**Op-Amp Practical Applications: Design, Simulation and Implementation**

**Prof. Hardik Jeetendra Pandya**
**Department of Electronic Systems Engineering**
**Indian Institute of Science, Bangalore**

**Lecture – 10**
**Op-amp Applications: Full Wave Rectifier**

Welcome to this module. And in this module we will be looking at the Full Wave Rectifier and oscillators. So, another application of operation amplifier even we write this basic operation amplifier circuits. Even this basic operation of amplifier circuits will get little bit complex as we move on alright. So, what we have seen in the last module is the half wave rectifier right. And I told you the application of the rectifier in the DC power supply. In the DC power supply that is right in front of me right. Yesterday we last lecture or yesterday I do not know when we recorded this particular lecture we have seen that how a rectifier would work right.

And the idea is that you have the 230-volt AC and you have to convert this AC to DC, then you need to first use a step down transformer is a transformer within this DC power supply. And then step down transformer you have to attach or connect a rectifier circuit that will give you the final DC output. So, from AC to DC the rectifier is extremely important circuit. Now yesterday we have seen a half wave rectifier; that means, that if I have a signal right if I have a sine wave only half wave will rectify another half will not, but do we need half wave rectifier are we interested in using half rectifier or we need a full wave rectification; that means, that if I have a single it should be completely converted to DC right.

So, that depends on the type of application that we want. Now what if I want a full wave rectification, What if I require a full wave rectification? In that particular case I need to design a full wave rectifier right. And again we keep in mind we will use operational amplifier and use this operational amplifier to rectify the AC signal and get the DC output. So, how we can do this AC to DC that to full wave rectification that is the today's module. And we will see first we let us understand quickly what is a full wave rectifier and then we will continue the experiment part ok.

So, if you come back to the screen, what you will see is we have to understand what are the basic Op-amp circuits and today we will understand rectifiers and oscillators. Very important applications of operational amplifier circuits alright. So, these are the experiment modules as you can see here right. We are completed the theory modules these are experiment modules that we will be using that are used for us to understand how we can apply theory to the experiments alright how can use our theory knowledge to find out the solution in terms of experiments.

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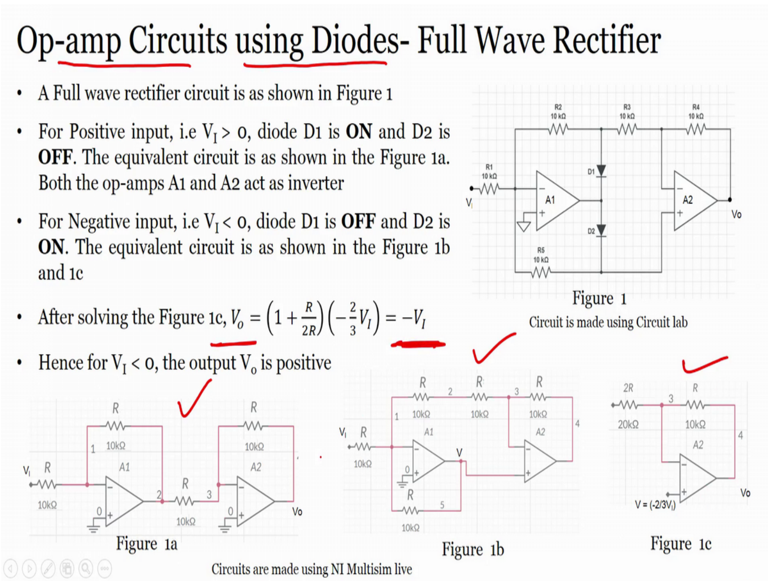


So, if you see the first slide we have the Op-amp circuits right. Op-amp circuits using diodes to act as a full wave rectifier, to act as a full wave rectifier.

That means if I apply a signal if I apply a signal my output would be DC output should be DC. Maybe there are some ripple voltage is that is different case there are some ripple and of something are there that we are not considering right. Now our just simple thing is if I apply a AC can I get the DC or not. To get the DC signal from AC signal I need a rectifier right. Yesterday we have seen that if I apply AC signal to a half wave rectifier it will rectify half right. So, will only have rectification like this; this top was rectified right this is gone only half wave rectification.

But here we will be looking at the full wave rectification. So, to understand the full wave rectifier, let us see the circuit which is here in figure 1, alright. Here we are using 2 operational amplifiers, 1 and 2 right. And we are using 2 diodes a and b easy we are using 2 diodes we are using a inverting amplifier inverting right. See signal is given to the V i is given to the inverting terminal of the Op-amp inverting amplifier right. And let us see how this circuit operates let us see how this circuit operates alright. So, you can see a full wave rectifier circuit in figure 1, which is this one. For a positive input that is V i greater than 0 this V i greater than 0. In this particular case what will happen? You see V i is greater than 0, then my output then my output right will be such that my Op-amp will start my diode D 1 will start conducting my D 1 will start conducting and D 2 will be off right.

D 2 will be off because my inverting input V i is greater than 0, means what is greater than 0. What is non-inverting amplifier, non-inverting input? Non inverting input here is grounded right you can see this is grounded; that means, that is 0. So, if my input voltage V i is greater than 0; that means, is greater than the non-inverting terminal. Then my output would be minus or it will be 0 right. It can be minus 0 whatever it is; that means, that this will be plus this will be minus this will be minus this will be plus correct.

That means my diode right, my diode that is diode D 1 right or diode A will start conducting. And I would be will not conduct. Because this is a opposite polarity to conduct the p-n junction diode we need to apply positive to anode and negative to cathode right. So, if I draw diode you see this is anode. This line represents cathode if I want to conduct; that means if I want to operate this diode then I had to apply positive here and negative or ground here then only this diode will operate. If I do reverse of this; that means, I apply negative here, and sorry if I apply positive here and apply negative here, than this diode will not operate.

This we all know correct. So, using this principle of the diode, what we find? What we find is that if my V i is greater than 0 we are concentrating only on the, only on this particular operation amplifier, ok. If I V i this one V i is greater than 0 then my diode D 1 will conduct D 2 will not conduct; that means, D 1 is on and D 2 is off. So, if I want to draw equivalent circuit in this particular case, then the equivalent circuit is as shown in figure 1 a, this one, right. Because you see R this is ok, then we have R 2 this 10 kilo ohm, alright? Then we have this diode conducting, right; that means it will have directly conducting; that means, connected here, then we have R which is another one and R 4, right.

Correct, you got it? Again see, super easy was that when I apply V i greater than 0 then this diode starts conducting. Means, I can just draw a line this will not conduct. So, it will block right. So now, what I have? I do not, I cannot see this one, I cannot see this one right, I can only see the remaining part. When I have remaining circuit and how it will be this one would be there, this one would be there which is here and here, correct. Then I have R 3, I have R 4, I have R 4, I have R 3, this is connected here like this, this is connected from here to here, ok. And then we have A 2 we have A 2. So, you see here, A 1 A 2 that is the equivalent circuit in case when VI is greater than 0 right.

So, this is what we are saying that equivalent circuit is as shown in figure 1 a, which is this one when you have V I greater than 0 both the Op-amps A 1 and A 2 will act as a inverter. Now you see here right here if I apply voltage, that say 1 volt the output will be my gain is one. So, this will be minus 1. If I apply minus 1 that will go to here, right my gain is again one, this will act as one. So, this will also act as inverter, this will also acts as a inverter. That is why this sentence is that in this particular case, the first case when I have V I greater than 0, when I have V I greater than 0 both the Op-amps A 1 and A 2 acts as a inverter, alright?

This is easy, now let us see the second case. Let us see the second case, let us see the second case. What is second case? Second case is when V I is less than 0. When my V I is less than 0, in that case, what will happen; in my V I is less than 0, then diode D 1 is off, right if I V I is less than 0, now in this case what will happen this will be positive compared to this terminal, right. And this will be positive, this is ground right. So, this D 2 will start conducting D will D 1 will not conducting, D 2 will start conducting. D 1 will not conduct; that means, that for negative input for negative input V I is less than 0, V Iis less than 0. In this case diode D 1 is off and D 2 is on, correct?

The equivalent circuit is as shown in figure 1 b and figure 1 c. That is equivalent circuit, alright. So, what we have seen at V I is less than 0 this will not conduct. So, we cannot consider this. This will conduct so, we can short this like this, right, is not it? Now what we have? We have this one let me just write down here, like this right, this is there, this is there, this one is there, here R 3, R here R 4 here, correct. Now this resistor here, correct, why? Because this diode D 2 is conducting, diode D 2 is conducting right. And D 1 is not conducting, D 1 is not conducting so, here you can see the D 1 is not conducting we have no circuit are we have no connection in this particular case, which is your figure 1 b figure 1 b right.

So, it is very easy to draw the equivalent circuit of the diode of the figure 1, right when D 2 is conducting and D 1 is not conducting, right. D 1 is not conducting; that means there is nothing here D 2 is conducting; that means, there is short here, this is the circuit, this is a circuit, figure 1 b. Now what we see in figure one b is that you have resistor R and resistor R in series, right that gives you 2 R, right. Or if we final if you further work on this particular circuit and you solve it what we find is that the equivalent circuit of this particular figure 1 b will be this one, right.

This is the voltage that we have minus 2 by 3 1. So, how it comes? If I consider this, right then the voltage at the non-inverting terminal will result in minus 2 by 3 of V I, minus 2 by 3 of V I; this is the circuit which is equivalent circuit of figure 1 b. Now from this particular figure what we can see? That after solving figure 1 c my V o will be nothing but minus V I, right if I solve further this figure right 1 c what will happen? V o will be equals to minus V I. This is what we get when we have D 2 conducting D 1 not conducting, right anyway. So, what will happen? So, hence for V I is less than 0, V o is positive for V I less than 0 your V o is positive, right.

And for V I greater than 0 we will see what is a V o we will see what is the output voltage. So, the point is that when we want to understand a full wave rectifier, the concept is super simple, and when we apply input voltage greater than 0 my diode D 1 is conducting, D 2 is not conducting, the circuit will be like this, when I apply V I less than 0 diode D 1 is off, D 2 is on. I have equivalent circuit like this, which is equivalent circuit to this and from serving this, we have V o equals to minus V I, right.

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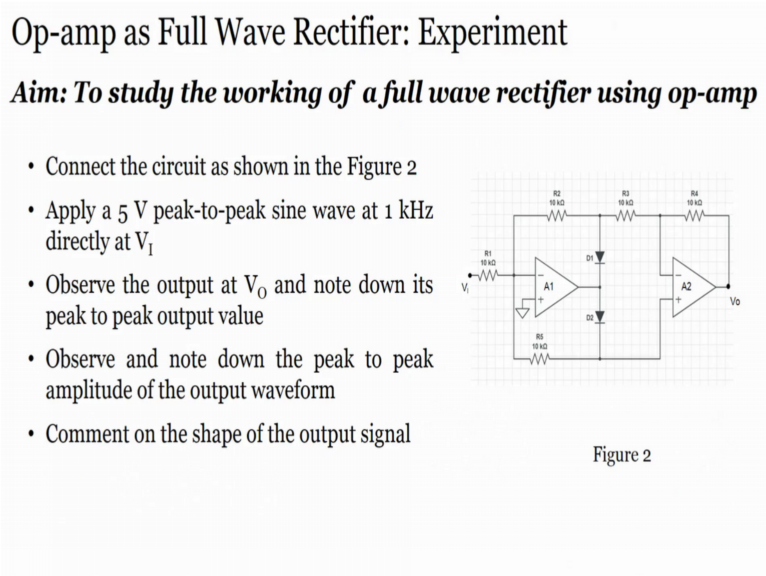


Now let us see the experiment. So, we had to first perform the experiment for the full wave rectifier for the full wave rectifier.

And here what we see is if I want to perform the experiment for full wave rectifier, I had to connect the circuit which is shown in figure 2 which is shown in figure 2. So, what we will do is, we will connect this circuit which is shown here, we have to see that we have to apply 5 volts peak to peak at 1 kiloHertz where we apply here 5 volts 1 kiloHertz, right at here. Observe the output V o, we have to observe the output here V o. And you will note down the peak to peak voltage value, you will note down the peak to peak voltage value. The same time will observe the amplitude of the waveform, you have to also observe the amplitude of the wave form. And then finally, as usual will comment on the shape of what? Comment on the shape of the output signal, right.

So, what we have to do? We have to connect the full wave rectifier, right in this particular configuration. And will apply 5 volts peak to peak sine wave and will measure the output voltage and we will also see the wave form. So, to this do this particular circuit, right what we had to do? We have to have 3 different things. One is for here we need function generator, we need function or frequency generator. Then we need output voltage to measure the shape comment on the shape we need digital oscilloscope, ok.

So, we need 2 things. One is functional generator and one is DSO and we have to apply biasing voltage; that means, we need we need what? We need the DC power supply. Now we will see how we can use simulation using Multisim tool to see the rectifying action of the signals. At the same time, we will also use T I board for the experimental part. T. Anil and Sitharam will take the experiment, and we will show you the experiment how it can be done. If you have any questions, feel free to ask me in the forum and I will get back to you.

Now, will see the working of the full wave rectifier using Multisim so, let me open Multisim, right. So, I will keep both side by side right. So, this is a circuit that I am going to build. For this I will take 2 Op-amps so, one Op-amp I am taking this, as well as other app. And this one this is e 1 rename it as A 1 and A 2. So, that it will be look similar to what we have seen in the circuit and this as A 2, right. Let me flip this, ok so, I will take all 6 5 resistors here. So, in this case we have used a 10 k resistances, 10 k this is 10 k, this is another 10 k. This is another one, and this is the other one, other resistor as at this point.

I will take 2 diodes, because since we are realizing a full wave rectifier it requires that 2 diodes. Let me place the both the diodes one diode and other diode here. So, I will make the connections. So, first R 1 has to be connected to the negative terminal and whereas R 2 the positive terminal of A 1 operational amplifier has to be connected to the ground, right. So, if you remember our circuits we will generally connect 2 resistance even at positive terminal of operational amplifier in order to remove the offset currents. Those resistance are the feedback resistance and input resistance.

So, in this case we have not connecting it, right. So, let me connect all the; let me make all the connections. And resistance should be of 10 k that is what the complete explanation the theoretical explanation was carried out by considering the 10 k. So, I will replace one k resistor with 10 k; that means, since it is a simulation I will simply change the resistance values 10 k, even this one as 10 k and 10 k, right. So, this negative I will be connecting it here whereas this to here, right. So, the input will be connected at in R 1 resistor. So, what I will do it as will take AC voltage. I am connecting AC voltage here the peak to peak value, I will be making it as 5.

So, peak to peak is 5. So, 2.5 is the peak value, and the other term will be connected to the ground connecting it to the ground. So now, the circuit it is ready. So, in order to visualize the input and output, and to do the comparison what we have to do is that we have to consider the props. So, I will take one at the input side, right other one at the output side. So, if you remember so, when one when D 1 is on, this is the complete the system will be. So, what happens? A diode D 1 is on, it acts as an inverter. So, that whatever input we have given you will get as an output; that means you will get the first peak.

Whereas, when D 1 is off during the negative when input is negative peak, when D 1 is off D 2 will be on, and this will be the circuit. So, finally, we will get a minus V I so, since this is also negative and this is also the negative in the output. So, both together we will get a positive peak, right. So, let us see whether we are getting the same response even here. So, in order to do that I have to go to split we will see and let me run, yes.

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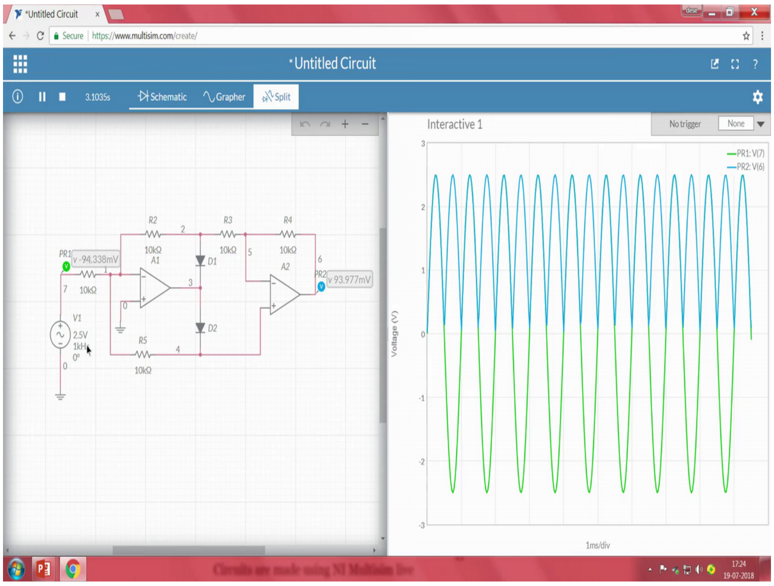


When we see here, right the green represents are input right where as the blue represents are output.

So, if I see that when you compare with half wave rectifier as well as full wave rectifier. During half wave rectifier, we will see the pulses only whenever there is first peak. Whereas, in case of here full wave even during the negative cycle the output will be you know converted into the positive cycle. So, that is the specialty of this circuit, as a result of pulsating circuit. So now, if you observe here carefully, even in case of the negative peak we are getting a positive pulse. That is because of you are this particular circuit. So, when we realize a complete circuit that the complete when the D 2 diode. So, that means, when you observe carefully during the positive peak of input signal the D 1 will be on and D 2 will be off so that it will it is nothing but a virtual ground.

So, as a result we will get a minus of minus. So, this is a minus and this is a minus, whatever we apply the same thing will get it as an output. Whereas when the D 1 during the negative half cycle, when the input is a negative half cycle, the D 1 will be off the D 2 will be on. So, as a result when we realize circuit it will become minus V i. So, it is nothing but minus of here input voltage. So, since input voltage is a negative so, minus of your input voltage will become a positive. So, the amplitude will become there will be changed in the phase of your amplitudes.

So, that is why you will get a positive peak even when there is a negative signal. As a result, you will get a complete a pulsation, right. So, let me change some frequencies, I will start with some 100 Hertz. So, we can observe so, to realize it was I will do is that, I will change this time divisions, even then you can see here and I will go with the 500, right same and 1001 kilo looks similar then I will go to 5000, right. We can clearly see that no matter what any frequency whichever the Op-amps can be operated. During that frequency, this particular circuit is completely converting into a full wave rectification.

Now, we will see the experimental working of the same circuit using T I board when we look into that a T I board

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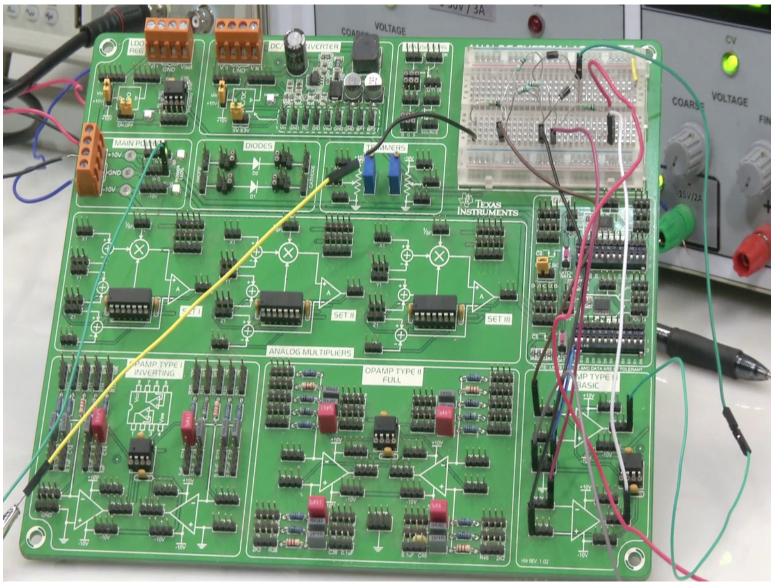

So, here we can see that complete construction of whatever the circuit that we have seen in the Multisim. So, we can see the both diodes here 1 and 2. And we have other resistors. So, total we have a total of 5 resistances here. So, all 5 resistances you can see here connected. And we are using this particular portion of an operational amplifier. So, since this is TL 082 we are using the both Op-amps in single IC. So, one part we are connected to the first portion and other, but we are connected to the other portion.

Now, when you look into function generator; so, we will be applying input voltage of one 1 volt peak to peak and a frequency of 1 kilo Hertz as an input to this particular operational amplifier so; that means, through the circuit. And we will see how what is a response, what is a response using CRO. So, let me connect the input to input to the circuit, right when we see when we see what is input connected to the on the CRO. So now, here we can see what is the input that we have connected to the circuit. So, that input we are generating using a function generator. So, the peak to peak voltage is of 1 volt and the frequencies of 1 kiloHertz.

So now in order to understand what how exactly the circuit output is of, we will connect the output of the circuit to CRO. So, let me connect it to the output. So, this particular pin is the output. So, when I look into the CRO, right here we can see the input is completely sine wave, we are getting the rectified output. So, we can see the pulsation. So, no matter what whatever the input we have, right whatever the frequency that we have we can completely see the first peak as well as the negative peak will be completely rectified and converted into converted as a positive peak.

And the amplitude remain same only thing is that the phase will be different. Now when I keep on when I change the frequencies, let me change the frequencies. So, I will go to frequency, I will I am just going to 2 Hertz. So, here we can see 5 Hertz sorry, 3 hertz even then it remains same, right. Now it is an 5 Hertz, 6 Hertz, 5 Hertz you know. So, let me slowly decrease to the lower frequencies to right. Still the input is of sine wave, but output you can see the pulsation output. So, that means, whatever the input frequency that I am applying as an input right, as long as it is a sinusoidal signal the negative peak, the negative pulse will be converted into a positive pulse so, as a result will get a pulsation output.

Thank you.