Op-amp Practical Applications: Design, Simulation and Implementation.
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Lecturre – 24
Measure of Unknown Resistance by Constant Current Drive Circuit Implemented using Op-amp

So, welcome to this particular module. In this module we will see, how we can Measure the value of Unknown Resistance of a cable by a Constant Current Drive using operational amplifier. So, let us see what exactly we mean by such a long title right.

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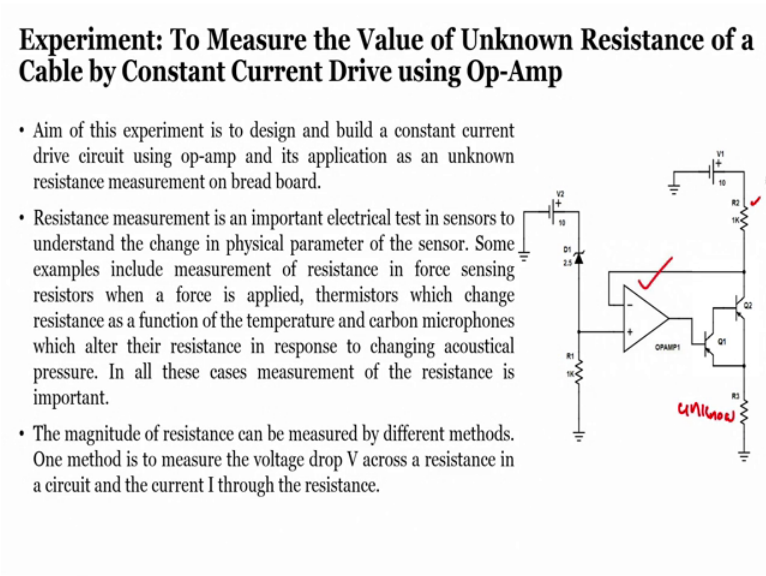

So, when you look at the slide what you see here and I think this particular portion is not too much visible, but I will just try to re draw it if required let us see first aim ok. The aim is aim of the experiment is to design and build a constant current drive using operational amplifier and its application as an unknown resistance measurement on breadboard.

So, this particular resistance R 3 which is shown here right, we need to measure what is a current flowing through the resistance R 3. And if you want to know that, we need to have either a constant voltage source or we need to have a constant current source. But if you see here, we if you do not have that, then how can we design such a circuit which will give you a constant current or constant voltage source so, that we know the value of current flowing through R 3 and to do that we are using operational amplifier.

The one correction here is we this is a inverting and this is non-inverting terminal. So, here we are using zener diode, we are using a resistor R 1 and we have a voltage source V with just ten volts. Now if you see here zener we are we are taking of 2.5 volts; that means, the drop across the zener will be 2.5 and here what you will get is about 7.5 volts constant right. So, this 7.5 volts, we are giving to a non inverting terminal of the operational amplifier; that means, because of the concept of virtual ground; if the non inverting terminal is at 7.5 volts; that means, the inverting terminal also would have 7.5 volts.

That means this 7.5 volts appears right over here right. So, if you see here is 10 volts here is 7.5 volts; that means, the voltage drop here is 2.5 volts correct. Now this 2.5 volts if we know; that means, we know how much is the current flowing through the collector of Q 2. If you know the current flowing through collector Q 2, we will also we can also calculate the current flowing through emitter because it is related with constant call alpha right and we can measure this value.

So, thus if we know the current flowing through collector and emitter we know what is the current flowing through resistors resistor R 3. This is the idea of this particular experiment and if we just look at the look at read the paragraph, what it says that resistance measurement is an important electrical testing sensors to understand the change in physical parameter of sensor. Some examples include measurement of resistance in force sensing resistors when a force is applied right.

One of the application is when you apply force and you want to see the change in resistance right, then they are you need to have a sensor which can show you the output in terms of change in resistance. Second example is thermistor when you heat the sensor, the output will be change it will be in terms of change in resistance. Then another example is carbon microphones right. So, which alter their resistance is response to changing acoustical pressure. So, there are lot of examples where you see that resistance measurement will be a very important factor.

Now, the magnitude of resistance if we again see the slide, what is a last paragraph? The magnitude of resistance can be measured by different methods: one method to measure the voltage drop V across a resistance in a circuit and the current I through the resistance right. This is one of the method which we can use and the similar kind of concept we have used right over here in this circuit and we will see show you this thing in detail in terms of the experiments.

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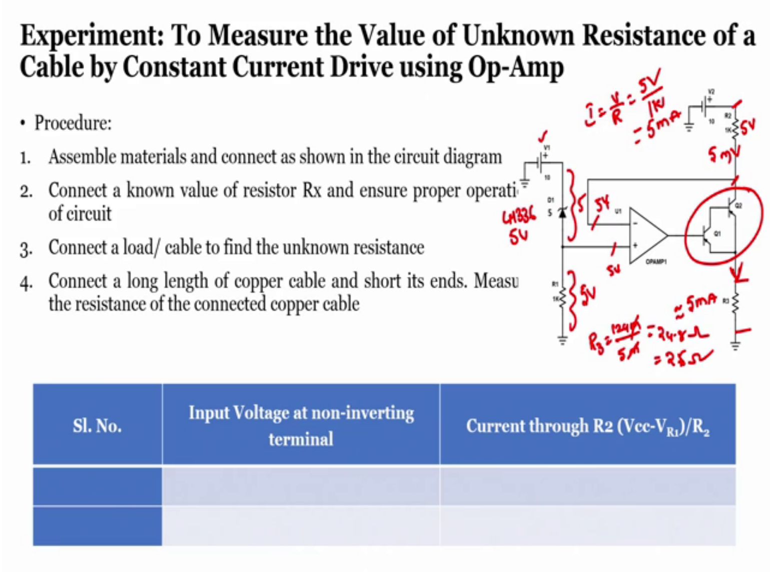

So, the experiments are like I said we will be taken up by the TA. But let us see the procedure. The procedure is to assemble the circuit the component and the materials as as shown in the circuit. We need to connect the op-amp zener diodes resistors transistors and voltage source in a as shown in the circuit. The next one would be to connect a known value of resistor R x, you can be R 1, R 2, R 3 and ensure proper operation of circuits. So, R x can be a unknown value of resistor, then you can have connected load or cable to find unknown resistance this is can be unknown resistance that we want to measure. And finally, connect a long length of copper cable and short it ends measure the resistance of connected copper cable.

This idea of this particular experiment, let us see in the experiment we will continue this in terms of the experiment class. Let us see I will call my TA to continue this particular session. If you any questions, do feel free to ask me through the portal. Till then take care I will continue the class in terms of experiment.

Now, we will see how to use operational amplifiers in order to find out unknown resistance. We know that in most of the cases, generally in case of even sensors right most of the simplest way of designing a sensor is resistive type.

So, and by measuring the resistance, we also have we will be understanding the physical parameter so; that means, we should have to have a circuit in order to measure the resistance value. As you also seen in the theory session, what are the different ways of measuring a resistance and as you all already seen in another different ways of measuring a resistance, we are now going to show you know implementation of this particular circuit in multisim as well as on the bread board. And before implementing it, we will understand how exactly the circuit is going to work in order to measure the unknown resistance.

Now, if we recall the simplest way of measuring any resistance is by applying some known amount of voltage to a system or by applying some constant current as an input to the system and measuring the voltage drop across a resistor. As a result, since I know the current as well as the voltage drop across the resistor right. So, suppose if this is my resistor, if I am applying some known current that should be a constant current; some I and if I measure the voltage drop across this V. So, if I want to find out R based on the ohms law, we can say V by I is nothing, but I R.

So, if I know this parameter as well as this parameter, this is easy to find out, but the problem is that getting a constant current source is of really difficult and even providing a constant voltage source is also really difficult and those are expensive too. So, any fluctuation in the voltage voltages or any fluctuations in the current from the current sources, it results in change in resistance value. As a result the accuracy of the resistance measurement entirely depends upon I value. So, in order to avoid these problems, we have also seen we know that other ways of doing it by using wheat stones bridge circuit or voltage divider circuit. But basically write those are other ways of doing it.

Now, I am going to show you how to make a make use of operational amplifiers right in a; as a result by making use of operational amplifiers with transistors, how can we measure resistance unknown resistance value? So, it is similar to that of the circuit that we have seen that we are going to seen our temperature controller systems too have the plan that we have realize, but there was slightly different. Now if we recall, if we understand if we look into this particular circuit right, in this case the purpose of the op-amp here as well as transistor right. The transistor here is in order to provide a constant current to the unknown resistance.

In this case R 3, I am considering as an unknown resistance right; we can use any R 2 resistance value and R 1 resistance values too, but R 3 is an unknown resistance. So, the only intention is we have to find out what is a unknown resistance here. Now how to understand the circuit?

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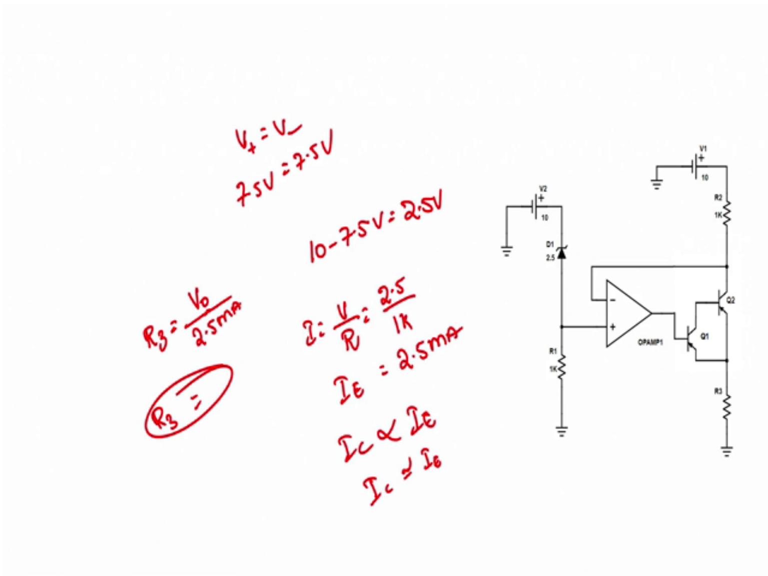

Just to understand the circuit just we have just recalling, what we have seen in the been in the theory session. So, what we are doing? We are using a zener diode, we are using one resistor here and we are using an operational amplifiers and this is PNP based Darlington pair right. This is PNP based Darlington pair and this is another resistor.

Now what is the purpose of Darlington pair? Generally when you go with Darlington pair, the total gain of the system will be higher right. So, because the amplification factor will be multiply multiple of this as well as this right, as a result the current gain the current gain will be held. So, whenever we are going with a high current applications, you will always go with Darlington pair transistor. It is not compel compulsory that you only have to go with a Darlington pair right, that entirely depends upon the requirement. In this case if you are limiting to milliamps are one amp of current, we can go with a normal single Darlington pair based transistor or even smaller; we can go with normal no basic general purpose transistors too. But when we are going with the high current applications, Darlington pair should be must. Otherwise the transistor cannot with such a high current flowing through the circuit.

Now what about the whatever the op-amp, we will see why what is the important that op-amp. But before that let just have a look on what is the use of having a zener diode here and what is the purpose of having this R 1 resistor right. Now if you recall the working of zener diode zener diode, generally been worked in a reverse bias condition. Now when we see the value is the cutoff one, they have mentioned it as 2.5.

It means that in reality, if you observe no matter what voltage that you apply as an input of the system and moreover when you see this is completely in a reverse bias condition right, the drop across the zener diode will be always 2.5 volts right; the drop across is 2.5. Now so; that means, if I see the drop across the zener diode is 2.5 good, now what we about the voltage across the positive terminal? Since the voltage across this positive terminal is connected to the R 1 resistor and the input voltage we are applied is of 10 volts. As a result, so, 10 minus 2.5 energy neither be created nor destroyed. So, 10 minus 2.5, 7.5 volts will be across this R 1 resistor right.

So; that means, the voltage across the positive terminal is 7.5 volts right, but why one k resistor? Why not some other value why not 10 ohm? Why not one ohm? The reason going with higher resistance value is when you looking to the data sheet of zener diodes are any semiconductor based system; they will always provide you the information of high amount of current that it can with stand for right; operating current.

So, when we look into the zener diode this particular diode, we can see somewhere around 10 to 20 millions of current is maximum current that can withstand. So, basically the resistor R 1 here is a current limiter circuit to protect the zener diode not to damage and since it is connected the current flowing through this will be completely limited.

So, in this case the current will be somewhere around 7.5 divided by 1 k. So, this will be the current flow across this right. So, it will be in milliamps right; it will be somewhere milliamps of current. So, as a result because of smaller amount of current it cannot damage, it will not damage the zener diode. Now what is our use of op-amp? The purpose of op-amp here is to maintain the constant current across your R 3 resistor, how? If I take a simple transistor if I take a simple transistor if I want to understand; if the transistor is in on condition right, the voltage drop across entirely depends upon what is the voltage that you apply right and what is a resistor.

And if the resistance value is higher the voltage drop across this will also be higher right. But in this case since we have to understand what is unknown resistance value; if I know the current flowing through the circuit and if I measure the voltage drop across this particular circuit, it is very easy to realize the resistance value. So, the for that case we required to have a constant current, but as long as if you are going with this method, you cannot guarantee that the current flowing through this and moreover that entirely depends upon the resistance.

But in this case we required to know this particular resistance value right. So, that is the reason in order to maintain the constant current across the collector as well as emitter of the transistors, we are using a negative feedback by using an op-amp. So, as a result what happens since if you recall your op-amp golden rules, one important golden rule is that virtual ground concept; that means, the difference between the positive and negative terminal should be always equal to 0 or the V plus is equal to V minus.

And from the previous circuit, we understood that the voltage drop across is somewhere around 7.5. So, as a result since it is 7.5 volts, what will be the voltage across this negative internal that will also be at 7.5 volts. So, this is also at 7.5 volts. Now so, since it is directly connected to here; that means, the drop across this if I want to calculate the drop across this particular value it is nothing, but 10 minus 7.5 so; that means, it is 2.5 volts of top right. So; that means, I know what is the voltage of across my transistor sorry across my resistor and I know the resistance value.

So, is it easy to calculate the current flow? Yes right. So, how do we calculate the current flow? So, as we know from the ohms law, I want to find out I which is nothing, but V by R right. So, V is 2.5 and R is 1 K. So, the total current flowing is 2.5 milli amps of current. So, this is 2.5 milliamps of current is flowing. This is at this is at emitter right. So, and you also know since it is obesity right, we know the relation between I C and I E. So, this is nothing, but my I E and the relation between I C and I E is directly proportional right.

So, I can also say it is almost equal to I E approximately equal to I E right. If you want to calculate accurately, what we have to do is that we have to look into the data sheet and that depends upon what type of transistor that we are using. Generally it will be somewhere around 0.99, the gain alpha value. So, if I multiply with alpha, then we can easily find out I C value too right. Now since our intention was to find out I C, so, I am considering I C is also almost equal to I E. So, all equal to I E. So, if I know this value and if I measure the voltage drop across this particular value right, so, I will be knowing V out. So, I need to know R 3; R 3 is nothing, but v out divided by this 2.5 milli. So, this gives me the resistance value of R 3.

So, the main use of op-amp here is to maintain the constant current through the circuit, no matter what no matter what the current flow in the complete circuit will be 2.5 milliamps. That entirely depends upon what is a resistor that we are using and what is a resistance that you are using here as well as sorry not, this resistance basically it depends upon what is a zener diode cutoff voltage as well as what is the power that we are applying it here.

So, these are the important things one has to understand right, in order to realize or understand about the working of this particular circuit. I have this is clear. Now we will see what are we have calculator is theoretical. We have calculator will compare the result with the simulation. So, since we have to compare the result with simulation, what I will do is that I will go with I will open multisim right.

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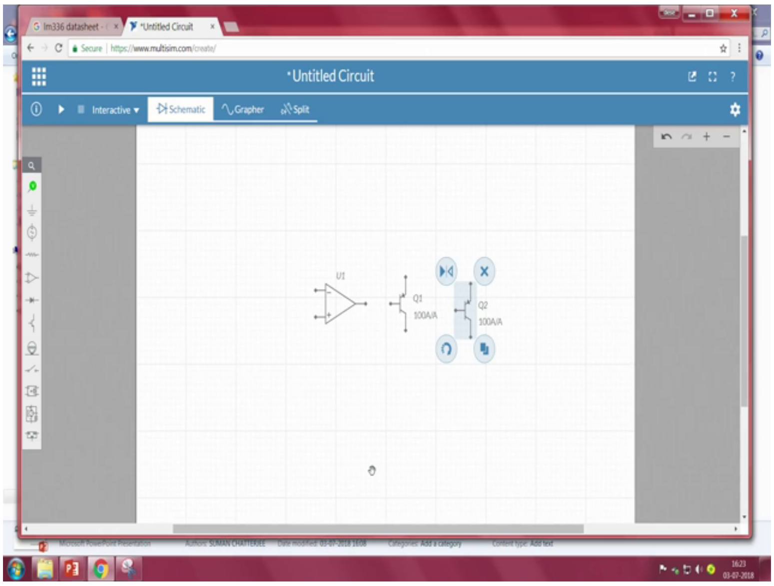

So, if you recall the complete multisim since we have we are seeing the multisim from long time. So, I do not want explain everything. If you want to understand, just look back to the multi introduction through multisim media that we have created.

So, I am placing an op-amp right and the positive should be down, if we recall what we have seen in our circuit and we require PNP transistor because we are using PNP. So, we require Darlington pair. So, I am using the Darlington pair configuration. So, we can see here.

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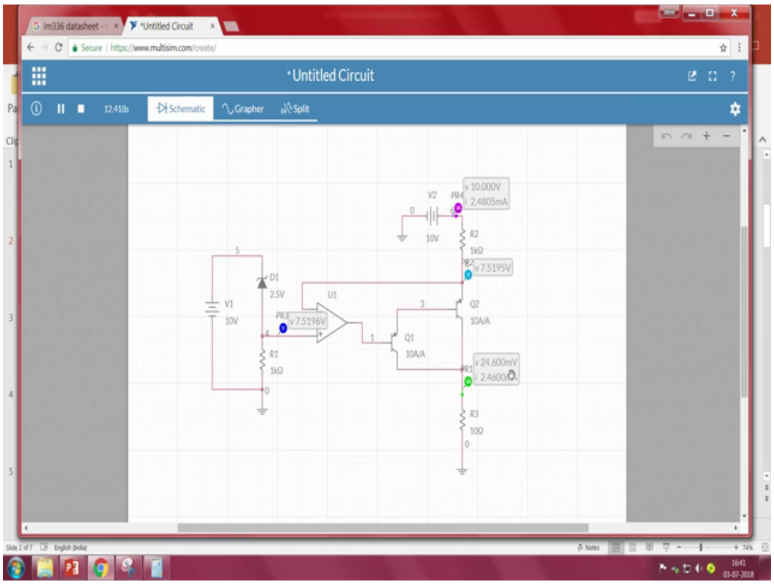

Now, when we see after constructing right, so, what I will do is that I will put probe here. So, this is 2.5 and the alpha value somewhere around 0.99. So, let me run the circuit and we have constructed based upon what we have seen in the circuit.

So, here we can see that 10 is input the drop across D1 is 2.5 so; that means, since it is 2.5 10 is input the drop across R 1 will be 7.5. We can easily s 7.5196 volts. Now since it is in positive terminal, the negative terminal will also be at the same value 7.55195. Now the input voltage is 10 volt. So, if I want to calculate the drop across R 2 resistor, it is 10 minus 7.5. So, 10 minus 7.5 is somewhere around 2.5 volts right. So, 2.5 volts is the voltage drop.

Now, since it is 2.5 this is 1K, it will be 2.5 milliamps. So, when we calculate the value 2.4805 milliamps approximately 2.5 milliamps. Now see our intention was to find out this unknown resistance, since we do not know how to calculate the unknown resistance what we are doing is we know the resistance. But I know this current value I will be measuring the voltage drop across R 3. So, if I look in to the voltage here, it is showing somewhere around 24.6 millivolt right. Now if I look into the alpha value, it will be somewhere around 0.99 right. So, it is 2.485, 2.4805 into 0.9 0.99.

When I do 2.455 approximately equal to 2.46 milliamps. It is a 0.99 by right that is why 0.3. So, no matter, so, this is my the voltage across sorry the current flowing in collector right. So, if you recall the relation between I C and I E, I C is always equal to alpha times of I E. So, as a result the current across here collector will be always smaller than the current flow across here emitter. So, because of that even though it is flowing 2.48 42.5 milliamps, it will be smaller than the collect the emitter current it will it is somewhere around 2.46 milli.

So, now what is the voltage drop 24.6? So, 24.6 milli divided by 2.455 milliamps so; that means, somewhere around 10 ohms. So, see observe what is the resistance 10 ohm? So, forget about 10. So, what I will do is that I will go with somewhere around 100 ohms. Now I do not look into the current, I only require the voltage. So, voltage is 246 milli. Now we know that the current flow is 2.4805 milli that is the current flow current in near emitter into 0.99 that will be the current sorry 2.4805 into 0.99; so, which is 2.455 is the current flowing through the emitter sorry collector alpha times of I E and the voltage drop across is 246 milli.

So, 246 divided by answer are 2.455 which is 100.2. So, observe here the resistance value that we have connected is 100 ohms. So, go with the other resistance values too. So, I will go with somewhere around 500 now. So, 2.455 and this is 1.23 divided by 2.455. So, which is 501.5. So, this is volts and this is milli; so, 0.5 kilo 0.5 kilo right that is nothing, but 500 ohms.

So, almost equal to the value is almost equal to 500 ohms. So, this is a, so, by using an operational amplifier, we can provide a constant current to a resistor and by finding the drop across voltage drop across the resistance. Since we know the voltage since that is a constant current, it is easy to identify the unknown resistance right. So, we will see whether it is working in the same way in our circuit too in the experimental mode. So, an experiment we will connect everything a breadboard we will use LN336.

So, LN33 6 is a zener diode with a reference value of 2.5 volts right. So, either we can go with the 10 volts or 15 volts. If we go with a 15 volts, the voltages will be little different right. Now we will see the experiment on this. So, actually the experiment we have usen we have choosen LN336 of 5 volts. So, while when we are solving, we have considered the zener diode voltage as 2.5, but for the experiment purpose just to understand about the next value, we have chosen the diode voltage reference voltage is 5 volts. So, if it is a 5 volts, let us consider how what will be the current flow and everything.

So, since it is a 5 volts, the voltage drop across this will be 5 volts and now the input voltage connected is 10 volts and since complete 5 volts is dropping here, the voltage across R 1 resistor will also be at 5 volts. Since as you know important property golden rules of an operational amplifier if the positive terminal is at 5 volts because of the virtual concept, the negative voltage will also be at a 5 volts. Since this particular terminal is connected to at this point and the another end of the resistor is connected to 10 volts, the drop across the resistor will be 5 volts, is not it?

So, because the drop across a resistor is a 5 volts, since we know the resistance value we can calculate the current flow through this. So, as you know according to the Ohms law I is equal to V by R. So, the voltage drop across resistor is of 5 volts because this is 10, this is 5 10 minus 5 will be 5 volts and the current and the resistance that we are using is 1 kilo ohm resistance. So, 5 by 1 will be 0.5 milliamps. So, the current flow will be 0.5 milliamps ok. So, the drop is 5 volts and the current is point 5 sorry 5 milliamps right 5 milliamps this is also 5 milliamps because 5 by 1K right. So, since 5 milliamps and then since this is a Darlington pair, configuration the current flowing through this particular resistor will also be 5 milli approximately equal to 5 milli right. So, since our intension was to find out unknown resistance value, if I measure I can measure the resistance across this.

Sorry if I can measure the voltage across this R 3 resistance and by looking into by looking into the voltage and the current right. So, voltage and the current will give us the resistance value right.

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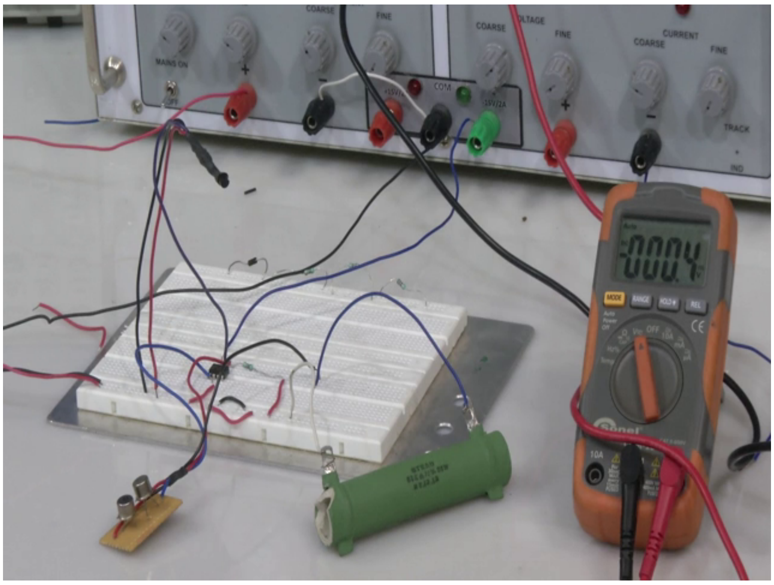

So, if I look into the board look into the experiment board here, we can see this is an unknown resistance that we are considering. Since it is a unknown resistance value by looking into the voltage drop across this resistor, this is a resistor by the way and by looking at the current flow through the 1 kilo ohm resistor here, current flow through this resistance we can understand the resistance value.

So, since to compare the theoretical as well as with the actual resistance value, we have chosen we will be choosing as well as right now we have choosen 10 ohms resistance right. We will see the calculation and this is PNP Darlington pair configuration we have done it whereas, this is LN336; if I look if you closely look into this particular value, it shows that 5 volts.

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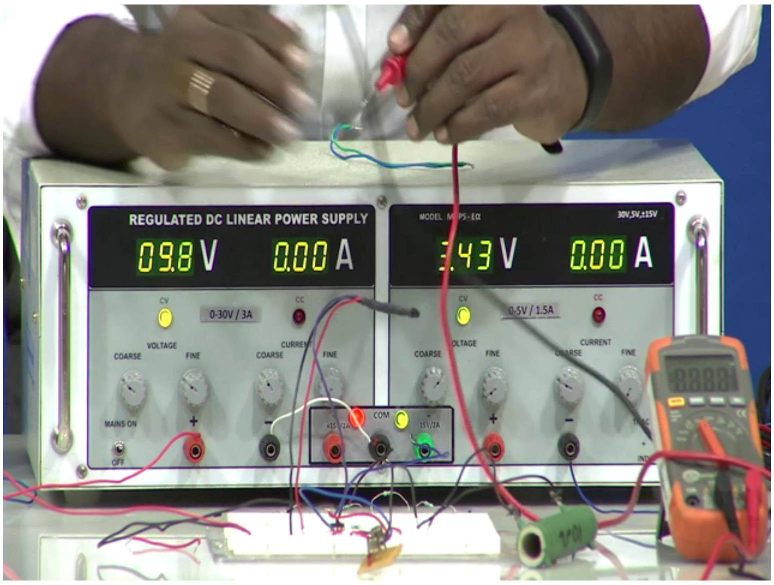

So, when you see the input voltage applied to the power supply which is of 10 volts here, we can see the input voltage applied is a 10 volts. When you see the voltage drop across the resistance; so because this particular in a zener diode has onboard connected with a resistor internally, it has resistance as well as zener diode configured together. So, when I look the drop the voltage that we have connected at third terminal which is nothing the first 2 input of operational amplifier, it shows 5 volts. The reason is that the zener diode whatever we consider is a 5 volts and internally. It has a 1 kilo ohm resistance and since we are measuring across the resistance value and power supply is a 10 volts, it will be 5 volts 4.97 closely 5 volts.

Now, what about for the negative terminal? It is also at the same voltage the reason is that virtual ground concept. Now what will be the voltage drop across the resistance? Input is 10 volts connected and other end of the resistance is also 5 volts 10 minus 5 closely 4.95 which is also 5 volts. Now we know it is a 1 kilo resistance, it is a 1 kilo resistance and the drop across the resistor is of 5 volts. It is easy the current flowing is a 5 milliamps that is clear.

Now let us find out the drop across resistance. So, this is a resistance. So, I am checking the voltage drop across the resistance here and here. How much it is showing? 57 millivolts right. So, when we calculate, so, we got; so, we need to calculate R 3 resistance value. We got it as 57 milli volt and the current flow is up roughly 5 milliamps

57 by 5 right. When we calculate it is of 11.4 ohms right, the value is almost close to 10 ohms; the difference is because one thing is the resistance is very smaller that is one thing and the voltage that we got is not 5 volts 4.96. So, when we calculate 1 by so, all put together and the current flow through the collector right will be always at you know smaller when compared to the emitter value. But we have roughly considered as a 5 milliamps.

So, all put together we got an the precision of sorry we got a difference of 1.4 ohms and moreover we cannot say it is 1.4 ohms difference to the reason is that the resistance will also have some tolerances right. We will take we will take another resistance value. So, right now I have a different other resistance here; if you observe. So, this is one more resistance, the resistance value is 25 ohms. Here we can see and 25 ohms and this is of 10 watt 50 watt resistance where as this is 50 ohm and 50 watt resistance.

So, what I will do is that I will connect this resistance resistor once. Let me switch it off, I will remove this the current will not change. What will change is the voltage drop across resistor. The reason is that the reason is the resistance at that particular terminal is already fixed and since we are forcing to have a drop across the resistor is of 5 volts and the resistance is of 1 kilo ohms, it will be always at 5 milliamps no matter what. So, everything same nothing I am changing.

Once again I will check the voltage across positive terminal 4.98 and negative terminal again 5 volts 4.98, the voltage of across one kilo ohm resistance right same. Now when I check drop across resistance, how much it is showing? 246 millivolts. Now if I calculate if I calculate here, it shows 246 milli right divided by 5 milliamps. So, what is the value? 246 divided by 549.2.

So, the value is; so, what is the resistance that we have connected? When I look into the resistance it is of 50 ohms. When I look into the resistance on the circuit, here if you see it is of 50 ohms right. So, the value whatever we got is also almost close to same. Now I will change the resistance value from 50 ohms to 225 ohms. Let us see with the theoretical whether we get the same value or not.

So, the resistance the connected resistance in this case is of 25 ohms. Let me switch on the supply and I will take the multimeter probes. Let me connect the voltage across this resistance it shows 124 point ah; so, 124 millivolts right 124 millivolts. So, when I calculate the value its exactly half of the year the previous one 124 milli divided by 5 milli. So, this is nothing, but 124 divided by 544.8 ohms. So, the connected is also 25 ohms and whatever we get got is also 24.8 which is most close to that of what we have connected.

So, by using such kind of a driving circuits by using such kind of a system, even we can even find out unknown resistance value. The only thing is that it is forcing to have the current flowing through the system to be of always constant that is because of your negative feedback connected to your operational amplifier. And because of your zener diode connecting in a reverse biased condition, you can fix a reference value as a result the current flowing will always be fixed. And the speciality of LM336 is that you can even adjust your reference values to right. I hope this complete experiment is clear to you.

Thank you.