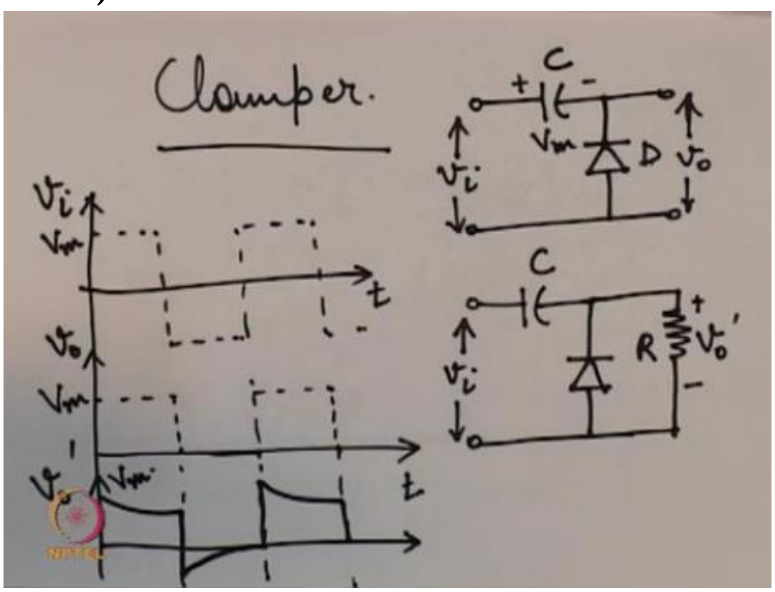
Analog Circuits

Prof. Jayanta Mukherjee
Department of Electrical Engineering
Indian Institute of Technology – Bombay

Week - 08
Module - 03
Clamper, Peak Rectifier, Super diodes

Hello, welcome to another module of this course analog circuits, in this module we will be covering some of the remaining topics on analog nonlinear circuits namely the clamper circuit the peak detector circuit and also what we call super diodes so let us go through this circuit.

(Refer Slide Time: 00:38)



So let us see the clamper circuit, so clamper is a circuit which when an input voltage Vi of this form is given to it will produce an output like this okay, so basically what it does is remove the negative part of the input so the circuit to achieve this operation is given like this, now here what happens is that when Vi is positive this diode D will be reverse biased and this capacitor will charge all the way to the maximum voltage Vm and when Vi goes negative what happens is that the voltage across the capacitance will not change immediately because that is the property of the capacitor that it always resists any change to its to the voltage across its terminals.

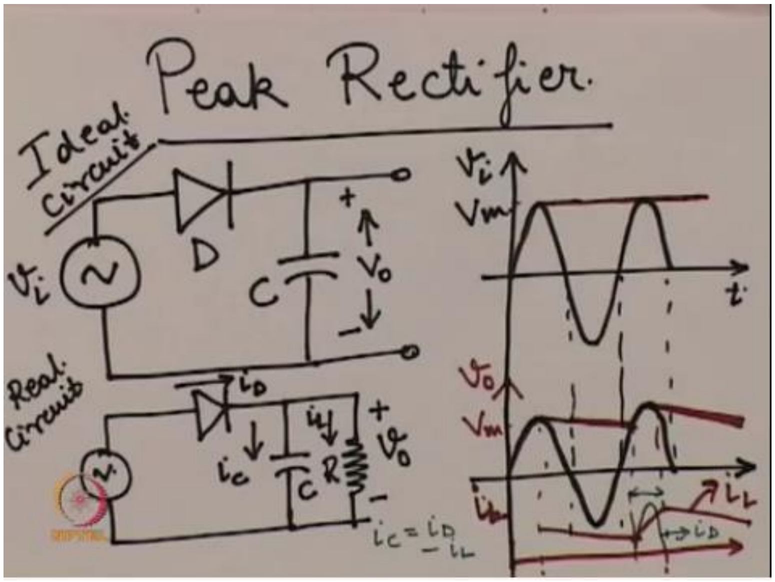
So instead the negative voltage that appears across Vi will be transmitted to this diode D and once this terminal becomes more negative as compared to this terminal what will happen is this diode will go to the forward bias mode once this diode goes to the forward biased mode this terminal the volt V0 will be shortened and that is the reason we see a short appearing here.

Again when Vi increases or becomes positive the voltage across Vm across the capacitor will continue to be Vm and the voltage that will appear across the output will also be Vm, because D is now in reverse bias mode and therefore op amp and this way the cycle continues in a practical circuit, of course we will not find an ideal capacitor therefore in a practical circuit our circuit will look something like this there will be a resistor through which the capacitor will discharge okay and because of this what happens we will get an output like this.

So this is Vo and this is Vo dash now what happens is the capacitor does charge up to the voltage Vm but then after that is slowly starts discharging as a result of which the output voltage decreases gradually when Vi is negative then again there is momentary shift towards the negative region but then because now the capacitor is again in a charging mode so what happens is the voltage across the Vo will slowly reach the value 0 okay.

So, this is the cycle that repeats and because of this discharging and charging we get these slight distortions in the output waveform the next topic that I would like to discuss is what is known as a peak rectifier so we have already seen rectifier circuits in the last module these circuits are similar but they just produce an output that follows the peak of the input voltage, so let us see what are these.

(Refer Slide Time: 06:02)



Consider this circuit, now in this circuit suppose my input is a sinusoid like this, so this is Vi and this is T now during the positive half cycle this diode will be forward biased and the capacitor will simply charge right till its peak value say that is I call the at peak value Vm, however once the input voltage decreases after reaching the peak value the capacitor will not discharge because this diode will now be reverse biased and so the voltage across the capacitor will continue to follow or continue remain at the value Vm and it will continue to remain at the value Vm till again the input voltage reaches the value Vm at which time this will again get short.

But once the input voltage starts decreasing from Vm the capacitor this diode will again go to reverse bias and therefore the voltage across the capacitor will be given by this curve this red line, now because the output voltage is same as the voltage across the capacitor the output voltage simply follows the peak of the input sinusoidal wave if in place of a sinusoidal voltage we have some other form of other function like a triangular waveform or square waveform then also the output voltage will follow the peak value that is that this given by the input.

Now of course just like the previous circuit the capacitor will not be ideal in reality what will have is, so this is my ideal circuit ok and this is my real circuit suppose the current flowing through the diode is given by the Id and the current flowing through the capacitor is given by Ic and the current flowing through the load is given by IL, so this load resistance had a value RC then my output will be something like this.

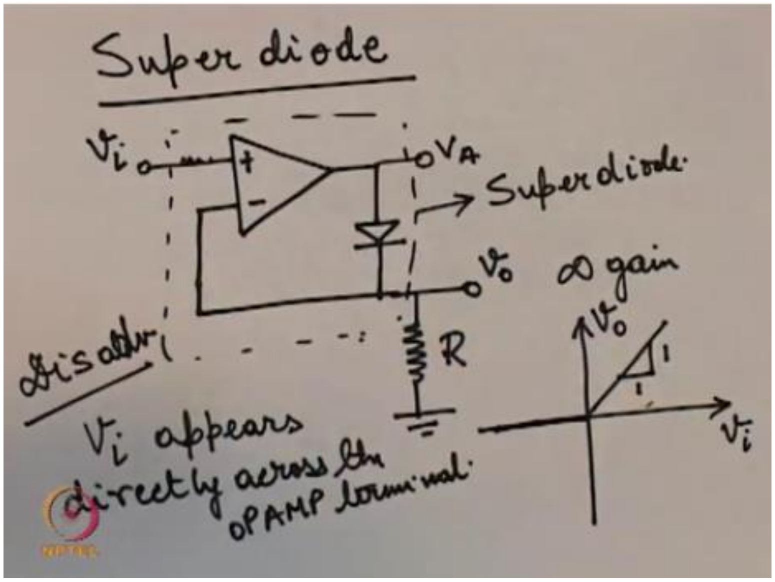
So say again this I provide the same input as that for the ideal rectifier okay the voltage across the capacitor once on reaching the maximum value Vm will stay there momentarily but because of this discharging resistance present the voltage will slowly decline ok this is my V0 and then again it will increase when the input voltage exceeds this value and this way it will continue, so my output will follow a pattern like this what about this load current if I want to plot the load current as well then it will be somewhat like this.

So it will follow a pattern like this what about the diode current was if I use green pen, so this is my IL since IL the diode will be conducting only during this phase right only during this phase therefore during this phase we will find a surge in the diode current like this okay and then it will again become 0 so this is my ID, so this is how the situation is and if you can I leave it as an exercise for you to try to plot IC which is = ID - IL okay, so I leave it as an exercise for you to find out how the waveform for IC will be.

So in all these circuits we are using and at least in the last 2 circuits that is the clamper and the peak detector we were using ideal diodes, so ideal diodes as I had mentioned earlier our diodes where the threshold voltage is 0 and also the diode resistance is 0 but in reality threshold voltage is present in all diodes and because of that we have seen a number of problems especially while discussing the half wave and full wave rectifiers we found that the peaks of the input and output of the rectifiers are separated by the threshold voltage have a difference and that difference is given by the threshold voltage.

So would not it be ideal if we could get a diode which would be which would which would have no threshold voltage is it possible to have such a diode which has no threshold voltage as I mentioned a few seconds ago that such a diode does not exist, however we can obtain a circuit using an op amp and a diode which behaves nearly like that of an ideal op amp such a diode or such a diodes base circuit is called a super diode circuit and we shall be using this circuit for rebuilding our half wave rectifier and we shall see that the threshold voltage problem does not exist using this super diode circuit.

(Refer Slide Time 15:13)



It is called a super diode as I mentioned because there is no threshold voltage that appears is very negligible, so this part within this dotted lines is my super diode R is a load and output voltage is taken across this resistance R. Now let us see how this circuit operates, first of all this is say an ideal op amp and as you know an ideal op amp will provide infinite gain, so whenever the input to the non-inverting terminal is higher than that of the inverting terminal I will get an output which should be very high or for practical op amps it should be = the upper saturation voltage of the op amp.

So inevitably because this diode is connected in this fashion whatever voltage we present here whatever positive voltage we present here this will cause this diode to go to forward bias mode the threshold voltage will not matter here.

Because this output VA of the op amp is very high because of the infinite gain and that will in all cases be greater than the threshold voltage of this diode and therefore for even small inputs we will have this diode operating in the forward bias mode with no threshold voltage problem and so because for small voltage inputs also this diode goes to the forward biased mode, hence what we will have is that the output will be positive whenever Vi is high or positive even for small positive values of Vi we will get a positive output voltage of course for negative values of Vi V0 will be 0.

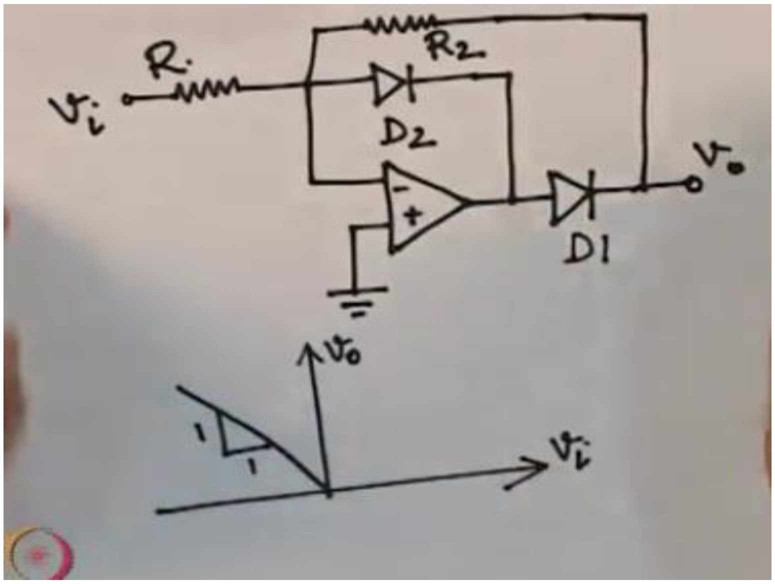
Because of negative values of Vi VA will reach the lower saturation voltage and this diode will be in reverse bias mode, so if I try to draw the Vi versus Vo curve it will be something like this there will be a slope of 1 so V0 will directly follow Vi whenever Vi is positive and V0 will be 0 whenever Vi is negative.

Now there is one small problem with this circuit which is that Vi appears, so the disadvantage of this circuit is at Vi appears directly across the op amp terminal so the reason this is a problem is because in all practical op amps there will be some resistance between the input and the op amp terminals and then also since all op amps have some current though negligible but still there is some input current because of the presence of the small resistance see if I represent the small resistance like this there will be a voltage drop at the input and therefore Vi needs to be high enough to overcome this voltage drop.

But of course if we consider our ideal circuit then there is no need to consider this voltage drop but in all practical circuits there will be some voltage drop appearing at the input so to get over this problem we have another circuit and the advantage of this circuit is that it operates in the negative or negative values of Vi.

So the circuit super diode circuit that we just saw it operates only when Vi is positive or it produces as output only when Vi is positive what if we want the other case also so suppose we need to have a super diode circuit or an or a circuit which produces an output for negative values of Vi, so such a circuit is given like this, I leave the analysis of this circuit as an exercise for you but we should get an output in input output characteristics which is like this.

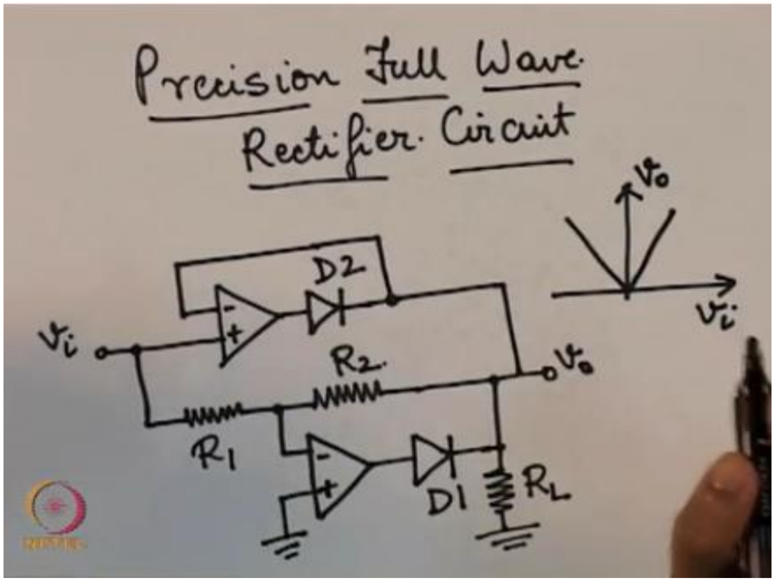
(Refer Slide Time 21:29)



So then you know we already saw the super diode which can be used for a half wave rectifier the previous circuit that is this circuit this will act as a half wave rectifier because of this kind of input output characteristics if we want to make a full wave rectifier then we can combine this circuit with this circuit to produce a full wave rectifier, now if we just for a moment go back to this second circuit that I mentioned this also has the advantage that there is an input resistance or resistance connected to the input and this acts like a buffer for any small voltage drops that might occur.

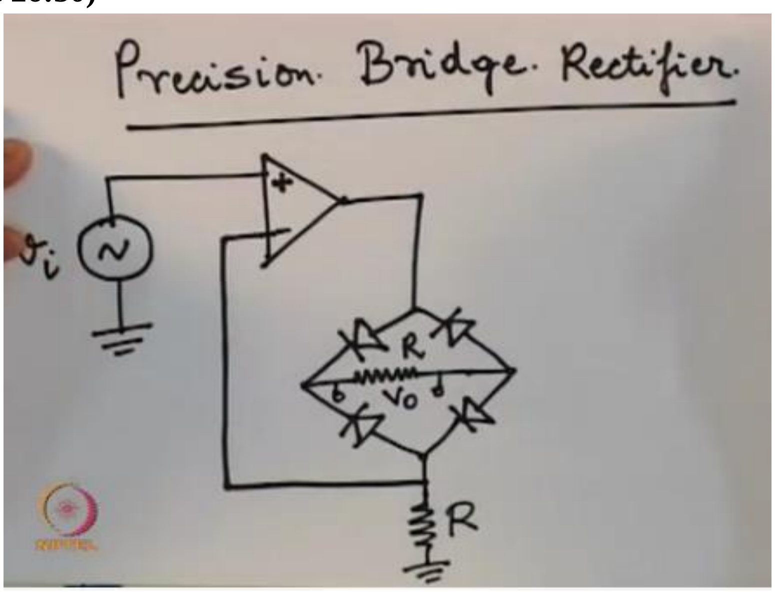
So since there is already a resistance present the input is tuned to any small voltage drop due to any small negligible current that might be flowing into the inverting terminal of this op amp, so that second problem that we had that there was a finite voltage drop at the input of the op amp is removed by this circuit this is also another advantage of this circuit, so if we go back to if we go back to a circuit of a full wave rectifier using both these super diode circuits that we have just discussed the full wave rectifier circuit we get it.

(Refer Slide Time 24:26)



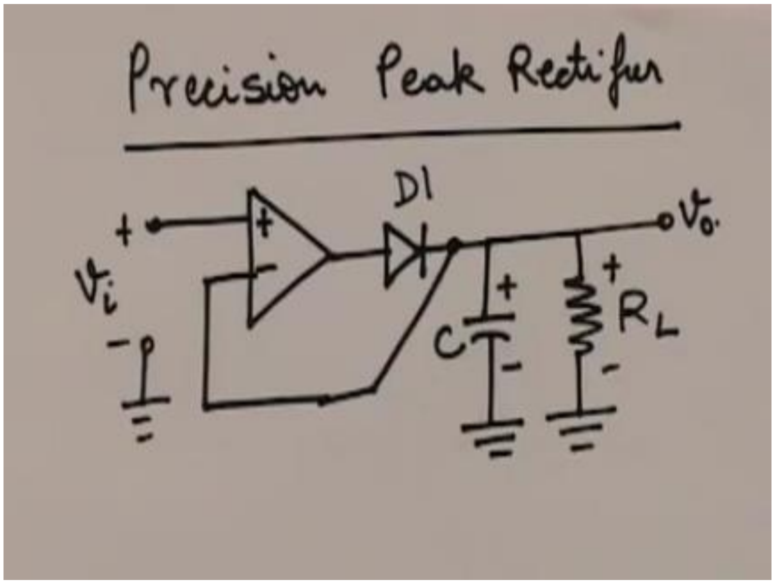
We can all that a precision full wave rectifier circuit so this is just a combination of the 2 this is the first circuit that we had discussed and this is the second circuit we had discussed and the output and input relationship is given by this graph in face, we can obtain a bridge rectifier precision bridge rectifier version of the same circuit also and that is given by.

(Refer Slide Time 26:50)



So this is my bridge rectifier circuit, Vo is taken by between these 2 points and I leave it as an exercise to analyze for you to analyze this circuit and show that indeed the threshold voltage problem will not be here and finally we can also find the same, we can also apply the same technique to the peak rectifier circuit that we had discussed earlier.

(Refer Slide Time 28:58)



So, this is the circuit for my peak rectifier and again I leave it is as an assignment for you to analyze this you will find the peak the threshold voltage problem is not present in this circuit because of the presence of this op amp, whenever Vi is positive this my this will always be in forward bias mode even for small values of Vi and therefore even for small values of Vi that is when Vi is lesser than the threshold voltage of this diode.

Say I call this D1 even when Vi is lesser than the threshold voltage of D1, we will get an output which is proportional to the input of course for Vi being negative this diode D1 will be in the reverse bias mode and therefore the output voltage here will be 0 and the rest of the circuit is simply the repetition of the peak rectifier circuit which we had discussed earlier, so that brings us to a conclusion to all the topics on analog circuits based on op amps only.

We have been covering the, these circuits for a long time, now we started in right in the beginning in the first few weeks with the inverting and non-inverting op amps, then we also saw how to build up filters using op amps and then finally we moved on to the nonlinear circuits where we have discussed a number of them like oscillators, clampers, peak rectifiers, peak full wave rectifiers, bridge rectifiers.

In the next module we shall be moving on to the specific device the BJT the bipolar junction transistor and we analyzing its DC properties because DC properties of a BJT are very important in especially for circuits which provide voltage at a given value at specific points in the circuit, so that is why these DC based circuits for BJT's become very important and we shall be discussing the DC the BJT's used for generating specific voltages or basically what we call the DC characteristics of a BJT, so that is what we will cover in the next module, thank you.