Integrated Circuits and Applications
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AC Applications of Operational Amplifier
Lecture – 06
Clipper and Clamper circuits

Ok. In the last lecture we have discussed some of the non-linear applications of the operational amplifier such as half wave rectifier, full wave rectifier. Today we will discuss some more non-linear applications such as the clippers, clampers they are called as in general wave shaping circuits, wave shaping circuits using op-amp. So, this wave shaping circuit is basically can be this clipper circuit or clamper circuit. As the name clipper implies it cuts a portion of the waveform, clamper means it will move the it will shift the entire waveform this can also called as the DC restorer. So, in the clipper and clamper again there are two types, it can clip only the positive portion or negative portion they based on that this can be positive clipper or negative clipper. Similarly, clampers can be positive clamper or negative clamper.

First I will discuss about the positive clipper circuit using op-amp. The circuit diagram of this positive clipper circuit is as follows. So, at non-inverting terminal this AC voltage is applied which is v_i, this is diode D, this is output v_o, this is load resistance R_L. Let us call the output of this op-amp intermediate output as $v_o{}'$.

So, what happens to the output during the positive clock cycle of v_i and what happens during negative clock cycle of v_i? So, here what we are going to do here is so, this will have positive and negative power supplies $-V_{CC}$ and $+V_{CC}$. So, this output we are going to connect through the this v_{ref}. So, the voltage between this ground point and this point we will call as v_{ref}. So, you have to clip with respect to some voltage so, that clipping voltage is v_{ref} that we are going to take from $+V_{CC}$. So, now, what happens during the positive half cycle and what happens during the negative half cycle? Let us assume that this is the output waveform v_i with respect to time.

So, what is corresponding v_o? And this is v_{ref} voltage, this v_{ref} is positive because so, because this is $+V_{CC}$ so, v_{ref} is positive. So, what happened to the circuit during positive half cycle? If $v_i < v_{ref}$ this will cover two cases. So, here also $v_i < v_{ref}$ and here also $v_i < v_{ref}$ except for this portion to this portion here $v_i < v_{ref}$ here also $v_i < v_{ref}$. So, during this portion and during this portion what will be the output? You can see that here v_{ref} is applied to the negative terminal. So, of course, there will be some small drop across this R_L.

So, here the voltage is almost v_{ref} which is positive applied to the negative terminal whereas, v_i is applied to the non-inverting terminal positive terminal of op-amp. If $v_i < v_{ref}$ what will be the difference voltage? So, the voltage at positive terminal is less than the voltage at negative terminal resultant the difference voltage between these two points is negative. As a result of that what will be the output the amplified version of this negative voltage? So, v_o' is sufficiently negative. So, we are going to design this such that to drive diode D into conduction because this voltage is negative and here this voltage is positive this is positive. So, diode will drive into conduction if I assume the diode as ideal implies diode will acts as short circuit SC stands for short circuit.

So, what will be the equivalent circuit now? This will be short circuited. So, as a result of that this will acts as a closed loop circuit and this will be basically a voltage follower. You can see that this will be equivalent circuit will be now something like this. This will be short circuited and this will be connected here and here this input voltage v_i this one v_i and here we are taking through resistor v_o this is basically voltage follower. So, implies the circuit acts as voltage follower CKT short form of the circuit implies output $v_o = v_i$.

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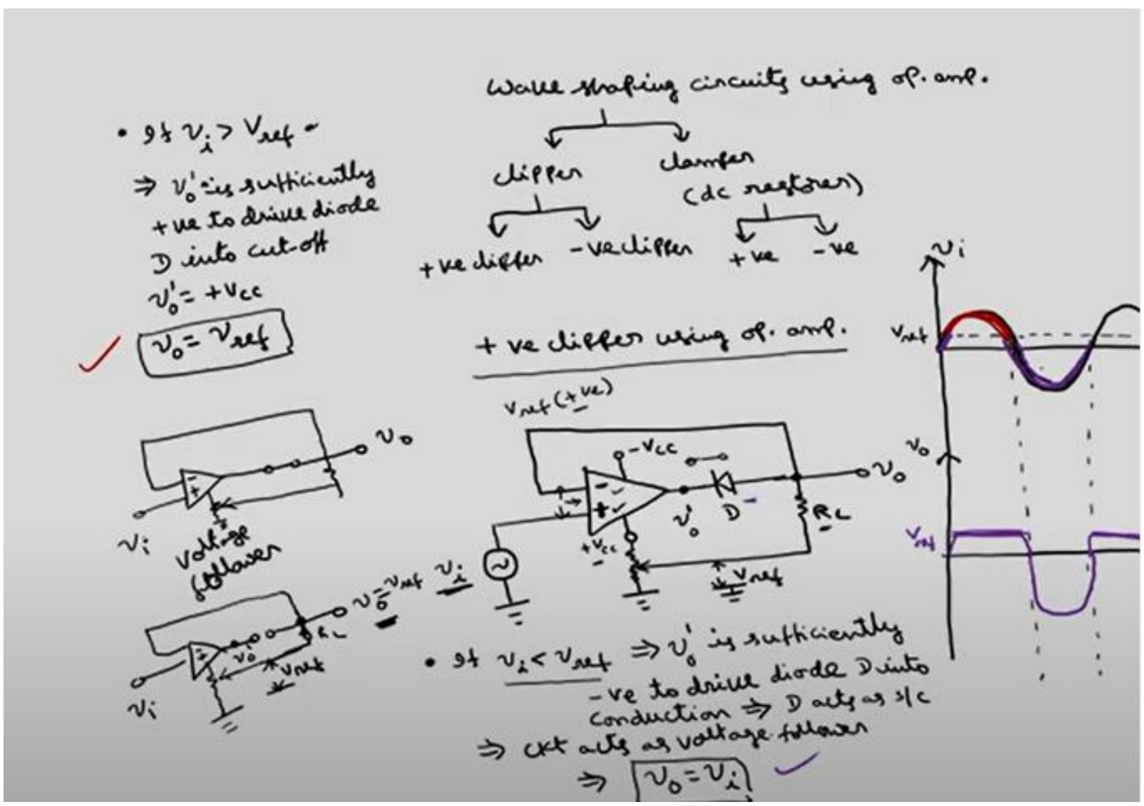

So, this is when $v_i < v_{ref}$ that is during this portion and this small portion. Now, the second case is $v_i > v_{ref}$ if $v_i > v_{ref}$. So, v_i is the voltage applied for the non-inverting terminal and v_{ref} is the voltage applied to the negative terminal. Now, v_i is greater than means so, this difference voltage here this will be positive because v_i is applied to positive and v_{ref} is applied to negative $v_i > v_{ref}$ means the difference voltage of this operational amplifier is positive. So, output by v_o' is sufficiently positive to drive diode D into cut off.

So, once the diode is cut off what will be equivalent circuit? This will acts as a open loop configuration this is v_i this will be connected to output, but here this is a open circuit. This is of course, connected to the v_{ref} through load resistance. So, what will be output voltage? Basically, this voltage is this is v_{ref}. So, this also will be v_{ref} because this resultant voltage is positive this will go into the positive saturation because the open loop this is open loop configuration open loop gain is very high. So, this will drive this v_o' into saturation.

So, +V_{CC}, but what happens to v_0 final output? This final output is basically this is connected to this v_{ref}. So, output is v_{ref}. So, during this small portion this is v_{ref}. So, during this portion only during this portion this $v_o = v_{ref}$, during the other three portions. So, during this portion this portion this is the case.

So, if I draw the output waveform up to v_{ref} this will follow the input whereas, at v_{ref} this will be output will be v_{ref}. And during negative portion as it is same as the input again during positive. So, this is v_{ref} this is the output waveform. So, this will clip this input signal at v_{ref}. So, this type of operations are required in communication system especially in amplitude modulation and demodulation schemes where if you want to limit the noise which occurred during the transmission of the signals we can use this clipper circuits in the AMD modulation.

So, this is about the positive clipping you can clip this positive portion of the signal. Similarly you can have negative clipping circuit also. So, the only difference here is the direction of the diode you have to change and this instead of connecting to +V_{CC} you have to connect to -V_{CC} negative clipper using op amp. So, the circuit diagram will be like this. So, here this direction of diode has been changed and also this output voltage will be connected to -V_{CC}.

This is R_L this is output voltage v_o this is input voltage v_i and there will be feedback connection. So, only two differences are here instead of +V_{CC} you have to use -V_{CC} here direction of diode has been changed that this is v_o' Now how do you demonstrate the operation of a negative clipper circuit? If you take the input output waveforms of this clipper circuit this is inputs signal. So, it will be corresponding output signal. And this is v_{ref} or this v_{ref} is negative.

This is your v_{ref} signal. So, we take again the two different cases one is $v_i > v_{ref}$. So, which portion this entire positive portion this entire positive portion $v_i > v_{ref}$ and also this portion up to here. So, this red area is the portion where here also again. So, this red area is the portion where $v_i > v_{ref}$.

So, now what happens to output? So, v_i is connected to the positive terminal. So, this is more positive than the voltage which is applied to the negative terminal negative terminal this is negative voltage because v_{ref} is negative. This is the v_{ref} that we are going to apply this is v_{ref} which is negative. So, this is negative this is positive or even a negative value which is greater than this v negative. So, what will be this difference voltage? Difference voltage will be positive as a result of that v_o' will be positive is sufficiently positive.

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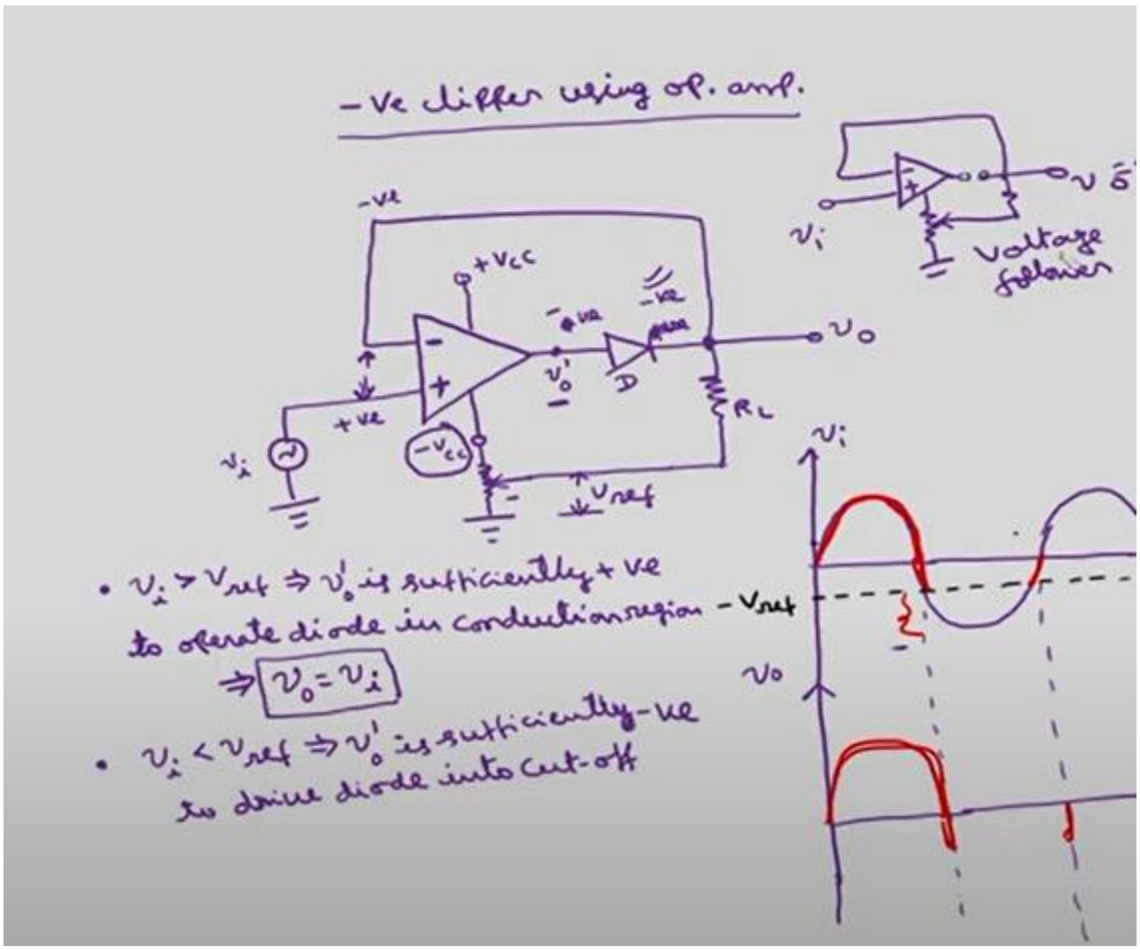

So, this is positive and this is negative. So, the diode D will becomes conduction sufficiently positive to operate diode in conduction region. So, as a result of that what happens diode will acts as short circuit and what will be equivalent circuit? This is voltage follower basically. This will be short circuited this is the output voltage this is basically voltage follower. So, output is equal to input.

So, during this red portion output is equal to input. So, here this output is equal to same as input from here to up to here and again here. Now, during this portion so, this portion is nothing, but $v_i < v_{ref}$. So, what happens now this difference voltage this is this voltage at positive terminal is less than the voltage negative terminal resultant signal is negative. So, this $v_o{}'$ is negative.

So, we are going to apply here the negative signal and here this will be positive because this v_{ref} will be this is also negative, but this is also negative, but between these two negatives this is more negative. As a result of that diode will be off $v_o{}'$ is sufficiently negative to drive diode into cutoff. So, then circuit will behaves like here instead of closed circuit will be open circuited. This will be no more voltage follower this is open loop configuration. So, open loop configuration gain is more.

So, $v_o{}'$ will be almost saturated this is -V_{CC} this is saturation and what about v_o? v_o is nothing, but this is open circuit this is v_o this is v_{ref}. So, this will be a small drop across R_L the other entire voltage will be drop across this v_o, $v_o = v_{ref}$. So, this becomes v_{ref} because this v_{ref} is negative this is also v_{ref}. Again positive also during this portion this is positive during this portion same as the input up to here and here again. So, this is the output waveform of negative clamper this is going to clamp at negative portion that is why the name negative clipper.

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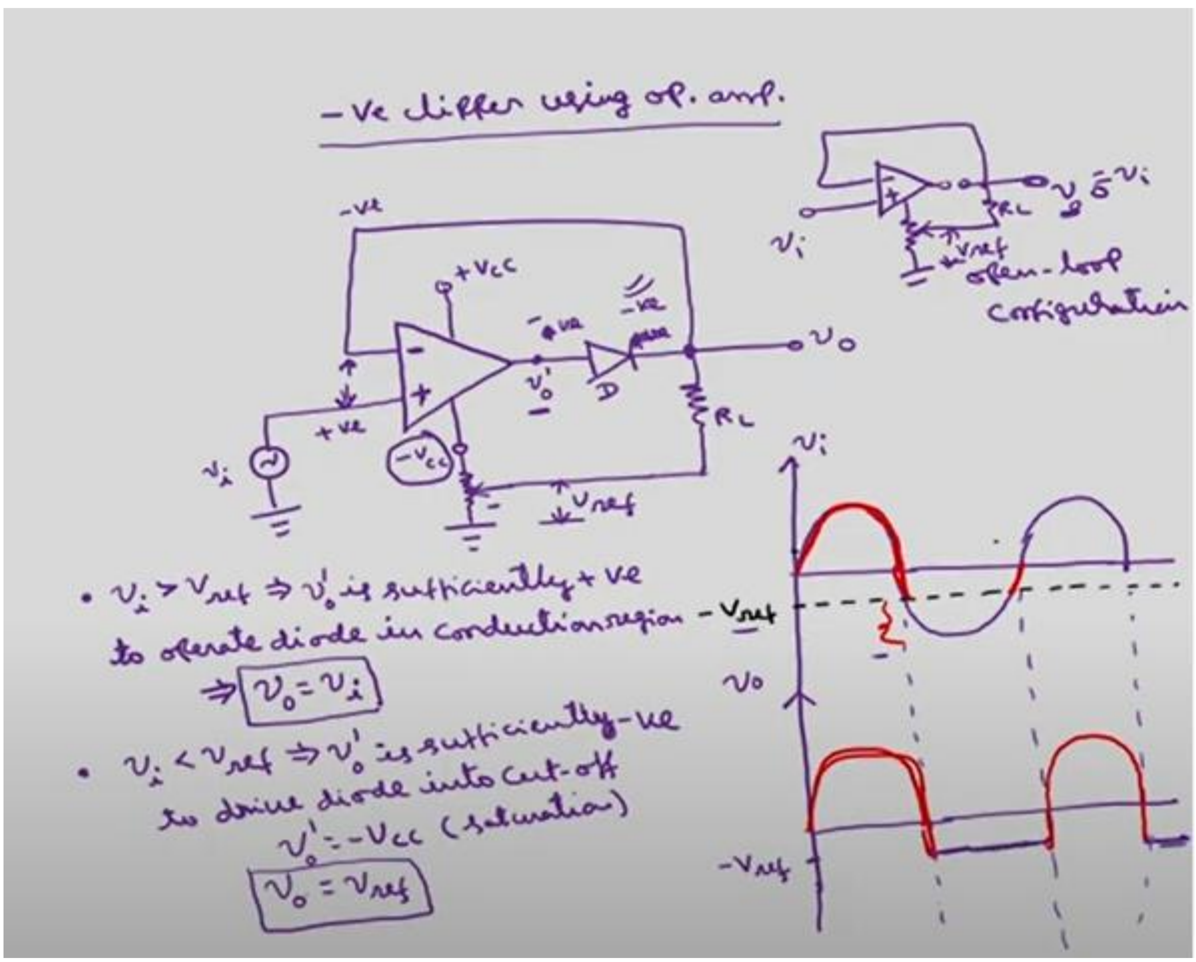

So, the next diode circuit is the clamper circuit. Similar to this clipper positive and negative clipper here also we have positive clamper and negative clamper first I will discuss about the positive clamper circuit which clamps the waveform either to the positive side or negative side. So, the circuit diagram of this positive clamper circuit is this is the operational amplifier this is +V_{CC} this is v_{ref} here the output v_o is taken v or I will make a capacitance here the input AC voltage is applied this is +V_{CC} this will be +V_{CC} also. This is circuit diagram of positive clamper circuit say given a input like this we will see what will be the output. So, you can see that the output is going to be clamped in the positive direction.

So, let us assume that this is v_m is the maximum peak voltage $-v_m$ this is input voltage v_i. So, in order to explain this operation here because this positive terminal will be having DC this is DC voltage a part of this one will be v_{ref} will be the voltage division V_{CC} into this resistance divided by total resistance. So, this is DC whereas, here AC is applied. So, this circuit consists of both AC and DC responses. So, the output voltage depends on both AC as well as DC first I will see what is DC response.

So, in order to obtain the DC response you have to make AC response 0. So, $f = 0$ implies X_C the capacitive inductance $\frac{1}{2\pi fC} = \infty$. So, it will acts as open circuit. So, this is open circuited and here the current through this terminal is 0. So, this is also 0 means here the resistance will not be there and here this V_{DC} the input voltage for positive is v_{ref} , v_{ref} is applied at positive terminal of op amp.

Then what happens to this diode? Because this is positive voltage and negative voltage is 0. So, the output is positive if I call this output as v' say because v_{ref} is positive v' is also positive this is going to drive this diode D into conduction. So, this will acts as short circuit. So, this will also open circuit here the resistance even though if it is there because of this 0 current resistance will not be there then what will be the equivalent circuit? This is something like this here we have v_{ref} and this part is connected to output this is nothing, but voltage follower. So, output you can call this as $v_{o,dc}$.

So, $v_{o,dc} = v_{ref}$ itself. So, when the input is DC output v_0 simply follows the input DC voltage. Now, we will see what is the AC response. So, in AC again we have positive cycle as well as negative cycle. I will first take during the negative half cycle.

So, in order to get the DC response AC response DC is equal to 0. So, this point will be 0 grounded. So, because this v_i is negative minus plus during negative half cycle. So, this negative voltage output of this one will be v' will be negative this will make diode off. So, diode is off then the capacitor C charges to peak value of v_i .

If I assume that $v_i = v_m sin\omega t$, then C charges to v_m in this direction minus plus. So, this will charge to v_m. So, this entire input voltage will be drop across the capacitor and the output voltage $v_o = 0$, $v_{o,ac} = 0$. Of course, $v_{o,dc} = v_{ref}$. So, overall during the negative half cycle the AC component is 0 DC component is v_{ref} output will be v_{ref}.

So, I am going to plot this output here. If I take this as v_{ref}. This sort of the output will be this is v_{ref} this is v_m this is another v_m. This is the type of output obtained it is the output of this circuit. So, during the negative half cycle you can see that output is v_{ref} and what happens during positive half cycle. So, during positive half cycle what will be this output voltage v_o? So, now, this becomes positive this becomes negative and this output is plus with respect to minus.

So, this capacitor has charges to $\pm v_m$. So, if I apply the KVL this is minus to plus is v_i and v_m is also this capacitor is minus to plus plus v_m voltage v_o is plus to minus. So, this is v_o. So, v_o is equal to this is due to AC $v_i + v_m$. So, the total output voltage $v_o = v_{o,dc} + v_{o,ac}$.

This is equal to $v_{ref} + v_i + v_m$. This is during positive half cycle during negative half cycle simply v_{ref}, this is 0. So, $v_o = v_{o,dc}$,which is v_{ref}+0, v_{ref} itself. So, you can see here that during the positive half cycle. So, you can say this is v_o this is v_m this is v_m this is v_{ref}. So, this is v_{ref} this is v_m this is another v_m total $2v_m + v_{ref}$, this v_i also will becomes v_m and during negative half cycle this is v_{ref}.

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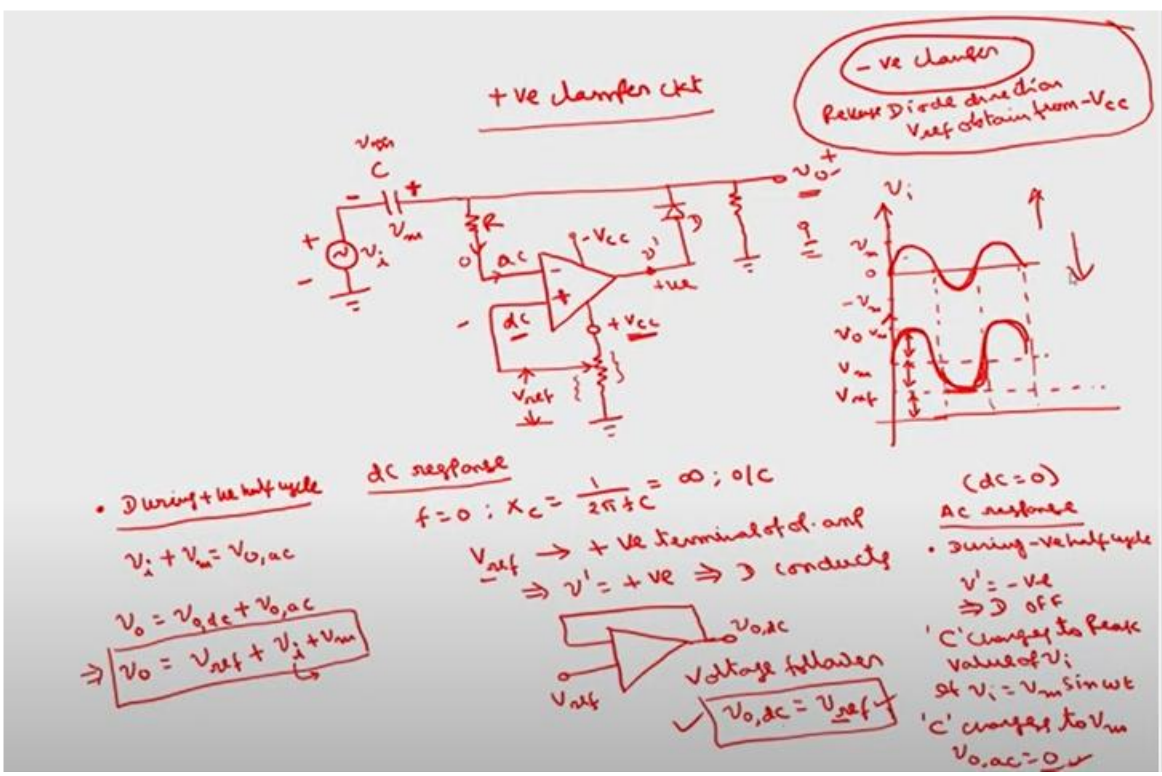

This is how this entire this waveform will be clamped in the positive direction with respect to v_{ref}. This is about the positive clamper circuit, this is also called a DC restorer. So, this can be used to double the voltage, voltage doubler also you can implement by using this type of clamping circuit there are several applications of the clamping circuits. So, if you want negative clamper circuit only two differences are you reverse the diode direction reverse diode direction is 1 and you apply this instead of $-V_{CC}$ you apply $+V_{CC}$ to reference v_{ref} obtained from $-V_{CC}$. So, with these two changes the circuit will acts as negative clamper means this entire waveform will be clamped in the negative direction.

So, this is about this clamper circuit. So, in the next lecture we will discuss about the some other non-linear applications. Thank you.