

Op-Amp Practical Applications: Design, Simulation and Implementation
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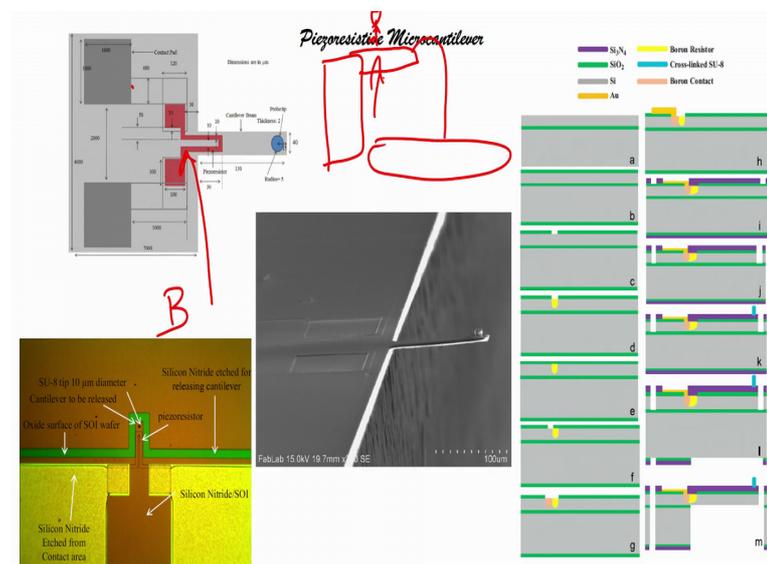
Lecture – 04
Effect of Loading and Input Impedance: Part 1

Welcome to this module, like last time we have seen few experiments related to our course right. So, today a very interesting applications of Op-Amp we will be looking at. So, what happens if you have a resistive output? That means, if the sensor is changing its output or showing the output in change of resistance, what kind of electronic module you can attach with this particular sensor.

So, yeah if that is the question and that can be also of a small undergrad project right or a M. Tech project, where if you want to make a 4 sensor or if you want to make a tactile sensor and you want to see the output. And then you have to design an electronic module to finally, display these the output of the sensor on to the screen right? Then what kind of electronic module you can you can design. So, to understand these concepts first we should understand a basic or the application of the operation amplifier.

So, today if you come on the screen and see what we have today experiment to understand the effect of loading and input impedance, so, what is the effect of loading and how the input impedance would help or act on the change of the output.

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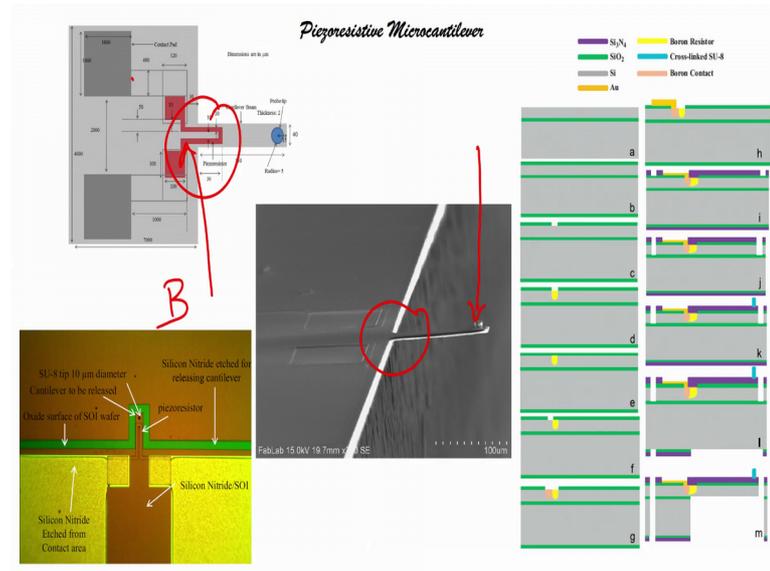
And this is what we have studied is not it? What we have seen is how to fabricate the Piezoresistive microcantilever.

So, if you recall what we have seen; here this particular is a sensor from here to here is a contact, here to here is a contact. You can see that red mark right. And then this one is our resistor this one from here it goes to all the way here. This is the resistor, so this one is a resistor. How we can diffuse a resistor into the Polysilicon that what we have seen in the theory class. Let us quickly call and then we will see why we have taken this example to understand the loading effect or to understand the when there is a change in the sensor output in terms of resistance, now what kind of electronic circuit we can use alright.

So, coming back to the screen like I said this one is your resistor and because the material that we have used to diffuse into this silicon is boron right? It will be B type B type Piezoresistor right? Why because the Polysilicon is n type. Anyway that we do not really worry about a point is that; if there is a resistor diffused into this silicon, now cantilever we all know right what is this cantilever looks like if there is a person right. This is the example of cantilever, but what is the real example of cantilevers. So, if you think about board in the swimming pool right, there is a board, there is a person standing he jumps into the swimming pool right.

So, what is this is also cantilever it is also example of a cantilever, cantilever we see around in daily application. So, understand how the cantilever will work when you press right.

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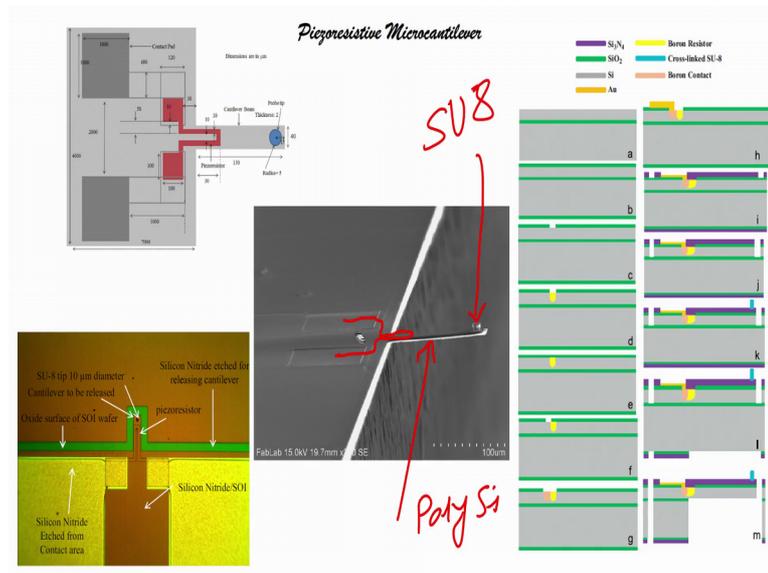
So, if I press this particular cantilever, the resistance within the cantilever would change, why? Because there is the diffused resistor as you can see here is a diffuser in this particular Piezoresistive cantilever.

So, when I apply a pressure or apply a force then the resistance would change and corresponding change will tell us how much force we are applying. So, to understand the effect of force or to measure how much force we are applying, we can use resistance as the output resistance is a parameter, in this resistance can be used if you have a diffused resistor which is our Piezoresistor. So, Piezoresistive material any material in on which we are applying pressure and it is shows correspondingly the change in the output in terms of resistance is called the Piezoresistor.

If we talk about piezoelectric material, if you apply pressure right, the output would be change in voltage. So, you have seen piezoelectric resistor right. So, these crystals are used on the basis of piezoelectric. The resistance that we are talking today is nothing but piezoresistive; that means, you apply pressure or apply force and there will be change in resistance alright, so coming back to the screen.

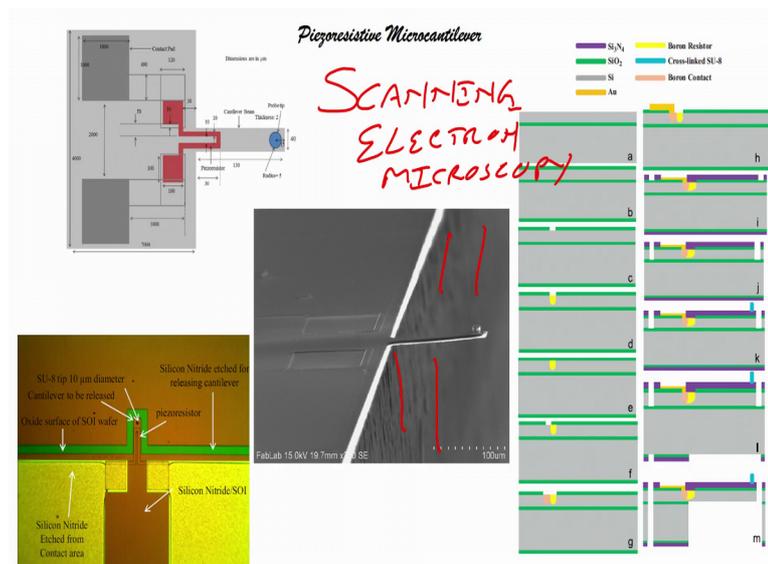
Here what was the application? The application was to understand the change in the elasticity of a material, how?

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So, this you see if you recall last time what we are discussed in the theory class, this is a S U 8 tip right, this is the S U 8 tip. This is Polysilicon, Poly silicon. This one it goes here, goes here, comes here this is a resistor diffused, diffuse that are we cannot see this is the cross section, this is called S E M is called S E M, what is S E M? S E M is nothing but scanning.

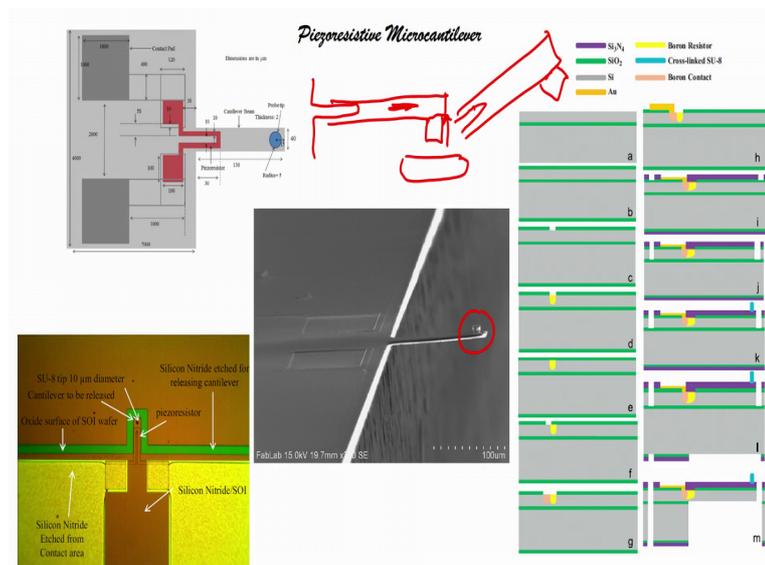
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I write it down here S C A N N I N G scanning electron E L E C T R O N electron microscopy M Y C R O S C O P Y all right S E M hm.

So, S E M is a material characterization equipment used to take used for taking the images of the systems or of the devices, which are extremely minute in size and difficult to take, difficult to get the images using the optical microscope. So, we can another advantages we can have a cross sectional image. So, what we see here is the cantilever which is all the way as there is nothing here only cantilever is there all right. So, you can see this cross section by using the S E M.

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Now, what was I telling, I was on the topic of S U 8 tip. This role of this particular is S U 8 tip to see this tip S U 8; is that it will help to press the material of our interest; that means, that I will use this cantilever and I have also talked to in the theory class right? I have this cantilever; I have this S U 8 tip. And I take a material and I press this cantilever on to this material. Now this S U 8 tip will help to translate the amount of force back to this cantilever. And this cantilever has a Piezoresistor.

So, depending on the deflection of this cantilever, how much it deflects we could see the change in this resistance all right. So, that is the role of this particular Piezoresistive micro cantilever right. Now what we have seen? We have seen that; when we apply a pressure when we apply a force on to this particular micro cantilever there is a change in the resistance.

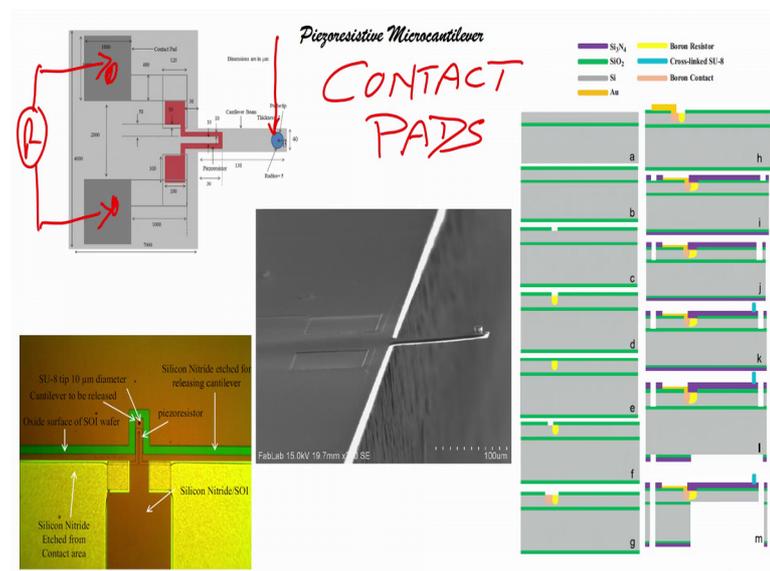
How you will; so for example, if I say that let us use this micro cantilever to understand the elasticity of a tissue, or of some material right, of a gel gelatin. So, how you will

know what is elasticity of that particular gelatin by using the Piezoresistive micro cantilever that you have to figure it out all right.

If you see I will also show you some of the research papers that, you can go through, and you can understand how we can use this kind of what devices for understanding the elasticity of the material.

However, for this particular experiment, let us focus on how we can use this micro cantilever and how we can use the output of the micro cantilever with a electronic module all right on it. So, the output that we have we can take it is using the contact.

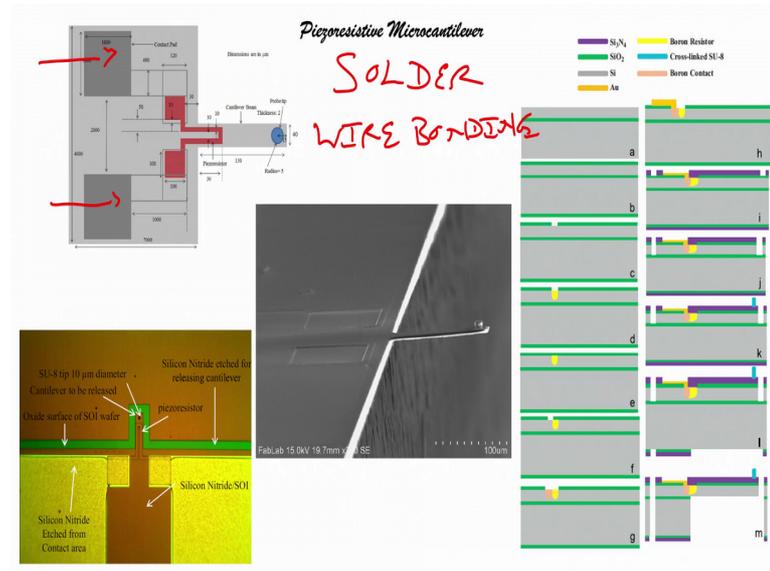
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You can see here there is one contact there is a second contact these are called contact pads what is called contact C O N T A C T pads P A D S.

All right so using this contact pad we can take the value of resistor and we can measure the value of the resistor right. So, between these if I put a multimeter and if I measure the resistance, then I will see that depending on how much force we are applying there is change in resistance that; we can measure using the contact pads all right. Now to measure the resistance through this contact pad through this and this contact that we have to use either a process called soldering or a process called wire bonding right.

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To take the contact from this pad and from this pad, either we can use soldering S O L D E R solder or we can use wire bonding B O N D I N G, wire bonding right 2 process.

Now, once we perform soldering wire bonding. We can measure the resistance. Now if you have this and if I apply pressure and if I see the change in resistance right, there resistance how can I further connect or calculate or use it to convert it to a some form at the output using the electronic module. So, for that we it is very important for us to understand, what is loading and how the loading will come into picture and what kind of operation amplifier or we can using the operation amplifier work and of circuit we can formulate all right.

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The Effect of Loading and Input Impedance

$R_x = 1\text{ k}\Omega = 1000\ \Omega$
 $\rightarrow \text{If } R_{in} = 950\ \Omega$
 $50\ \Omega$

- Resistive sensors are one of the most commonly used sensors. They are inexpensive and easy to use and interface with ADCs
- The output voltage or sensitivity of the most sensors are poor. Hence it requires an amplification stage before the ADC to use all its levels
- An Op-Amp is generally used as an amplification stage due to its electrical characteristics
- Resistive elements can be made sensitive to temperature, strain and light. Using these basic elements, many complex physical phenomena can be measured, such as: fluid or mass flow, pressure, load, humidity, temperature, etc
- In the Figure 1 shown below, in a resistive divider circuit if R_2 is considered as a sensor any change in R_2 resistance results in voltage change. For $R_2 = 1\ \text{k}\Omega$, the output voltage is 1 V
- To amplify the circuit, a gain amplifier can be used. We will now look at different amplifier configurations and how they fare with each other

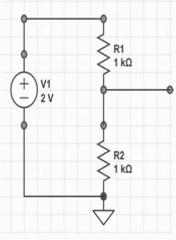


Figure 1

So, let us see the Effect of Loading and Input Impedance. There is a first topic that we have to understand. I told you about the episode is tomato can deliver. So, that you have an example of the sensor, which can show the change in resistance all right, that if that was the reason of talking on repeating the Piezoresistive micro cantilever which we have seen in detail in theory classes.

So, resistive sensors, sensors right are one of the most commonly used sensors. So, when I say or when you get this statement here to immediately see what are other sensors that also change the output terms of resistance right, because somebody is claiming the resistive sensors are one of the most commonly used; that means, we have to find out that what are the other sensors right? What are the types of resistive sensors, one I have told you Piezoresistive micro cantilever is a sensor right. Why they are most commonly used in the sensor? The reason is because they are inexpensive they are cheap and easy to interface with ADCs, easy to use a interface with analogue to digital converters. So, the output voltage or sensitivity of the most sensors are poor.

Now particularly when you talk about resistance to change in the distance. So, if you talk about the microcantilever, the change in the resistance of the microcantilever would be extremely low extremely small. So, if there resistance is small that is let us say you have a base resistance value of for example 100 kilo ohms or you can write 1 2, let us say 1 kilo to make it easier let us write 1 kilo ohm, which is 1000 ohms right. Let me

write clearly; let us say we have a resistor 1 kilo ohm, which is 1000 ohms all right. Now if the change in the resistance is 50 ohms change in the resistance. So, when we apply pressure or force right, the new value this is let us say base resistance BR, new value B delta R or change in resistance is 950; that means, the difference is only 50 ohms.

This will determine the sensitivity, how sensitivities; how much more changes there, more change from thousand 2 new value better than sensor is all right, better the sensor. That means that if I give you a sensor, which is one kilo and if you see that there is a change of 500 ohms. Then it is really sensitive sensor and you have a broad range, you have broad range to operate in that case real life becomes easier of how to create electronic module, what is the changes small then it is very difficult.

So, we are talking about the commonly used sensors or resistive sensors. So, if we can see on the screen again that; these sensors are inexpensive that is good easy to use beautiful interface the ADC easy to interface amazing, but what the output voltage or sensitivity of most sensors are poor. Hence it is required or it requires an amplification stage before convert before interfacing with the ADCs all right. There is very important that it requires an amplification stage.

So, how this amplification is done and when you do the amplification, how the loading effect will come into picture you will see. First let us see this one and Op Amp is generally used as an application stage due to it is electrical characteristics. Resistive elements can be made sensitive to temperature strain and light right. So, for example, if you have temperature sensor the output would be resistance. If you thing about strain gauge the output would be resistance right. If you take about the optical sensor again you will lot of the thermo resistor or sensors, that are used for under understanding the change in the intensity or a gain has a output in terms of resistance all right.

So, the temperature thermistor if you say a gain resistance is the output. So, using this basic elements many complex physical phenomenon can be measured such as; fluid, mass, pressure, load, humidity, temperature etcetera right. So, what is the basic elements? Just that there is a change in resistance. So, by understanding the change in resistance using different sensors we can see that; what is the or we can measure what is the fluid mass, we can understand what is temperature, we can understand what is humidity, we can understand what is strain right and not of other phenomenon. So, is this

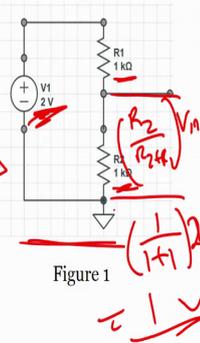
the sensors are heavily used, but the, but the important point is we have because the signal or sensitivity is poor, we have to use op amplifier. And to use amplifier we are using operation amplifier all right.

So, coming back to the screen, so until here is ok.

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The Effect of Loading and Input Impedance

- Resistive sensors are one of the most commonly used sensors. They are inexpensive and easy to use and interface with ADCs
- The output voltage or sensitivity of the most sensors are poor. Hence it requires an amplification stage before the ADC to use all its levels
- An Op-Amp is generally used as an amplification stage due to its electrical characteristics
- Resistive elements can be made sensitive to temperature, strain and light. Using these basic elements, many complex physical phenomena can be measured, such as: fluid or mass flow, pressure, load, humidity, temperature, etc
- In the Figure 1 shown below, in a resistive divider circuit if R2 is considered as a sensor any change in R2 resistance results in voltage change. For R2 = 1 KΩ, the output voltage is 1 V
- To amplify the circuit, a gain amplifier can be used. We will now look at different amplifier configurations and how they fare with each other



First is resistors are most useful, output voltage is poor sensitivity is poor, operation amplifier use for amplification stage, resistor remains can be used for several applications. Now let us see this particular figure, what is this figure? Very easy way to understand is a potential divider, it is a potential divider. You are applying a voltage there are 2 resistors and your measuring the voltage across resistor R 2 right. So, in the figure shown below is not exactly below one side. So, you can see the figure one side right, in a resistive is a resisted divider if R 2 right is considered as a sensor. So, let us assume that this R 2 is a sensor. If this is a sensor that mean that; this will change the resistance this all right.

So, if R 2 is considered as sensor any change in our 2 resistance results in voltage change. For R 2 equals to 1 kilo ohm output is 1 volt right. So, what is the voltage we are applying; 2 volts. What is the value of R 1; 1 kilo ohm. What is value of R 2; 2 kilo. What is the potential divider R 2 upon R 2 plus R 1 into V in V in is 1 volt. So, if I place value 1 by 1 plus 1 into one is it into 2 right, input is 2 volts this is equals to 2. So, sorry

this is equals to 1 divided by 2 this is 0.5 into 2 which is equal to 1 volt right approximately 1 volt.

So, this is how the potential divider works right, we can measure the change in the r voltage across value of R 2 and what we find is; we find that if I apply a voltage it will be half of what you I have applied in the input signal. So, this is a potential divider and we all know about potential divider. So, quickly let us see why we have taken this circuit and how it is going to help us to understand the loading an input impedance.

Now so to understand here; what we have seen? To amplify the circuit a gain amplifier can be used right? We will look at the differential amplifier configuration and how they are how they can be used with resistor, how they can used or interface with each other all right.

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The Effect of Loading and Input Impedance

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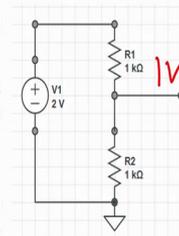


Figure 1

That means, that here I have output is 1 volt. If I want to magnify this out, if I want to amplify this output; I have to use a amplifier right. What is an amplifier? So, let us see that amplifier.

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The Effect of Loading and Input Impedance Contd..

- If a gain amplifier of inverting amplifier of gain 10 is designed (shown in Figure 2 below) and connected to the output of the voltage divider circuit, ideally it should give an output of - 10 V (gain*input voltage = - 10*1 V = - 10 V)
- But it results in lower output. This is due to loading effect caused by the input resistor R4 in the circuit shown below. Moreover another Op-Amp should be used to convert the phase
- If the same circuit is connected with a non-inverting amplifier shown below (Figure 3) with a gain of 2, it results in an output voltage of 2 V (gain * input voltage = 2*1 V = 2 V) as expected
- This is due to the fact that the input voltage is directly connected to non-inverting amplifier which provides a very high input impedance and an extra Op-Amp is not required for phase conversion

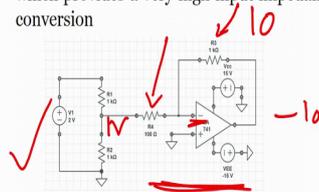


Figure 2

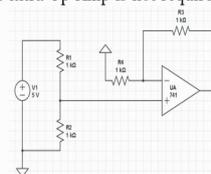


Figure 3

So, you understand here, so if I want to if a gain of amplifier of inverting amplifier. So, if a gain amplifier or a inverting amplifier has a gain of 10 right is design like you see here right. So, if you see here this is a amplifier right, and you see value of R 3 and you see value of R 4, then you will find that the gain is 10, is designed as shown here and connected to the output of the voltage divider circuit ideally you should given output of minus 10 right, correct? Because this is a 10 this is output voltage divider circuit is what 1 volt this is 1-volt 10, 10 is a gain 10 is gain, then the output this is inverting amplifier.

So, inverting amplifier output would be minus 10 because input voltage is 1 volt right. This what it says; that if you use a inverting amplifier with a gain of 10, then the output would be minus 10. If it is connected with the potential divider as shown here, easy?

Now, let us go to the next section, what is that? But it results in lower output how this is due to loading effect caused by the input resistor R 4. Now you see here very important interesting.

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The Effect of Loading and Input Impedance Contd..

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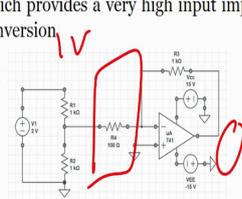


Figure 2

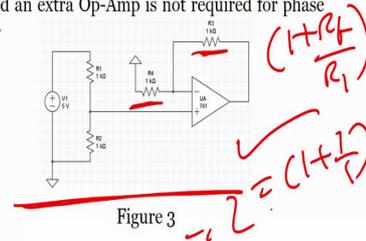


Figure 3

So, understand this thing, what is that? The output should be minus 10 all right, but when you measure practically you will find that the output voltage here is not minus 10, why because of the resistor R 4. This R 4 creates a loading effect on the circuit all right.

So, we can see here the, but it results lower output this is due to loading effect caused by the input resistor R 4 in the circuit shown below. Moreover, another open should be used to convert the phase, why because you see here is 1 volt, here is minus 10 volts. So, we do not require minus 10, we required plus 10 if we require plus 10 a gain Op Amp to convert your phase back to is positive value.

So, another Op Amp is required that is if the same circuit is connected with and non-inverting amplifier. Now you see same circuit non inverting amplifier right which is bigger 3 this one. With a gain of 2 right with the gain of 2 why because you have here 1 kilo ohm, we have here 1 kilo ohm, gain of non-inverting amplifier was 1 plus R f by R 1 right, which is 1 plus 1 by 1 which is equal to 2 right.

So, what we are saying; that if you connect the potential divider output with a non-inverting amplifier which is here right.

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The Effect of Loading and Input Impedance Contd..

- If a gain amplifier of inverting amplifier of gain 10 is designed (shown in Figure 2 below) and connected to the output of the voltage divider circuit, ideally it should give an output of -10 V (gain*input voltage = $-10*1\text{ V} = -10\text{ V}$)
- But it results in lower output. This is due to loading effect caused by the input resistor R4 in the circuit shown below. Moreover another Op-Amp should be used to convert the phase
- If the same circuit is connected with a non-inverting amplifier shown below (Figure 3) with a gain of 2, it results in an output voltage of 2 V (gain * input voltage = $2*1\text{ V} = 2\text{ V}$) as expected
- This is due to the fact that the input voltage is directly connected to non-inverting amplifier which provides a very high input impedance and an extra Op-Amp is not required for phase conversion

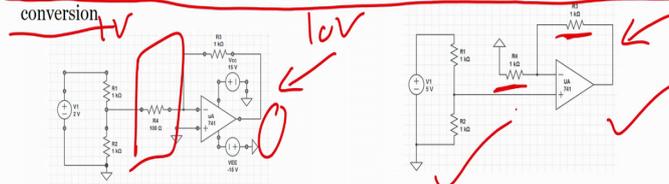


Figure 2

Figure 3

What do you will see? You will see it results in the output of 2 volts as expected. So, there is no phase shift, we have seen inverting amplifier 180-degree phase shift, non-inverting amplifier no phase shift right. This is due to the fact that the input voltage is directly connected to the non-inverting amplifier, which provides a very high input impedance and an extra time is not required for phase conversion.

So, if we talk about the inverting amplifier and we talked about non inverting amplifier here what we are seeing he said we can use non inverting amplifier to remove the loading effect. There is no phase shift and that is why for this particular application that we have taken an example this can be a good circuit all right, so this much is easy.

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The Effect of Loading and Input Impedance Contd..

Solution

- Using voltage buffer along with the inverting amplifier connected between resistive divider circuit and the inverting amplifier as shown in Figure 4 below will provide a very high input impedance
- This is an advantage of buffer amplifier or isolation amplifier. The output voltage for the given circuit is -10 V as expected. (since gain is 10)

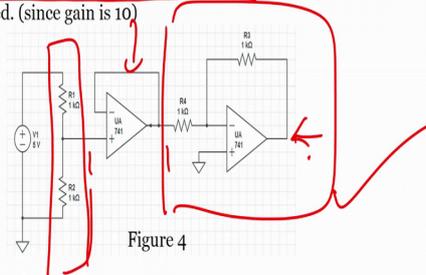


Figure 4

Now we will do an experiment to understand these concepts

Now, let us see the solution. So, what are the solution? All right so what is the solution? Using the voltage buffer along with the inverting amplifier connected between a resistive divider, as you can see here right this is a voltage divider circuit connected to a inverting amplifier circuit using the buffer voltage follower or buffer right. So, using a voltage follower along with the inverting amplifier connected between the resistive divider an inverting amplifier right, as shown in figure he this figure will provide a very high input impedance right.

This is an advantage of buffer amplifier isolation amplifier, you we have seen last lecture what is a buffer amplifier, we seen what is voltage follower. Now we are looking at how voltage follower can be used in a electronic circuit, which is the example given here right.

So, you can understand that use of voltage follower used to remove the loading effect on the following circuit all right. The output voltage of the given circuit is minus 10 volts as I expected. So, because is inverting amplifier the output would be minus 10 volts here at the out, is it correct? Let us see 1 volt here it is goes here minus 10 volts is it correct all right.

So now, let us do the experiment. So, let us let us will do the experiment to understand these concepts. We have understood what concepts; we understood the effect of loading. Let us do some experiments. So, actually see that if I use the circuit that we have just

seen how exactly it gives you the output voltage or output waveform. Or what happens when we use only voltage divider, what happens when we integrate the inverting amplifier, what happens we integrate voltage divider with non-inverting amplifier, what happens when we use voltage divider with a buffer an inverting amplifier. So, we will see this few concept in the next slide and we will actually do the experiment all right.

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The Effect of Loading and Input Impedance - Experiment

Aim: To study the effect of loading and input impedance

Part 1

- Connect the circuit as shown in the Figure 5
- Apply 2V DC input at V1
- Observe the output at V_{out1} and note down the value in table
- Now, connect the circuit as shown in the Figure 6
- Apply 1V DC input directly from power supply at V2. Observe and note down the output voltage at V_{out2}

Sl. No.	V1	V_{out1}	V2	V_{out2}	Expected V_{out2}
1	2.01	1.011V			
2	4.00	2.007V			

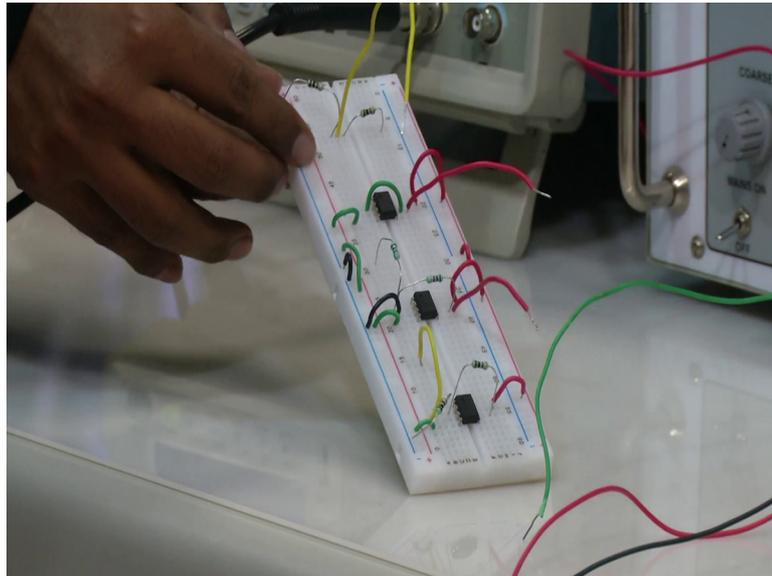
So, first experiment that we have to do is to study the effect of loading and input impedance to affect the these experiment right, to study now all of you know what is loading, all of you know how input impedance can be increased right by using what kind of amplifier right or a voltage follower. So, let us see this one, figure 5, what is this? Voltage divider. Figure 6, what is this? Inverting amplifier right.

So, connect the circuit as shown in figure 5. What we will do we will first connect the circuit as shown in figure 5, which is the voltage divider all right, then we will apply 2 volts D C at here input and we will observe the output and note down the value all right, this is first thing we will do.

So, we will see what is the input voltage if it is V out 1. So, whatever input voltage we are giving let us say we are applying 2 volts, what is V out 1? V out 1 is the voltage between a voltage across resistance R 2 all right. So, we will measure what is R 2.

Then we will apply, then we will do the second experiments. Let us do one by one. For first experiment and when for next few assignments we will take help of Suman Chatterjee, last time you have met him. So, I will request him once again to come and help us, to show the circuit on the breadboard.

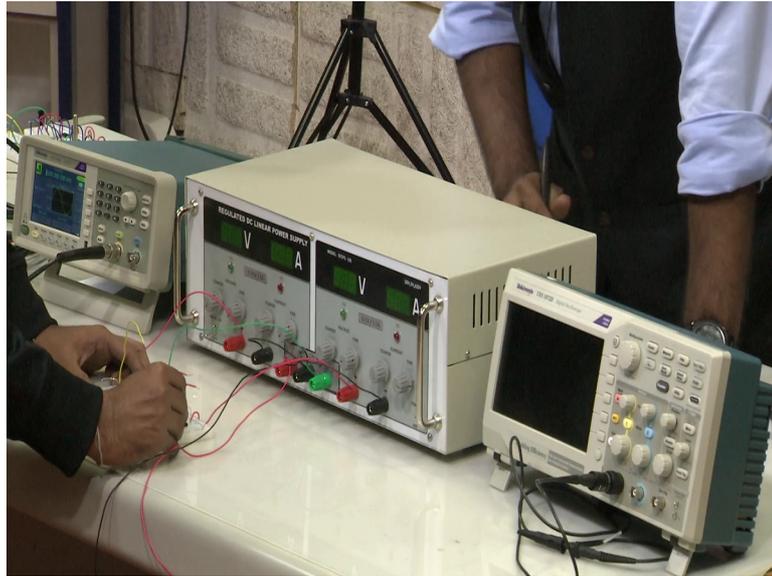
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So now you see the voltage divider circuit right over here, which is the first one all right. The first one that he is holding here, this is these R 2 resistor right connected in series and now we will apply voltage, which is our input voltage right this resistors. And we will measure the output voltage across resistor R 2 let us see that.

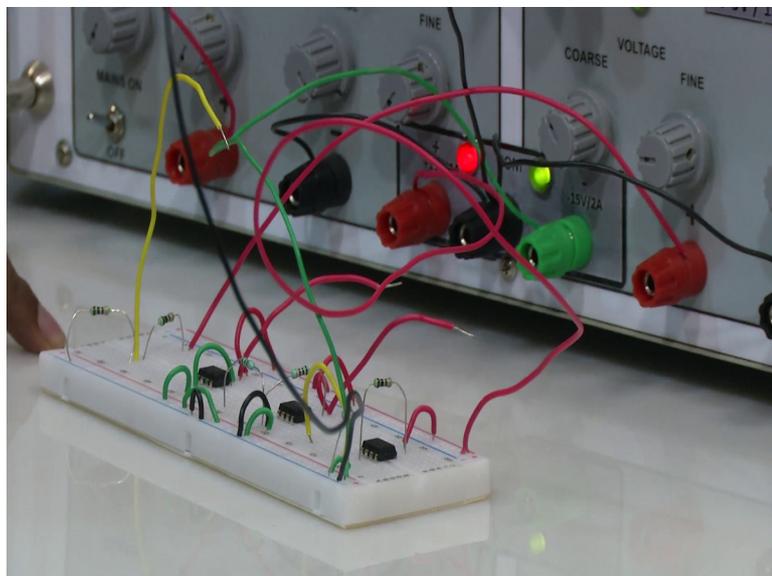
So, how we can apply voltage? We have to apply voltage using the D C power supply, which is in front of us.

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So, he just he sets connecting the voltage plus and ground across the resistors ok. So, what he has done; he has applied if you see here closely this red wire all right.

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This comes from where; this comes from the plus 15 volts (Refer Time; 28:04) 15 volts yeah, this plus 15 right ok. So, this is plus 15 volts and are we applying plus 15 volts. So, we are applied 2 volts right (Refer Time: 28:17). No right now we are showing the potential divider ok. So, we are applying 2 volts, which is here which you can see here right 2 volts. Have we apply 2 volts and D C voltage can you please show 2 volts.

Yeah so here is 2.02 volts, we applying right across the resistors across the resistors here all right. So, so this is the red wire for 2 volts is coming through here. It is this the red wire right it comes through a resistors here or right. And ground which is the another wire this is ground, which is black color wire which I am holding, I am moving right now into to show it to you, this is the ground all right.

So, I am applying 2 volts across this resistor what I (Refer Time: 29:12) to move a measure and to measure, what is the value of voltage across R 2. So, I have this yellow color wire right, I will connect it to the multimeter and ground to ground all right.

Let us see when you connects the ground and yellow wire what we see?

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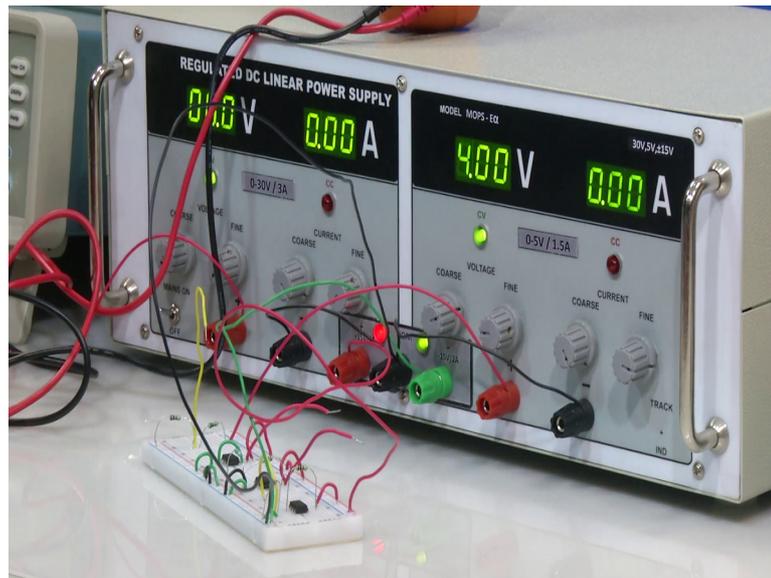
We see output approximately half of what we have applied at the input; 1.01 volts right. Now you will say that Hardik; why we are have 1 volts at the 1.011 volts at the output. It should be exactly 1 volts right? But one thing is 2.01 was is the input. Second thing is the resistors that we are assuming as one kilo ohm may not be exactly 1 kilo ohm, but it may have some tolerance. This tolerance in the resistance can cause or will cause the change in the output voltage slightly different than their expected output voltage or calculated output voltage right.

So, this is very easy now what we have done; we have applied 2 volts. So, if you if you come by to the screen if you apply to volts and what we have reached here 1.011 volts

1.00 it is right. So, actually when you want to do the experiment, you do get exact value right. So, do not just assume that it is 2.01 1.01 volts write exact values ok.

Now, we will do one more experiments, instead of 2 volts; let us apply 4 volts at the input. So, if you see in the D C power supply.

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Now, he is increasing the voltage to 4 volts, you can use fine very good. So, this is 4 volts at he have a here is applied; across the potential divider circuit which is 2 resistors and he is again measuring the voltage. And what we can see the voltage at the output is 2.007 volts right 2.007 volts. So, 4, 4 volts at the input 2.007 volts at the output understood very easy, how to measure the voltage across resistors right? So, this is the potential divider circuit.

Now, we will go to the second part of part 1, that is part 1 let us consider this as a, now let us consider this one which is your second part. Now connect the circuit as shown in figure 6, what is figure 6? If you see here on the screen this is figure 6 this is the circuit of a inverting amplifier, you see you are applying voltage at the inverting terminal of the operation amplifier. You have a feedback resistor, you have a input resistor right, you have minus the V C C or V E E, you have plus V C C. Here you have to measure output V out to this is the circuit.

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The Effect of Loading and Input Impedance - Experiment

Aim: To study the effect of loading and input impedance

Part 1

- Connect the circuit as shown in the Figure 5
- Apply 2V DC input at V1
- Observe the output at V_{out1} and note down the value in table
- Now, connect the circuit as shown in the Figure 6
- Apply 1V DC input directly from power supply at V2.
- Observe and note down the output voltage at V_{out2}

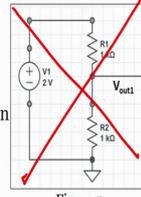


Figure 5

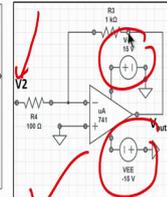


Figure 6

Sl. No.	V1	V_{out1}	V2	V_{out2}	Expected V_{out2}
1	2.01	1.011V	1.01V	-10.09V	
2	4.00	2.007V	2V		

So, we are now we are now considered anymore figure 5. We are not considering the circuit, right we are just considering figure 6, which is the circuit all right. So, right now do not see this one, just see this one we have already seen this. So, let us see figure number 6, figure number 6 what it says? Connect the circuit shown in figure 6 connected, now apply 1 volt D C input directly from the power supply at V 2, we have to apply here 1 volt. So, I will write here 1 volt exactly what is a voltage we will see 1 volt and observe and note down the output voltage V out 2 ok.

So, V let me just write down 1-volt V 2, let us let us apply. So, this is the circuit we have seen inverting amplifier this is similar circuit. So, he is not showing you how to connect the resistors across a Op Amp to form inverting amplifier. We have already seen inverting amplifier, if we had inverting amplifier we have to apply bias voltage.

So, if you see here in the DC power supply, we have already given bias voltage plus minus 15 here plus minus 15 using the power supply to the operation amplifier. So, this is the circuit right this the inverting amplifier circuit, you can see one resistor here, which is here and another resistor here right 2 resistor one here second here all right. So, these 2 resistor as you can see very clearly this are R f and R in, there is operation amplifier we have applied plus 15 and minus 15. Now we are going to apply input voltage to the inverting terminal of the inverting amplifier, can we please apply input voltage? So, how much input voltage applying? We are applying 1 volt 1 volt at the inverting terminal.

When we apply 1 volt to the inverting terminal, what is the output? Voltage output voltage is measure between 0.6 of the operation amplifier or pin 6 number pin and ground and the output voltage is it correct no yes. So, what is the output voltage? You can see output voltage is minus 10.09 minus 10.09 right. So, it should be minus 10-point minus 10, but it is minus 10.09. So, input voltage and applying input voltage of 1 volts approximately 1 volts or to be precise 1.011 volts output voltage is minus 10.09 volts right?

But you remember if I make it 2 volts right do not make it right now. If I make it 2 volts then because of the gain of 10 my output should be minus 20, is not it? But I will not get minus 20 because my supply voltage bias voltage is 15 minus 15. We have seen this in previous experiment here you to remember all right. So, I am not applying 2 volts I am not applying the 2 volts. Instead of that just to see we will just change instead of 1 volts; we apply half volts which is 0.5 volt.

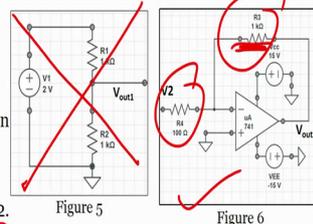
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The Effect of Loading and Input Impedance - Experiment

Aim: To study the effect of loading and input impedance

Part 1

- Connect the circuit as shown in the Figure 5
- Apply 2V DC input at V1
- Observe the output at V_{out1} and note down the value in table
- Now, connect the circuit as shown in the Figure 6
- Apply 1V DC input directly from power supply at V2. Observe and note down the output voltage at V_{out2}



Sl. No.	V1	V_{out1}	V2	V_{out2}	Expected V_{out2}
1	2.01	1.011V	1.01V	-10.09V	-10.00V
2	4.00	2.007V	0.5V	-5.13V	-5.00V

Can you please change it to 0.5? So, if you see in the dc power supply, if you see in the dc power supply now we are applying 0.5 yes.

So, an applying 0.5 volts at the inverting input of the inverting amplifier or the input of the inverting amplifier what output we get? Minus 0.5 into 10 times, 5 close to 5 volts we should get minus 5 right? Minus 5.13 volts, so when applying 0.5 volts, we get minus 0 minus 5 point; 5.13 volts all right.

So now we know how to use inverting amplifier, how to use potential divider right? What is the expected output? Expected output is 10.00 volts here expected output is minus 5.00 volts right, because here we have assumed gain of 10, why? R 3 is one kilo ohm R 4 is 100 ohms that is why; gain of 10 that depends again I am telling this change that you see in actual values compared to our expected value is there is because of the resistance, the change in the resistance. If I say 1 kilo ohm, why is my resistance can be 1 kilo ohm plus minus few ohms. Plus, minus few ohms would change my entire amplification factor.

So, keeping in mind if you want to have precise values of the output, then you should have precise value of the passive components that you used in the operation amplifier got it.

So, what we have seen? Seen we have seen that; if I apply voltage across potential divider, how can I measure the voltage across a resistor R 2. Second is if I have applied voltage in the inverting amplifier what is the output voltage, this 2 things we have seen right.

Now, let us see the another part and that would be to if I merge both if I connect this with this, then what will happen all right. This is another part where I have to see that if I am instead of using individually, only buffer or sorry only potential divider and inverting amplifier. If I integrate both that means, output of my potential divider is the input of the inverting amplifier. What is the overall effect all right to see this we will continue in the next module. And we will see how we can integrate both the circuits together to form the output or we will see the effect of loading, at the output in the next module all right. So, till then take care, I will see you in the next module bye.