Analog Circuits

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Week - 08
Module - 02
Rectifiers

Hello, welcome to another module of this course analog circuits, so we have been talking about various nonlinear circuits over the past few weeks and in this module we are going to introduce you to another nonlinear circuit which is very popular and this circuit is known as the rectifier. So a rectifier is a circuit that putting its simply converts an AC voltage to a DC voltage.

So basically what we do in rectifier design is that we allow the voltage to conduct or to pass through in one half cycle and let it just not pass through in the other half cycle, so this is the simplest construction where only the voltage is allowed to pass through in the first half cycle and the other half cycle we do not allow the voltage to pass, so that is the principle of a half wave rectifier.

In this module, we are going to study about other circuits which allow voltage to pass through in both half cycles but in the other half cycle they invert the half cycle thereby making the sense of the voltage at the output the same for both half cycles, so let us see those circuits.

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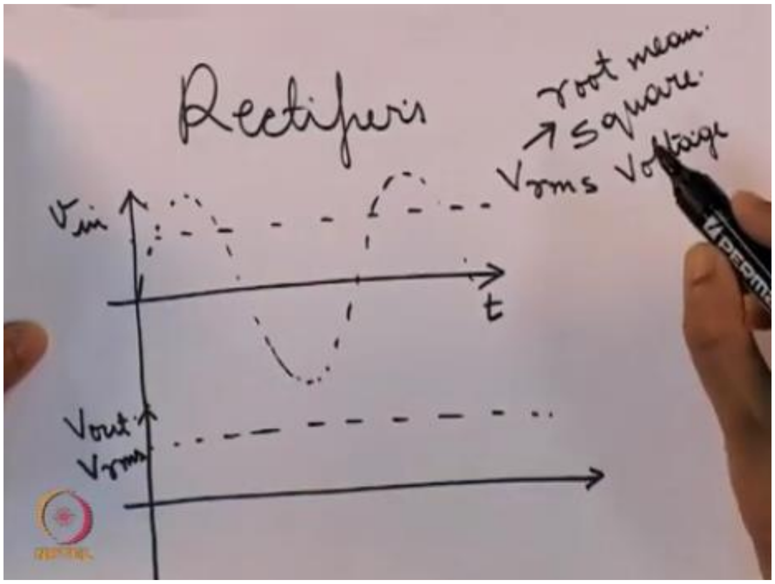

So ideally you know ideally if suppose you have an AC signal like this, you should get an output and let us say this is the RMS voltage then you should get an output which is like this, so Vrms is the root mean square voltage and after rectification the output should ideally be = Vrms but that is never possible that is never possible because there is no ideal rectifier which can do such a conversion but we can approximate it or go nearby, for example this negative half cycle of the input sinusoidal voltage if we can flip it over so if you flip it over then we would get something like this.

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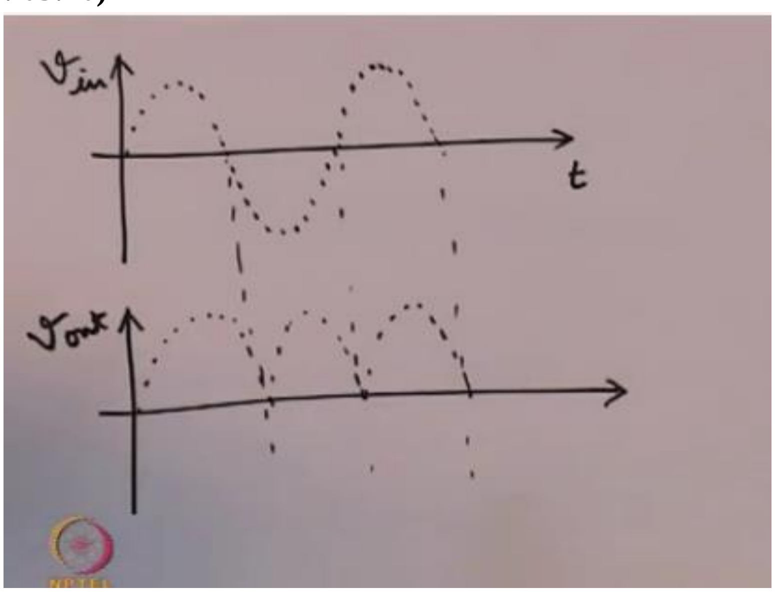

So after flipping over, we get something like this you see the negative half cycle here now has gone become here so this is my Vout, so this is also form of rectification because now all the voltages at the output have only they have no negative component we have only positive components and so through now = the ideal they do approximate DC of course a DC voltage which kind of varies slightly with time, so this is the principle on which we are going to design our rectifier circuit, so the first type of rectifier is known as what we call the half wave rectifier.

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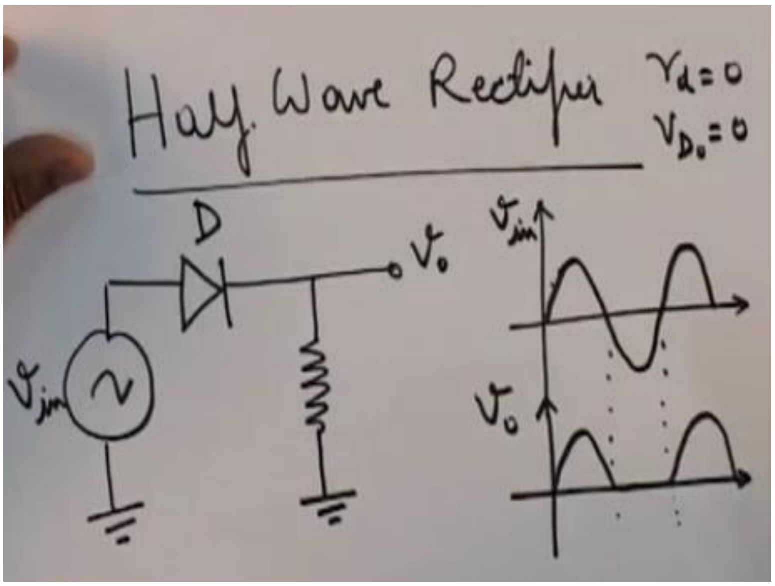

As the name suggests this rectifier only allows half the sinusoidal voltage only a half cycle of the sinusoidal voltage to pass through it okay it does not allow the other half cycle to pass through it, so the circuit for this is now usually if we consider an ideal diode then of course our rectification will be like this, so for an ideal diode the resistance Rd is = 0 and the threshold voltage is also = 0 so for such a diode this is what will happen if this is my input this is what my output will be but in real diodes where we have a finite value of our Rd and Vd0 the characteristics of such a diode will be of this form the Vi characteristics that is.

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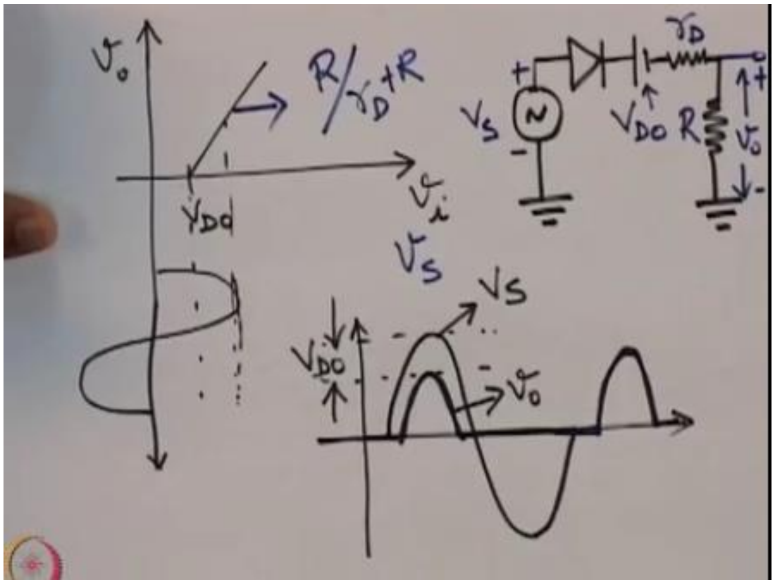

So the circuit corresponding circuit is like this, this is VS the slope of this line is given by R upon Rd + R so with this kind of you know here is my Vd0 okay and suppose my input if I draw it on this way along the Y-axis then you should touch here so then the output that I will get will be something of this sort this is VS and this what the supply voltage is and this inner curve this is my actual output. So this V0 and the spacing between the peaks of VS and V0 is Vd0 and of course after this we will again get a 0 voltage and then finally after some time we will get again the reputation of this curve, so this is how it will repeat again this curve.

So, my output if I use a blue marker, output will follow like this to go here follow this come down like this follow up and like this so this blue curve this gives my actual output voltage when I consider the presence of this threshold voltage VD0 and also a finite resistance diode resistance Rd in order for us to rectify the circuit even during the negative half cycle of the input we need to modify the circuit and the circuitry obtained is known as a full wave rectifier.

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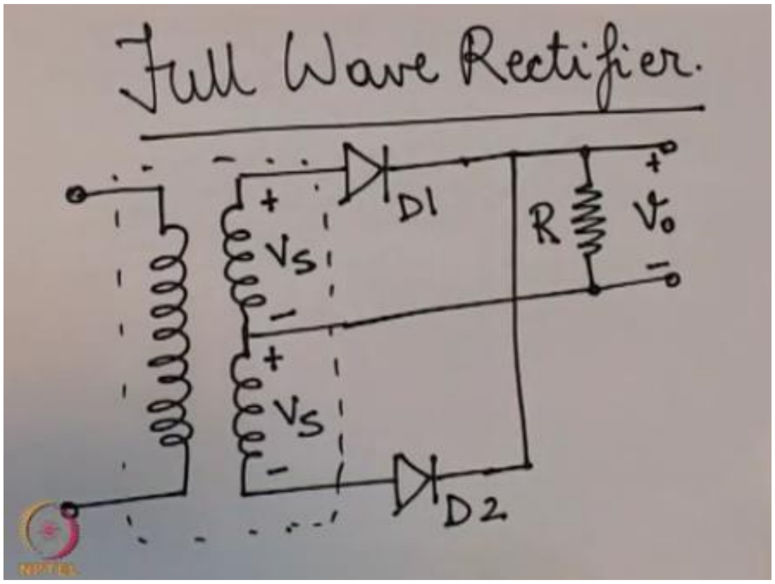

The circuit for that is given like this, so here this part which was not sure not present in the circuit for the half wave rectifier this is actually a transformer this whole thing now the transformer does not really play any role in the rectification, but it is necessary to show it show this element just to just to let you know that there are actually 2 sources + - Vs and + - Vs.

So, the transformer takes in an output and after up conversion it produces 2 different in out outputs which are our actual source inputs VS and Vs okay, so each of these small windings in the transformer will produce + Vs + Vs voltage output line shown like this now how does this circuit operate say we are in the positive.

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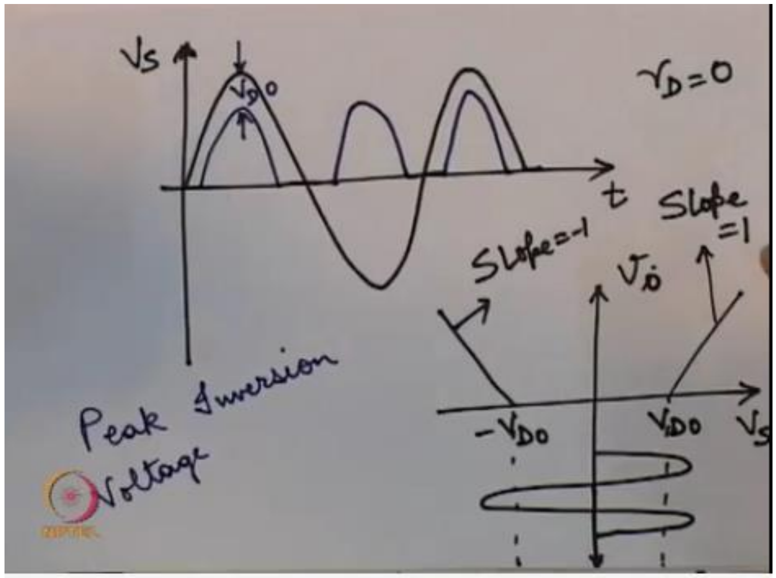

Let me draw the circuit say Vs is positive so then, so this is T this is Vs, so when this is say this voltage is positive Vs is positive then or in the pause or we are in the positive half cycle of Vs this diode D1 will be forward biased and when Vs is above the threshold voltage of D1 this will start conducting when Vs is in the positive half cycle however diode D2 will be reverse biased and will not conduct.

So the voltage Vs will therefore appear across the resistance R0 that is it will appear across the output voltage V0 during the positive half cycle in the negative half cycle D2 will be forward biased D1 is reverse biased therefore the negative half cycle also we will have Vs appearing across the voltage V0, so now ideally if our diodes were ideal then we would have simply out output would simply reflect the input but since our diodes are not ideal and if we consider both the negative and half and positive half cycle of the input voltage then the output characteristics of this diode will be something like this.

So this is this is Vo and this Vs here so it will be something like this the slope = 1 here the slope = -1 this is - VD0 and this is + VD0 where VD0 is the threshold voltage and suppose we have input sinusoidal voltage like this okay so this my Vs this curve I have shown it here like a exaggerated version of this one now here the slope is 1 because we assuming that the internal resistance of the diode is = 0.

So if this is my Vs which is which I have drawn along the Y-axis which is in this graph is shown along the X-axis then the output that I will get is something like this let me use the blue so my overall output will be as shown by the blue marker just like you know just like the previous case we will have a diode drop VD0 between the supply and the actual output fine now an important parameter in determining the success of any circuit of any rectifier circuit is known as the peak inversion voltage.

I am calling it is necessary it is important success of any circuit of any inverter circuit because peak inversion voltage is a gives us an idea about what is the maximum voltage that a diode is subjected to when it is present in a rectifier circuit, so in this case if we go back to our circuit for a moment the full invert full wave rectifier any of these diodes will experience the maximum voltage across their terminals when they are in reverse bias mode in the forward bias mode.

It is conducting the diodes are conducting therefore the voltage drop across the diode will be same as the threshold voltage but it is in the reverse bias mode when the diodes phase the maximum voltage across the terminals now suppose D1 is conducting that is Vs is positive and D2 is negative is in the reverse bias mode, so what is the maximum voltage that D2 will be subjected to.

So here we have - VD0 right and here we have 2 VS right, so the maximum reverse bias voltage across D2 I can write this peak inversion voltage as 2VS - VD0 what about the case for a half wave rectifier if we can go back to the circuit for a half wave rectifier for a moment what was the maximum voltage that this diode D that it could experience in the reverse bias mode, so peak inversion voltage for this diode will be = Vs which is the supply voltage, since we do not have any diodes conducting in the reverse biased mode.

So the peak inverse voltage is = Vs now this is a problem of this kind of full wave rectifier circuit if our Vs is very large then there is a risk that the diodes can break down and therefore to avoid that we always try to reduce the peak inversion voltage so one circuit where we are able to do such a where we are able to do a full wave rectification yet reduce the peak inversion voltage is what is known as a bridge rectifier, so a bridge rectifier has a circuit as follows.

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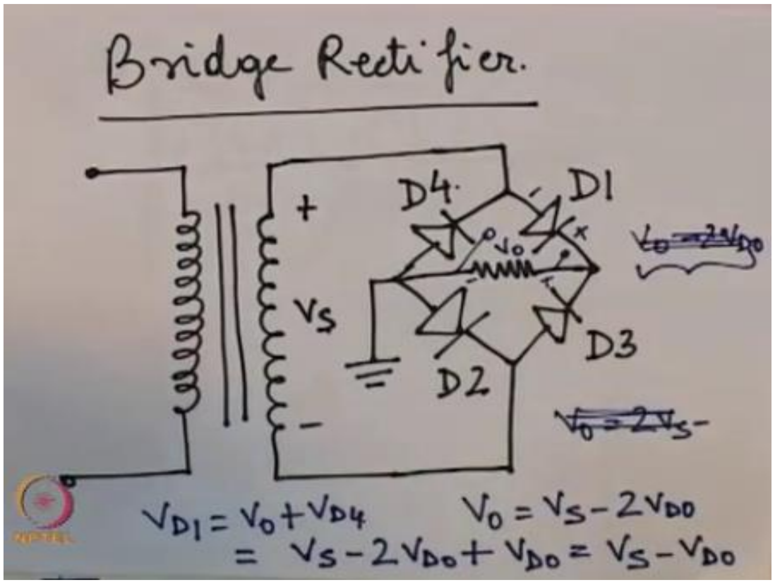

So again, we have a transformer which supplies a voltage of + and - Vs and then we have a bridge circuit, so the bridge circuit consists of 4 diodes connected as shown ok and the principal operation is similar to that of the full wave rectifier see during the positive half cycle this say when Vs is positive then D1 and D2 will be forward biased and during the negative half cycle D3 and D4 will be forward biased, so overall the output input and output relationship will be something like this.

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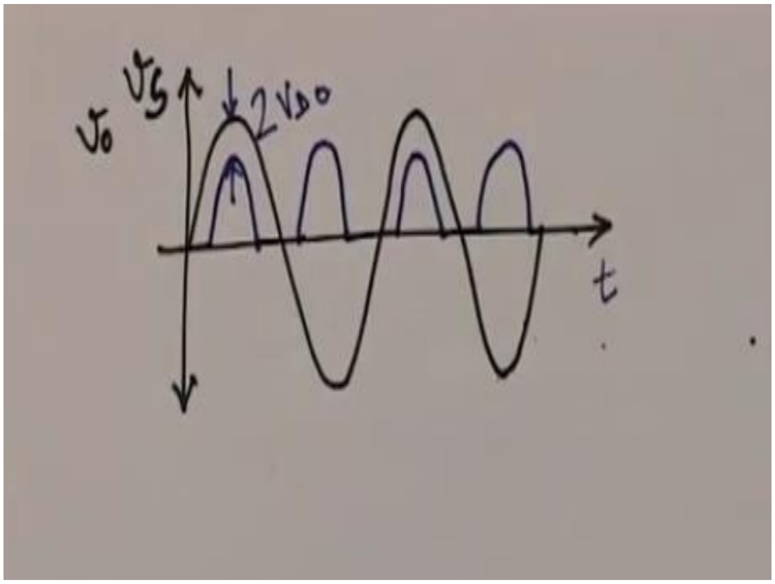

So the shape of the curve is similar to that of the full wave rectifier but the difference between the 2 peaks of the input and output is now = 2VD0 because of the 2 diode drops that we have to that the input, so this is my input my output by the way is taken between these 2 ports ok it is taken across the bridge so every time we take the output we have to undergo 2 diode drops and that is why the difference between the peak of the input and the peak of the output is 2VD0, however what about the peak inversion voltage.

Now let us consider the case when diode D3 and D4 are conducting ok then what is the voltage across this diode set so the voltage across this diode D1 can be consider to be = V0 - 2VD0 so this is sorry I just want to correct it so we have V0 = 2Vs - we have V0 = Vs - 2VD0 just note this correction and that the voltage the reverse bias voltage across this diode D1 is = V0 okay suppose we are taking, so this is my positive this is my negative this voltage + the voltage across this transistor D4 okay so I have VD1 = V0 + VD4 the voltage across D4 is = the diode drop isn't it VD0 so this will be = Vs - 2VD0 + VD0 which is = Vs - VD0.

So what we see here is that for the bridge rectifier the peak inversion voltage is = Vs - VD0 which is much less compared to the peak inversion voltage for a full wave rectifier which was = 2Vs - VD0, so that is one big advantage of the reverse of this bridge rectifier in that the diodes do not break down easily, the disadvantage of course for this bridge rectifier is that the difference between the peaks of the input and the output is now to VD0 as compared to VD0 for the full wave rectifier.

So in this module we covered some topics on rectifier design there are some variation of this rectifier designs as well something known as a peak rectifier and then we are and of course there is the problem of threshold voltage as we are seeing in all kinds of rectifiers the output never matches the input there is always the diode drop present between the output and the input, so to get rid of this problem we have some special circuits known as super diodes where this threshold voltage problem is removed so that is also something we will be covering in the next module, thank you.