Op-Amp Practical Applications: Design, Simulation and Implementation
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Lecture – 23
Op-amp based Voltage Controlled Current Source

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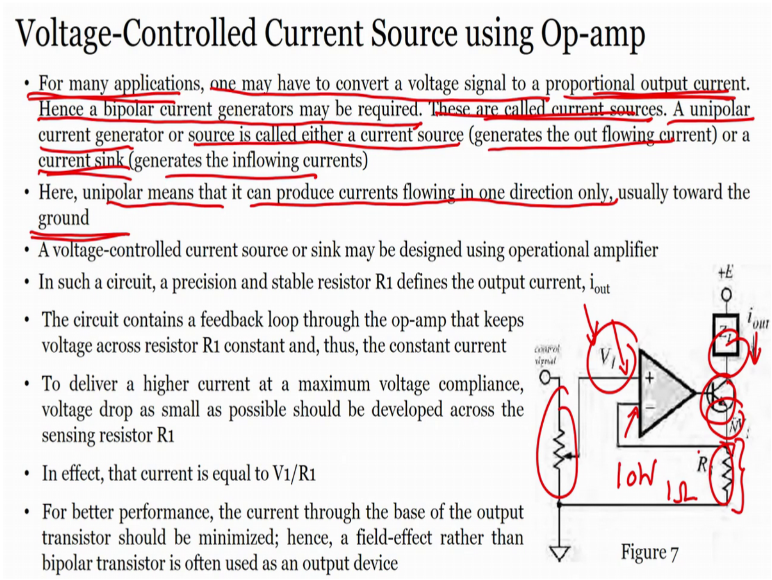

Welcome to this class there are several application of operational amplifier, that we have seen until now, and there are a lot of applications which we can still use op amp for. We will see in today's module very important application of an operation amplifier and that is voltage controlled current source voltage controlled current source.

So, what exactly voltage controlled current source means that, if you by changing the voltage by changing the voltage, you can change the current by changing the voltage you can have the, you can design a current source. And we will see several the current source voltage controlled current source, not only on the breadboard not only on the bread board, but also using multisim both the ways we will see and we will see the low current application high current application.

So, on the breadboard probably we will see high current application, and on the multisim we will see a circuit which can be used for low current application. Now, when you talk about current source or voltage controlled current source what as the what is the application of voltage controlled current source right, is there any other thing like constant current source, constant voltage source, if yes where are they used if it voltage controlled current source what is the application if it is a constant current source, what is the application constant voltage source, what is the application. So, try to understand as much as you can try to find it as much as you can all right.

So, for this particular module let us see what exactly voltage control current source is all right. So, if you come on the screen, you see that for many applications, for many applications one may have to convert a voltage signal to a proportional output current right is nothing, but V to i voltage to current converter right. So, hence a bipolar current generators may be required we need to require current. So, current generators are required these are called current sources these are called nothing, but current source all right. A unipolar current generator or source is either a current source, or a current sink it can either source the current or it can sink the current right.

So, if it current source then it generates the out flowing current, if it sinks the current then generates the inflowing current right here, unipolar means that it can produce current flowing in one direction only usually towards the ground; that means, we see if you look at this particular circuit, if you look at this particular circuit. You know that the voltage there will be some voltage over here, which can be generated using a potentiometer, we can generator using potentiometer. Now, you know a concept of virtual ground, we have already seen what is virtual ground with the concept virtual ground, whatever voltages here same voltage would try to appear over here right, same voltage try to appear over here.

Now, what is this the circuit is nothing, but a voltage follower a voltage follower. So, when this happens; that means, that the this transistor conducts and the resistor the current across this resistor the current across this resistor right, it depends on the voltage that is we have applied over here, because trying to follow the same voltage depending on that if you have your emitter current here, then the same current would be there in the in the collector same current we will have in the collector. So, if I change this keep on changing this voltage I will constantly be able to see the change in the voltage across this resistor. And this change in resistor will keep my current constant, will be generate my current will keep my current across the load resistor flowing.

Because this transistor is in conducting state transistor will be in conducting state, one thing you have important remember is the in the high power application, this particular resistor should be 10 watt 1 ohm, but we will see two different application of this voltage controlled current source one is in high power and they can easily low current applications low current applications all right. So, we will see two different circuits as well. First thing is now you understood how this circuit operates, then unipolar as we have discussed it is only that, it will follow in from the source to the ground, it is has to go to ground. Now, voltage controlled current source or sink maybe designed using operational amplifies.

This is nothing, but you are operational amplifier right in such a circuit a precision and a stable resistor R 1 defines the output current i out right stable current resistor R 1 right, this one defines the output current i out ok. The circuit contains a feedback loop through the op amp that keeps the voltage across R 1 constant.

Now, you can see that there is a feedback across the operation amplifier because of which the voltage across this R 1 is constant right. Now, to deliver a higher current at maximum voltage compliance, voltage drop as small as possible should be applied developed across sensing resistor.

Voltage drop as small as possible, how we can develop this kind of resistor voltage drop.

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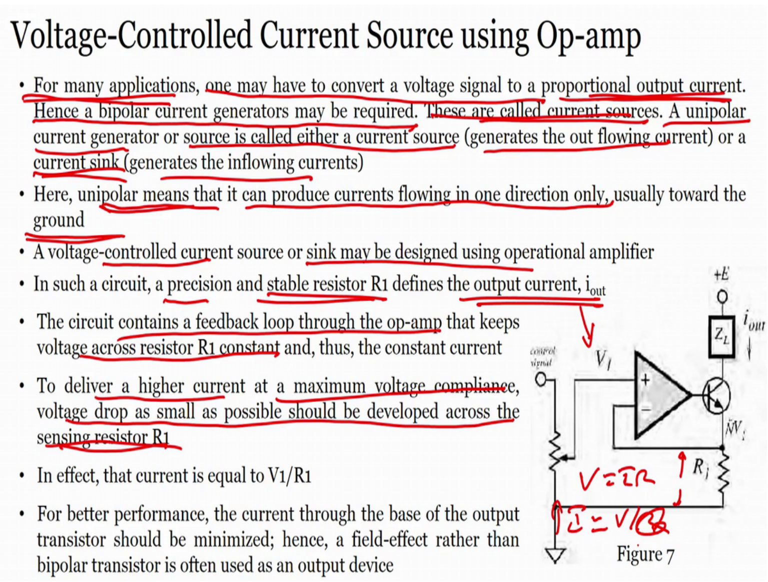

Because we know that the value of current here or V equals to IR then I equals nothing, but I equals to V by R right; that means, if you want to have a higher current then my resistance value should be extremely small resistance value should be extremely small.

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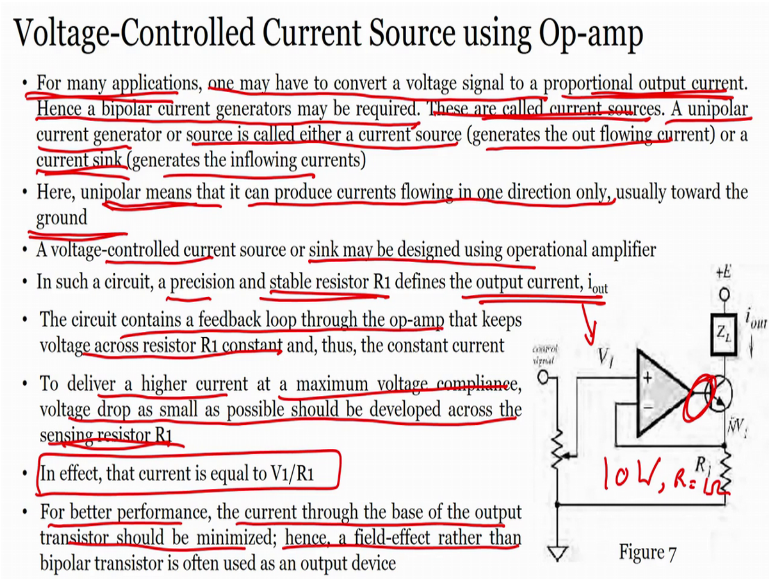

And that is why what we have earlier shown is that the current here, the resistor here is high watt resistor power resistor with a resistance value of 1 ohm resistance value of 1 ohm. So, in effect the current is equal to V by R current is equal to V by R right.

So, for better performance the current through the base of the output transistor should be minimized, hence a field effect transistor rather than B j t is often used right the current is base should be optimized or is to be minimized rather right and that is why instead of the B j ts if we use IFTS it is better.

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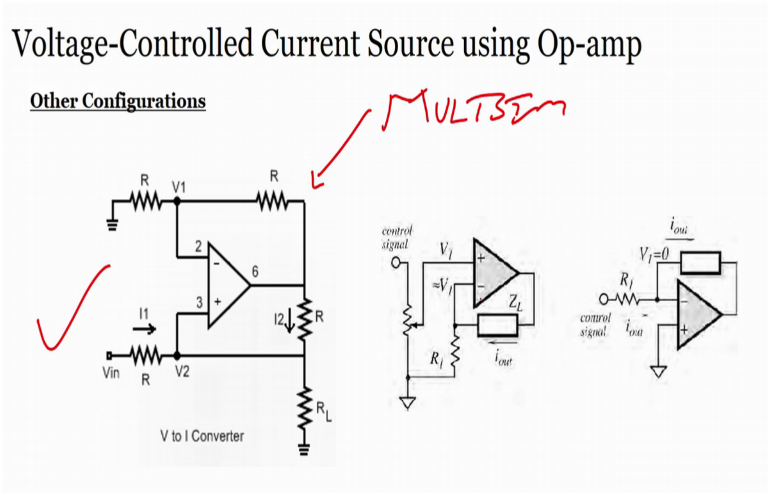

Figure 8: Voltage to current converter with a) grounded load b) floating load with non inverting configuration c) floating load with inverting configuration

So, if I want to design this voltage controlled current source right and how can I design one way is of course, this one which is right in front of you right in high current application we can use this particular circuit, but what if I want to use a circuit for low current applications. For low current applications for low current applications, I can use this particular circuit which you can see here in is nothing, but voltage to voltage to current converter voltage to current converter right.

And if I want to use the op amp as a in the so, this is all are grounded load you see the ground loads are grounded right load is grounded here load was grounded earlier right, but here what I have to use here if I see this particular circuit, which I call as b, this is I am calling as a and this I am calling as c all right. So, if I use this particular circuit which is my b and c, I see there is a floating load there is a floating load, you see the load is floating here, also you can see the load is floating right it is not grounded in this situation whether I am using inverting or non inverting amplifier that is another case.

So, this b is showing on non inverting amplifier, the voltage that is given is across the non inverting terminal in case of the see the voltage is generated at the inverting terminal voltage is generated at the inverting terminal right.

So, now I can have three different circuits one is the voltage connect with the grounded load one with floating load and, with inverting configuration non inverting configuration and inverting configuration right. So, what I will see; what we will do today is we will see, how we can design this particular circuit this one with multisim.

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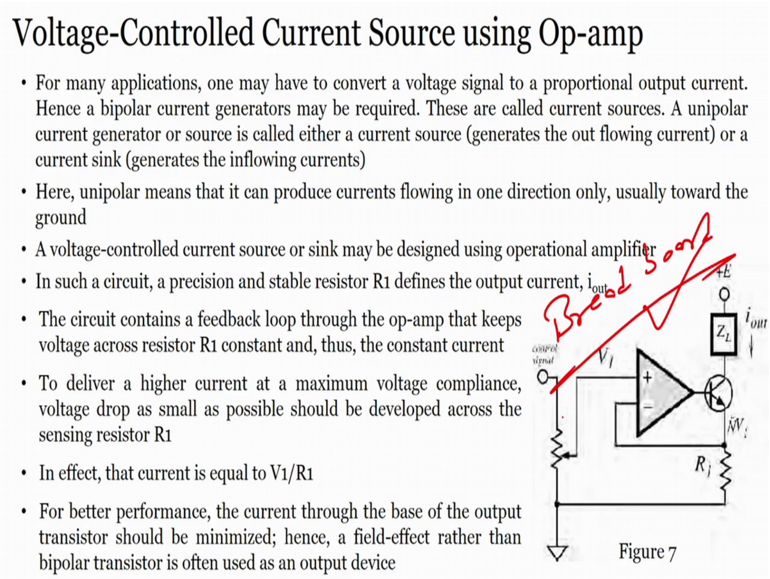

And the previous circuit that is this one on our bread board right. So, two things we have to do, in this particular experiment to understand the voltage controlled current source is one we will design the circuit using breadboard. And second we will also see using the simulation; you will also see using the simulation.

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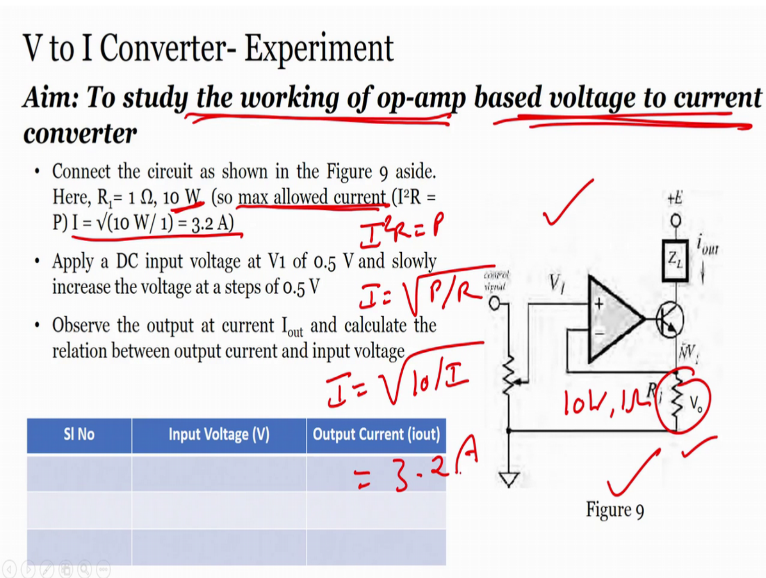

So, if I want to perform the experiment, if I want to perform the experiment I have the them would be m would be to study the working of op amp to study the working of op amp based on voltage to current converter all right, voltage to current converter. If you see this circuit is similar to what I have told earlier where you have to use this resistor which is a power resistor and that is why the value is about 10 watt 1 ohm 10 watt 1 ohm..

They connect the circuit as shown in figure ok, we will connect it here R 1 is 1 ohm R 1 is 1 ohm which is here this one and 10 watts. So, maximum allowed current right is 3.2 ampere maximum current would be three point ampere, because I square R equals to P so, I equals to under root of P by I P by I and that is why 10 watts by I which is your so, 10 watts by 1 sorry, because one is your resistor right see I square R equals to P so, you can write I equals to under root of P by R right. So, I equals to what is power? Power is given power is 10 watt resistance is 1 ohm.

So, 10 by 1 ohm if you do this mathematics simple mathematics you understand I would be 3.2 ampere which is the current all right. So, this we know this we know all right. Now, next what apply a DC voltage input voltage DC input voltage from where from here, all right of 0.5 volt and slowly increase the voltage a step size of 0.5 volts, we will apply 0.5 volts we increase with the step size of 0.5 volts, observe the output at the current i out observe the output here, all right and calculate the relation between output current and input voltage, we do understand what is the relation between input voltage and output current.

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V to I Converter- Experiment

Aim: To study the working of op-amp based voltage to current converter

- Connect the circuit as shown in the Figure 9 aside. Here, R_I= 1 Ω, 10 W (so max allowed current (I^2R = P) I = √(10 W/ 1) = 3.2 A)
- Apply a DC input voltage at V1 of 0.5 V and slowly increase the voltage at a steps of 0.5 V
- Observe the output at current I_{out} and calculate the relation between output current and input voltage

Sl No	Input Voltage (V)	Output Current (iout)
1	0.5V	
2		
3		

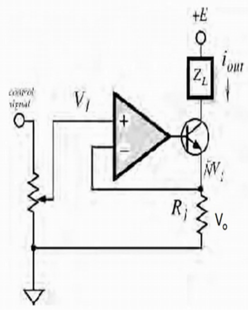

Figure 9

So, we will have 1, we will have 2, we will have 3 let us see input voltage, what we apply right in DC input voltage starting at 0.5 volts we start at 0.5 volts, then we go on increasing it and we look at the current at the output right. To perform this particular operation we will design or implement the circuit shown in figure 9, which is right over here in your on your screen and we will implement the circuit using the breadboard using the bread broad. So, when you went to implement circuit in bread board, let us see how it will look like and we will we will ask Sitaram to join us to show us, how the circuits how this circuit can be implemented using the breadboard, how the circuit can be implemented using the breadboard.

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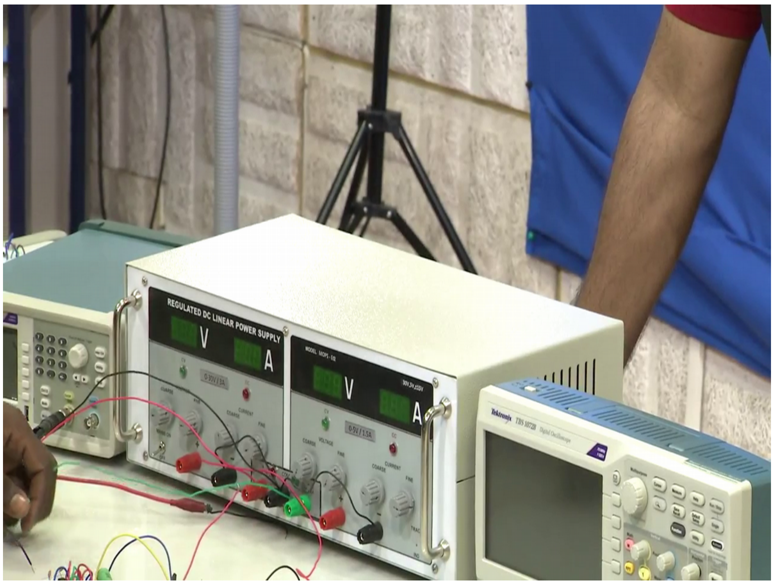

So, now, you can see if you see the circuit right the green big boy is your resistor is a power resistor, you can see its 10 watt right tolerances is plus minus 5 percent and the value is 1 ohm all right value is 1 ohm.

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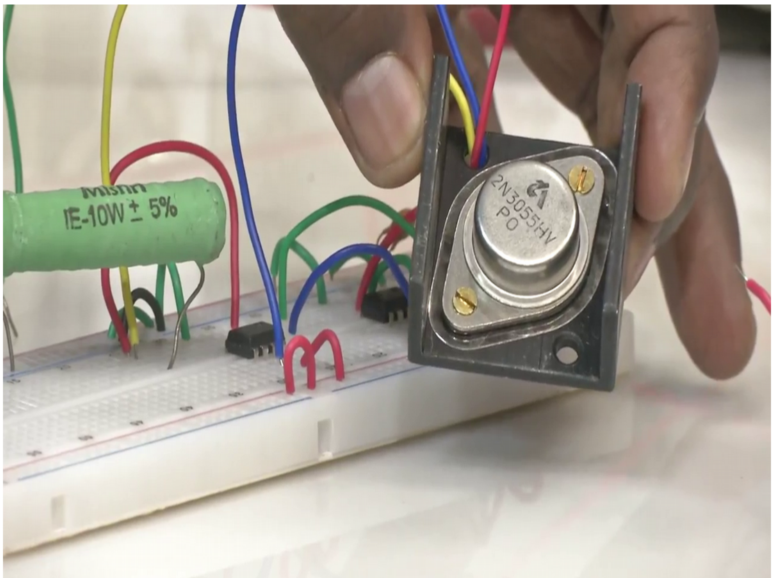

And then you can also see transistor right is a power transistor and you have the heat sink, why there is a heat sink because huge current is going to get generate, and if it flows through the transistor right the transistor will get heated up and to dissipate this heat, we requires the we require the heat sink. Now, what we have to use? We have to use a operation amplifier. So, we have to apply we have to apply plus minus 15 volts plus minus 15 volts across the breadboard, all across the op amp that is your bias voltage that is a bias voltage.

So, we will use the multimeter, we will use a multimeter to measure the current to measure the current, because we already know how much voltage we are applying, because we will apply through the DC power supply which is 0.5 volts right. So, and then we keep on increasing and we will see the change in the current ok. So, we have to measure the current at across the load resistor across the load resistor, and we can see the current on the multimeter, we will we will be able to see the change in the current on the multimeter as well.

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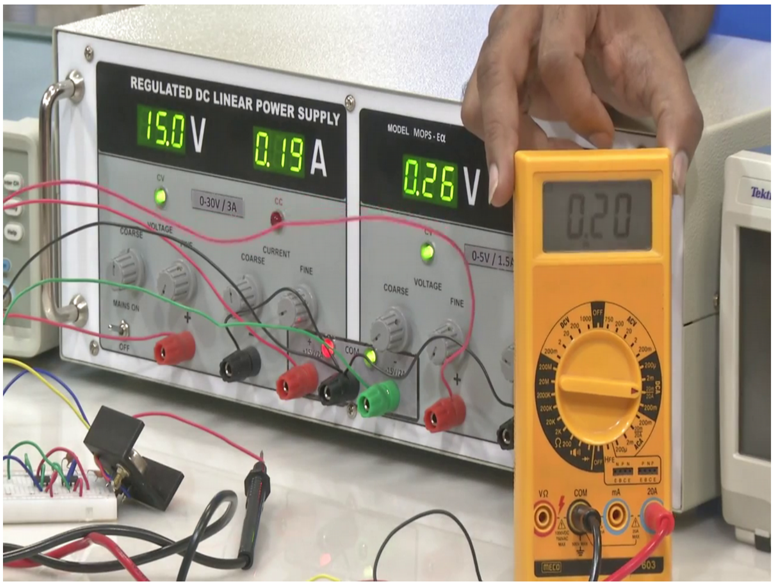

So, now we are connecting the voltage we have connected the voltage. So, we are connecting the voltage DC voltage, at the input of the voltage at the input of the voltage to current converter input of the voltage to current converter ok. Now, we have to start our power supply right DC power supply DC power supply. So, we will start the DC power supply right and we will increase in step of 0.5 volts. So, first we will apply we are applying right, now plus VCC to a transistor applying plus VCC to the transistor and you can see plus fifteen volts ok. And we are applying the same way you can see when we are changing the voltage the current increases the current increases.

So, let us not go with very high current yeah ok, for 0.25 volts, you can see there is a current of 0.9 0.20 or 0.19 ampere you can see in the. So, DC power supply also you can see in the multimeter also right, we will see the multimeter right. Now it is in ampere. So, its 0.20 amperes 0.20 amperes right, if I reduce the voltage if I reduce the voltage yeah it is 0 directly, but can you increase this slowly 0.7 you can see the change in the current all right guys.

So, this voltage to current you see voltage to currents it is converting here, voltage to the current it is converting the voltage to the current there is some loss, there is some loss and that is that is obvious that is obvious, because of the circuit there are components we will have lot of voltage drop across the components and, you can see basically the loss is due to the transistor, that is connected in the circuit.

But anyway the point is that, now we have designed a voltage to current converter with a simple circuit that you are see looking at here, the main point that you have to find it is that you have to you have to use a power resistor, you have to use a power resistor you have to use a power transistor with a sink all right with a sink, you can see at 0.5 volts we have 0.39 volts 0.39 amperes right 0.39 amperes. Thus this is the way that you can design the voltage to current converters all right. So, we have we can I have not writing down on the screen, but I am showing it to you here how we can how we can implement actually voltage to current converter and how you can see this voltage to current converter working all right.

Now, if I want to do the similar study if I want to do the similar study with multisim with multisim, but in multisim let us see this circuit which is for the lower current, which does not have require high current all right. So, for that one what about circuit? Circuit was this one, which you can see here which is multisim multisim multi multisim all right. So, we will implement this particular circuit and we will see that, what happens when we change the voltage and we will see the change in the output current, we will see the change in the current in the output ok.

So, performing this experiment we will open the multisim and of course, Sitaram will continue he is here.

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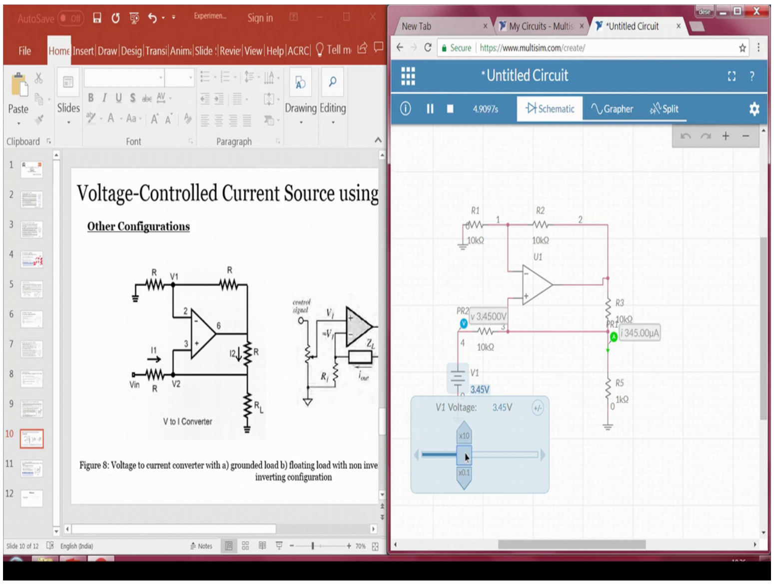

So, we will again open the multisim software we have open the new file and we have to design the circuit which is V to i converter right. So, now, you all are expert in using multisim. So, you know what we are doing here we are we are dragging the resistors from the library, we are we had already take the op amp right and we had to just use different resistors here. Now, this is a low current application that is why we are not using a power resistor in this multisim ok, we are not using power resistor.

So, we are adjusting or we are writing on the values of the resistor that we want to use right 10 kilo ohms, we have our op amp ready a load resistor is 1 kilo ohm. And, now as you see what will happen as we change the input voltage you see input voltage, the output voltage follows the input voltage, output voltage or we can the output current here we are measuring the current right voltage to current converter, you can see the output current right it is depending on how much voltage we are applying at the input this voltage is converted into current.

And you can see that you know the voltage what we are applying is getting converted into current and is a local current application that is why you cannot see current which were like 0.3 ampere or 0.4 amperes right, here you looking at microamperes to milliamperes. Again if you drag it slowly back then you will see that as you change the input voltage, your current output at the current at the output also changes and an in short the circuit is nothing, but your voltage to current converter voltage to current converter.

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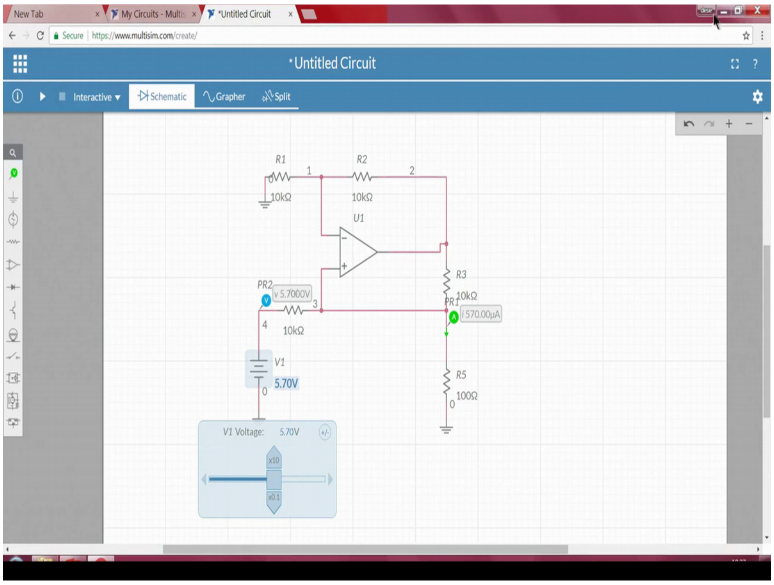

So, if I change the value if I change the value of the load right in that case what happens, in that case what happens you can still follow and still follow, the voltage you can see the voltage, we are we are applying the input and the output is a current. So, we can see that the output current is getting generated by the input voltage applied at the non inverting terminal right.

So, this is how this is how you can design this is how you can design a voltage to current converter a voltage to current converter in multisim right. So, if you have seen what we have seen here is nothing, but the voltage controlled current source or voltage to current converter right guys.

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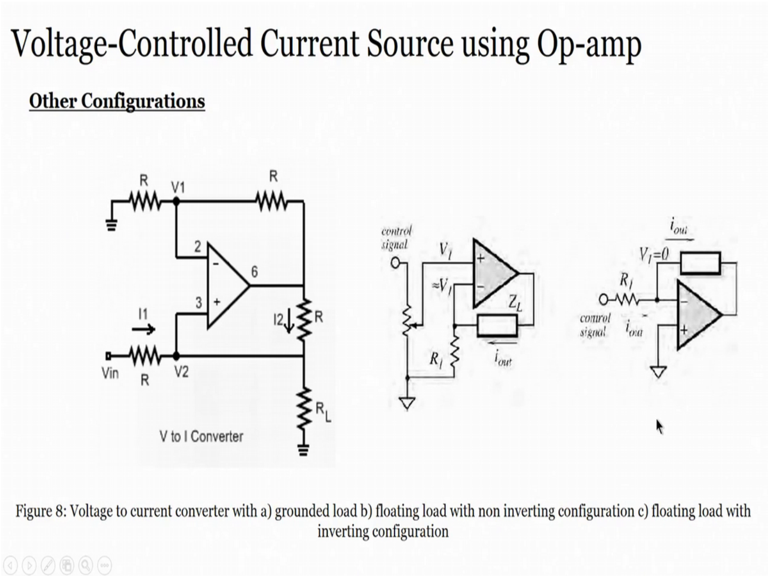

So, this is the application this is the application of the operational amplifier, this is the application of the operational amplifier, which is the voltage to current converter right. And we have seen two things here, in this particular module one is the voltage to current converter using the breadboard, and second was voltage to current converter using multisim right.

So, I hope I hope you understood what we have discussed in this particular module right, I hope you are understood in this particular module and I you have to you have to understand this particular video, understand how voltage to current converter works and see the application of voltage to current converter.

And what I feel is that once you understand how the voltage to current converter works and see the application, try to see the same application for all the other modules that we are previously discussed for all the other modules that we have previously discussed all right. So, if you really understand all the topics that we will discussed till now, you will find that we have discussed huge amount of applications right, or large amount of applications starting with the basic thing to coming to this kind of circuits, where it can convert your voltage to current.

So, now understand what is the application of solar cell, if I have a solar cell what is the output and, if I have a photodiode what is the output can I convert my voltage to current, can I convert my voltage to current voltage that is generated can I convert to current. So, I have given you some hint, but you have to find out the real applications of the circuits that. We have discussed during entire series of the modules particular at the experimental part of this particular lecture all right. So, I will see you in the next class and that class will be the final class for the experiment portion and final class for this particular course as well.

So, read it right understand it look at the video right try to figure it out, try it using multisim at least right if you do not have the equipment forget about it, at least use multisim if you have multisim equipment please use both the recommendation from my side would be theory simulation experimentation right, but if you have no experiment, if you do not have the equipment do not worry at least perform simulation all right. So, with that I will see you in the next class, till then you take care bye.