Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture - 45
Experiment op amp as non-inverting Amplifier

Alright, welcome once again. So, last module we have seen inverting amplifier. This module we will see non-inverting amplifier, right.

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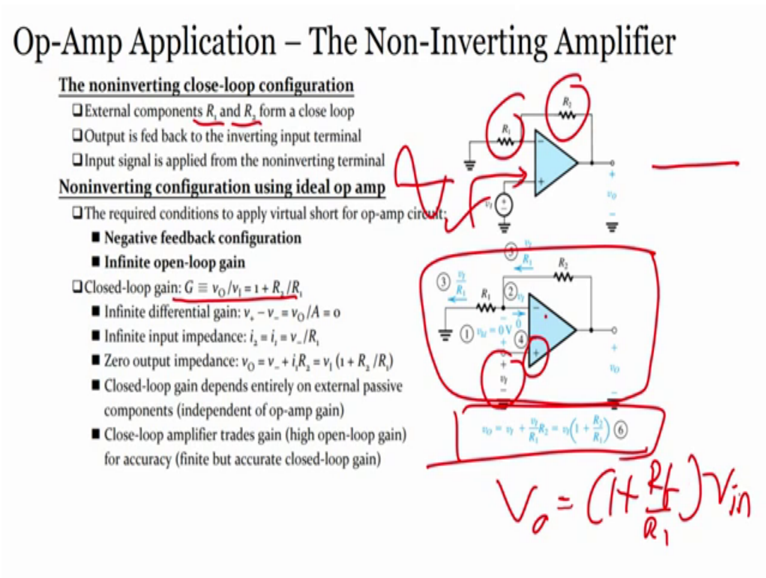

So, let us quickly see the screen, and what we see here? We see here a circuit for non-inverting amplifier. We have already seen again in this in theory class theory classes, just quickly let us recall. So, non-amplifier close loop configuration, external components R 1 and R 2, right. R 1 and R 2 we have also used in the inverting amplifier, right? So, these are non-inverting amplifier; that means, the signal will go to the non-inverting terminal, and whatever signal we are giving here, we have to check the output, at the output voltage.

Output is feedback to the inverting amplifier, this is here, input signal is applied for non-inverting amplifier, which is this one, non-inverting configuration using ideal op amp. So, again the same thing you see, you do not have to really worry when somebody asks you that, what are the required condition to apply virtual-short circuit for op amp circuit or virtual short for op amp circuit in case of inverting amplifier. Or in case of non-inverting amplifier, it is it is kind of same you see negative feedback configuration infinite open loop gain is kind of same, right. Op amp characteristics once you know it becomes easy.

Now, closed loop gain, what is closed loop gain? Closed loop gain formula we have seen is nothing but 1 plus R 2 by R 1. So, if you see here, this particular circuit, right this circuit, what we see? We see that the input is given, 2 terminal non-inverting terminal, right. And if you calculate the current, right; then v 1 by R 1 is flowing here, v 1 by R 1 towards this side, v 1 is going towards this the differential voltage is 0 volt, right. We have grounded this terminal, this terminal and now we are we are applying voltage at the non-inverting amplifier, therefore, the output that we have seen in the theory class that will be nothing but V o equals to 1 plus R f, right by R 1 into V in, this is what we have seen in the class, right?

The same thing is here, it is same thing. So, let me just move this thing out. So, you can just concentrate here, let us remove this ok, what you see here? Concentrate on only this, alright. It is written V o equals to V in into 1 plus R f by R 1. R f here is what? R 2, that is why we are saying 1 plus R 2 by R 1, very easy, extremely easy. In finite input impedance, same thing we are we are saying 100 times.

So, it is it is it is very difficult to forget, if somebody ask you it is very difficult to forget this thing, right. In finite differential gain, infinite input impedance 0, output impedance closed loop gain depends entirely on external passive components. Same thing we have repeated inverting amplifier, same is there for non-inverting amplifier. And finally, closed loop amplifier trades gain; that means, that for accuracy finite, but accurate closed loop gain; that means, we can change the gain if we apply closed loop, right. We can we have control over the closed loop gain, then we apply the feedback to the amplifier.

Now, the one thing that we have to understand clearly is, that in non-inverting amplifier, the case was that if I say this is, let me write it down so, if this is input.

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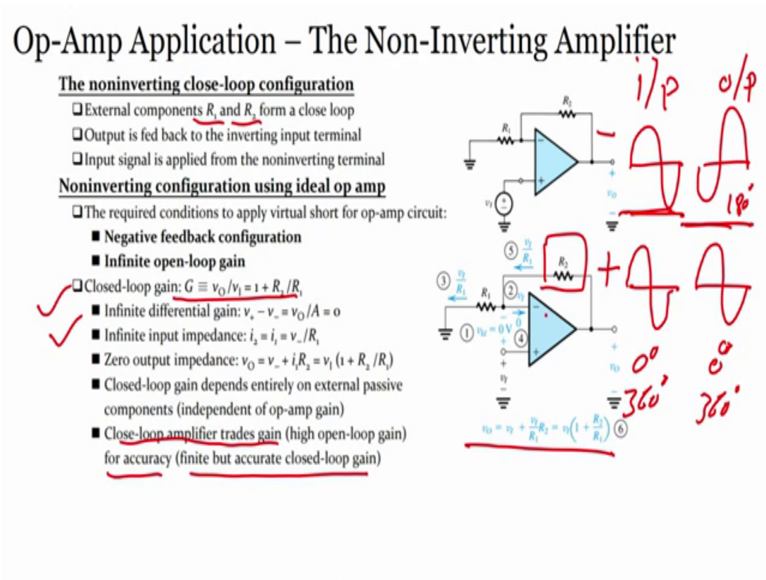

This is output, alright, then in case of non-in in case of inverting amplifier, I am writing just minus as inverting amplifier, signal if I apply here, output would be opposite, right, 180-degree opposite.

In case of non-inverting amplifier, I am just showing by plus symbol, right? This is not an actual symbol, I am just for ease of communication, I am showing with the particular symbol which is plus ok. So, non-inverting amplifier, when you apply input signal, the output signal will be in phase, you see this is 180 degree out of phase. This is 0 degree, this is also 0 degree, right. Or like yesterday we have seen or few other classes, that 360 degree is the input, then 360 degree is the output. So, it is same thing phase is not change, phase remains same, there is amplification in non-inverting amplifier.

Inverting amplifier, the amplification is there, but there is a phase change of 180 degree, that is the main difference between non-inverting and inverting amplifier from ease point of view to understand it quickly, alright? But now we have to see this thing happening with the circuit, right, so, if what how can we perform an experiment and validate that whatever we are claiming here; that means, that whatever claiming here in non-inverting amplifier, that when we apply as input signal which is this one input your output would be output would be in phase with input, your output would be in phase with input so, we have to validate it, right?

So, validating this particular thing, we have to perform an experiment, experiment with what experiment operation amplifier, experiment with resistor, experiment with your with your signals, and let us see what exactly the experiment consists of this is the process.

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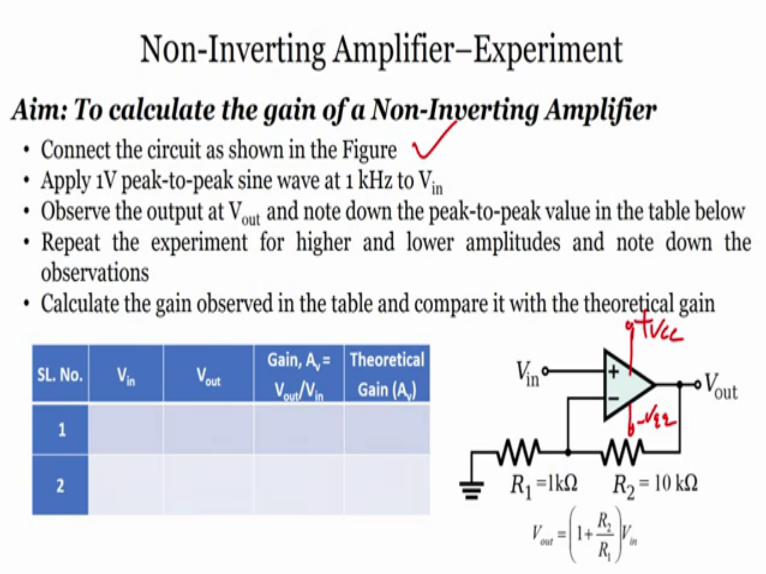

So, again you understand this table, if you see the table looks exactly similar to your inverting amplifier, right. Inverting amplifier what we are looking at, V in V out V out by V in, same thing we are doing an non-inverting amplifier. Only here is the formula is changed, formula for output voltage is 1 plus R 2 by R 1 into V in formula. For inverting amplifier was, V out equals to minus R 2 by R 1 into V in, only thing is the change in formula, right.

So, first what is the first thing? We have to connect the circuit as shown in figure, this is the figure, this is the figure, alright. We have to connect the circuit. Now generally when you show this, right that does not mean that we are not applying the bias voltage. Even it is not shown it is assumed that, there is a bias voltage applied across the terminal plus Vcc minus, Vee this already applied plus minus 15 we have applied, alright?

So, even some even you see the circuit where there is this is not given, that does not mean that the Vcc and Vee is not given. Because without bias voltage you cannot operate the amplifier, alright? Then same thing again see, apply 1 volts peak-to-peak sine wave 1 kilohertz to V in. So, we are applying the same voltage, what is the voltage peak to peak?

1 volts peak to peak is this peak to this peak peak to peak 1 volts, 1 kilohertz is the frequency, right.

Observe the output V out and note down peak to peak voltage in the table below, so easy. So, apply V in measure the output note down the output, right. Repeat the experiments for higher, and lower amplitude and note down the observation. So, let us see how we can perform this particular experiment, alright.

So, again I will request Suman Chatterjee to help us with the experiment.

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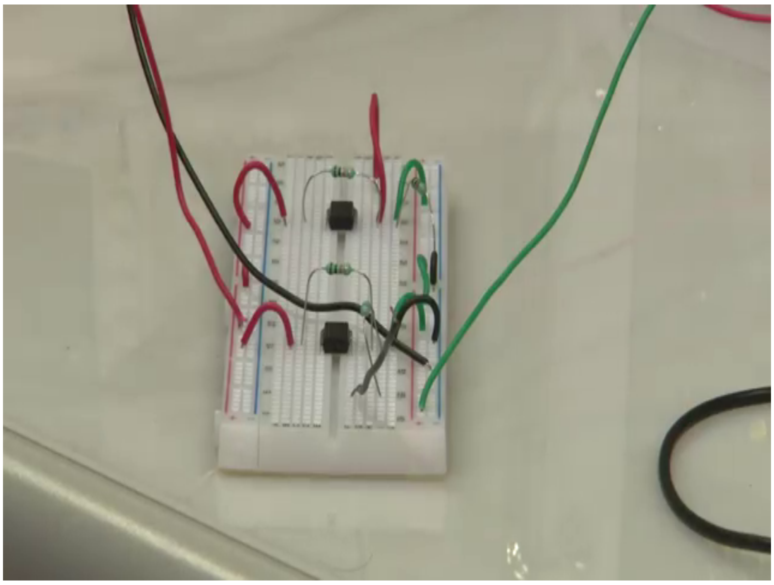

So, if you see the breadboard, then the breadboard we have already connected the non-inverting amplifier, we have not given the input signal to the non-inverting amplifier yet, but the circuit; that is, where I am pointing my finger, right, this particular circuit or this one here, right. This is the non-inverting amplifier, now do not get confused is not really different, it is same thing that we have seen on the screen exactly same thing, right?

What we have to do? We have to apply the bias voltage plus minus 15 and we have to connect our function generator; that is, signal generated from the function generator to the non-inverting input of this operation amplifier. The output of the operational amplifier, we will connect to the oscilloscope. So, first he will apply connect the bias voltage. So, if you see DC in this one DC supply, please, yes switch it on plus minus 15. So, he will first connects plus minus 15 to the circuit. This is the first thing that you have to do, alright. So, plus 15 and now it is already on so, we have to first switch it off, switch it off, alright.

Now, you apply plus minus 15, it is already there actually you have to switch off the this one also, but I am not doing that that is fine, alright. See the there is no voltage coming from the DC regulator, right, to the circuit, right. Even you do not have to take this much of chance, alright, be extremely safe when you perform any experiment, alright.

So, we now have connected what we have annotated plus 15 minus 15 to the non-inverting operational amplifier; that means, 7 and for pin number 4, and number 7 are connected with minus 15 and plus 15 respectively, alright? Now, we will apply input signal. So, this is your input signal, first before that we have to start the operation amplifier.

So, we can now start we can apply the power here DC voltage excellent. So, DC voltage again you know, right here it is plus 15 minus 15 in this 3-red black green, alright. Now we will apply the input signal from the frequency generator. So, what is the frequency generator input signal, can we focus on frequency generator please? Right, so, I have shown you, right you can change the input signal very easily.

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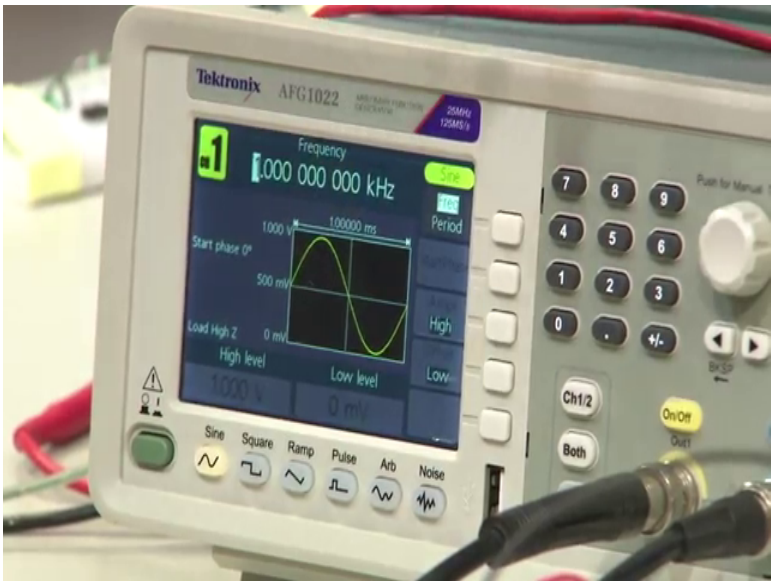

1 volt if you see high it is 1 volt is applied, right, what is the frequency? 1 kilohertz is the frequency voltage is 1 volt, right. Voltage is 1 volt, and frequency is 1 kilohertz, this is the input signal.

Now, he is going to connect this particular circuit, right? And he is applying input signal to the operation amplifier, again you see DC voltage we can switch it off when we require then we can switch it on, alright. So, we can switch it off again DC voltage please, yeah when we require we can switch it on, alright. Can you please connect it?

So now he is connecting the signal to the non-inverting amplifier, another terminal to ground thus how signal is given, alright. Another terminal to ground ok. So, if you see the breadboard, let us see little bit of breadboard ok, you see so, this black one is connected to a breadboard, right. With a to a ground terminal, these are all ground, alright. And this side of the bread board we have kept plus Vcc, plus Vcc ground, plus Vcc ground always remember this thing, alright? This how we have done.

Now, we have we are applying signal through this one, right, to the non-inverting terminal of the operation amplifier. So, this wire is connected to the circuit, you see here, this wire is connected to the non-inverting amplifier, Non-inverting amplifier and input of the non-inverting terminal, this op amp non-inverting terminal, input is here, alright? So, understand from here frequency generator input goes to the non-inverting terminal.

Now, what we have to do we have to check the output. So, let us see the output, if you connect the output, the oscilloscope again see, this is oscilloscope here, alright? So, these are the probes for the oscilloscope you see the probes, right in my hand these are probes, right. Now we have to connect this probe to the output of the operation amplifier. So, that we can understand what is the signal. So, he will connect it to the output, connect it to the output, and another terminal to ground excellent, right?

So now what we are expecting? When we connect this thing, when we connect this thing, what we will be able to see? We will try to see what is the output signal when we are applying a input signal of 1 volt one kilowatts ok. So now, the circuit is connected, right. We have to look here so, you can see that when power was not on you are not able to see right. So, do not forget to apply the bias voltage, these are bias voltage you cannot see the signal.

Now, there is some problem with the circuit, right, isn't it? Because we cannot see exit application of the signal. So, let us find out what is the problem, alright? Let us find out what is the problem, and then we will be, I will tell you what is the problem so that you also understand, then when actually you are fabricating or actually you are testing the circuit, there can be this kind of problem where you suddenly see that the signal is not replicating. And that is absolutely fine, there is not a problem in that.

So, but the main thing is can you rectify this problem that is the main thing. So, we will try to rectify it and we will continue. So, I told you, right there was some mistake, right. and that is perfectly fine, the point is can we identify what was the error in the circuit, now actually there was no error in the circuit, what we found is that you see here, the display it is showing a sign rival right here, but there are 2 channels, you see channel 1 and channel 2.

So, channel 2 is configured in square wave, channel one is configure in sign wave, what we did is, last time, we applied square wave to this circuit. So, when we apply square root of circuit, what we are assuming? We are assuming at the oscilloscope square wave signal, you can see, right. That is absolutely fine. So, what if you apply input a sign you will get a sign you apply square, you will get a square.

But the point is, what was the input signal? Input signal was 1 volt's peak-to-peak 1 kilohertz, what is the output signal? Output signal is we have to see here in the oscilloscope, can we please focus oscilloscope? So, I can show them what is the output signal, can you please point it out here?

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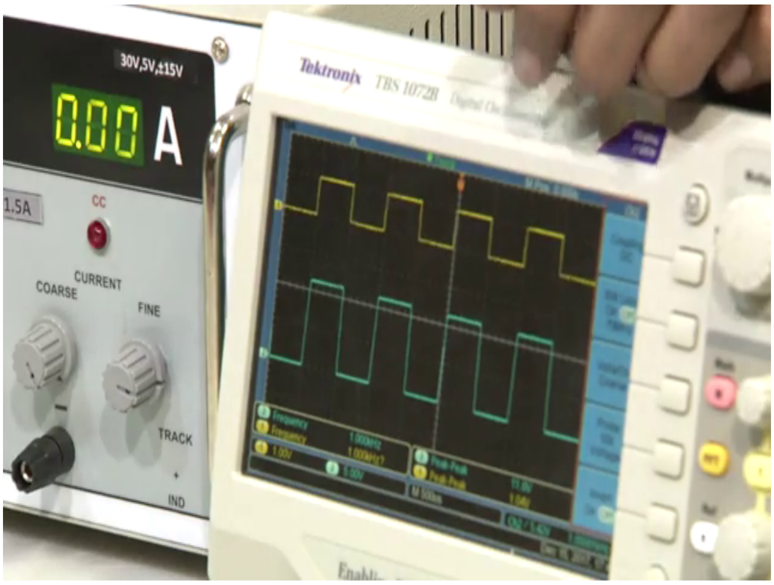

So, if you see it is around 11 volts 11 volts peak-to-peak when we apply 11.2 to 12 volts peak-to-peak, right blue one. And the input voltage is 1.04 volt; that means, that it is amplified the signal is amplified.

But one thing that we have to keep in mind is this is the non-inverting amplifier. So, you can see the phase, phase is 0-degree phase shift, right. You see here, then you see go down, no phase shift right. So, phase shift is 0 degree, but in case of inverting phase shift was 180 degree. Now, let us see instead of applying square wave, if we apply sign wave so, if you again focus on the on the frequency generator. Now we have configured our channel one there are 2; 2 channels, we have already seen in the previous modules, how? What are the what is this function generator? And how many channels are there, right?

So now channel 2 is square wave let us change it to channel 1 please. So, see by pressing a button p convert to channel 1. What is channel 1? Sign wave, right, what is channel one sign wave. So now, we are applying sign wave to the circuit, when we are applying sign wave to the circuit, we have to connect the probe that is for the sign wave to the circuit, isn’t it? Otherwise we cannot, we cannot get the signal.

So, what we have to do? We have to so, we are we are taking out the probe, alright? You need to be gentle, right, when you take out the probe when you insert the probe, it is it is a easy way of doing it, right? Use any equipment be extremely gentle, ok. Do not take out your frustrations on equipment, guys, it is very easy operation is extremely simple, alright. So, when you connect your frequency generator, now we are applying sign wave, right?

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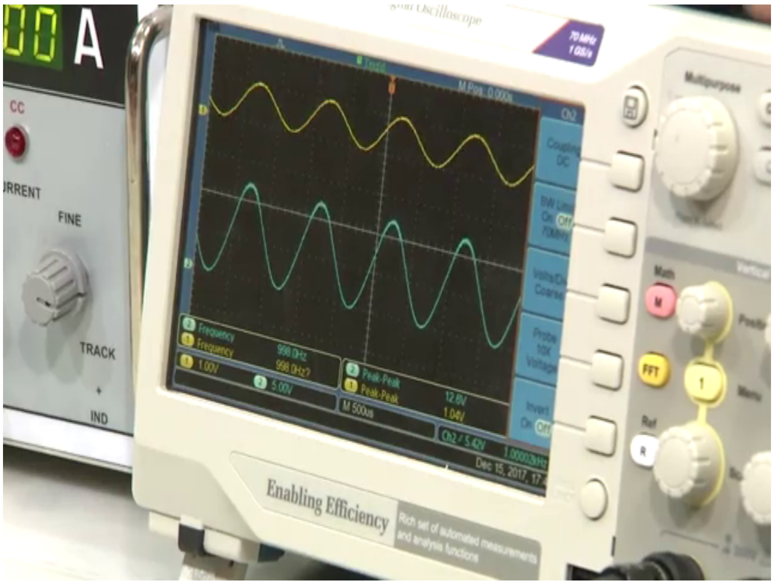

So, we have to now see the oscilloscope, oscilloscope, what we see is the amplification of the signal amplification of the signal, sine wave, 1-volt whatever amplification we get around 12 volts 1.04 is a input 12 volts is the output. Phase shift 0, degree phase shift 0 degree, very easy, right. If you say inverting phase shift 180 non-inverting phase shift 0 degree both are amplifiers so, there will be amplification non-inverting terminal the formula is 1 plus R non-inverting amplifier formula is 1 plus R f by R 1 or R in into V in inverting amplifier formula is V out equals to minus R f by R in into V in.

So, using that formula, if you calculate theoretical calculation of amplification or gain and actual gain you will see their difference little bit of difference, now significantly, so, once we know this we can go back to our table on the screen, and we can note down the value, what is the value? V in, what is V in 1.04, what is output? 12 volts, right.

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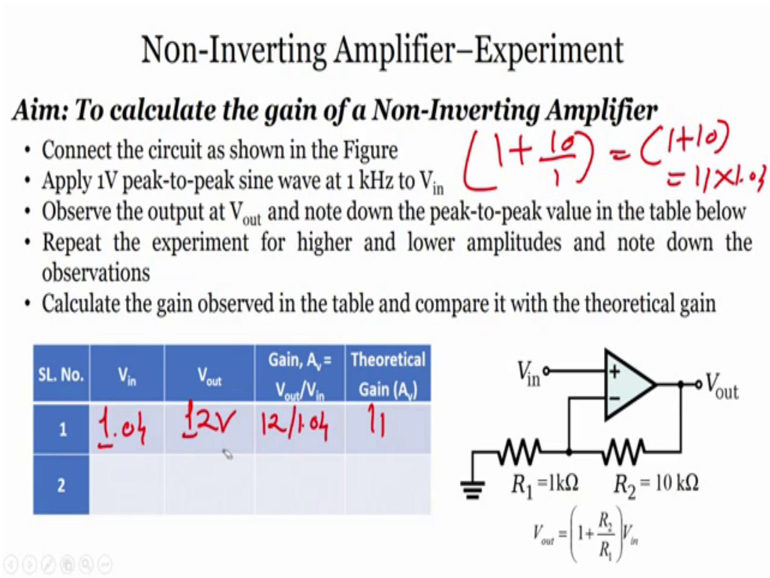

What is V out by V in 12 divide by 1.04, that is your gain. So, easy theoretical gain R 2 by R 1 into 1 plus R 2 by R 1. So, what is that? 1 plus R 2 by R 1, 1 plus 10 by 1, right? 1 plus 1 by 1 is 1 plus 10 or 11.

So, let me write out on clearly. So, you can see here, right. 1 plus 10 by 1, which is equals to 1 plus 10, which is equals to 11, correct? 11 volts or 11 times amplification vector, into V in, into whatever v in is v in is 1.04. So, when we multiply 11 by 1.04, you the gain is 11, directly gain is 11 right, but what is output voltage? Output voltage would be different so, we can see there is a little bit different between the actual experimental value and the theoretical value, alright?

Now, what is another thing that if we have written here in the experiment the second part. So, we have what we have done we have done this we have done this, right. We have also calculated observe this one 3 things are done, what is 4 thing? Apply higher voltage, right, higher amplitudes. Let us see when we apply higher amplitudes what happens. So, if you again go back to the frequency generator, function generator, yes. So, if you can see function generator please, yes now let us apply high voltage right. So, instead of 1 volts instead of 1 volts what he is doing now he is applying another voltage.

Let us apply 2 volts, right, let us apply 2 volts, now what is the amplification? Amplification is about gain is about 1 plus R 2 by R 1 about 11. So, 2 into 11 will be 22, right, 2 into 11 will be 22, now what is the input bias voltage, bias voltage is plus minus

15 volts. So, output how output will be look like, output will be clipped, can we see the output now? So, this input signal is applied to the circuit, from the circuit it goes to the output. So, if you see the output voltage you will see a clip, you see the clip?

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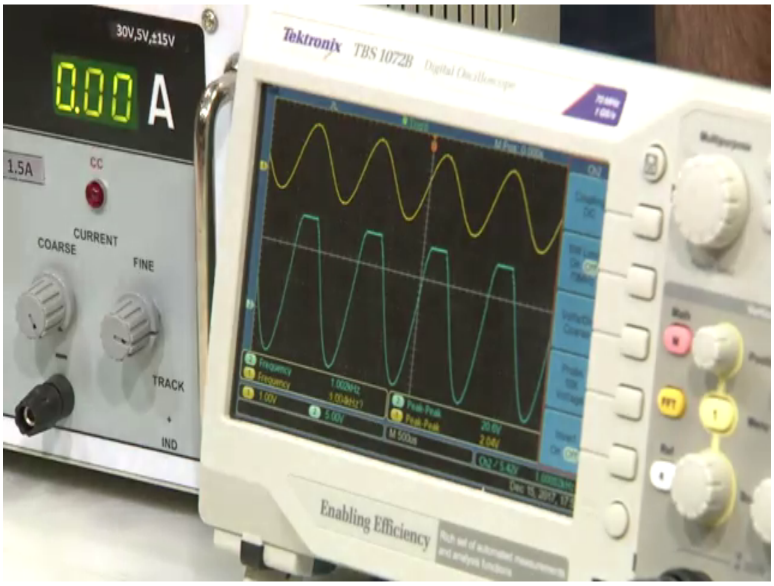

The clipping is because the output is more than the bias voltage, that is what I have told you earlier, right. As an example, one single op amp cannot amplify infinitely, or it can amplify infinitely, but it has to depend on the bias voltage.

So, bias voltage is extremely important when we are talking about the amplifier, alright. Without that it is not useful so, what we have found, we have found that if we use inverting amplifier? We see 180-degree phase shift, if you use non-inverting amplifier we see 0-degree phase shift in both the cases when we when we apply the input signal and we have gain which gives a output signal more than input bias voltages that is plus minus 15, we see a clipping, right?

But what if we decrease, it in decreasing condition. So, if we if we can quickly decrease, it decreases the voltage here in the input. So, decreasing the voltage will give us, let us say we are applying about 0.5 volts peak-to-peak, 0.5 volts peak-to-peak will give us output, which we can see here in the oscilloscope, right?

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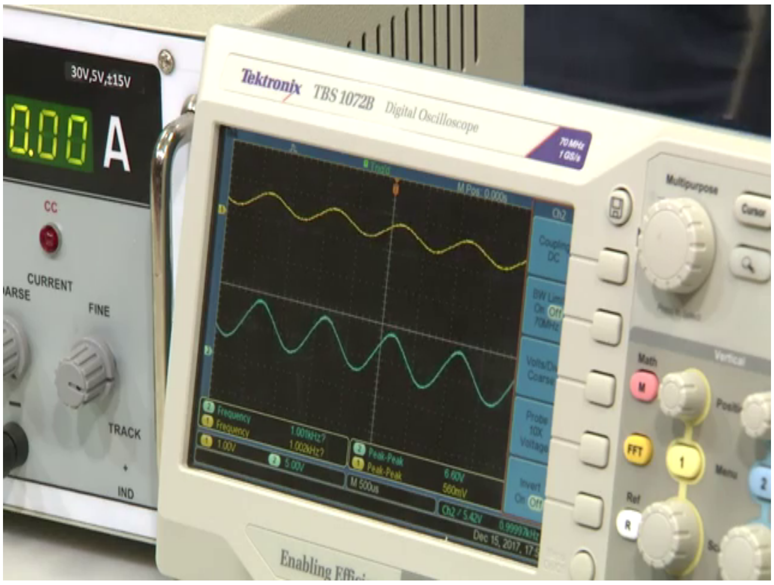

So, it has amplified about 11 times. So, 11 times 0.5 would be around 65.5, right? Around 5.5, so, that is what we can see about 6 point something volts actual, so, the so, why there is a change? You see so, we have calculated about 5.5 volt should be at the output, but when we see in the oscilloscope, we find that the it is around 6 volts, right. So, that is because the resistor values, that we are we are using it, that is your 1; 10 kilo ohm and 1 kilo ohm, it may not be 10 kilo ohm or it may not be 1 kilo ohm. Even the change of few ohms will change the gain, will change the gain, right?

So, it is extremely important, when we when we use the circuit, we should measure what is a resistance of the resistor, and then you understand theoretical and experimental calculations. So, anyway the point is in non-inverting amplifier there is no phase shift. Inverting amplifier there was a phase shift. Take care of using the resistors, right, it is value should be accurate, then only you can compare theory with practical, alright?

So, this is the end of this particular module, like I said it is absolutely when you when you are trying experiment on the breadboard, and you are trying different circuits, right. And you are not able to get the answer what you are expecting that is absolutely ok. So, what we have to rectify, we have to understand what was the problem.

So, here if you have seen in this particular experiment, the problem there was no problem with the circuit where problem with the input signal, right. Input signal given to the circuit was square wave, and we were we were assuming or we were under the impression that input is sign wave and why the output is square wave. So, we have to understand if the input is something, we cannot expect output which is different then what is input signal you can only amplify it, right.

But we can also use clipping it is clipping is there when you are amplification of the gain or of the amplification of the voltage is more than the bias voltages. So, keeping in this mind, I will see you in the next module, and next model will be on understanding the input and output ranges or the range of the operation amplifier. See you.