waveform are clipped away. This is upper portion, this is lower portion. Both are clipped.

Depending upon the magnitude of V_{B1} and V_{B2}, this voltage waveform will not be symmetrical. Because V_{B1} and V_{B2} when they are equal then only it will be symmetrical otherwise we can have asymmetrical waveform. If V_{B1} is higher than VB2 then we will be getting an asymmetrical waveform or even if V_{B2} is higher then also depending upon which voltage is higher this portion will be higher or lower where the diode is clipped. This is another example.

Let us take one more example of a clipper circuit. Here in this circuit we have to find V_o and we have to assume that the diodes are ideal. D1 and D2 are ideal. As D1 and D2 are ideal this drop is zero here. This drop also is zero here and the resistances are ignored. That means they are zero for both the diodes. In this circuit we have to find out V_o. We are applying a sinusoidal wave. V_i is equal to 6 sin omega t. 6 sin omega T has peak value of 6 volt. It is sinusoidal waveform having a peak value of 6 volt. What will happen to these diodes when you apply this voltage? You have to be careful because we have 2 batteries. 2 volt and 4 volt are connected in this fashion with D1 2V battery is there which is reverse biasing this diode and this voltage of about 4 volt is also reverse biased this diode D2. Both these diodes are reverse biased by these two batteries.

When will it conduct? When input voltage is 0 to 2 volt that means less than 2 volt then the diode D1 cannot conduct and in the positive half cycle when V_i is less than 2 volt then there is no possibility that the diode D2 will conduct because it is reverse biased already and in the positive half cycle of V_i up to say V_i less than 2 volt it is also reverse biasing this diode D2.

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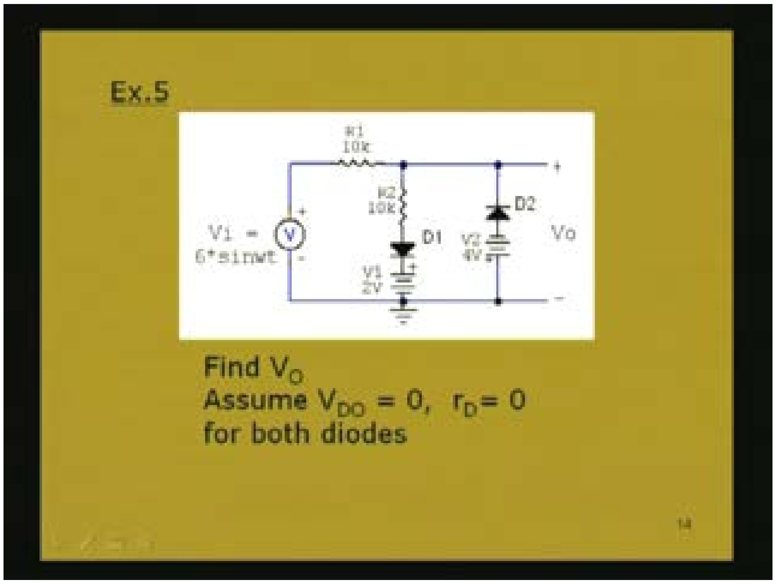

In the positive half cycle if you consider a portion when V_i is less than 2 volt, for zero to 2 volts, we find that D1 and D2 both are OFF; both are not conducting. Both are reverse biased and both are not conducting. What will be the output voltage? Output voltage is equal to the input voltage exactly equal since these are ideal diodes in consideration.

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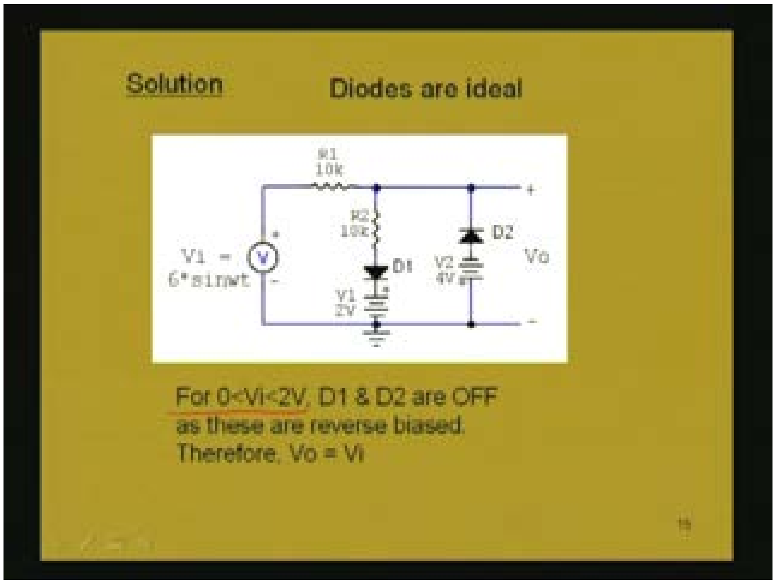

There is no voltage drop in the diode as well as no resistance. Output voltage will be equal to input voltage for the portion when input voltage is less than 2 volt. That means if we consider input voltage waveform V_i sinusoidal this is 6 volt. This is time. Suppose 2 is here, from zero to 2 you will not find any of the diode conducting. V_o and V_i are exactly equal. Up to this portion V_o and V_i are equal. What will happen? V_i is greater than zero less than 2 volt. When V_i is greater than 2 volt, in the positive half cycle, this portion this diode will be conducting. When this diode conducts current will flow in this circuit. The other diode does not conduct even now because in the positive half cycle it is being reverse biased. This diode is conducting. When this diode conducts what will be this voltage? That can be found out if we find out the voltage drop across these two points. If we want to find out what will be the voltage drop across these two points this is 2 volt and this is zero drop in the diode. A current will be flowing in this direction. This point is positive, this point is negative. With respective to this ground point what will be the voltage that is asked? This is 2; again plus i into R2 minus plus minus plus. With respective to this point the whole voltage across these two points are 2 volts plus i into R2.

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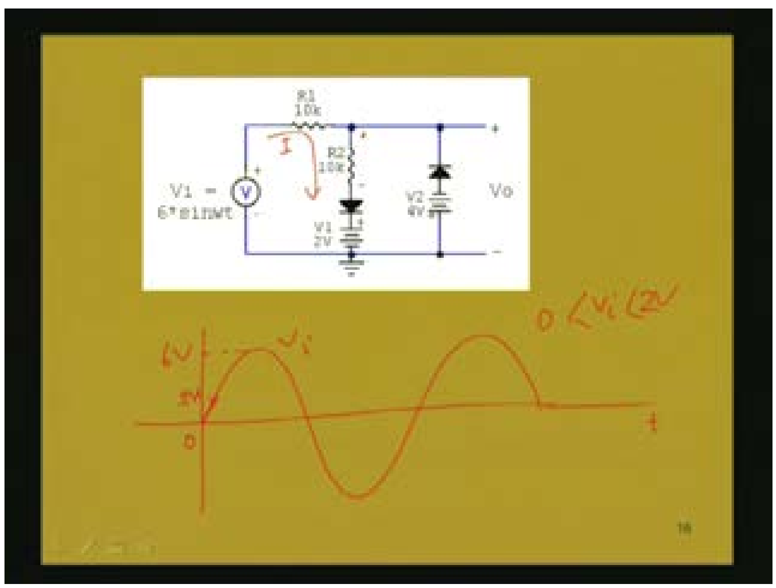

What is i? That has to be found out. i is equal to V_i minus 2 divided by 10 plus 10 k, 20 k. When V_i is greater than 2 volt D1 turns On and this i_1 we find out is V_i minus 2 divided by 10 plus 10 kilo ohms. Let us find out what it the voltage drop, V_o when this diode is conducting. This diode is conducting. The voltage across these two points is 2 volt plus this drop because as the current is flowing in this direction the diode conduction will be in this direction. This point is positive with respective this point. What will be the voltage at this point with respect to ground? That is 2 plus i_1 into R2 minus plus minus plus. Total voltage is summation of these two voltages. What is this current? V_i minus 2 just applying Kirchoff's voltage low. V_i minus 2 divided by 10 plus 10; it is in kilo ohm. V_i is sinusoidal waveform. We can find out only the slope and from that we can find out shape of the output voltage. For that we first replace this i_1 by V_i minus 2 by 10 plus 10, 20 into

R2 is 10 plus 2. This give after simplification V_i by 2 minus 1 plus 2 that is V_i by 2 plus 1. Depending upon what is the V_i at any particular instant it will be giving the output voltage.

If V_i we consider the peak voltage that is if we consider the peak point let us consider the limiting points. Starting from zero sinusoidal waveform is 6 voltage of peak. V_i is 6 sin omega T. What will be this voltage at 6 volt? You put this value of 6; 6 by 2 plus 1 that is 4 volt. That means when this input voltage is 6 volt your output voltage will be having a value of 4 volt. It will be like this.

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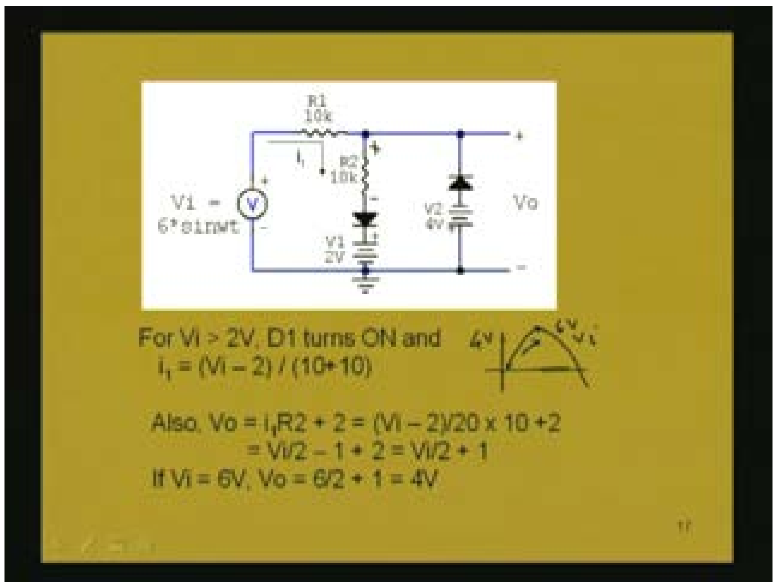

For the positive half cycle we get the output voltage waveform when the other diode will be conducting. This diode is being reverse biased by 4 volt already. In order to conduct then up to -4 volt that is in the negative half cycle if you consider because in the positive half cycle it cannot conduct at all. When the input voltage will be in the negative half cycle then till the point when the input voltage magnitude is less than 4 volt then this diode will not conduct; D2 will not conduct. When the negative voltage has magnitude greater than 4 volt, it will be conducting, this diode will be conducting. This point is at a higher potential than this point. In the negative half cycle you are considering, so the diode will be conducting and then when this conducts or this diode D2 turns ON, what will be this voltage? As this diode is ideal there is no drop. This voltage is nothing but -4 volt. The voltage here you see this point and this point when the diode is turned ON it's like this ideal diode does not have a drop. It will be simply this type of circuit at these two points. V0(t), with this polarity we are considering what is V_o? This is 4 volt. This point is positive, this point is negative. It is falling direction plus to minus. So V_o with respective to this point is -4 volt.

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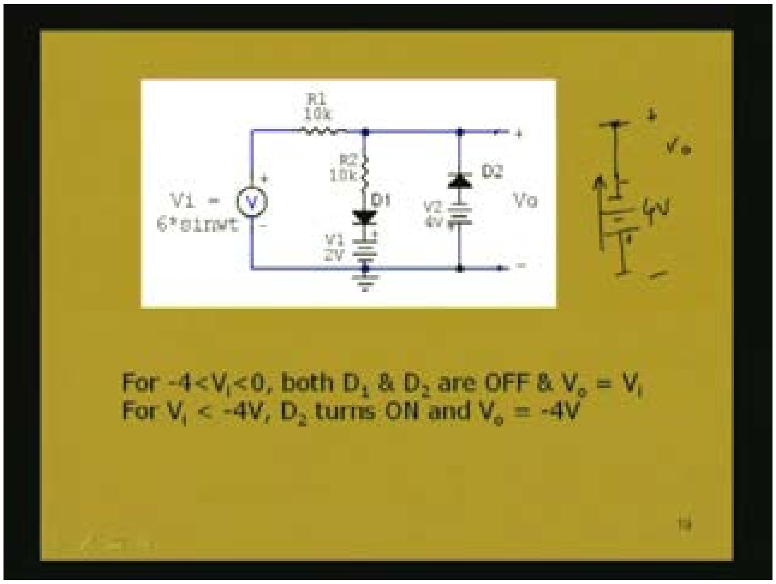

So V_o is -4 volt when the diode D2 is turned ON. Combining all this we can now draw the output voltage waveform versus input voltage waveform. Input is this one, black one. Output will be the green one.

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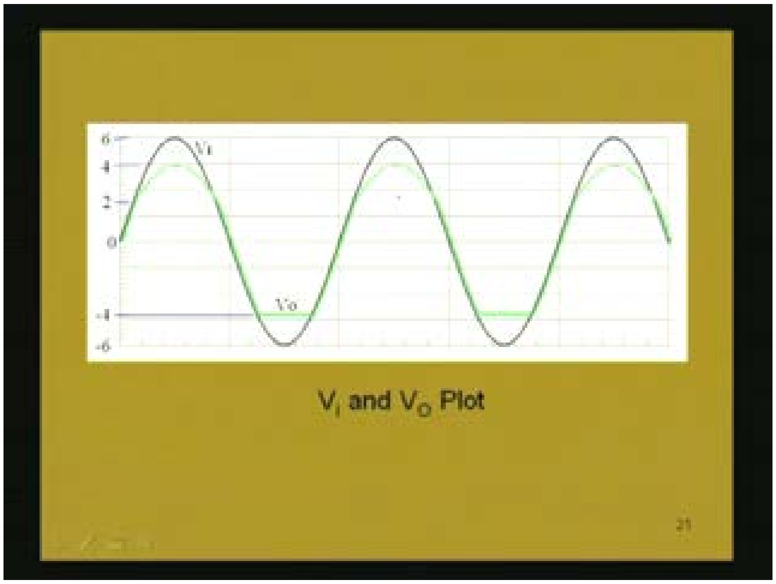

From 0 to 2 input and output is same and at input 6 volt, output voltage is 4 volt we have found out and again when it is less than 2 it will not conduct. It will not conduct till the negative half cycle when the magnitude of the input voltage is greater than 4 volt. That means if it is more negative than -4 then only it will conduct and the voltage will be -4 volt. It will be constant voltage drop. When V_i is again less it will not conduct. Input and output; we will be getting such a waveform. This is also clipped. But the difference between earlier one and this one is that here we are not having a constant voltage drop but there is a slope. This waveform is similar to a sinusoidal waveform but the lower portion we are getting a constant clipping. This is a difference than the earlier circuits that we considered. V_i and V_o plot will be like this.

We can draw the transfer characteristic also for this plot. If we plot V_o versus V_i from zero to 2 volt as you have seen output and input voltage are same having a straight line relationship with slope 1; 10 to 10 is 1, output and input are same. This will be a straight line passing through the origin up to 2 volt. When it is greater than 2 volt from this point to the peak point when V_i is 6, the voltage at the output is 4. These 2 points you can just connect. To get a straight line only 2 points are needed minimum 2 points, so we connect these two. This will be the slope for this portion of input voltage.

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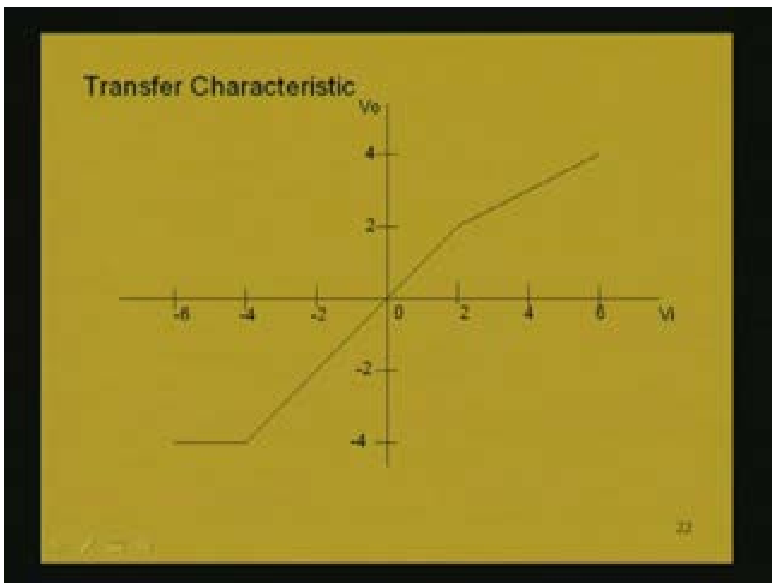

That is when input voltage is greater than 2 volt. In the negative half cycle again up to -4 volt input and output voltage are same because the diode D2 is not conducting. When the diode D2 is not conducting these two points are same as these two points. Since there is no drop there is no current. When the diode D2 is not conducting in the negative half cycle this cannot conduct because it is already reverse biased by this as well in the negative half cycle again it will be reverse biased. P will be connected to N. So we get input and output voltage same for this portion. That is why it is a straight line having slope 1. But when it is crossing that -4 volt V_i, the magnitude of the reverse voltage is greater than 4 volt then diode D2 will conduct. When D2 will conduct the output voltage V_o is equal to that voltage -4 volt. It is constant at -4. This characteristic is called transfer characteristic. This discussion whatever we have done is about the clipping circuit which clips a portion of the waveform given to you.

Another circuit which is of practical importance is clamper. A clamper is a circuit which will be clamping the DC level of a waveform at a different value than what is actually the level. Suppose we consider a sinusoidal waveform. If it is periodic sinusoidal waveform like sin omega T then its average DC value is zero. But this average DC value can be clamped at some other value. The DC voltage can be shifted by clamper circuit. A very simple example of this clamper circuit we will be showing here having an RC that is a capacitance and a resistance. It is connected like this as is shown in the circuit and a diode and let us for simplicity and easy understanding consider first an ideal diode. Ideal diode is having a zero drop and resistance is ignored. Suppose we are applying a square wave that is this type of waveform. It is an AC but this peak and this peak are exactly equal and it is a square.

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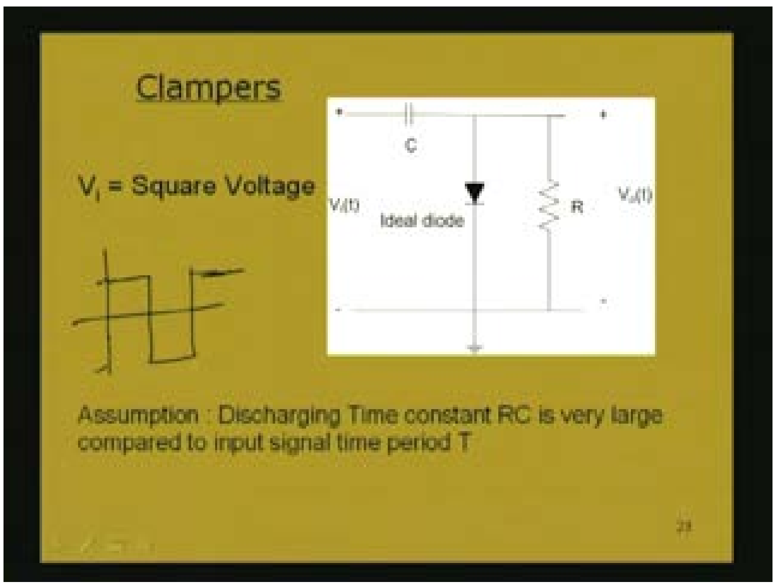

One assumption that we will be making here and which is very important is that the time constant of this circuit, the discharging time constant RC is very, very large compared to the time period of the input voltage. That will be the important assumption that we will be seeing here later. Suppose we are applying a square waveform to this circuit. What will happen? In this positive half cycle of the signal the diode will be forward biased. Let us consider this half cycle. We are giving a voltage like this V, -V. We have this input voltage and we have this capacitance. This is the diode and there is a resistance and this is C. RC time constant is very large. That is very, very large compared to the time period of the input signal which is V_i. This is V_i. In the positive half cycle this capacitance will be charged because this diode will be conducting. This is an ideal diode. There is no drop and it will be like a short circuiting. It will be conducting through this part. This capacitance will be charged to a voltage of V and as charging time constant is almost zero because diode has a very negligible resistance and in this case we have neglected that resistance, so the charging time is almost zero. It is zero and instantly it will be charged to a positive voltage V. This voltage will be V when it is charged to the peak value. Instantly it will be charged.

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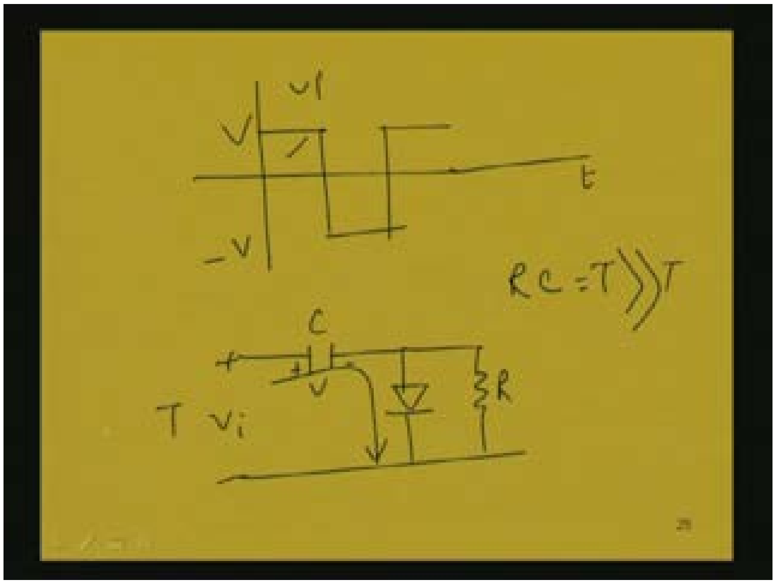

Then what will happen in the negative half cycle? This point is negative, this point is positive. This is the half cycle. This was already V, now again a V. Across these 2 points if we consider this voltage minus plus, minus plus it will be twice V and this diode is biased by a voltage twice V with polarity, this is negative, this is positive. It is reversed biased, so the diode will not conduct. But what will be this voltage? This voltage will be equal to this plus this, twice V in the negative half cycle. In the positive half cycle what will be voltage? When it is conducting this diode has a drop zero. V_o will be zero in the positive half cycle. In the positive half cycle V_o is zero. That means it will be zero and V_o if we plot this will be zero. But in the negative half cycle this will be -2V. That is this output voltage will be -2V in the negative half cycle.

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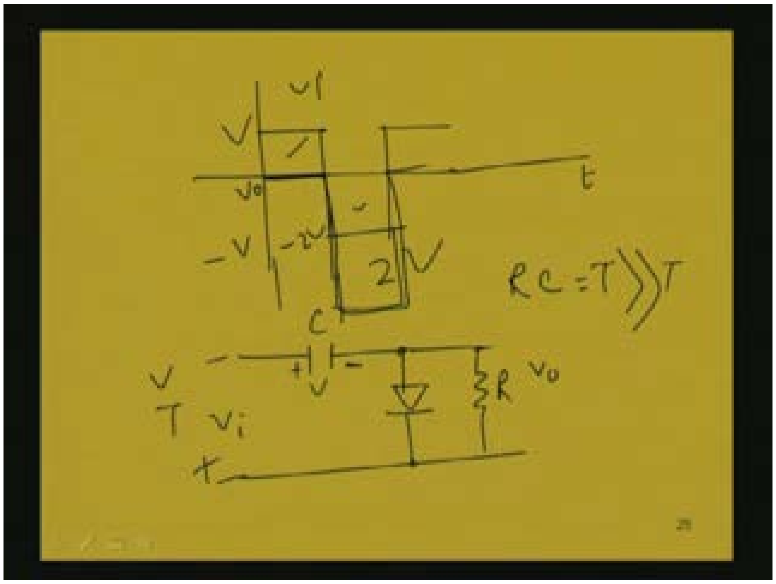

That is what we will be getting if V and -V are the peaks of the input voltage. Output voltage will be having zero voltage when this conduction takes place because when conduction takes place we can see here this diode drop in the positive half cycle is zero and in the negative half cycle when it does not conduct the voltage across these two points is 2V. We get this voltage. Here you can see that the voltage waveform given was this one. But now we are getting a voltage where the DC level is clamped differently at different voltage. We are getting -2V earlier it was –V.

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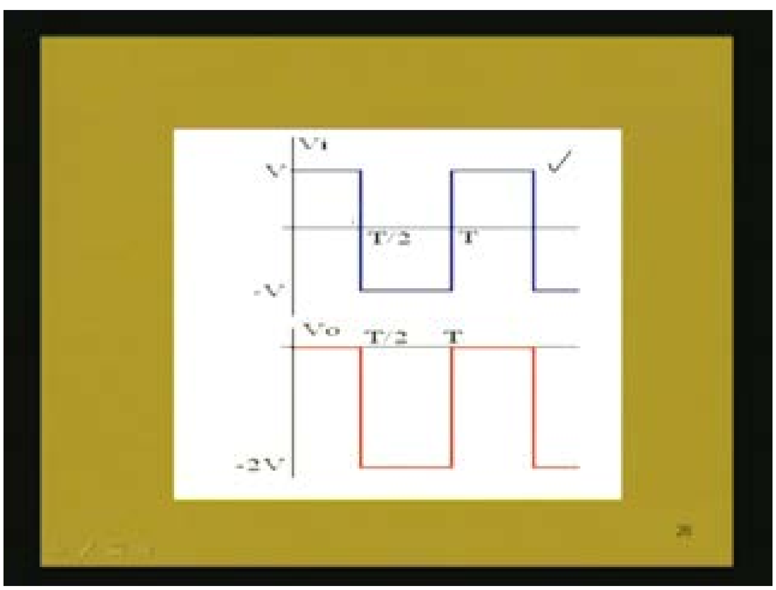

At a higher voltage T waveform is clamped. This is the example of a clamper circuit. Let us consider another example of the clamper circuit. Let us consider that this diode is not ideal. 0.7 voltage drop is there. Resistance is zero but we are applying V_i which is an asymmetrical square wave. An asymmetrical wave having square wave shape and peak voltage in the positive half cycle is 20 volt, negative is -5 volt. What will happen? For this if we consider the diode equivalent circuit it will be like this. This is an ideal diode. It's drop will be in this direction, 0.7 volt. Again this voltage is there which is plus minus plus minus 2 volt and this is the input voltage and this is the resistance. I want to find out this voltage. What will be this voltage? The voltage across these two points is the voltage across this resistance. Current multiplied by this resistance is the voltage. 5453

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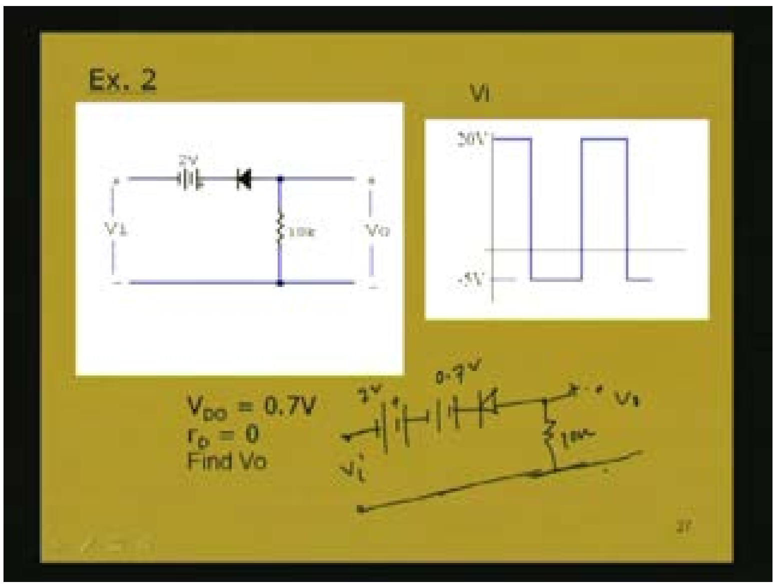

In the positive half cycle 20 volt is applied. This 20 volt plus minus, in this way it is applied in the positive half cycle. Will it be conducting? You have to see across these two points what will be the potential? Here it is minus. So this point is minus. It is reverse biasing and this diode if we consider it has a positive voltage. But that is 2 volt only. In the positive half cycle this negative voltage is higher. That means this point is at lower potential than this point. It will not be conducting. If it does not conduct there is no conduction of current and this drop is zero. We get this zero drop when it is in this positive half cycle. That is it is not conducting.

Let us consider another example of the clamper circuit. Here there is voltage 2 volt which is reverse biasing this diode. Applied voltage is a square wave but peak value is different. 20 volt in the positive and negative is 5 volt peak. If we want to find out when the diode will conduct we have to find the potential across this P and N. In the positive half cycle when 20 volt is applied this polarity is positive with respective to this. This point is having the N or negative of the input. 20 volt will be reverse biasing this diode and the potential at this total potential plus minus plus minus 2.7. This is 2.7 but here it is 20. This is higher at a negative. This will be reverse biasing and it will be not conducting.

When it does not conduct the voltage across this resistance will be zero since no current flows. You have to be careful where you want to find out the voltage. Here it is across this resistance. In the negative half cycle when this point is negative this point is positive. It is forward biasing with +5 volt. The potential here is +5 volt. This potential is 2.7. That is N point is having plus minus plus minus 2.7. Here this point is having a higher potential 5 volt than this point. It will be conducting. In the negative half cycle what will be this voltage? If we apply now Kirchoff's voltage law V_o minus plus is rising minus 0.7 minus 2 minus plus is raising +5 equal to 0. This is Kirchoff's voltage law. From here we get V_o minus 2.7 plus 5 equal to 0. What is V_o? V_o is equal to minus 5 plus 2.7 is minus 2.3.

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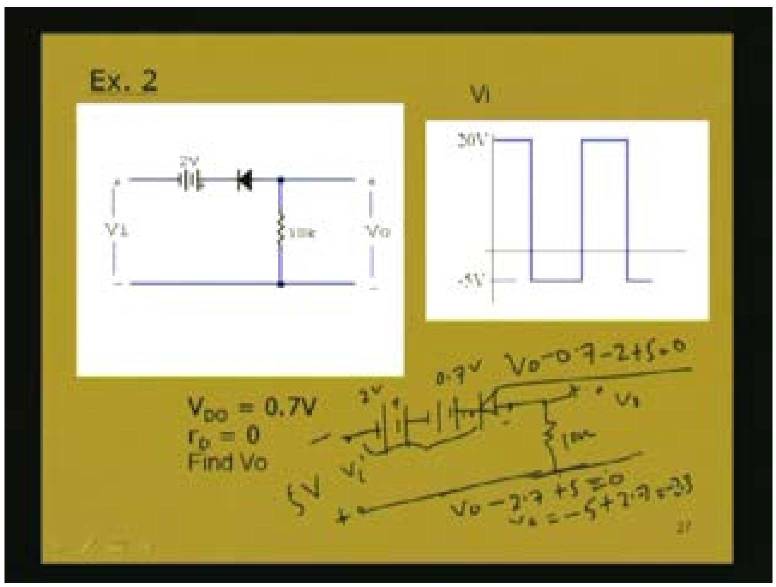

So -2.3 volt you will be getting at the negative side. We get zero voltage in the positive half cycle. It will not be conducting. Resistance R or 10 K will not have any current rates. This voltage is zero in the positive half cycle. But in the negative half cycle the voltage will be clipped at -2.3 volt. This kind of an output voltage waveform we will be getting for this circuit.

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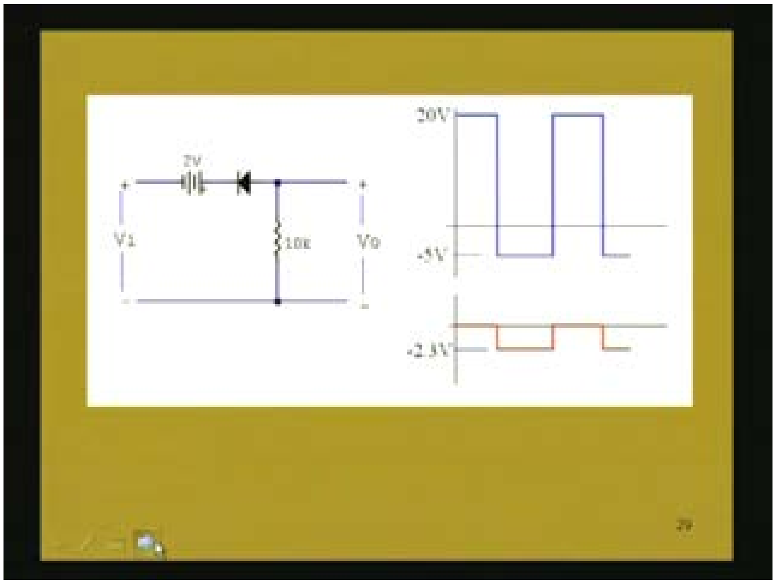

Consider this circuit having Zener diode. Zener diodes are also used for clamping; both clipping and clamping. This circuit is having two Zener diodes and these are ideal Zener diodes means in the forward direction the diode drop is V_{DO} and the resistance is zero and it has a Zener voltage V_z V_z.

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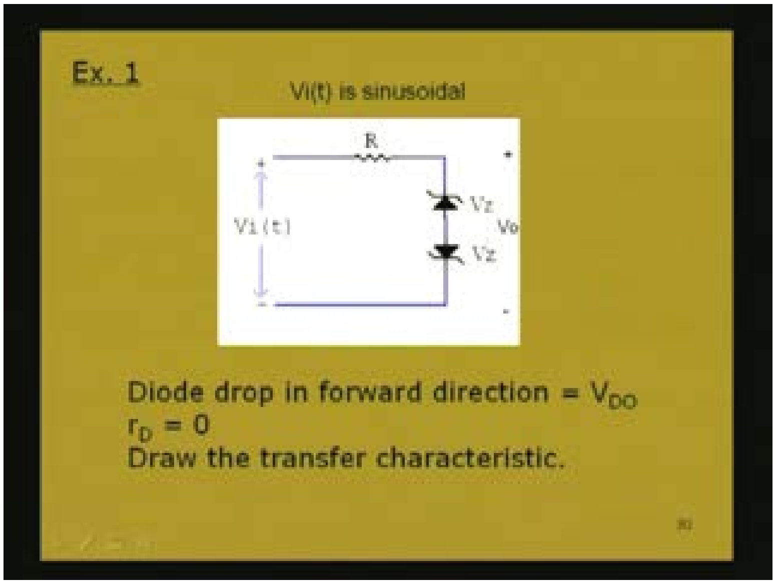

V_{DO} is the diode drop in the forward direction. Because in the forward direction Zener diodes can conduct and like normal diode it will be having the voltage drop V_{DO}. If you give a sinusoidal voltage what will be the output? Whenever the input voltage is in the positive half cycle this Zener diode will be reverse biased. Positive will be reverse biasing but this Zener diode will act like normal diode when this point is positive with respective this point in the positive half cycle. But when the voltage at these two points is such that it is lower than the whole voltage drop across these two points that voltage drop is $V_z + V_{DO}$.

If you draw the equivalent circuit this will be having this drop. This will not be the correct direction. The Zener will be having a drop if plus is here it will be breaking down. It will be breaking down when it will be greater than V_z+V_{DO} and the voltage across these two points will be then V_z+V_{DO} and in the negative half cycle this point is negative with respective to this point. This diode will reverse biased, Zener diode and this will be a forward biased like a normal diode. That is when the input voltage is greater than V_z+V_{DO} in the reverse bias condition then again it will be conducting and the drop will be V_z+V_{DO}. Finally we will be getting the output voltage clipped at the upper and lower portion with V_z+V_{DO}. This is plus V_z+V_{DO}. That is minus V_z+V_{DO} and this will be the output voltage versus the input voltage V_i.

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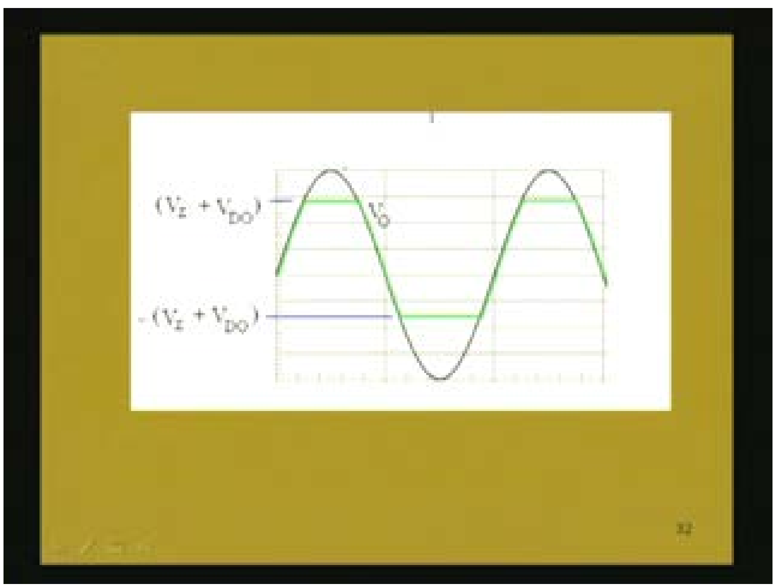

In all this type of circuit what we have to do is that we have to simply draw approximate equivalent circuit. This Zener diode approximate equivalent circuit will be a Zener voltage and similarly this diode will be having a normal diode drop and in the forward bias and the reverse bias the other diode will be Zener and this one will be forward. The total voltage we have to find out and the condition when it will be conducting.

Today we have seen a very important application of normal as well as Zener diode along with resistance and capacitance to build (01:04:58 min) circuits known as clipper and clamper and these circuits are used in practical applications where we want to use a waveform having one portion clipped of or clamping the level of the DC voltage of the waveform to some other value than what it is.