Integrated Circuits, MOSFETs, OP-Amps and their Applications

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Lecture - 43
Experiment: Op-Amp Characteristics: Input Offset Voltage

Welcome, this module is for understanding what is input offset voltage, alright. And then another point is slew rate, 2 things we will see in this particular module. Again, these are the characteristics of an operational amplifier. these are the set of experiments that I am covering as a part of this particular course which we have already seen in theory part. So, this is the theory part we learn what are the things input offset voltage input offset current slew rate, and then we have seen CMRR, we have also seen inverting amplifier non-inverting amplifier oscillators and so on so forth.

Here we are actually testing it by making the circuit, right. and that will help you I I hope that will help you understand how you can use the operational amplifier and how you can find different parameters. So, with that let us see what you mean by input offset voltage.

Now, assume that you have given no voltage at input terminal, or input terminal op amps are are grounded; that means, is inverting terminal is ground non-inverting terminal is ground. So, what you expect at output, what you expect at output output should be 0, right. But when you actually measure the operational amplifier by testing this particular experiment, that is you keep inverting terminal ground, non-inverting terminal ground. And you measure the output voltage what you will find is you will find that the output voltage is not 0. So, is the output voltage is not 0, how we can make it 0, right? And the voltage required at the input to make output voltage 0 is your offset voltage, this is what offset voltage means.

Now, let us see the on the screen what what the definition is and how we can measure the output offset voltage, right.

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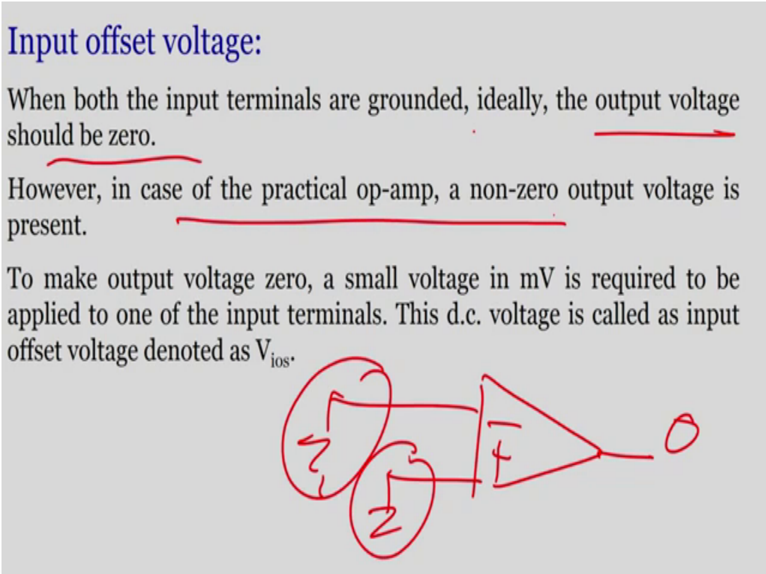

So, what what we have seen? When both the input terminals are grounded right; that means, I take operational amplifier, and I ground both the input terminals. Now this is just just an example ok, we will see example in the next slide, circuit in the next slide just I am showing.

So, when the input terminals are grounded, ideally the output voltage should be 0, right, but in case of practical operational amplifier a non-0 output voltage is present, right? And to make this output voltage 0, a small voltage in millivolts a small voltage in millivolts is required to be applied to one of the input terminals, alright. So, this small voltage which is required to make to make the output voltage 0, right? This small voltage that is required to make the output voltage 0 is called the input offset voltage. And it is denoted by Vios Vios, alright? Easy easy to understand what is the input offset voltage, but how to calculate it, right how to calculate it?

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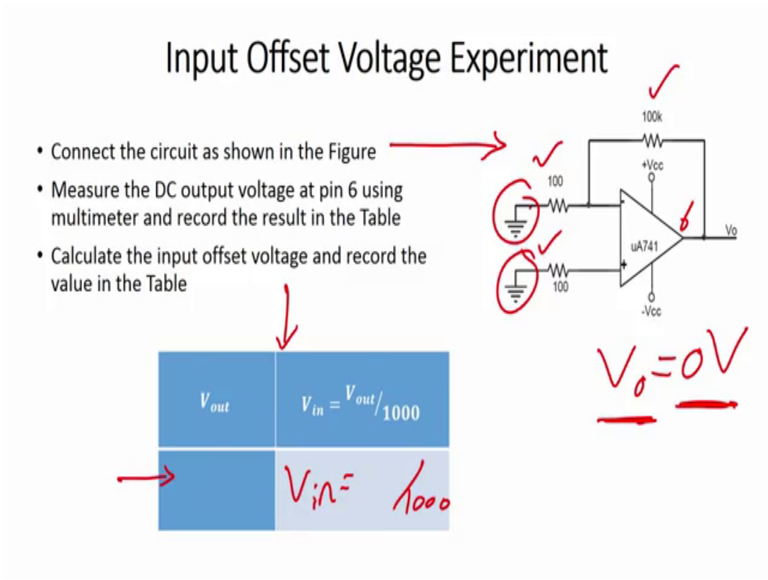

So, let us see input offset voltage experiment um. So, if I want to measure the input offset voltage, now you see here these are mu a 741 we have used resistors, right. Same value of resistors or 100, here it is 100 k, right. And plus, Vcc minus Vcc Vo, we have to value measure the value of voltage Vo. So, in what we are assuming that input? We have grounded, input we have grounded, means output voltage should be 0 volt, right..

Let me write it down here. So, output voltage would be 0 volt when inputs are grounded, right is what we think. So, if you want to understand whether output voltage is 0 or not, and how much voltage we have to give at the output, then you have to do you have to connect the circuit, like this, now let us see the connect the circuit as shown in figure it is very easy, right. And I am sharing this slides with you. So, you can do it anywhere connect the circuit as shown in figure.

Now, measure the DC output voltage at pin 6 this is pin 6 we know, right using multimeter you can use multimeter, you know, how to use multimeter now and record the result in table where is the table table is here. This is the table calculate input offset voltage and record the value in table, so easy right. So, V out, V out whatever V out is there we will write it here, right. We can measure V in by this formula, whatever V out we get divide by thousand, why? Because of the ratio, alright.

So, let us see this actually in the experiment, we will connect we will take a operational amplifier 3 resistors of this value, we connect it, and let us see the output voltage initially. And then we understand that we will not see this output voltage 0 volt in practical op amp we will see some millivolts, alright?

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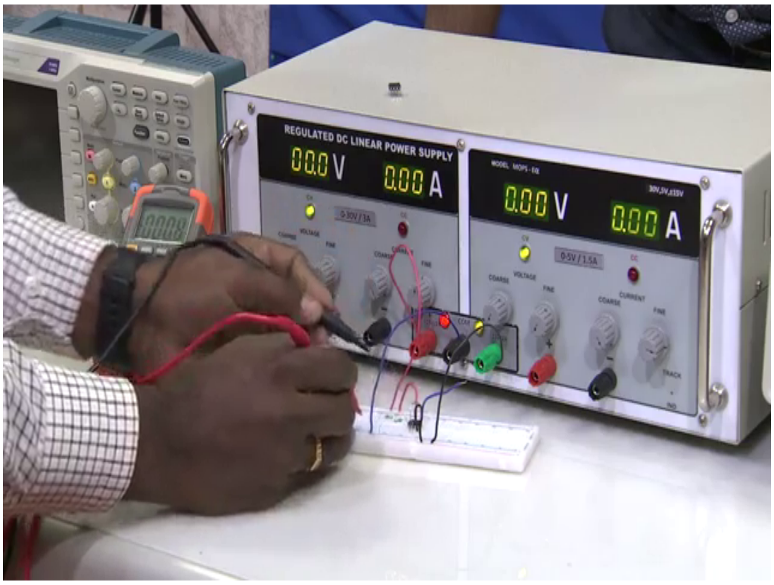

So, let us see this experiment so, again we can see on the breadboard which is right over here, right? So, can you please come? Yeah so, those who cannot no, whom I am calling? Sitaram, once again. So, he is involved with this experiment, he is helping us to understand, how the circuits are connected, right? So, there is a breadboard as you see here there is a breadboard 3 resistors, right. And then we have the indicator circuit, we have given the bias voltage plus 15 minus 15 through the DC power supply, right?

Now, we are measuring the output voltage. So, with the input voltages are ground both the terminals are grounded ok, now we are understanding output voltage, from where output voltage, we can measure the output voltage at pin number 6 with or between pin number 6 and ground. So, what is output voltage let us see. Again, the multimeter is in DC degree centigrade.

So, he is connecting the the positive to 6, and the another terminal to ground, what we see there is some output voltage, you can see 7.6 millivolts. Now what should be the actual thing? Actual thing is, the output voltage should be 0 right, but in actual op amp in the practical op amp, we are not able to get the value output voltage 0, right. Thus, we can if we if we get the 7.6 millivolts, right. Whatever we have obtained using the multimeter, if I put the same value, in the table which is on the screen, right. Then I can write 7.6 divide by 100, right. That will be my V in; that means, this much voltage at the input I have to apply to make my output 0, easy right? So now, you can do this experiments at home what experiment input bias current input offset current input offset voltage, right?

Now, let us see the another characteristics of an operational amplifier which is the slew rate, very important characteristics of the operational amplifier let us see, slew rate right.

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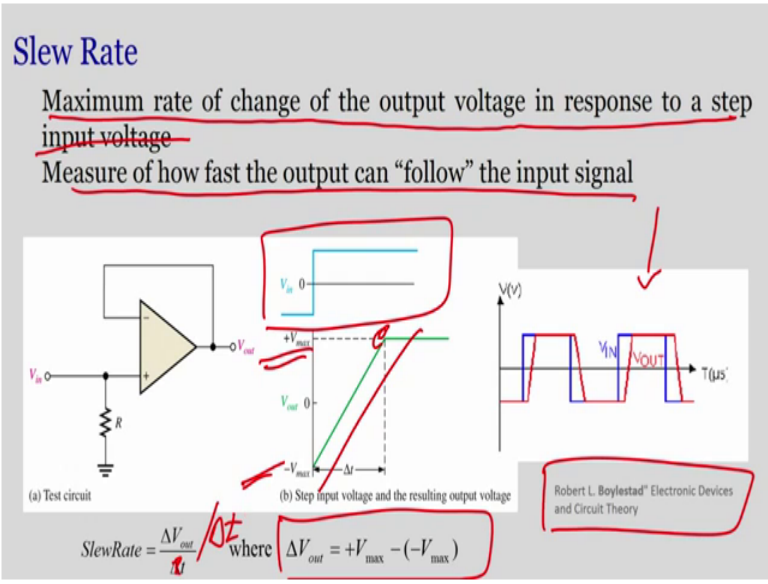

So, what is slew rate? Um, so, given on the screen what is slew rate? Maximum rate of change, maximum rate of change of the output voltage in response to a step input voltage, right. Maximum rate of change of output voltage.

So, if I apply step input voltage, which you see here, what is the change in the output voltage? What is the change in the output voltage, right? Maximum change, now measure of how fast the output can follow the input signal, this is also the slew rate all, right? It can help us to understand, how fast the output can follow the input signal. So, when I give a input signal, how fast I I get the output? How fast I get the output, right? There is a measure of slew rate; that means, if you see in this particular graph, what we see?.

There is a x axis is your time in microseconds, y axis is voltage, right? this I have taken from robort boylestad, electronic devices and circuit theory, this particular graph, just to help you understand what exactly this means; means that, you can refer to this book as well, right. You can refer to this book, and you will get in detail what exactly the slew rate means. But let us understand from this lecture, what what this graph means. Graph is very easy there is a input voltage shown in blue colour here, right. And then this output voltage is shown in red colour, right? So, everything is red, because my pen is red. So, just not to confuse you, now you can see, in this particular graph, there is a blue and red signal right.

So, how fast your output that is your red follows your blue. That is your slew rate, very easy to understand, isn't it? So, slew rate is also given by delta V out upon delta t upon delta t change in the time delta V out is change in voltage, where delta V out is nothing but plus V max minus V max. So, plus V max minus V max, this is difference of this, right. is your delta V out, we can see here in this particular formula, right? That V out delta V out equals to plus V max minus minus V max, we can also see in the slew rate, the the formula is not visible completely. So, just ignoring this one and light here delta t, alright delta V out by delta t. This is your slew rate.

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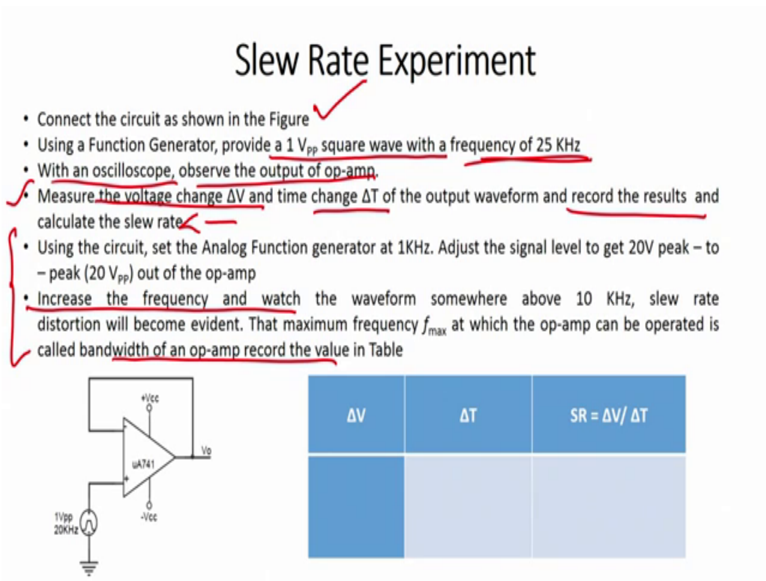

Now, in reality if you want measure slew rate right; that means, experimentally we want to measure slew rate, what we can do what kind of circuit we can have. So, let us see the circuit, now you can see the screen again, right? In the screen what you see there is a mu 741, right. And you have applied voltage at the non-inverting terminal one-volt peak to peak. So, you what are the steps? First step is connect the circuit as shown in figure. So, again this slides are with you you try to do at wherever place you have the access to work on this, right? Laboratory, you can use at laboratory, home you can work at home wherever you are comfortable.

Again, always understand understand how to operate any system, right? Safety first. So, if you do not know how to use it, do not try it at home. The same thing, right? Even even simple things, do not try until you know, right.. So, be cautious when you use anything, right. Because finally, we are applying DC voltage, we are applying voltage, we are we are using the equipment. So, we should always be careful.

But the point is, you if you want to measure slew rate follow the steps and you will be able to measure the slew rate. How the first is connect the circuit is shown in figure. Use function generator, now function generator we have seen how function generator is used, right. And we can apply one-volt peak to peak square wave. So, we will see in the experiment, how we are applying one-volt peak to peak square wave, at a frequency of 25 kilohertz.

Let us keep frequency of 25 kilohertz, alright. So now, we need another system which is oscilloscopes. And also, it may not be possible for you guys to have everything at home, otherwise people will get angry on you. So, do not get do not do experiment which are really costly or which consumes lot of space in your home. So, try to go to your laboratory, or you can access your friend’s lab, right. You can take permission from a teacher, and I am sure that anyone who is there to help student will give you an access to the laboratory where you can do the simple experiments, right.

So, with an oscilloscope observe the output of operational amplifier. You can see we will see an oscilloscope and we will observe the output of operational amplifier. We will measure the voltage change delta V with respect to delta t, right, why? Because we have seen in the last slide, the formula for slew rate is nothing but delta V out upon delta t, isn't it? With this one delta V out upon delta t.

So, what we are measuring? We are measuring the 4th point which is this one, measure the voltage delta V, and time change delta t of output waveform, and record the results and calculate the slew rate, alright? First step let us repeat connect the circuit second apply one-volt peak to peak at 25 kilohertz using functions generator.

Third, with an oscilloscope observe the output waveform. What we have to measure? We have to measure the change in delta V, change in voltage at time delta t of the output waveform, and from that we can measure the slew rate SR which is given by delta V by delta t. Using the circuit set analog function generator to 1 kilohertz now using the circuit adjust the signal level 20 volts peak to peak increase the frequency and watch the frequency somewhere about 10 kilohertz. Slew rate distortion will become evident.

So, this is this particular things here which is written, it this is not written in the table, it is not in the table, right? But this is just to understand what is the maximum frequency that operational amplifier can operate it. To to know that, we will if we keep on increasing the frequency, we keep on increasing the frequency, right? We will see that at somewhere somewhere the slew rate, right distortion will become, the there will be some distortion in the slew rate..

At this distortion, right we can say that, the maximum frequency at which the op amp can be operated is called bandwidth, and we can also measure this value in table. Here we are not measuring the slew rate that is why if you do not see a separate we are not measuring maximum frequency. So, that is why we are not looking at the table or a column in the table to measure the frequency, alright. We here our idea is just to measure the slew rate, and for measuring the slew rate, what we have to measure delta V and delta t. What we need? We need our frequency generator, we need a oscillator, sorry, we need oscilloscope, and we need a operational amplifier.

So, let us see how we can do it the same circuit, I will show it to you on the breadboard, and then we will see how it looks like.

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So, let us see on the breadboard like I said little bit while ago. you see the breadboard here, and the circuit is similar to what we have seen in the screen. And there are there is a operational amplifier, we have connected this operational amplifier. To the function generator, this is the function generator, like you can see here. So, I will ask again Sitaram to come here and connect it. So, the or change the voltage in the frequency so that we can understand how this slew rate can be measure ok.

So, Sitaram can you please? Come here, yeah, alright. So, what we have done here is, we have connected the frequency generator to the operational amplifier. So, the the signals are here which is holding the probe, this probe is connected with the frequency generator. If you closely see as a frequency generator, you can see that we have applied 25 kilohertz, right. You can see in the screen 25 kilohertz, correct?

Now, this is a square wave that we have applied, you can see square wave here somewhere here, right and there is 25 kilohertz. Now this when you apply this 25 kilohertz, the high level is 500 millivolts. So, 500 millivolts now you have to understand what is the output voltage and what is a time. What is change in output voltage? What is change in the time? That you can do by taking help of the oscilloscope.

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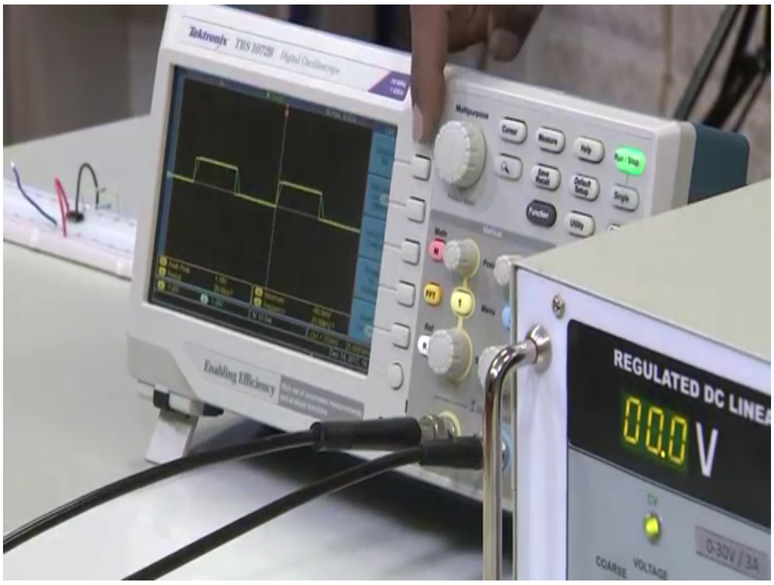

So, oscilloscope is right here, and here you can see the output voltage, right. And the change in output voltage is with respect to time. So, yes, now we can see, right? So, we can see the signals which we were able to look at the in on the screen, similar signal we can see here we are applying the input voltage, and there is some lag in the output voltage. This lag in the output voltage, we can see using the oscilloscope, alright?

So now if we know what is the change in the voltage, that we can understand using oscilloscope, right? And then we see this what is the change in time that is delta t. So, delta b V by delta t will give us the slew rate. So, it is very easy again you see here we are constantly applying plus 15 minus 15 to the operational amplifier. We are giving a particular frequency; that is, 25 kilohertz to function generator, and we are measuring the output voltage using the oscilloscope.

So, we require this all 3 things together, along with the operational amplifier to understand. The slew rate what slew rate is the change in the voltage output voltage, right divide by delta t. So, delta V by delta t, now one thing if you remember in the slide, we have said that increasing the frequency, and watch the waveform somewhere about 10 kilohertz, slew rate distortion will become evident.

So, let us do that experiment, let us bring the frequency low and let us increases slowly, and you will see on the oscilloscope the change, alright. Can you please do that yeah so, when he is going to change the frequency using frequency generator you can see the oscilloscope here, and you can see here the distortion will start occurring slew rate will start changing, right. So, he is changing from almost 220, 230 hertz, right 230 hertz, and he is changing so, guys you focus on the oscilloscope, alright?

Now, you see here, he is changing the frequency, right. He is changing 365, 375 you focus on here what happens? See he is increasing it 425 kilohertz, 465 kilohertz, you see, there is lot of distortion, lot of distortion, right? But if he goes and decreasing the frequency can you decrease it again, yeah, if you see that he is decreasing the frequency, the distortion becomes less, and it is easy to understand or easy to measure the slew rate.

So, this is how we can understand. So, from that what we also understand that a particular frequency, the op amp cannot be operated, that is a maximum frequency at which the operational amplifier can be operated. So, there is a 2 way or easier way to understand at what frequency operational amplifier can be operated, and frequency well this slew rate will be distorted, right. Or can we measure the slew rate yes when we apply input signal, you can see there is a input signal, right..

Which is yellow, you can see blue colour or greenish colour or light blue that is your output signal is a lag between input and output, this change in delta t, and change in delta V is your 2 values that you have to measure, when you measure these 2 values, you if you come back to the screen, and you will see that if you put this value substitute this value onto the table delta V and delta t you are able to measure the slew rate.

So, for this particular module, we will we will we understood of what what exactly slew rate is we have seen an experiment how we can measure the slew rate ok. So, this is the end of this particular module, I thank you one thing that you can see on this last slide also and every time I will try to bring one quote from some famous guy who has done something good in his life, right. Either in terms of science or in terms of engineering or in terms of academics, or in terms of society, anything a person who has done something on which we can also try to follow.

So, you may be knowing the scientist Thomas Edison, and he said that our greatest weakness lies in giving up. The most certain way of to succeed is always to try just once once more one more time; that means, that we generate try to give up the thing, right when it does not work. Suppose you work on this experiment what I have taught you, and you will see there is no single and you said, oh, this is not working do not do that try one once again, try once again, you will succeed that is what he also said that the most certain way to succeed is to try one more time. So, do not give up, try to see try to understand the series, try to understand what experiments we have done, try to understand the characteristics of the operational amplifier, and I am sure that you will understand more when you do it by yourself, alright.

So, always try to learn, and then perform the experiments by yourself. Once you perform experiment by yourself, you will have more idea, or more questions, or more difficulties that you can ask to me, or try to solve by yourself, right?

So, this is the end of this particular module, and I will see you in the next module with more experiments. Bye.