Basic Electronics
Learning by doing
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Lecture – 34
Active Diode Circuits
(Half wave, full wave, active peak detector, positive clipper, & clamper …)

Hello every body! In our series of lectures on basic electronics let us move on to the next. You might recall in the previous lecture we discussed about the comparators; operational amplifier used as a comparator. We discussed about different application circuits like the window comparator where you have the op amp sensitive enough to detect the transition at two different levels.

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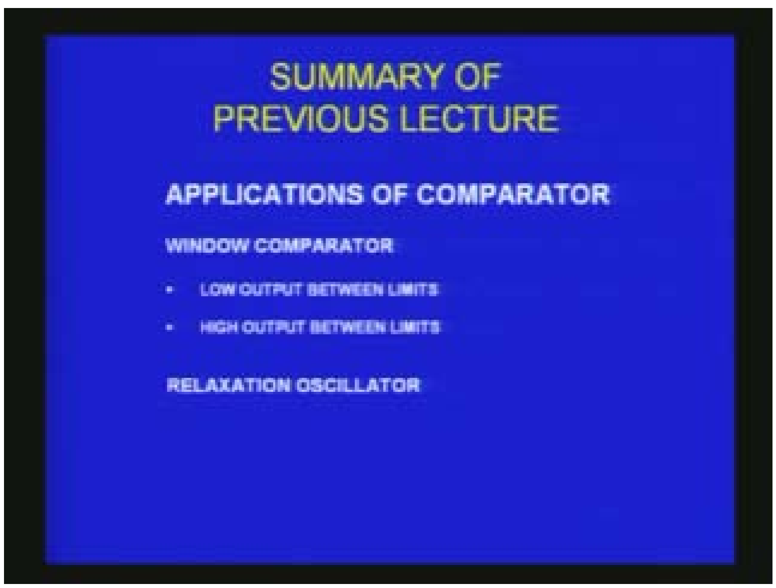

For example there is a low output between limits is one variation of the comparator and the other one is the output will become high whenever the input voltage is between the two limits. That is why it is called a window comparator. It is sensitive to two threshold voltages of the input. When the lower threshold is crossed the output changes state and remains in the state until you again cross the upper threshold by changing the input voltage. Window comparators have got very nice applications and we also saw another variation of a relaxation oscillator which you would have come across in transistors; the astable, bistable multivibrators which are basically relaxation oscillators. Here using comparator, a regenerative comparator to be precise you can use an additional RC and make a relaxation oscillator out of it so that you get a square wave output from the operational amplifier. You can generate the square wave and if you take the output across a capacitor you might recall we also got a triangular wave. So you can generate a square wave and a triangular wave. We also saw how to derive the expression for the frequency or the period of such an oscillator. These are the things that we discussed in the last lecture.

Let us now move on to the next one which is again a non-linear application of the operational amplifier. But in this case it is a very interesting scheme where we are going to use a diode, normal diode a pn junction diode made of silicon which is about 1 rupee in the market if you want to buy and that is not an ideal device. It is not an ideal device because if we look at the characteristics you have about 0.7 volts which is called the cutting voltage. Only when you cross 0.7 voltage at the input the diode will get forward biased and you will get sufficient current to the diode. That cutting voltage 0.7 volts is what you have to sacrifice when you are using diode in the normal rectifying action. For example I have an ac signal. How do I measure the ac signal? If I want to measure the ac signal one way to do that is you can rectify. You can rectify the ac signal and give it to a normal galvanometer or a voltmeter as a case and measure the voltage. The rectified signal will either have half wave rectified signal or a full wave rectified signal. We know what will be the average output of a half wave rectified signal or a full wave rectified signal and you know what magnitude of the average voltage will be read by the voltmeter. We can calibrate that voltmeter in terms of either the rms or peak voltage. This is a normal procedure to measure ac voltages.

If my ac voltage is very large for example 10 volts or 20 volts if I want to measure that I can directly put a full wave or a half wave rectifier and connect it to a normal voltmeter, dc voltmeter and from the magnitude of the voltage I will be in a position to calibrate the meter in terms of either rms. But unfortunately when my input signal is about 1 volt or even less then if I use a silicon diode, to forward bias a silicon diode you have to sacrifice about 0.7 volts which is a cutting voltage of the silicon diode.

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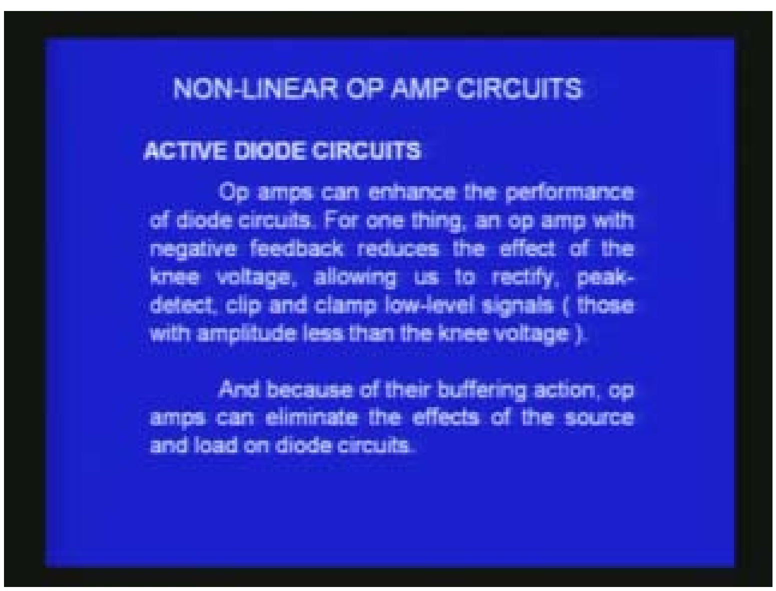

If I apply a signal with a peak voltage of 1 volt after passing through the diode for rectification you will be left with only about 0.3 volts or so which is a very, very low voltage. If I say 0.7 if I say it in millivolts it is 700 millivolts which is a very large magnitude of the voltage and you will get only 0.3 volts if it is 1 volt peak and that is about 300 millivolt. You have lost more than 700 millivolt of your input voltage across the diode. This is a very undesirable scheme.

How do I then detect the very low level signals how do I measure very low level signals? There is one option available for this and that is you can use a good ac amplifier. You can use an ac amplifier and amplify the voltage to a larger value so that 0.7 is very insignificant. When you amplify the 1 volt by 10 times it becomes 10 volts. In 10 volts 0.7 volt is not too much of a loss and you can calibrate using that by a normal dc. So you must have an amplifier. But amplifiers can be very expensive or difficult to construct. Is there a way by which I can use the same diode, pn junction diode and still rectify very low level signals which are less than 1 volt? The point is that is indeed possible to make the normal diode silicon diode as an ideal diode. For that all that you have to do is have an op amp. It is not vey expensive. If you use an additional op amp along with the diode you can make the diode behave like an ideal diode. That is the whole idea behind this active diode circuits.

When I have an op amp, the op amp has got an open loop gain of above 10 power 5; 100,000 as an open loop gain typically.

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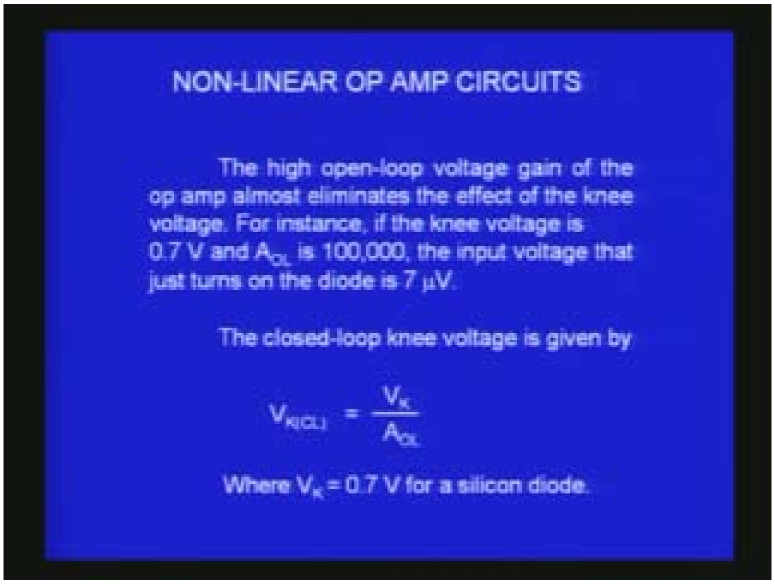

If I have a 0.7 volts as the cutting voltage in the case of a normal silicon diode then if I use an op amp the cutting voltage for the closed loop will be equal to V_K divided by A_{OL} where A_{OL} is the open loop gain of the operational amplifier. V_K is about 0.7 volts normally and A_{OL} is 10 power 5 and 0.7 by 10 power 5 is about 7 micro volts. The cutting voltage becomes reduced from 0.7 volts to 7 micro volts which is a very, very small value and this is the greatest advantage that you get when I combine an operational amplifier with a normal diode to obtain an ideal diode configuration. Having said that I will show you a typical circuit. You can see in the screen a typical circuit which makes use of an operational amplifier and a diode. This diode in the simplest case is a normal silicon diode.

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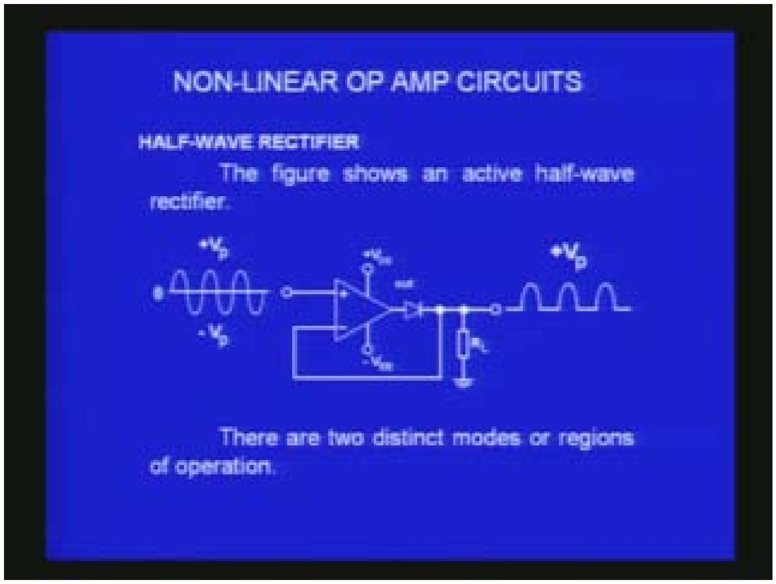

In this configuration the feedback loop from the negative input is connected at this point after the diode and the diode comes at the output of the operational amplifier. This resistor R_L is actually the load resistance and this is a non-inverting buffer type of thing except for the diode. When I give the sine wave input here I must get a sine wave input here if the diode is not there. But because the diode is there something else is going to happen. Let us see what is going to happen? When the voltage increases from very low value, initially the diode can be in open condition. That means it is not forward biased and there is no link. There is no feedback loop from this point to minus because this is open. It is equivalent to almost connecting this point to the ground. It is in an open loop condition. So when the voltages increases here this voltage will have to be amplified by the open loop gain of the operational amplifier and the open loop gain of the operational amplifier is 10 power 5. Whatever is the voltage here will be multiplied by 10 power 5 and that will be the voltage that will be appearing at the output terminal of the operational amplifier and even if it is about 100 micro volt, if the input voltage is around 100 micro volts I have to multiply by 10 power 5 and this will be about 1 volt at this point. You get 1 volt means the diode will be forward biased. Because at this point at the output of the amplifier it is about 1 volt and on the other side it is close to the ground and this diode will become forward biased. When the diode becomes forward biased there is a closed loop here and when the input is going positive the output is also going positive and it will be multiplied by 10 power 5 and it will be a very large voltage and it will forward bias the diode. It will be much larger than 0.7 volts and so it will be forward biased and I will get the same voltage as it is changing and when this will happen; whenever the diode cutting voltage is more than 0.7 volts. To become 0.7 volts here I must have an input voltage which is 0.7 divided by 10 power 5. That is 7 micro volt. Even when the input is beyond 7 micro volt as it increases here the diode will be forward biased and I will get the voltage here exactly in the same way as it is changing here at the input. I will get all the voltages; anything above 7 micro volts I will get here at the output.

What happens when the signal goes negative? When the signal goes negative the output will become negative and the output is open circuit. The diode is open circuit. It is no more forward biased. If it is not forward biased the output will have to be the same voltage as this voltage here at the ground. There is no current here and it will be zero. For all the negative excursions of the signal the output will remain at zero for all the positive excursions of the signal the output will go positive. Anything beyond 7 micro volt the output will follow exactly the same as the input and what I will be left with if I look at the oscilloscope will be half wave rectified with the amplitude starting even from 7 micro volts. You will have no difficulties with reference to the cutting voltage of the diode which in normal case should be 0.7 volts. But here because of the open loop gain of the op amp and because of the configuration, the way I have connected it the cutting voltage of the diode is reduced to 7 micro volts. This is the greatest advantage of using the diode along with the op amp so that even very low level signals, peak voltages anything beyond 7 micro volts also can be rectified and this output I can connect to a multimeter or a voltmeter and measure the average voltage. In this case it is 0.31 times the peak, Em by pie, peak voltage by pie. That will be about 0.318. If it is full wave rectified it will become 2 Em by pie. It will be twice that value. That value I can now calibrate in terms of either the rms or whatever that I want to do. This is a very, very simple configuration using one op amp and a diode in the proper feedback scheme. I can get a half wave rectifier circuit using this combination.

Once I have a half wave rectified signal then I can have all application circuits of the diode that we have already discussed at the earlier lectures when I discussed about the diodes, semi conductor diodes. This circuit corresponds to a half wave rectified signal. When the input signal goes positive the output goes positive also and turns on the diode and the diode then acts like a voltage follower and the positive half cycle appears across the load resistor.

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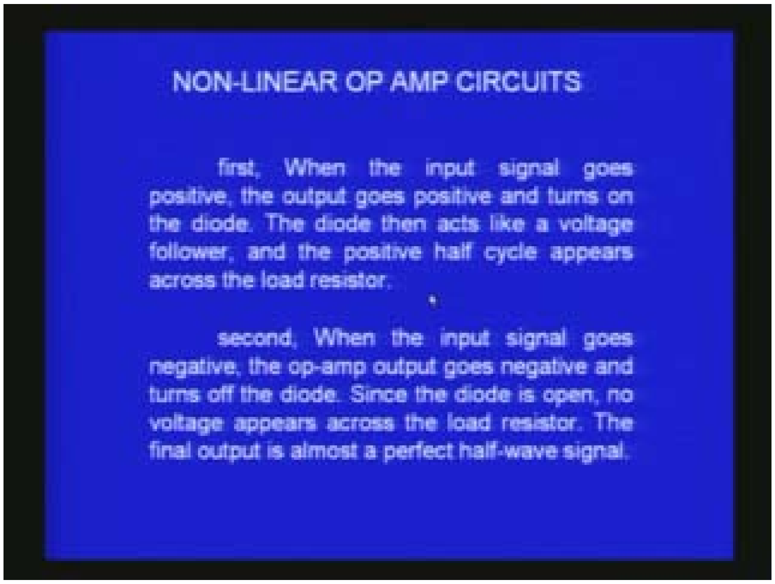

But when the input signal goes negative the op amp output also goes negative and turns off the diode because there is not enough voltage to forward bias. Since the diode is reverse biased or open no voltage appears across the load resistor and the final output is almost a perfect half wave signal because 7 micro volt is the only difference. Once we can get an ideal half wave rectifier the question then is how to build a full wave rectifier? We always require full wave rectifier when we want to amplify very small ac signal. When we want to convert it to dc it will be nice to have full wave rectifier. In the case of normal full wave rectifier you use transformer with a center tab so that with reference to the center tab the two ends of the transformer will be out of phase by 180 degrees and I can use two diodes to convert each half of the cycle and I can get a full wave rectified signal. We have already discussed that.

But when it comes to an operational amplifier applied ideal diode full wave rectifier the scheme is slightly different. You cannot simply use that scheme. But there could be other clever schemes available and one such clever scheme I want to discuss. You can see in the figure that I have shown on the screen you have the circuit of a full wave rectifier and also the corresponding output wave form. In the full wave rectifier both the half cycles should come in the same direction as it is seen on the bottom graph. This is a full wave rectified output and this is the input signal which is going back and forth. Both positive and negative excursions are available and even the negative excursion is pushed on to the positive side in the output and you get a full wave rectified signal at the output.

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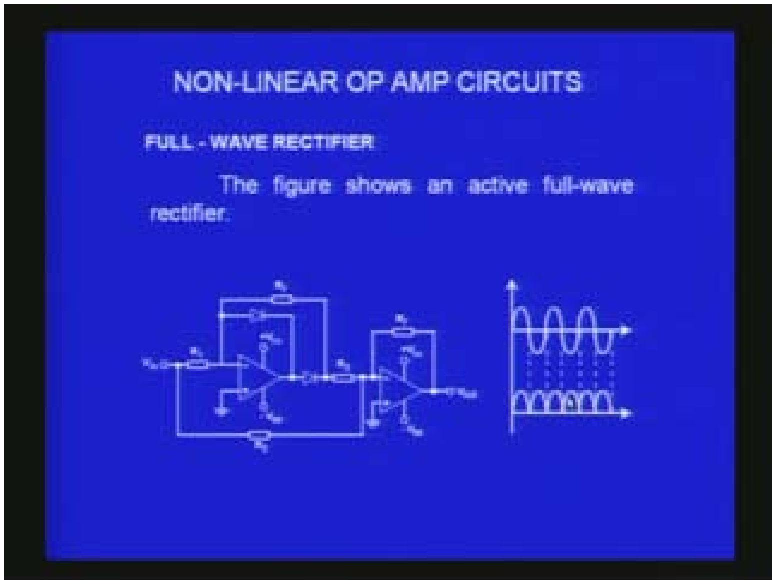

This is what you want to give as the signal and this is what you want to obtain at the output. What is the circuit? The circuit is what I have here. The first circuit here using the op amp is nothing but a half wave rectifier. I have used R_1 R_f here which has got a finite gain when it is in the reverse biased condition. This diode is the one which is going to do the rectification and I give the input signal which is in the form of sinusoidal wave at this pane and what I am going to get here will be a half wave rectified signal. Now that is given to the second stage. In the second stage what I have is a summing amplifier. This is one input V_1 here at this point and the other input is coming through this resistor here. This input itself is coming as another input for the summing amplifier. The output of the half wave rectifier is given as one of the inputs. These two inputs are amplified by the summing amplifier and the result is what you get here.

The question arises how we get full wave rectifier when I have also sinusoidal input as an input here. I will try to explain you with the signals that I have. Before that I should tell you R_f is $2R_3$; twice R_3. The gain factor here for the rectified signal is 2. R_3 can be 10K; R_f can be 20K and this R_2 again here is 20K. That means the gain for the input ac signal is only 1. But the gain for the rectified signal is 2. This is the important point that you should remember. With this back ground let us try to look at this various signals. You have a sinusoidal input and the half wave rectified signal will be something like this. One half is cutoff, the negative excursion. Only the positive half cycles are there and I still get the peak, V peak as the peak of the rectified signal.

Now when I give it to the summing amplifier, the summing amplifier amplifies the signal to twice and it becomes $2V_p$. This signal becomes $2V_p$; $2V_p$ as the peak voltage and the other signal is the input signal which is coming to the summing amplifier and for that the gain is 1 and the same output is also there. These two signals will be added at the output and what I get will be the sum of these two. If I add these two what is going to happen? This is too week peak this is Vpeak in the opposite direction.

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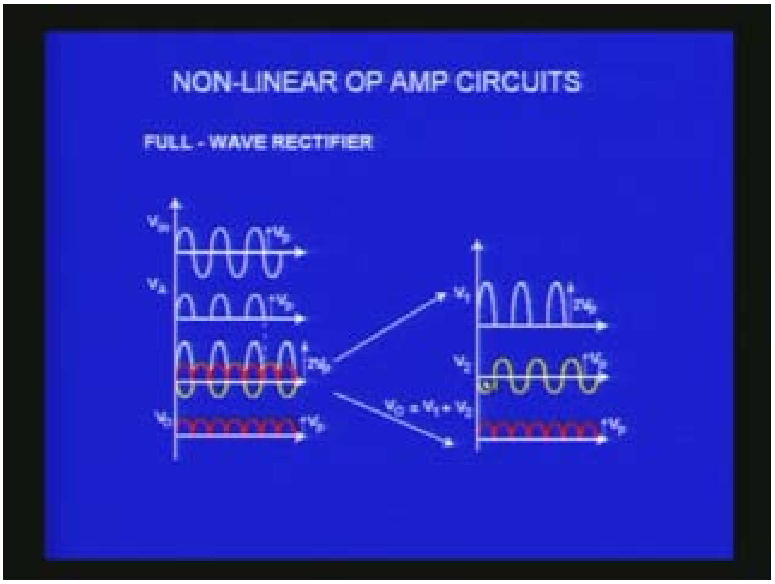

When I combine these two I will get only one Vpeak in the upward direction. If I come to the second stage, in the second stage there is only one peak voltage in the upward direction and there is nothing from the other input and when you sum them you again get a peak voltage here in the same direction. Like that for each wave you get only a net output peak voltage which is coming over here and when I monitor the output voltage of the summing amplifier I get a full wave rectified signal. That is what is again shown here. This is the V_{in}. This is immediately after the half wave rectification and after I have combined the two signals using the summing amplifier I get the output which is a full wave rectified signal.

There are some important points that you should remember with reference to a full wave rectifier. This is a precision rectifier. It is called a precision rectifier because it can rectify without that cutting voltage cutting in any of your voltage from the signal. It is only 7 micro volts which is very, very small value and the diode behaves almost like an ideal diode. The circuit is very common and is pretty much found in many of the text books. The most important point is the resistors that we have seen in the circuit R_1, R_2, R_3, R_f will have to be very, very precise resistors with tolerance 1% or even better. The tolerance of these resistors should be very, very good.

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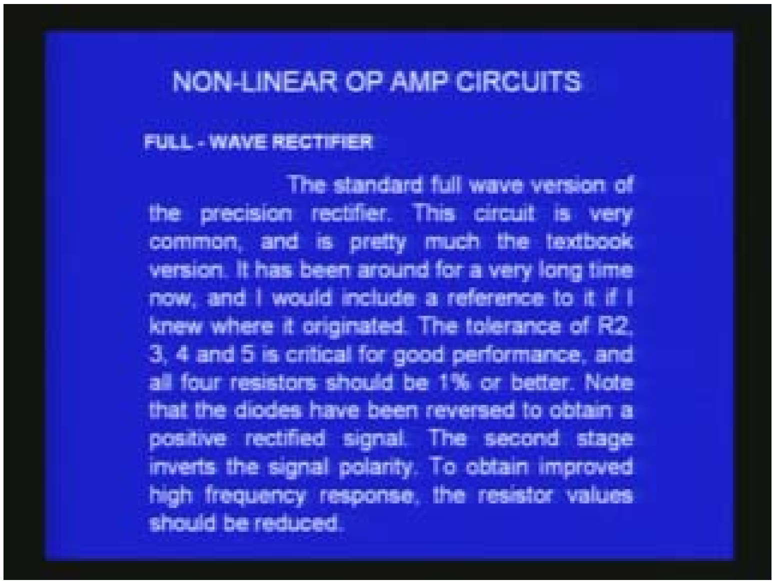

We have to also worry about the high frequency response. The high frequency response of this circuit is not good when you use very large resistors. If you want to improve the high frequency response you have to reduce the resistors that you make use of in this circuit and also you should try to use a low impedance output from a signal source, a sinusoidal source.

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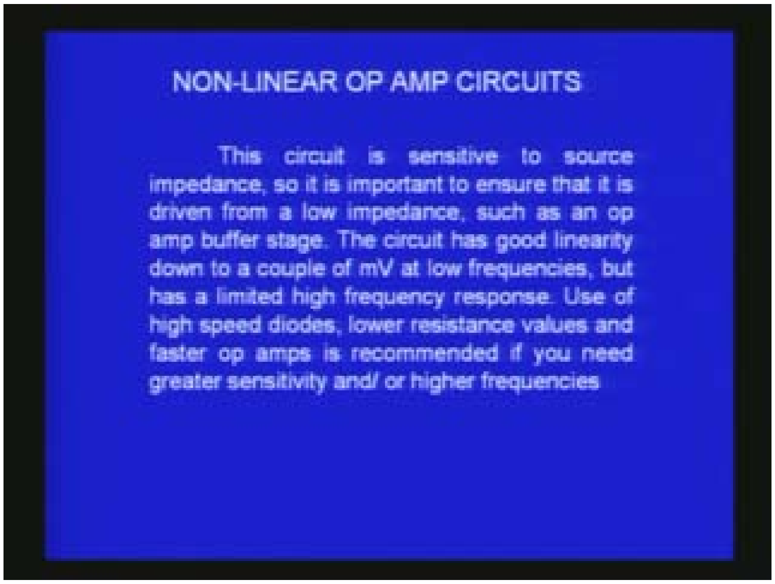

All these things we will also see and you can have a precision rectifier having very good linearity even at the millivolts range. Even couple of millivolts at very low frequencies a full wave rectifier works very well without any great difficulty. We have seen one circuit which is a half wave rectifier and the second circuit is a full wave rectifier which makes use of a summing amplifier and a normal half wave rectifier in combination. Now I will move on to the demonstration table and show you these two circuits and the working of the circuits. You can see the circuit board here.

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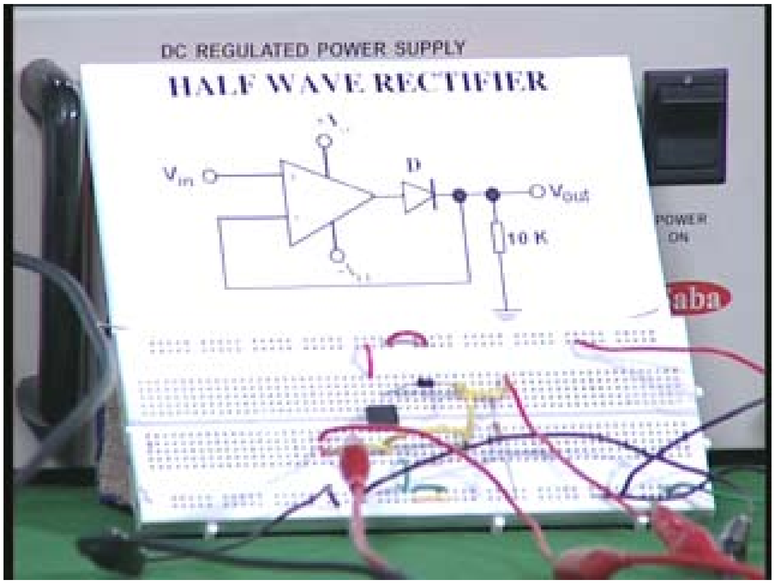

This is the same circuit which I explained to you. You have the V input here and the negative feedback loop contains the diode and you measure the output voltage after the diode and there is a 10K resistor as the load resistor. This is a normal 741 op amp. The same circuit is wired here. You can see the op amp here and the normal silicon diode connected here and this is a 10K resistor, the load resistor, V_{cc} and all are connected to the dual supply and the wiring is completed. The input is given from a function generator which you can see here. I can select the frequency here. I have now selected in the 100 hertz range. This is the one which is the depressed pin and it is in sinusoidal mode. I can have sine, triangular, etc. I am now in the sine mode and I am in about 100 kilo hertz range and the frequency can be varied using these two knobs and the output voltage can be varied in course 0.2 volts, 2 volts and 20 volts and this could be for continuous variation. There are two outputs here. One is 600 ohm and the other is 50 ohms. I have actually taken from the low impedance output the 50 ohm output and I have connected here. What I connect at the input is a sinusoidal input around 100 hertz and the output I am monitoring using an oscilloscope. This is a dual trace oscilloscope. We have got two traces and the bottom one is actually the input signal connected to the circuit. The top one is the output signal after rectification. There is a half wave rectification achieved. You don't have any output here. Then the signal is going negative and when the signal is going positive you get that alone coming here.

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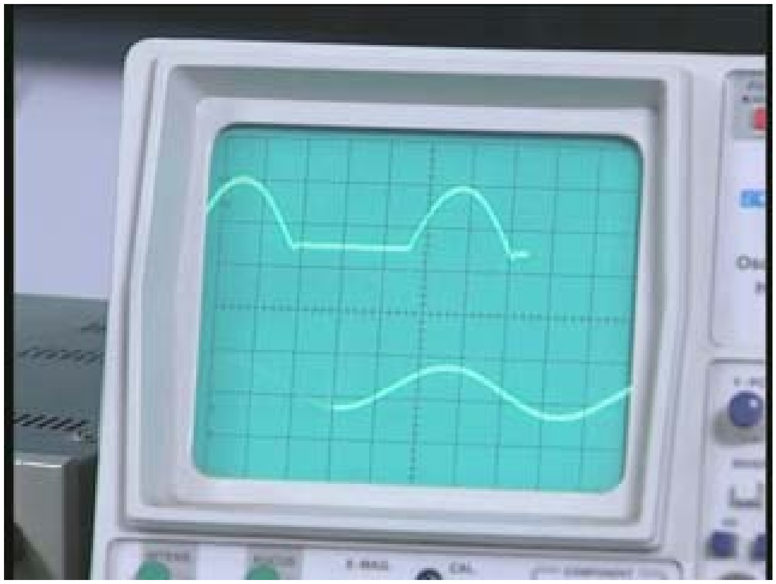

Now I will vary the amplitude and when I change that the output amplitude also varies and if I change the frequency the output also changes. I am changing the frequency now and if you look at the oscilloscope there again the frequency is changed. It is an output corresponding to the circuit and it is a half wave rectified signal. It is a very, very simple circuit. I have used only one op amp here and I have used one diode. That is all in the feedback loop; a very simple circuit which is able to perform output rectification even for very low signals. How do you know it is doing it for very low signals? You can see from the amplification factor in the oscilloscope. It is presently in about 0.2 volts per division and it is around 0.4. So even for 0.4 I do get a very nice signal here and that shows that even for very low level signals you will be in a position to have the half wave rectified signal.

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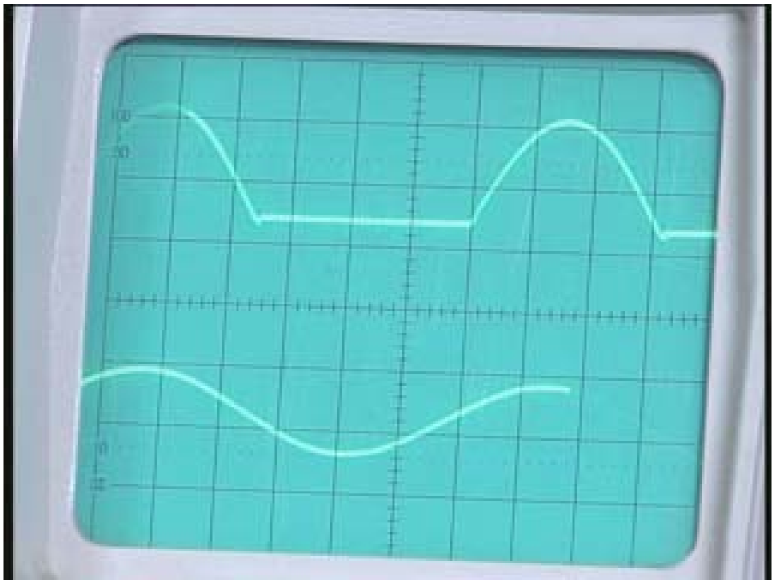

I will show you the next circuit which is a full wave rectifier signal. I want you to observe the circuit here. It is the same as what I discussed. The first circuit is an ideal half wave rectifier, precision half wave rectifier which we have already seen using an op amp and a diode and the second circuit is actually a summing amplifier with one input coming from here, the other input coming from the input.

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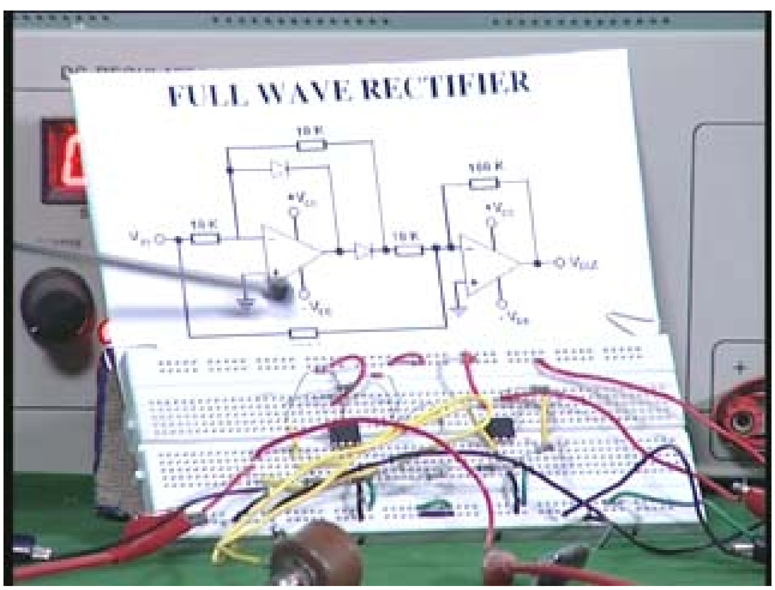

These two are summed and that is what you get and when you combine these two what you get will be a full wave rectified signal. The gain of signal for the half wave rectified signal is 2. This is 10K and this feedback resistor will be 20K in the actual circuit and similarly this will be 20K, 20K. This gain is only 1. What you see here is an op amp, first op amp in which I have used a diode here. This diode is 4148, slightly different diode from what I have used. But this is again a silicon diode and this is the second operational amplifier which is used as a summing amplifier. I have 20K in the feedback resistor. All of them are precision resistors, 1% resistor and at the input again I have a 10K resistor here. The circuit is exactly the same as what you see here and I have now given the input from the function generator as before. You have the sine wave input and the frequency is around 1 kilo and I can measure the frequency and the amplitude over here and now this input is given as the input for the circuit. The input is given here at the circuit and both the input and the output are monitored in the oscilloscope. The bottom one is the input signal and the top one is actually the output signal.

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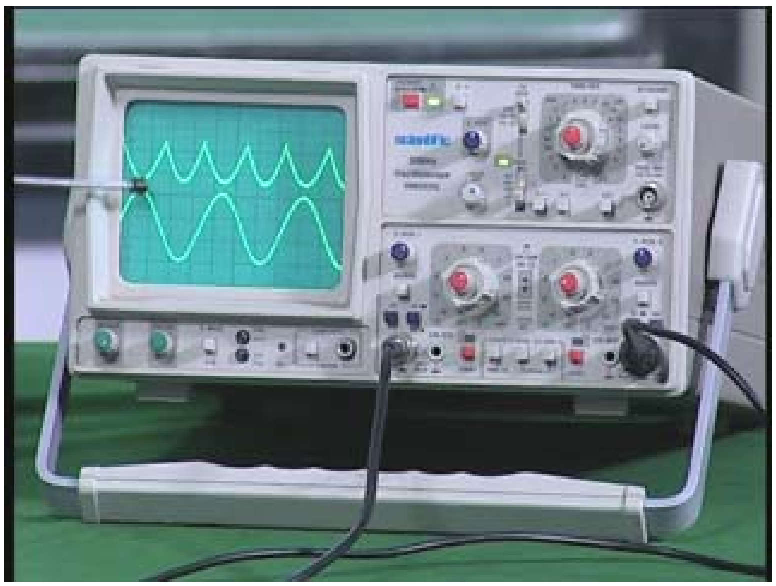

The bottom one is a normal sinusoidal wave which is the input I give and at the output it is a full wave rectified signal. Both the halves are coming in the bottom and if you want to have the other way if you want to have the signal coming up to the positive side all that you have to do is interchange the diodes that you have seen in the circuit. For example if you invert these diodes, if you change the orientation then you will get the full wave rectified signal corresponding to the other side. You do the full wave rectification easily by using one half wave rectifier and another summing amplifier. By properly choosing the gain you will be in a position to get the full wave rectified output as you have seen in the oscilloscope. If I vary the amplitude the output also is changing here and if you measure the voltage which is around 0.2 or 0.4 volts as you can see in the dial and it is for very low signals that you get the full wave rectified output and this is a precision full wave rectifier circuit.

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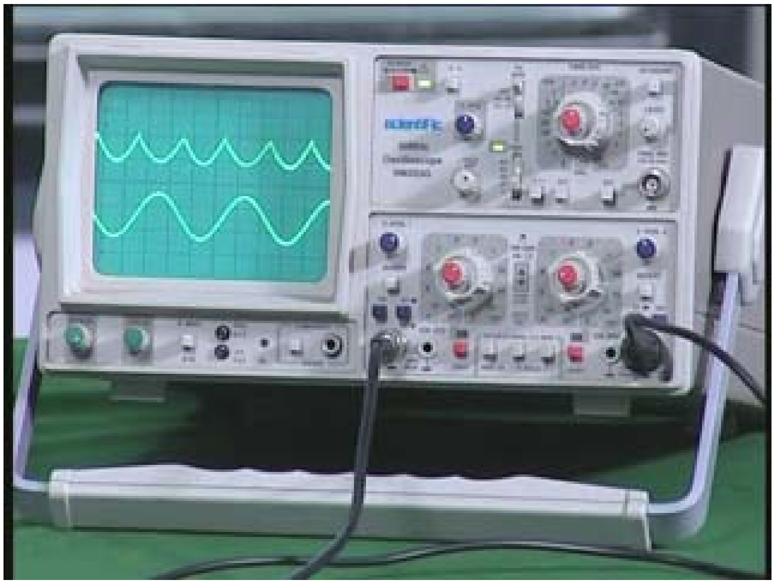

We have seen the demo corresponding to two circuits. One is the precision half wave rectifier using operational amplifier and the second one is the precision full wave rectifier where we have used a half wave rectifier along with the summing amplifier to cleverly obtain full wave rectified signal. This is all discussed in many of the standard textbooks.

Now we will go further and try to see how to make an active peak detector. The peak detector is very useful whenever you want to measure ac signals. The one way to do that is you rectify the ac signal and connect it across a capacitor so that the capacitor charges to the peak of the input signal and if the time constant of the output is so chosen the output will remain high at the peak voltage for longer period so that you will be in a position to make the measurement using a normal dc voltmeter. How do we make peak detector using the operational amplifier? On the screen I have shown the circuit of an active peak detector using a precision diode here. The diode and the op amp are in the form of an ideal diode by having in the feedback network and the output I connect to the capacitor along with the R_L. If the time constants of the R and C are very large then the input signal will charge to the peak value of the capacitor and before it discharges the next peak voltage will come and it will almost remain at the peak voltage except for the small loss due to RC time constant.

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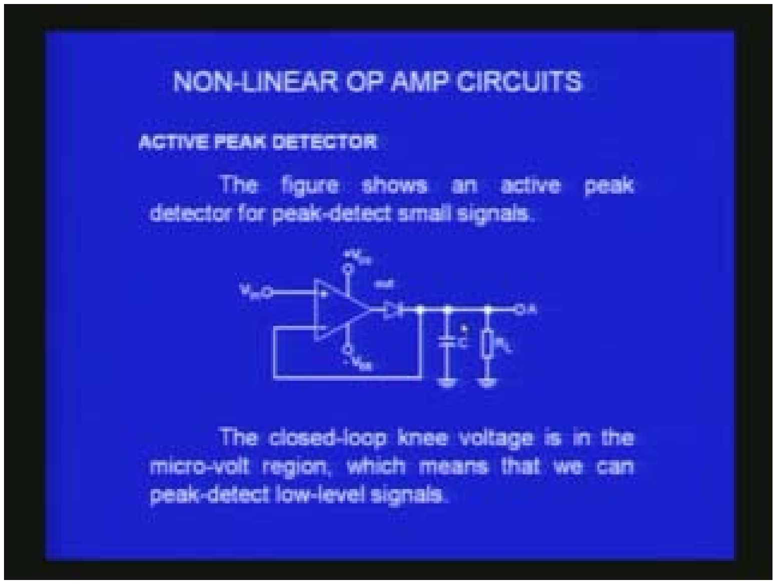

Here again you can do the peak detection for very low level signals; less than 1 volt you can comfortably convert them into peak voltage and then measure using normal multimeter or dc voltmeter.

Now I will show you the peak detector on the demonstration board and then I will come back and continue with the rest. of the demonstration Here you can see the same circuit which is a peak detector. You have the precision rectifier here with the diode and the op amp and you have a capacitor here connected for peak detection and this is R_L the load resistor.

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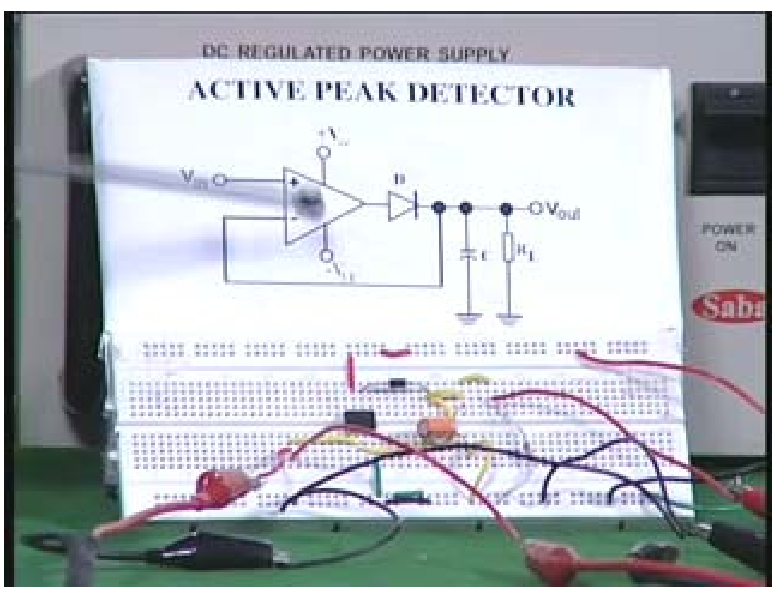

The corresponding circuit is shown here. You can again see the operational amplifier. You can see the normal diode and I have put about 100 micro farad capacitor in place of this and I have R_L which is around 10K here. The input is again given from the function generator. As in the previous case the output is connected to the input of the circuit and the output of the circuit as well as the input of the circuit is monitored on the oscilloscope which you see here. On the oscilloscope this is the input, a sinusoidal wave at the bottom and the output you see is a dc; it is a straight line.

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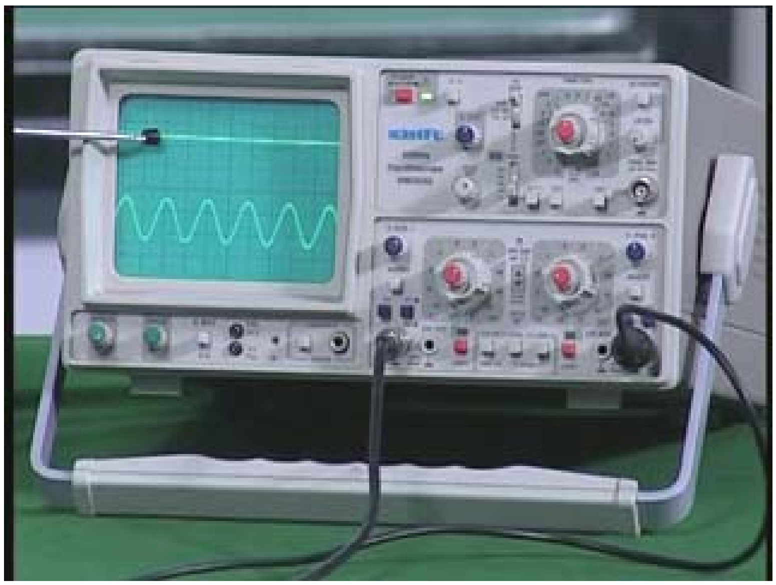

But how much is the dc you can measure by using the dc key here. I press ac and dc key. Now it is in dc and it is here. If I now release that if I make it into the ground now you can see the signal comes at this point if I release it it goes up so that much is the peak. What I will do is I will bring it at the bottom or at center. Then you can see it is actually going up to the peak value. When I put it into the dc it goes to the peak value so it has been charged to the peak value and I increase the input amplitude by using the function generator. I am going to increase the amplitude and at the output signal in the oscilloscope again you see a magnified signal and if I again make it peak detect it is going up to the peak, the corresponding peak.

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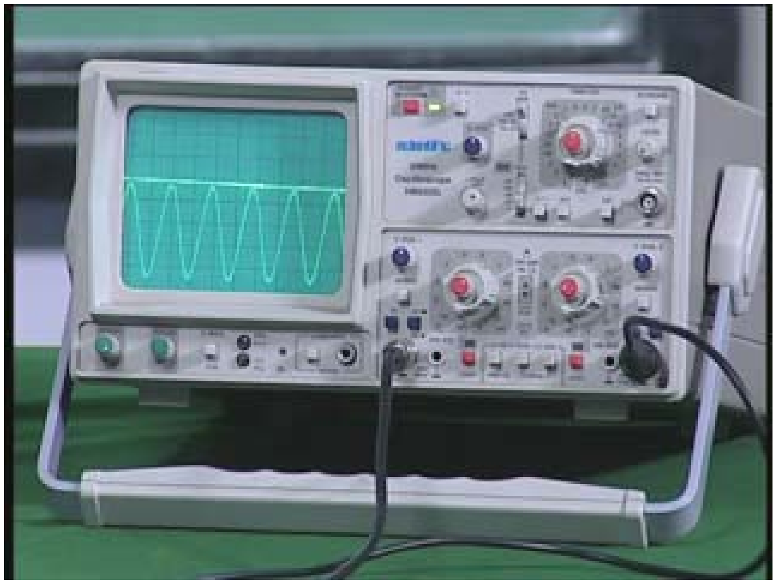

It is indeed detecting the peak. Instead of using a multimeter I wanted to show you by using the dc coupling here it goes from the zero line to the peak value here and this is the dc output that I get across the capacitor. This is the output. The output is a dc. It looks like a straight line but it is shifted with reference to the zero line up to the peak value. It is indeed a peak detector. With a very simple op amp diode and a capacitor we are able to make a peak detector and once I make a peak detector I can connect it to multimeter and calibrate it in terms of either rms or peak voltage.

We have seen three different circuits so far. One is the basic precision diode or a rectifier, half wave rectifier and then we also saw a full wave rectifier. How a half wave rectifier along with the summing amplifier can be constructed to give a full wave rectifier. We also saw a peak detector by using a capacitor at the output. Once I have a diode then I can have different types of application circuits with the diode and a capacitor. We have already discussed it when we discussed the pn junction diode; for example active positive clipper. You already know of positive clipper or negative clipper and the active positive clipper makes use of a precision diode. A diode which is along with an operational amplifier becomes an ideal diode that is used for generating various clipping circuits and the clamping circuits and that is what we are going to see now. Let me show you a very simple circuit of a positive clipper where again I have used an op amp and the diode. The diode and the op amp combined becomes a precision rectifier and I give an ac signal here with the peak voltage V_p at the input and at the output I should get a half wave rectified signal in principle. But then what happens the second input or the non-inverting input of the operational amplifier now I have connected to a potentiometer, a variable resistor, wiper of the potentiometer and the other end is connected to plus; the one end is grounded and when I move the wiper I can move it to this extreme. Then it will become V plus and when I move it to the this extreme it becomes ground.

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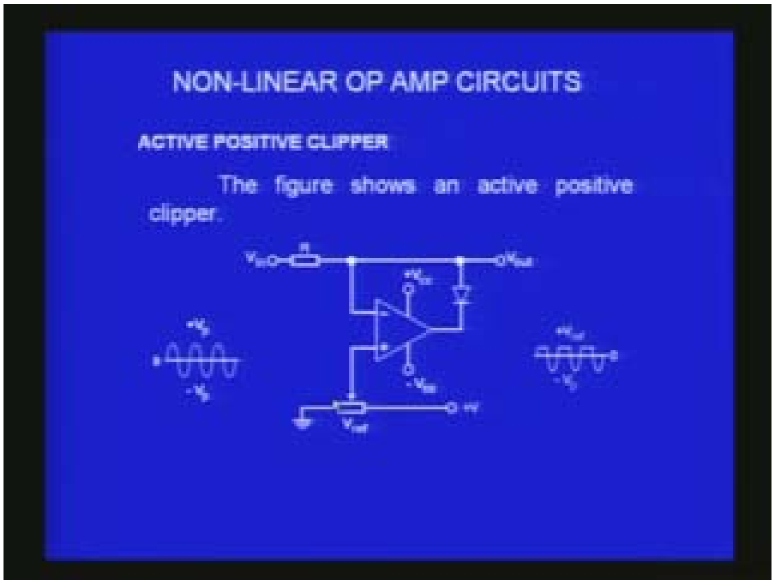

I can vary this voltage at this terminal from anywhere between zero to +V. +V could be any voltage 2V or 4V. I can vary this voltage here and I can change the bias here. When I change the bias what is going to happen? If it is at the zero this circuit is nothing but a simple half wave rectifier. Because this is now in this condition when it goes negative, when the input is negative the output is also negative and the diode will be conducting. So there is a short, there is a feedback loop and the output goes straight there. The output goes straight at the output terminals. But when the input goes positive with reference to the other terminal then the output will become positive. At that stage the diode will be reverse biased. So diode will not work. It will be open and the output will be equal to this voltage and that voltage here is what you get at the other terminal and initially you should get a half wave rectified signal. But if I now maintain this terminal at some voltage different from zero for example +2 volts then anything more than +2 volts if I apply here this voltage is more than this voltage and I get a negative and then it is shorted, the output goes straight there. If it is more than 2 volts this is opened up and you get the corresponding signal and also the output is clipped at this V reference, 2 volts in this case. If I make it 2 volts the positive peak will be cut off at 2 volts. If it is 1 volt the positive peak will be cut off at 1 volt. Depending upon where I put the reference this output will correspondingly be clipped. The negative input will automatically come because during that time there is a feed back and you get the exact output voltage coming over here, the unity gain clipper type of thing. You get a clipper with positive points clipped at this place depending upon what reference you have in the operational amplifier.

If you want a negative clipper what do you do? All that you have to do is reverse this diode and reverse this reference voltage. You can do that and have the positive cycle completely and the negative cycle can be clipped wherever you want. In some cases you want both sides clipped. When I take a sine wave and clip both sides I will get almost sort of a square wave. There is one such circuit which I want to show you. You can see here the circuit has got two zener diodes connected in opposition together and the output will be clipped on both sides at the $+V_z$ and $-V_z$.

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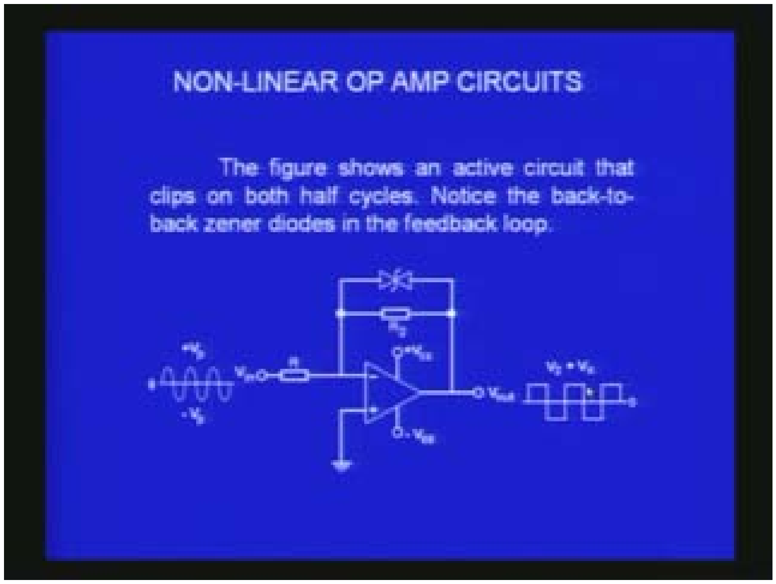

That is what you get and actually when one Zener diode is having break down voltage the other Zener diode will be forward biased. You will get about 0.7 volt in addition to the V_z. That is what is shown here as $V_z + V_K$. V_K is 0.7 volts which is the cutting voltage of the diode. $V_z + V_K$ will be point at which it will be clipped both on the positive side and the negative side because one zener breaks down for one orientation of the signal, for one excursion of the signal and the other zener diode breaks down for the other excursion and what you get will be a clipped sine wave or basically something close to a square wave. When you want to convert a sinusoidal signal into a square wave you can make use of the clipper of this type which uses zener diode in the feedback and you can get a square wave.

I will show you a simple circuit. The same circuit implemented for a positive clipper. The circuit here is the same as what I just now discussed as an active positive clipper. You have an op amp, you have the diode and you have the signal input here. You take the output and on this side you have got a potentiometer. The wiper of the potentiometer is providing the reference voltage for the positive terminal or the non-inverting terminal of the operational amplifier. This is the plus. I have used the power supply of the $+V_{cc}$ itself here and that is what is being used for the reference voltage here.

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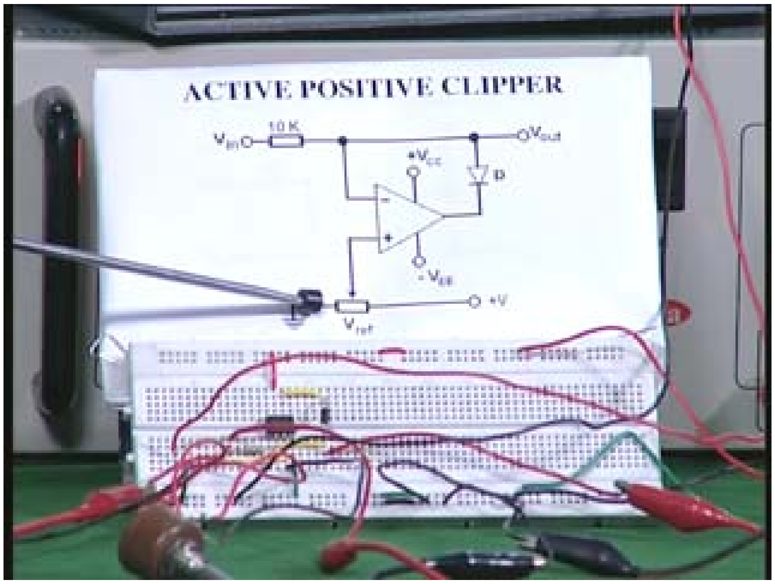

This is the circuit and the corresponding circuit is shown here. You can see the diode, you can see the operational amplifier and the resistors and the input is provided from a function generator once again. You can see the function generator here. You have again at 1 kilo hertz the amplitude and the sinusoidal wave and the amplitude is adjusted using these two knobs and this is given as the input in the board and the output is connected to an oscilloscope. In the oscilloscope both the input and the output are shown simultaneously. If I slightly move you can see the two signals.

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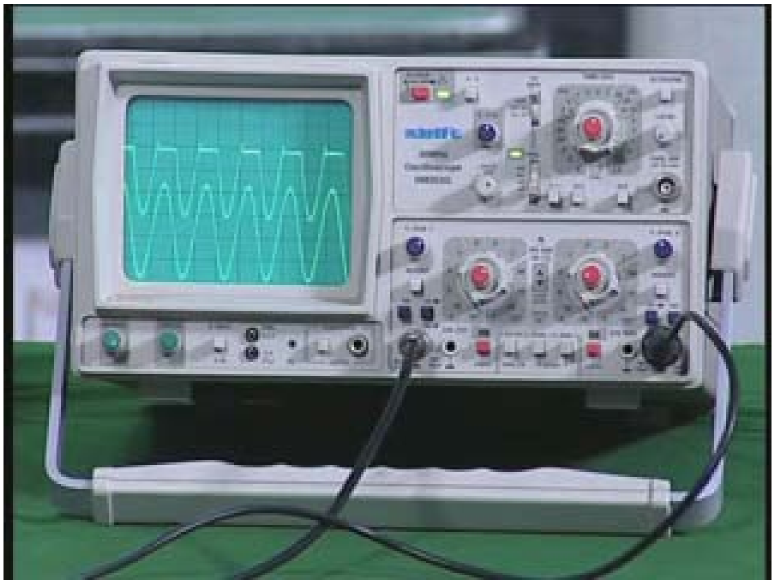

You can see the bottom one is the input signal, the top one is the clipped signal. You can see the clipping there. The clipping can be modified by changing the wiper position or by changing the reference voltage here. That is done by changing the potentiometer here. When I change the potentiometer I am able to change the point at which the signal is clipped by moving the wiper. The reference voltage is what is being changed now and thereby I am able to change the clipping voltage.

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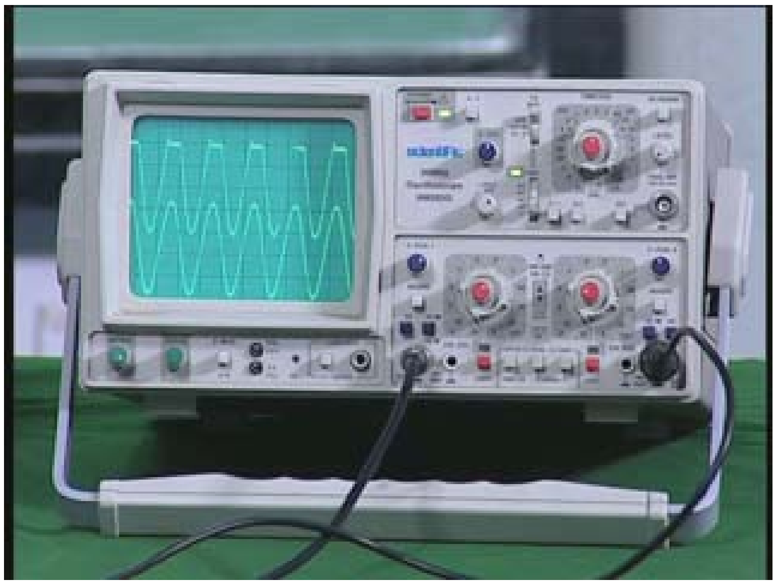

This is a positive clipper and if I want a negative clipper all that I have to do is change the direction of diode and change the reference voltage on this side. Then you will be able to get the negative clipping and you can also do a square wave clipping. That is both sides clipping, dual clipper both positive and negative by using Zener diode or combination of such circuits.

Having seen the clipper circuits we also know a diode can also be used for clamping. That means dc restoration as it is also called whereby you can take the sinusoidal wave, normal sinusoidal wave when you take the average of the sinusoidal wave you will get the symmetric sine wave with reference to the base line or the common line, the ground line. For example on the screen you can see example of the sine wave which is symmetric with reference to the ground, the common point. The excursions are equal on both sides +V peak and -V peak, maximum values and it goes back and forth on both sides of the ground. When I say I am clamping what I actually do is I change this line with reference to the sine wave. I can take it all the way to the top then I have clipped at the peak positive point and the entire voltage will not be negative or I can bring this line to the bottom and clip it at this point at the bottom so that the entire voltage is positively clamped. It is clamped at this point, the lower point. So the whole thing is positive.

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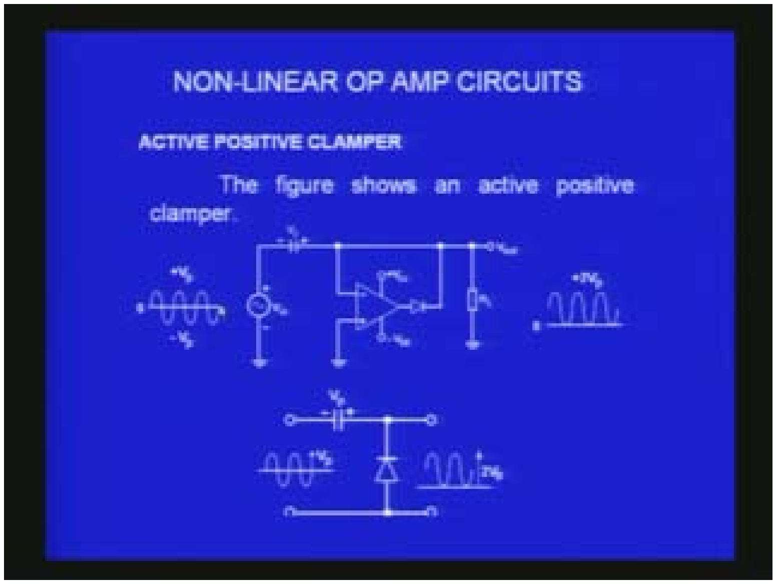

You can do either positive clamping or negative clamping and the circuit is very, very simple. Because it is much easier to understand from our earlier discussion on positive clamping I have shown the earlier circuits also here for recapitulation. You can recall what we did earlier. I have used a diode here and I have used a capacitor and I give a sine wave input at this point. What I get will be a clamped sine wave. How this comes about also I explained to you in the previous case. When the input goes negative then this diode can be forward biased. This is ground. This is going both positive and negative as the signal goes and when it goes negative the diode is forward biased and the diode will start conducting. When it starts conducting it will charge the capacitors in the path to the full peak value. During one negative excursion of the input signal the diode will start conducting and it will charge the capacitor to the full peak value.

Once that happens when the input signal goes positive the diode will become open circuit after the first cycle and you can almost ignore the presence of the diode now. What is going to happen is you have now a new situation where the input signal is applied in series with a battery. The capacitor charged to $+V_p$ and the diode open circuited acts like a normal dc battery of a value V_p. You have to now add this V_p to every instantaneous voltage of the input signal and that is what you get as the output. When the input is maximum V peak you have to add another V peak here due to the battery here or the capacitor and the total output will be 2V peak and when you go to zero you will have this V peak and when you go to the minus V peak this +V peak will add with that and you will get zero. The output will start going from zero to $2V_p$ as the amplitude and what I have effectively done is I have clamped this zero line at the bottom. It becomes fully positive and it is a positive clipper. The output signal has got $2V_p$ as the maximum voltage. This is a normal diode capacitor based clamper. Wherever I use normal diode I will still have the same problem of the cutting voltage. Because this is 0.7 volts when I want to clamp it using 1 volt signal it will all be lost. Only 0.3 will be charging this and the clamping will not be done very well. If I can make this into an ideal diode then I can even use very low signals and get the clamping action completely done.

I have used here an active diode which is an op amp with the diode connected as in the previous example. If you look at this as an ideal diode this is my capacitor. The circuit is very similar to this. The R_L is what I have at the output load resistor. This is the input signal. When I now give the input ac signal the clamper will charge for the first negative cycle. When it goes negative this diode will become positive because there is an inversion and the diode will start conducting even for about 7 micro volts and the output will come completely and it will charge the capacitor. Once the capacitor is charged this diode will become open circuited and whatever input signal I give it will be in series with this V_p and the output will be shifted with reference to average dc by a value corresponding to V_p. The whole output signal will become clamped at the positive side. Zero will be clamped at this point and the entire excursion will be towards the top.

The output has the same size and shape as the input signal. There is no difference except for the dc shift. Only there is an additional dc shift which is provided by the capacitor charging to the full value of the peak value voltage. In this case the output voltage is sum of the input voltage and the capacitor voltage.

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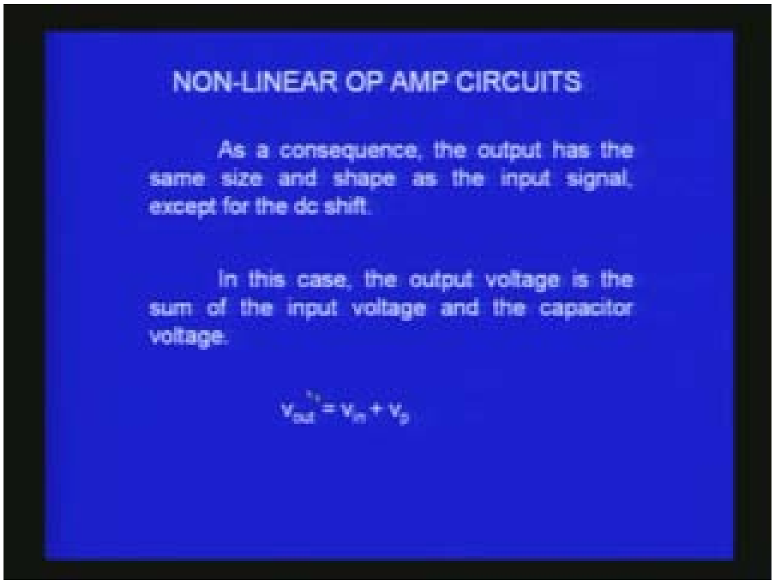

V output is equal to V_{in} + V peak and V_{in} is a sinusoidal voltage with the peak voltage V_p. When I add it with this when this becomes $+V_p$ the total becomes $2V_p$. When this becomes zero the output is V_p. When it becomes $-V_p$ the output is zero. There is nothing which goes below zero. Even though the signal goes below zero because you are adding with the V_p the output becomes only all positive starting from zero up to a maximum of $2V_p$. That is the active positive clamper that we wanted to discuss. Now I will show you the demo of the active positive clamper and then we will go further.

(Video needs to be edited here. Sir is speaking in Tamil).

This is the circuit of an active positive clamper which just now I discussed.

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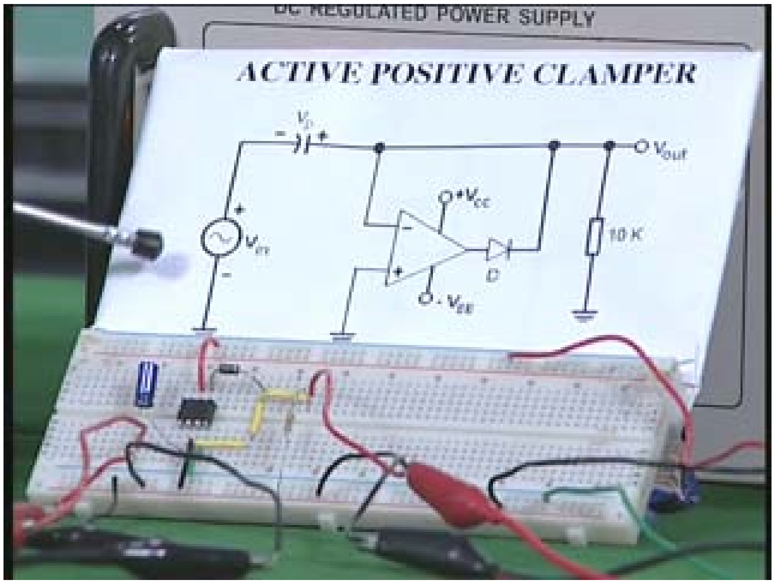

You have the input sine wave from a oscillator and you have a capacitor here and then you have the ideal diode with the operational amplifier and the diode. This is the load resistor and you take the output at this point. The positive terminal is connected to the ground. The non-inverting terminal is connected to the ground. The same circuit is wired here. The capacitor is here about 10 or 15 micro farad and this is the diode that I have here and this is 10K resistor. The wiring is done exactly in the same way. The input is connected to a function generator as before. It is in sinusoidal mode and it is about 110 kilo hertz and the frequency, the output amplitude, etc can be changed using these knobs and the output is connected to the input of this circuit which is an active positive clamper. Both the input and the output waveforms are monitored using an oscilloscope. Here the bottom one is the input signal, the top one is the output signal. You don't see any difference here. Both of them are identical. That means the gain of the amplifier of the circuit is 1. But there is a difference. What is the difference? That difference you can see by looking at the dc situation. I have a knob here. This is now ac mode. This is dc mode, ac mode. In the bottom sine wave the ac is with reference to the ground which is here.

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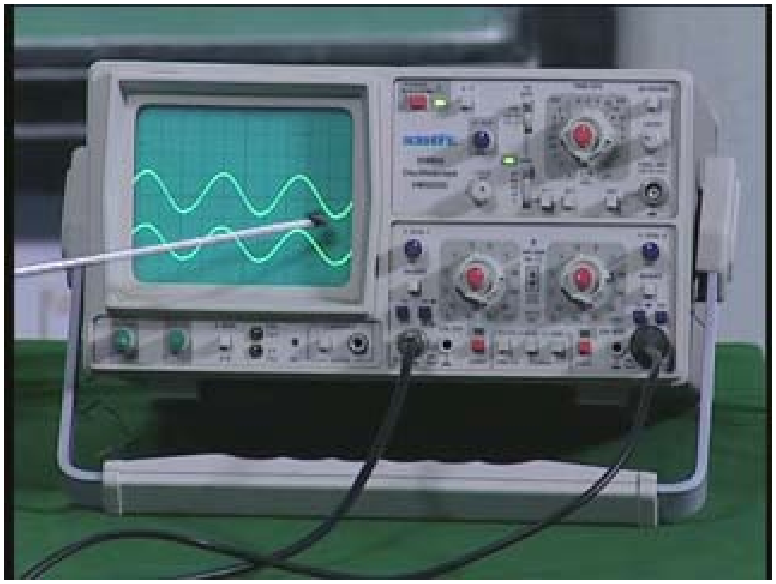

For the top one when I make it into dc still the sine wave is there and it has moved up to this line, the central line. It is symmetric to the central line and when I dc couple it, it moves up to this. That means the entire output has moved with reference to this as the reference line or zero line.

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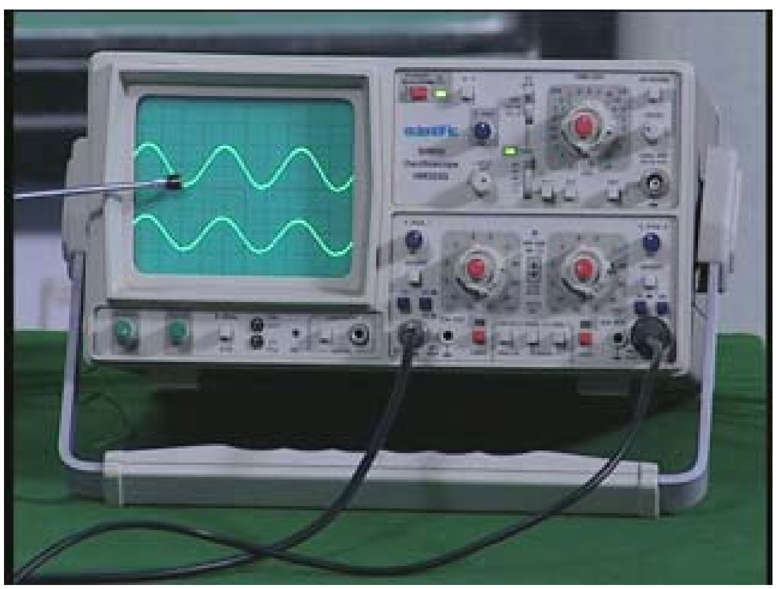

I have clamped it positive. I will show you again and again, number of times so that you can see on the screen that initially it is symmetric. When I dc couple it the whole sinusoidal wave moves up. That means it is positively clamped. That is what we see here.

Whereas the something if I do for the lower signal you can see that there is no dc there. When I put dc coupling I get only a straight line.

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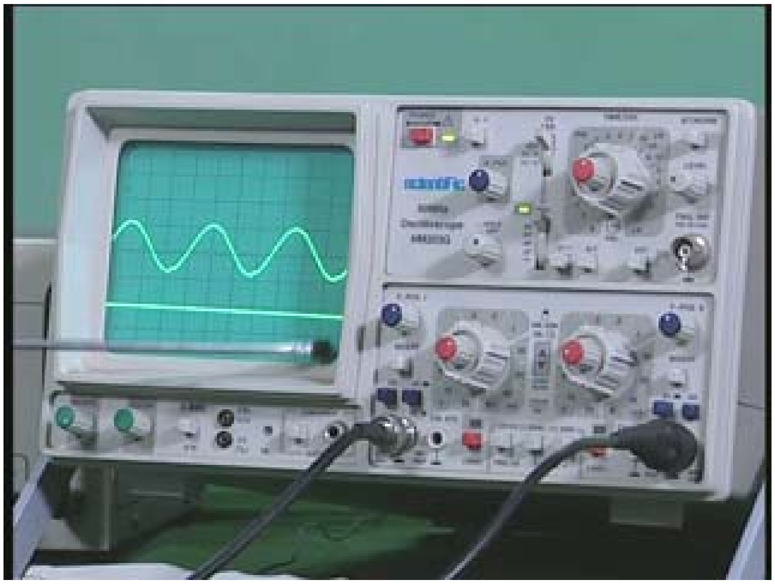

That means there is no dc. Everything is only ac whereas in the top one you see all of them are ac but with reference to a zero line which is at the bottom and it is a varying dc; sinusoidally varying dc all with reference to this reference point. It is positively clamped. That is what we mean. This is the way to identify the dc clamping. If I want a negative clamping all that I have to do in the circuit is invert the diode here and then you will get a negative clamping. That means the whole signal will move to the negative side the clamping will be done with reference to zero and the two peaks will be on the negative side. Just as we saw now on the positive side we can go to the negative clamping by just interchanging the diode, turning through 180 degrees and then …… the circuit you will be able to get the negative clamping. The positive clamping and negative clamping are also very useful in different applications in electronics.

What we have done today is look at how a normal diode can be made into an ideal diode with the combination of an operational amplifier and we also saw how different applications of an ideal diode can be used for half wave rectification, precision full wave rectification and then peak detection using a simple capacitor and then clipping circuit by giving some bias and a clamping circuit. All these different circuits based on active diode circuits using an operational amplifier, our precision rectifier can be considered and the applications based on those diode circuits have been discussed. Thank you!