Op-Amp Practical Applications: Design, Simulation and Implementation

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Lecture – 09
Op-amp Applications: Half Wave Rectifier

Welcome to this module. So, here we are changing us our gear to some other application of the operational amplifier, because there is idea that we start from simple things we end up in little bit complex things right and were able to design, design and solve the circuits related to the operational amplifier. And these are the applications also for the operational amplifier.

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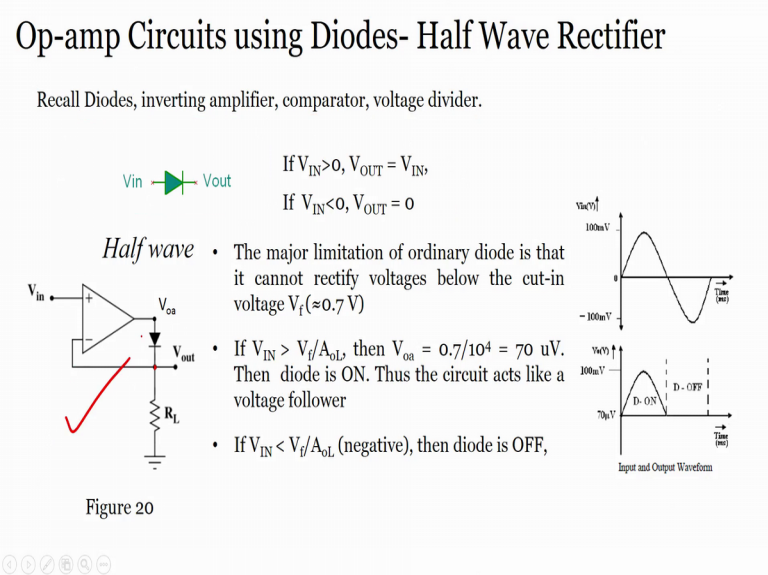

Figure 20

So, if you see on the screen, this slide shows the Op-amp circuits right using diode. And using this we will create we will design a half wave rectifier.

So, what exactly a rectifier means right and why it is called rectifier? So, it will rectify is it will correct, right what it will correct? It will correct the signal why they has to correct the signal, because the input is AC and we want output to be DC or DC that is why I am not doing anything right frequency is 0 or pulsating DC. In half wave rectifier, we can rectify half wave and we can allow the another half to pass. Where full wave rectifier we can rectify the full wave. We can have pulsating wave rectifier and we can have lot of

other rectifiers that we will see in few other modules, right now let us focus just on half wave rectifiers.

Now, all we know is about the diode, what is this? Diode; what kind of diode you see here p-n junction diode, p-n junction diode, right. What is this pin, what is this pin? This pin is anode; this pin is cathode, right. We have seen the diodes. If we have a diode with us here anyway we will see it when we will see show you on the on the circuit board.

Now, p-n junction diode, the diodes inverting amplifier we should know diodes, how inverting amplifier is used, how comparators are used and how voltage divider is used? Right, we have seen each of them, diodes we I am assuming that at least you know diodes, right which if you do not know that is fine do not worry about it. Diode is nothing very simplest way of component that we can use. And the idea is very simple, that if use diode right we can operate the diode when we apply voltage of 0.7 volts, it will start operating, alright.

Now, if here you see here what we are assuming here; if it is a comparator or is a diode right. So, V in is greater than 0 V out equals to v in, V in is less than 0 V out equals to 0. That is we are assuming, alright and this is actually correct. Now the major limitation of ordinary diode is that it cannot rectify voltages below the cut in voltage 0.7 volts; because it requires 0.7 volts to operate. So, it cannot do anything which is less than 0.7 volts. And there is a limitation of the ordinary diode, right.

So, suppose you are asked in your interview, what is the limitation of ordinary diode? Immediately you can say that limitation of ordinary diode is that it cannot rectify below the cut in voltage of V f in case of half wave rectifier. What is your V f is your operating voltage 0.7 volts is the minimum voltage to operate you diode, right.

Now, if your V in is greater than v f by A o L, then V o a is 0.7 by 10 raised to 4, right 0.7 is this voltage 10 raised to 4 is the open loop gain of the operational amplifier. So, when you get this, you get the voltage 70 microvolts. Now where is this V o a comes into picture? You have to understand this circuit. Look at the circuit, this circuit is nothing but we have connected a diode, right we have this inverting terminal connected to the cathode of the diode, and then we have a load resistor.

So, if I want to measure V o a here, then what is the V o a so, that my diode can start operating could be about 70 microvolts, right. So, then the diode is on, right. Thus the circuit acts like a voltage follower. If this diode is on; that means, my voltage circuit become voltage follower, right. When diode is off then it is a problem. That actually problem in this particular case I am just telling that I cannot consider it is a voltage follower if my diode is off. But if my diode is on; that means it is conducting. If conducting then it is similar to a voltage follower, right.

So, if V in is less than v f by A o L is negative, then my diode is off. So, if I apply this V in voltage you see V in is 100 millivolts, minus 100 millivolts peak to peak voltage. So, when this positive becomes my diode will start operating, because it will be greater than or equal to 70 microvolts. But if it goes negative, V in is negative then my diode cannot operate it will be off, when it will be off you cannot see anything here. Diode is on it will pass diode is off nothing is there, correct. So, this is the input and output waveform of the half wave rectifier, half wave. It is only rectifying the half wave, right that is why it is a half wave rectifier.

Now, this is the input of the half wave rectifier. This is the output of the half wave rectifier; input of the half wave rectifier, output of the half wave rectifier right. Now how to operate this operational amplifier as an half wave rectifier, how to implement using the breadboard, and can we see the change in signals, right. That is our question. So, let us see a circuit that we can design right a half wave rectifier circuit that we will design and we will implement it on the breadboard right using this particular circuit. Let us see in this is in the next circuit what were circuit we are using right in same circuit.

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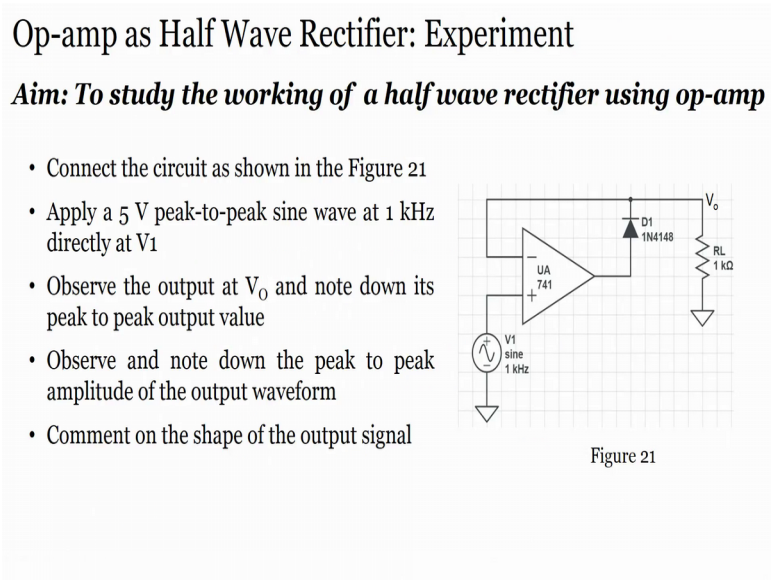

So, if you see here, the idea is that we have to study the working of a half wave rectifier using operational amplifier. Already we know right performs various operation. If we have already considered how this half wave rectifier works, when V in is greater than this diode will be on. V in is minus negative diode will be off. When diode off is there it will not pass, when diode is on this will be voltage follower, right we have seen. What we have to do to implement the circuit and how what we will apply as input and what kind of output we are measuring? Let us see.

First is you connect the circuit as shown in figure 21, ok connected. Now what now you apply 5 volts peak to peak sine wave at 1 kilohertz. Apply 5 volts peak to peak sine wave at 5 kilohertz; that means, that we will apply here 5 volts, 5 volts is peak to peak right, and sine wave is there and the frequency is 1 kilohertz. Where we have to apply? Apply at V 1. Observe the output voltage V o observe the output voltage V o and note down it is peak to peak voltage. Note down it is peak to peak voltage very easy, right? What you apply 5 volts 1 kilohertz observe the V o.

Now, observe and note down the peak to peak amplitude of the output waveform, ok. And then we have to as usual comment on the shape of the output signal. Comment on the shape of the output signal. So, here what you think; what kind of equipment we will require? We require of course, the component that we require is an operational amplifier, the component that we require is a resistor which is a load resistor of 1 kilo ohm, right.

The component that we require is a ordinary diode or p-n junction diode, here in their number is also given, right? The component we require is the connecting wires. And then equipment that we could add is equipment, that we require is function generator one. Second we require oscilloscope, right. And if we are using operational amplifier, then we have to apply the bias voltage. So, we require DC power supply.

Using only 3 equipment every time I am showing you multiple application of the operational amplifier. Now in this we will look at the experiment part and simulation part. So, if you guys remember we have talked about a half wave rectifier. Now we will see how we can use simulation by using Multisim tool to see the rectifying exchange of the signals. T. A. Anil and Sitharam will take the experiment and will show you the experiment how it can be done. If you any questions, feel free to ask me in the forum and I will get back to you.

Now, we will see the working of the circuit in Multisim, let me open Multisim.

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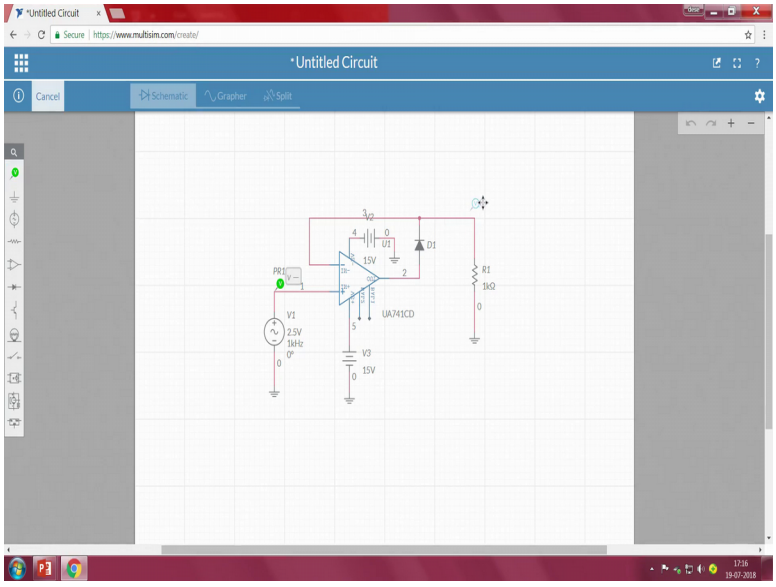

So, I will take an Op-amp. So, I will take 741. Now if I look into the details in the symbol. So, v s plus is positive v ss and v s minus is negative v ss. So, I will take sine wave say AC voltage which access sine wave and let me flip this. So, to the positive I will be connecting it to sine wave, right. And the peak to peak voltage; the peak voltage is of 2.5 I am saying. So, peak to peak will be 5 volts. The ground will be connected to

the other terminal of a source. And I will take a diode since it is a half wave rectifier. We should always have to have a diode and rotate.

So, let me connect. I will take one more one k resistor which acts as a load. So just to visualize our signal so, I will be connecting it to this point and take a ground and connecting here. So, since this is 741, it and we are you know taking an Op-amp which is 741. So, it always have to have a power supply of plus v cc and minus v cc. So, for that reason what I do is that I will take a power supply.

So, I will take DC voltage, and since this is a negative terminal I will connect the negative of this to here. And this I will be making it as a 15 where as the positive should be grounded. So, since a negative terminal of power supply is connected to the minus v cc terminal of 741. So, even though it looks like 15 volts, but it is actually minus 15. And similarly I will take another power supply DC voltage for applying a positive v cc to our 741. And another terminal should be connected to ground. So, this acts as your saturation or power supply units to your 741.

Now, to visualize the response, what I do is that the green the probe the green colour probe will gives you the response of the input signal; whereas the other probe sky blue colour will gives you the output response. So, we will see analyze whether it is doing a rectification whether it is performing a half wave rectification. So, just let me keep it in a split and let me run it once, yes.

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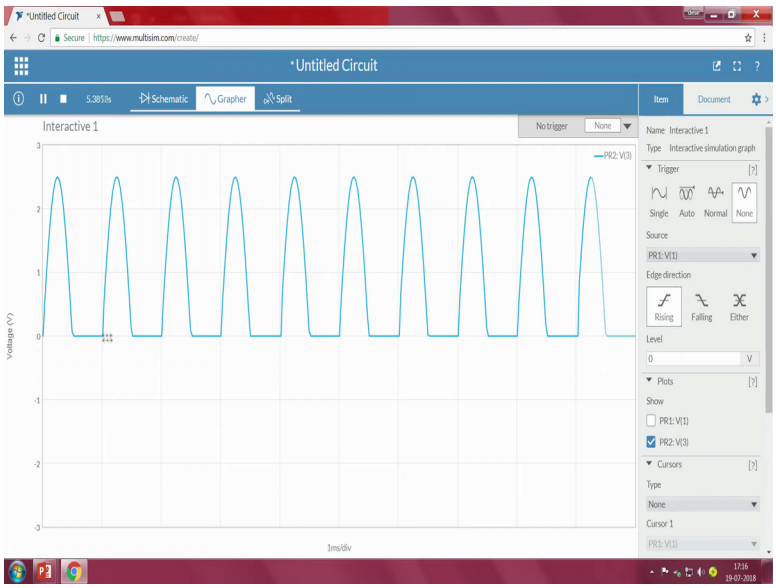

Now if I see here so, if you recall the green whatever it is representing is nothing but our input. So, what I do that right now let me disable PR 2. So, we can see here 2.5 is the peak. So, we can see it is going to 2.5 and minus 2.5. So, peak to peak is 5 volts.

And when I put when you disable PR 1 and enable PR 2 we can see that the output. So, when we see the output, it is completely right the negative peak of our; the input signal is completely removed; that means rectified. So, basically since it is an half wave rectifier and we are using a single diode. So, the negative peak of this particular input signal will be completely removed. So, let me change the frequencies and we will analyze.

So, I will just keep it to somewhere around 100 Hertz, I will start with 100 Hertz, right. So, because of that let me change it to scale, and this I will make it as auto. Then I will go with the 200 Hertz, right. Still it is performing same 500 Hertz is, right even we can see the rectification very clearly. 1K, 1000 you can see even that.

Then I will go with 2k, right and I will go with a 5k, right. So, no matter what whatever the frequency that we are using, right it is completely rectifying the input signal, input sinusoidal signal to only the negative peak will be completely removed, right. So, this is how we can understand about the working of a rectifier, half wave rectifier. If I want to implement this thing on the breadboard let us see how it looks like.

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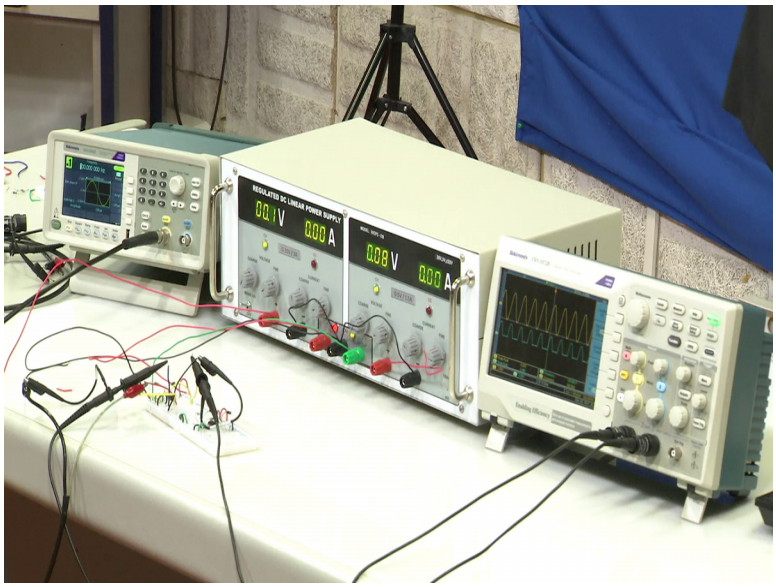

So, will see on the breadboard so, again Sitharam is here to help us. And he will show it to you on the breadboard, you can see that we have the half wave rectifier. If you can focus on this particular side, and if I see here there is a diode, right diode. There is a anode and there is a cathode. So, he is holding the breadboard and you can see very clearly there is a anode which is this one. And silver one is a cathode, right. Silver lining you can see, black is longer is a anode, ok.

Then we have a load resistor r l, we have a buffer which is here. And it will act as a buffer it will act as a voltage follower when this diode is on. When the diode is off it will not conduct, it will not be working as a voltage follower. So, that means, that I will apply input signal, and I will see the output signal on the oscilloscope. Now for this first thing he has to do is he has to connect the DC power supply plus minus 15 volts, right. He has to give to the operational amplifier. So, he is trying to give the plus 15 volts and minus 15 volts to the operational amplifier. And he is successful I think, but he has to start the power supply, nice.

Now, we are applying an input signal right which is 5 volts peak to peak at 1 kilohertz. Let us see the frequency generator function generator please. Say if I see the function generator, I will be looking at the frequency which is 1 kilohertz. And what is the voltage? The voltage that I have applying here is 5 volts, right. Voltage is 5 volts frequency is 1 kilohertz, alright. For this particular voltage and frequency, let us see the output on the oscilloscope.

Now, you see this is sine wave, alright. So, he is connecting now the output, another one is ground, the probe is connected to the oscilloscope. And you are able to see the output from the oscilloscope, let us see how it looks like, right. So, if you focus on oscilloscope, you will be able to see your input is yellow color which is signal right 5 volts, right and the output is half rectified you can see what is the peak to peak voltage now. It is half of what we have applied, right. It is half of what we have applied. That means, this particular circuit is rectifying half of my signal and that is why it is called half wave rectifier. If it rectifies full of my signal, full signal it will call full wave rectifier.

We will see the other the rectifiers in the following modules the; right now just focus on this, and what you can see is at 1 kilohertz frequency I can see the operation of half wave rectifier which is the voltage is half of what we have applied at the input signal. If I

decrease the frequency, now what will happen? Let us see if I decrease the frequency, can you please decrease the frequency? Can you decrease the frequency please? 100 Hertz, see at 100 Hertz also please change your output on y axis. So, that it is different than input yes easy to see. Do not put on it, that is it.

So now you can see very clearly, right? At lower frequency also we are able to see the rectification we are able to see the half wave rectification, right. A different frequencies we are able to see half wave rectification at; and the voltage is half of what we have applied at the input, right. So, same thing we are looking in case of half wave rectifier. We have seen that by using half wave rectifier, we can rectify the signal input signal right half part of the input signal and if we want to rectify the full part we have to use another rectifiers, alright.

So, the point is that this particular experiment tells us how we can rectify the signal. So, where we can use this rectification? When we are getting AC voltage and we are stepping down this AC voltage from the transformer, and we have to give DC voltage so, AC to DC. So, this particular DC power supply that you see also has a rectifier, right. That is why is a DC, but we apply right the power that I am giving, power I am, that I am giving is AC right.

You can see in my hand, if you can zoom out? Yes, this is AC power supply AC voltage given to the DC given to the DC power supply. So, it is converting my AC to DC using a transformer using a transformer, that will convert the AC voltage to step down, and then rectifying it to apply to get me the DC voltages, right. So, application of these rectifier is in front of you, but is it a half way rectifier is there a full rectifier, yes, alright. So, the point is now you can see operational amplifier can also be used as a rectifier, right.

So, if you go back to the screen, I think this is my last slide for this particular half wave rectifier. And let us see one more thought by William Burroghs, the purpose of technology is not to confuse the brain, but to serve the body. Very important, right purpose of technology is not to confuse the brain, but to serve the body. So, you see I will take the half of the sentence. The technology of what we are using right now right is we are communicating, right. So, we are communicating through the NPTEL video, NPTEL platform, right.

And you can see the advantage of that we are using advantage of the technology, right. And we are trying to show you the experiments, showing the experiments whatever we have studied in theory, right so that you are not confused further. If the technology is meant to confuse you, then it is very difficult to understand anything, right.

The technology should be easy, right. You may be using Facebook, right, WhatsApp, is it easy? Anyone and everyone can use it right. So, technology is not really, but if you want to understand how it operates, it is really difficult, right. But use is very simple, right use is very simple. So, using this platform that we have got right, I have got to teach, you have got to understand, right study then we can use together this technology to make our life simple and to understand electronics in much more easier way, right.

So, with this thoughts for today, for this particular module. We will stop at this particular time. And I will see you in the next module with more application of operational amplifier, right. In terms of rectifiers, we have seen today half wave rectifier, we will see few more rectifiers in the following modules, right. Till then you guys take care, and I will see you in next module. Bye.