Integrated Circuits, MOSFETs, OP-Amps and their Applications
Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture - 46
Experiment To study input and output voltage range of an Op-Amp

Welcome to this module. in this particular module, we will be understanding what exactly input and output range of an operational amplifier is. Now, last modules we have seen inverting and non-non-inverting amplifier, right. to understand the input and output range of an operational amplifier, you can use the same circuit which we used for the non-inverting amplifier.

So, let us quickly see how we can measure the input and output range using the non-inverting amplifier circuit right; that means, that we apply a signal at the input of the non-inverting amplifier; that means, non-inverting terminal of the non-inverting amplifier, and we will see the output corresponding output for that input with respect to the gain that, we have set um, so, let us see the screen first.

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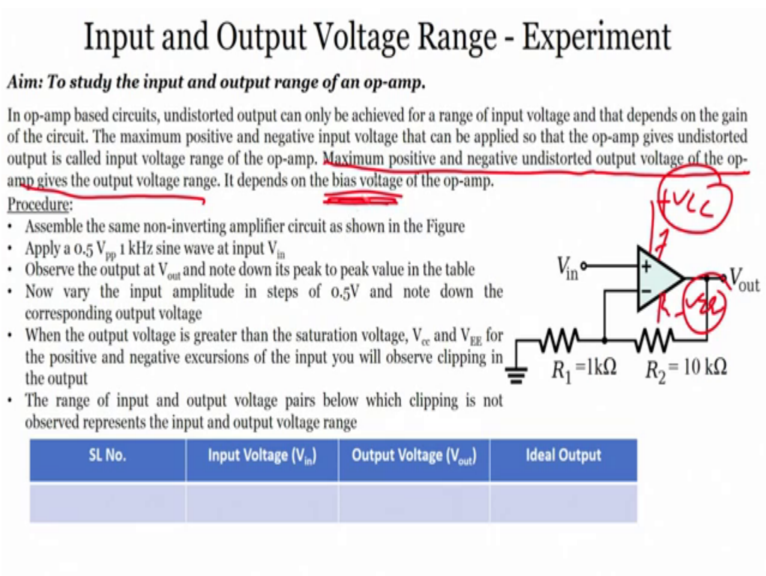

And let us understand what experiments we are going to perform. the experiment is to study to study input and output range of operational amplifier, alright. So, in op amp circuits undistorted output can only be achieved for a range of input voltage, and that depends on gain of the circuit. We have already seen this, that when we apply input signal and the gain of the circuit is high, right the output will be distorted only when it exceeds the bias voltages, exceeds the bias voltage, bias voltage is plus minus 15 volt.

So, the maximum positive and negative input voltage there can be applied so, that op amp gives undistorted output is called input voltage range of the op amp. It is very easy, let us understand once again, the maximum out positive and negative input voltage, right? Positive we can apply a negative, we can apply because we have bias positive bias negative bias. there can be applied so that op amp gives undistorted output undistorted output is called input voltage range of the operational amplifier.

Now, let us see what is the next definition. Maximum positive and negative undistorted output voltage of the operational amplifier gives the output voltage, so easy right; that means, what it depends on it depends on nothing but the bias voltage, it depends on the bias voltage of the operational amplifier; that means, that whatever voltage we are giving to pin 7, pin 4 plus Vcc minus Vee, this voltage, it depends the output and input voltage range depends on this particular voltage, alright.

So, for understanding this input and output voltage range, right; this is a procedure we will use the same circuit if you remember, the circuit this is circuit of a non-inverting amplifier, alright. And what we will do? We will use the circuit which is here apply 0.5 volts peak-to-peak 1 kilohertz, sine wave at input terminal input terminal is V in, right?

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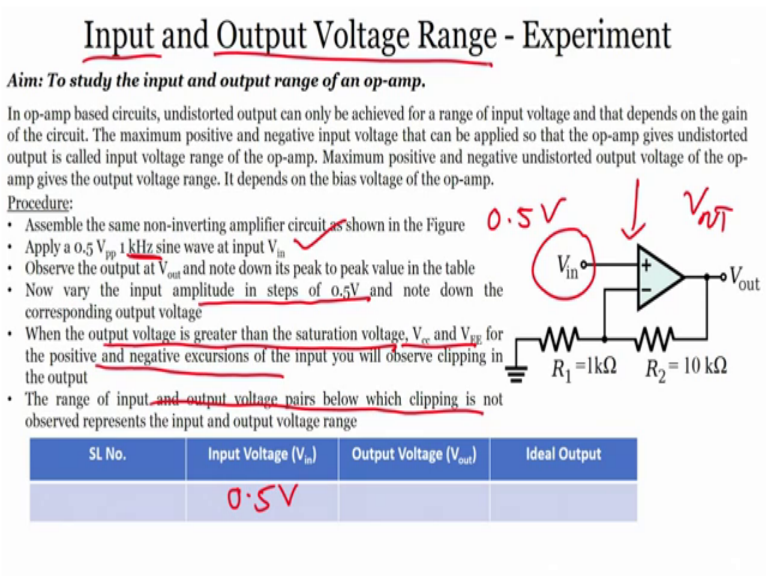

Here we will apply 0.5 volts peak-to-peak frequency, we can have 1 kilohertz, right. And we will keep on increasing this in a step size, see one once you apply 0.5 volts we will see what is the output voltage V out, right. Then we will apply another we 0.5 to 0.5 that will be 1. So now, we vary the input amplitudes in steps of 0.5 volts and note down the corresponding output voltage; that means, initially 0.5, then 1 then 1.5 then 2 then 2.5.

Now, one very important thing is, when the output voltage is greater than the saturation voltage, Vcc and Vee for positive and negative excursions of the input, we will be observing a clipping at the output have not we observe. The clipping we observe the clipping in input inverting amplifier, and we have observe the clipping at the for the non-inverting amplifier.

When the input signal in inverting and non-inverting amplifier, right, where 1 volts or 2 volts and the gain was about 12. So, 2 into 12 would be 24, right 24 volts we cannot see at the output because the bias voltage that we are giving is plus minus 15. So, it is so easy to understand, so easy to remember; that means, that the range of input and output voltage pairs below, the edge clipping is not observed represents the input and output voltage.

Now, if you see this particular table what we have to write we have to write input voltage. So, let us first input voltage we write 0.5 volts, what is the output voltage what is the ideal output, alright? This when we measure we can understand the input and output voltage range. So, we can perform this experiment in any laboratory condition, when I say any laboratory condition, means with minimum equipment if you have which is your DC power supply, a function generator or oscilloscope op amp breadboard, and some connectors to connect it. Then you can perform the experiment very easily, or all set of experiments in fact, that I have I will be covering and I have already covered in this particular series or modules.

So, let us see now on the breadboard of the non-inverting amplifier. So, if you see you can see on the breadboard, that there is already a circuit which is non-inverting amplifier that we have seen in the last module, I have not changed the circuit because there is no use of changing. The circuit for understanding input and output voltage ranges what we have to see now is if we apply input voltage of 0.5 volts 1 kilohertz what will be the output, right.

We see input we see output, we increase the input we see change in output, we keep on increasing input we see keep on increasing the output. But that output will clip at one point which is more than the bias voltage, right. Or it will be the output clip little bit less than what the bias voltage is, that is 15 volts it will clip somewhere around 13.5 13.6, we will see, alright.

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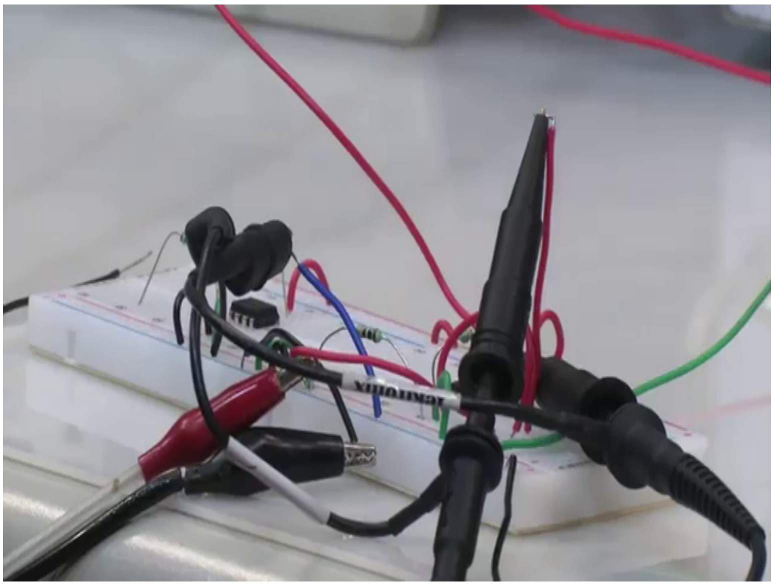

So, let us let us apply 0.5 volts first. So, again Suman is going to help us. So, Suman can you apply please 0.5 volts to the function generator.

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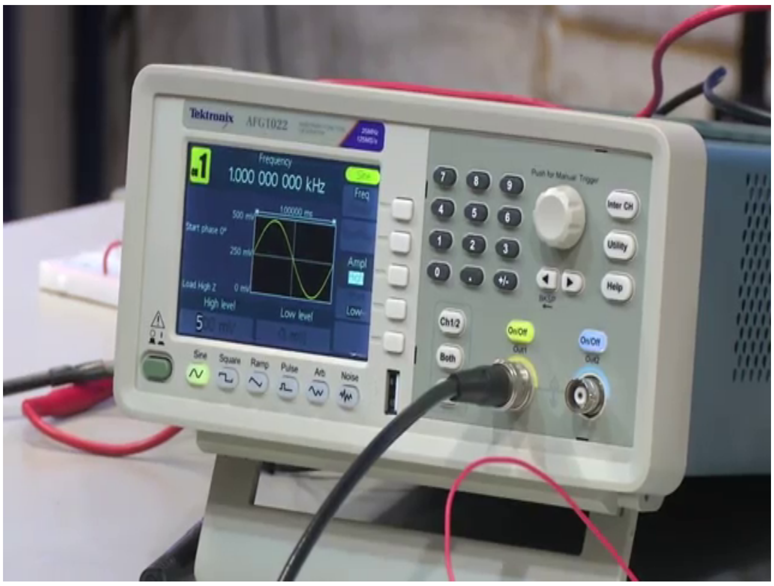

Yeah ok, so now, you can see it is already 500 millivolts, or we can say 0.5 volts at 1 kilo hertz frequency applied to the non-inverting amplifier of the non-inverting operation amplifier.

What we see at the output, we see at the output this into gain, right? So, we see about 6 volts 6.2 volts at the output.

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You can see blue color thing, right? 6.2 volts at the output, and the input is yellow one peak to peak 540 millivolts; that means, still the output has not been clipped so, 0.5 is ok, right, this depends this depends on your gain. So, do not forget, if you set a gain extremely high, then even 0.5 will be your voltage range.

So, anything below 0.5 only you can use it as the input voltage range so, that depends on your gain, alright? If I if I keep my gain around 11, then 0.5 times 11 would be somewhere around 6.5 or 5.5, right? 5.5 so, it will give us approximately 6 volts, because I told you last time of the resistors mismatching the value of the resistors are not accurate, that is why. Now, let us increase t o 1 volts. So now, he is increasing the voltage to 1 volts 1 volt he has increased right.

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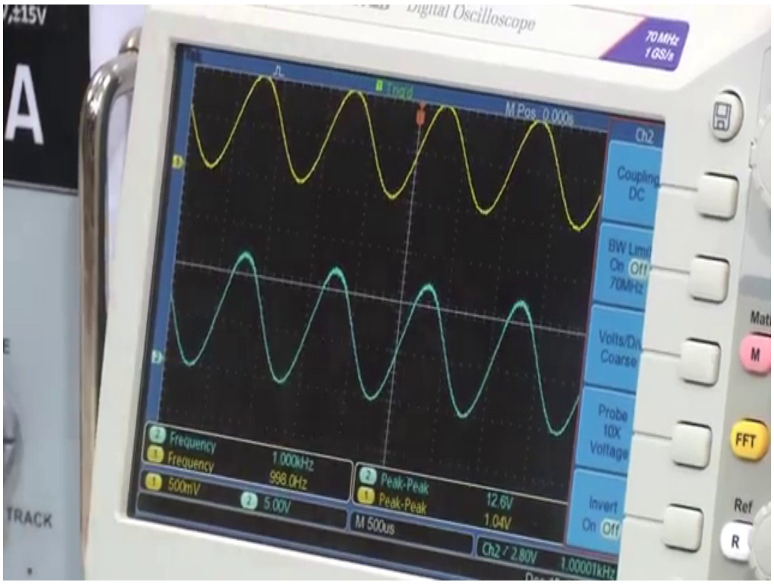

So now, when we apply 1 volt what is output let us see in the oscilloscope. 1 volt the output peak to peak value, output peak to peak value is difficult for me to see. So, I cannot tell let me see it is about 12.2 volts, alright. 12.2 volts yeah now it is better. So, around 12.6 volts right. So, an input of 1.04, we are getting output of 12.6, still it is not, still it is not clipped, still it is not clipped, why because, still this input or the output signal is less than the bias voltage, is less than the bias voltage.

Now, let us see if we increase it by another 0.5, that is 1.04 or 1 volt to 1.5 volts. So, he is changing again the frequency generator the signal from the frequency generator which is now 1.5 volts 1.5 volts, now for 1.5 volts, you will immediately see what is that? See this is the for levelling the signal, right. We have seen how oscilloscope works this digital oscilloscope right.

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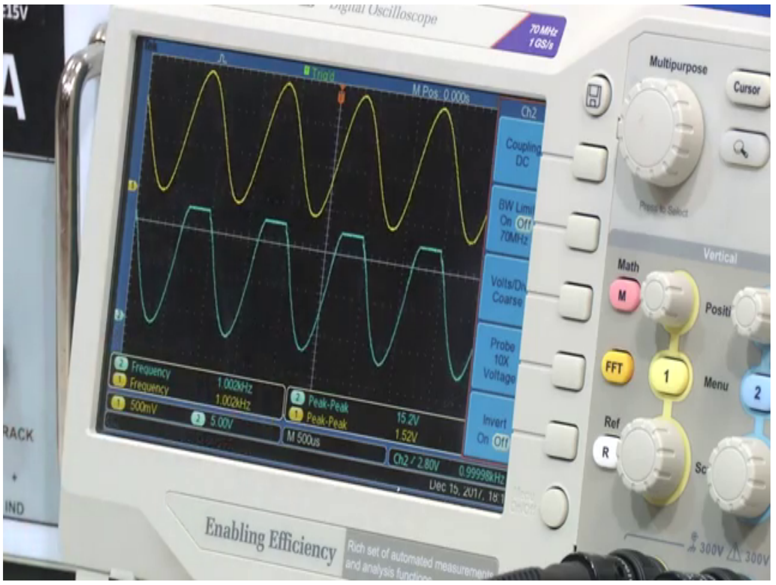

And now we can see there is a clipping, clipping occurring, right. Because the output peak to peak you see is around 15 volts, 15 volts very close to our bias voltage, suddenly, we will see the clipping; that means, that from this kind of experiments, we can easily find what is the input voltage range, what is the output voltage range?

So, this is extremely simple experiment, you can perform within 5 minutes, within 5 minutes of your time you can you can understand what is the input and output voltage range of the of the integrated circuit, that is your operational amplifier and also remember that it depends on the on the bias voltage that you are applying, alright.

So, let us quickly move to the next section, because we that is also very important which is call your voltage follower. Lot of time we have been studying voltage follower, we have been looking at voltage follower circuit, isn't it?

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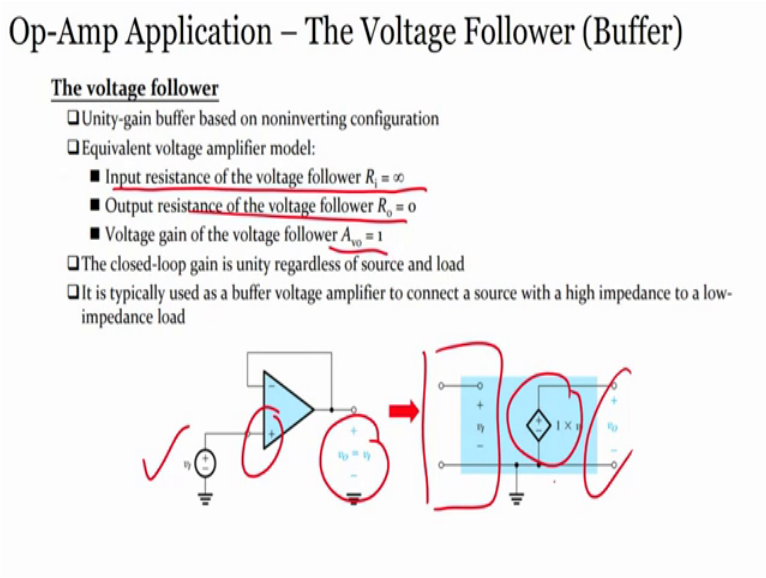

So, what exactly this voltage follower is, we know that voltage follower we use, it we use as a unity gain amplifier ah, right the equivalent voltage follower model, if you want to draw we can draw it as you can see on the screen, right. That this is a voltage follower we are applying input at the non-inverting terminal, and we have to just shot the output with the inverting terminal.

So, whatever the voltage will be at the input, the same voltage will be at the output you can see here, whatever voltage will be at the input same voltage it will appear at the output the input resistance of the voltage follower is infinite, right. The that is how we can draw the equivalent circuit, alright, or equal voltage amplifier model.

So, output resistance of a voltage follower is 0 output voltage is 0, gain is 1. So, we have drawn gain equals to 1. Very easy to actually understand the amplifier model. Um now what main thing is, what I want to tell you about the voltage follower is that where we use this amplifier it is a, it is very important to understand that once you know what kind of amplifiers you have, what are the practical applications of this amplifier, right?

So, or where exactly in which kind of circuits which kind of electronic modules you are going to use voltage follower. Or you are you going to use suppose you we all have studied if you talk about BJT, right. Common emitter amplifier, common base amplifier, common collector amplifier, right, common collector amplifier nothing but voltage follower again.

So, let me give you an example. So, yeah, right now we in India, right? We all are in India, we see a state called Gujarat, right, or Himachal Pradesh. So, recently it went through voting a lot of elections was going on, what happens under there is a voting? What happens that there is a leader, right.

He will come or she will come he will tell you or tell the people address the people address the public what is their 5 years plan, what is the next plan, what are they going to do, what not they are going to do, whatever the idea is not to not to understand how the election works the idea is that when they speak they are using mike see, I am also using mike is here, right they also use mike, isn't it?

So, what is the how this signal from my from the mouth goes to this mike through mike there is a electronic module, and it transferred to this speaker that finally, is a speaker which kind of circuit can be the input circuit here, and which kind of circuit can be output at the speaker. So, this is how we have to understand. From electronics point of view that common emitter amplifier, it has a high input impedance where it can be used. Common collector amplifier, right, it is a voltage follower, but can increase the current is follows a voltage, but current is amplified, right?.

So, where it can we used so, this is the very easy way of understanding you see when you connect your electronics with real life application it becomes extremely easy to understand. So, in case of this elections, when a leader is speaking he is using mike, right. So, the input signal the input circuit to the amplifier, right, can be a common emitter, amplifier electronic model input would be common emitter amplifier, yeah, I am just giving an example ok. The output is at the speaker right, so, there we require voltage follower, that is what we are learning right now how voltage follower circuit works, and how we can measure what is voltage follower circuit what is the voltage at the input what is the voltage at the output, that is the goal. That is the goal of understanding voltage follower, alright.

So, always try to understand that if I learn this particular circuit where I can use it alright. So now, let us quickly see if I have a voltage follower, and if I have not to do a experiment using a voltage follower, it is super easy you have to just use the circuit; that means, you have to connect the operation amplifier in the in the as shown in the finger.

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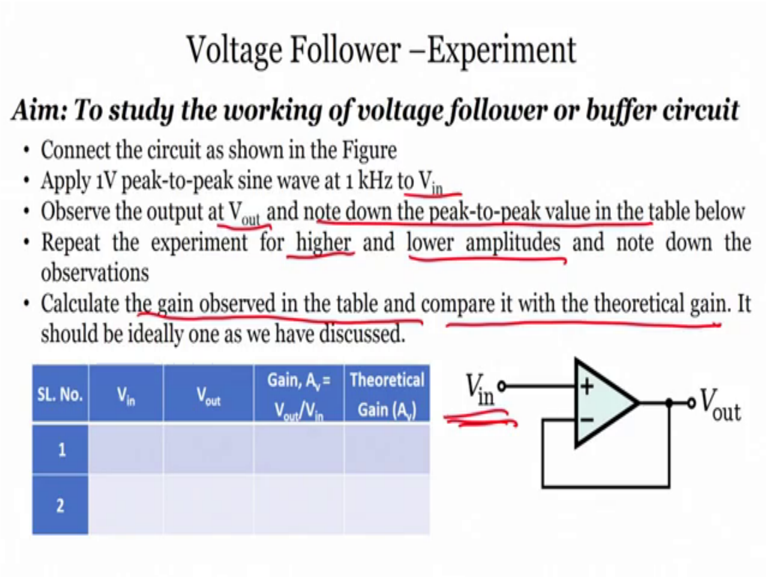

Then apply 1-volt peak-to-peak sine wave at 1 kilohertz to the input V in here, right. Then observe the output V out and note down peak to peak value in the table, right. Now repeat the experiments for higher and lower amplitudes, and note down the observations. Finally, calculate the gain observed in the table and compare it with the theoretical gain, right? So, this is what we have to do.

So now if you see again we have to use the breadboard, you have to use the breadboard. So, we are now understanding the voltage follower circuit which someone is, right. Now helping us. So, he will connect the voltage follower as shown in the screen as shown on the screen on the breadboard.

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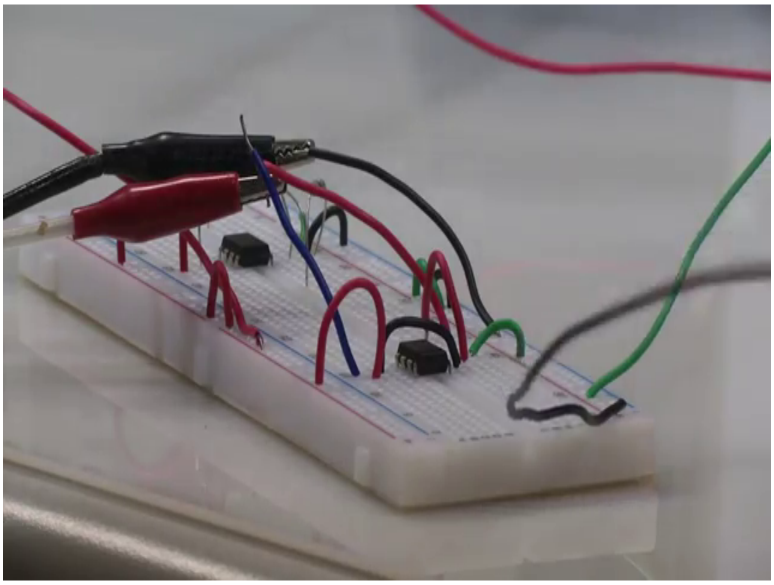

So, what he is doing he is connecting first he is applying the bias voltages plus minus 15, right? Plus, minus 15 so, in any time of a year in any time of year see this I am giving example because the lecture is around this time of a year where there is an election season. But you have to always understand and take an example any time of a year, how can you justify whatever knowledge you have obtained, right, in terms of explaining to a person who does not know see what I believe is the simplicity the way you can explain to a people in a simple way as possible the better you know, right?

So, when you when you want to really know whether you have understood or not try to explain the same thing to a person who does not know electronics. If he is convinced that what you are telling it makes sense, then it is you already know the subject, you can you can you can explain to people, right. It is very important that you try to put those things try to put the wordings in a simple form as possible, right?

So, life is also guys very simple we try to make it complex. So, do not do not really make your life complex same economic systems is very simple analog circuits VLSI ah, a technology or you can say microcontroller or you can say embedded IoT, we learn lot of things, which are really interesting. But when we make it our goal to understand in a easiest way possible and to further explain our friends, right, families or who are is interested in a simplest language it becomes extremely important.

So, voltage follower like I said I have given you an example, what about amplifier? Where we can use the amplifier right. So, give live examples, it becomes interesting alright. So, now we can see the voltage follower on the breadboard so, we have seen the circuit it is already connected, and what we will be doing we will be applying the input voltage, input voltage from the frequency generator, from the function generator here, right?

So, what is a voltage? We have to see, and then correspondingly what is the output voltage we will see, alright. So,. So, when is connecting the oscilloscope to the output, now all of us know, right. how to connect the ground you see there are 2 probes, one is longer one is shorter one just to help you out shorter one goes to ground longer one goes to the signal. So, output signal we have to measure when we apply the input voltage. You can start this ok, can you please adjust the output wave form? Yeah, change the amplitude of the output. Can you press the auto scale? See there is a very easy provision yes, alright, nice.

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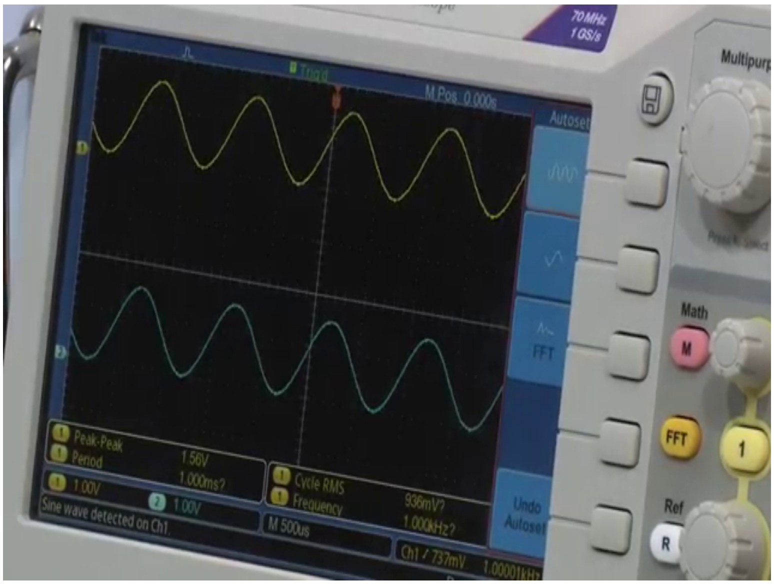

So, see guys try to understand oscilloscope, right. In case out of any reason you are not so familiar or you feel that you know how to adjust the things, just press auto scale button if there is one on your oscilloscope. It will auto scale it and it will be very easy for you to understand.

So, what we are looking at, we have applied 1 volts peak-to-peak, right. around 1 kilohertz frequency at the input is it 1? 1 volts can we apply 1 volts, please 1 volts at the input peak to peak and the frequency is about 1 kilohertz is it? Yeah, yeah, so, 1 volts peak to peak 1 kilohertz, and what is output? We see the output, please.

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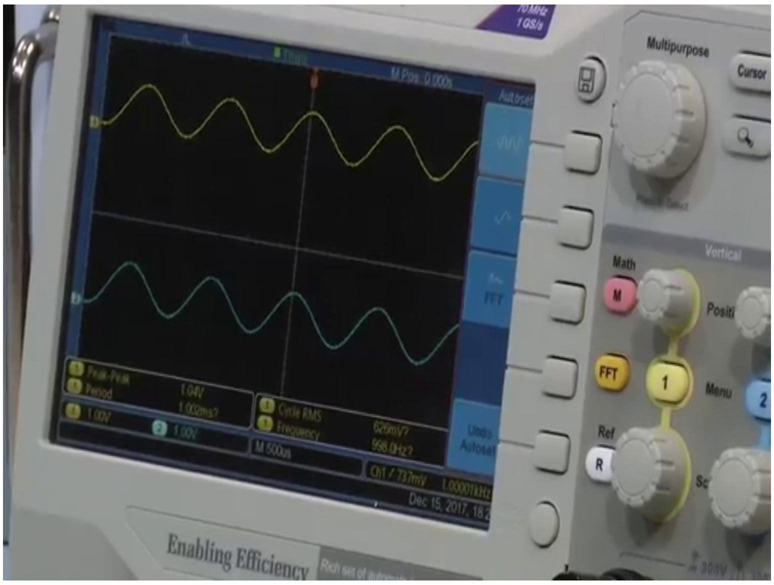

So, output will follow the input voltage follower, output will follow the input without any amplification, without an amplification.

So, if you if you see the voltage, right? Peak to peak voltage at the input and output DC channel 1, and 2 can you see here channel 1 and 2 it is right over here one and 2, right? 1 and 2, you see voltage is same, voltage is same, voltage is following input say voltage at output. So, voltage follower; that means, this circuit can be used to follow the voltage which is about the input, right. It will have the same voltage at the output. They I have told you the application you learn more, where exactly this voltage follower is used, why it is also called a unity gain amplifier, because the gain is unity.

But also, none it is also called buffer, why it is called buffer? Right, so, like I said when we when you when you understand or when you listen to new terminologies, try to understand why it is called buffer, why unity gain amplifier, what is the role? What is other role of this particular voltage follower in other practical applications, right? So, when you when you try to correlate your knowledge with a practical applications, you will understand more.

So, try to get more examples about unity gain amplifier, alright? So, we will just complete this particular module at the for the on the voltage follower circuit, and we will I will teach you the next circuit which is just summing amplifier. So, what exactly is summing amplifier, what is the role of summing amplifier.

So, for now I will see you in the next module, take care. Bye.