

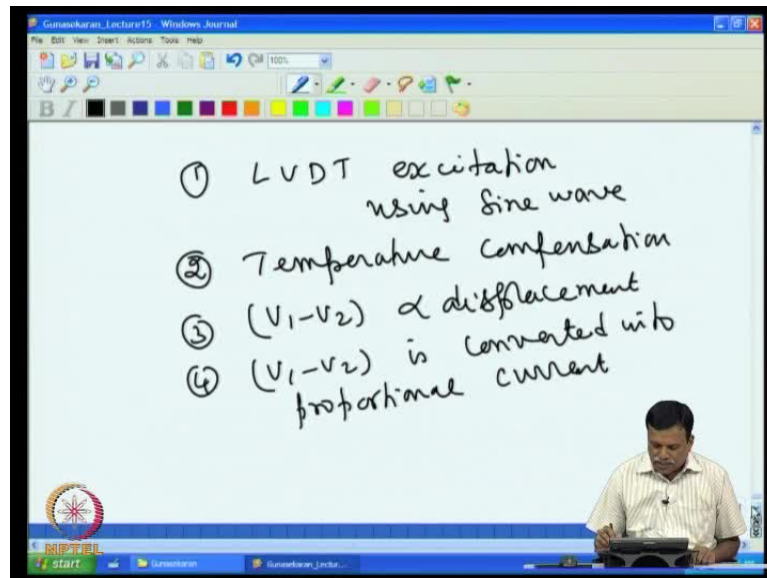
Circuits for Analog System Design
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Module No.# 05

Lecture No. # 26

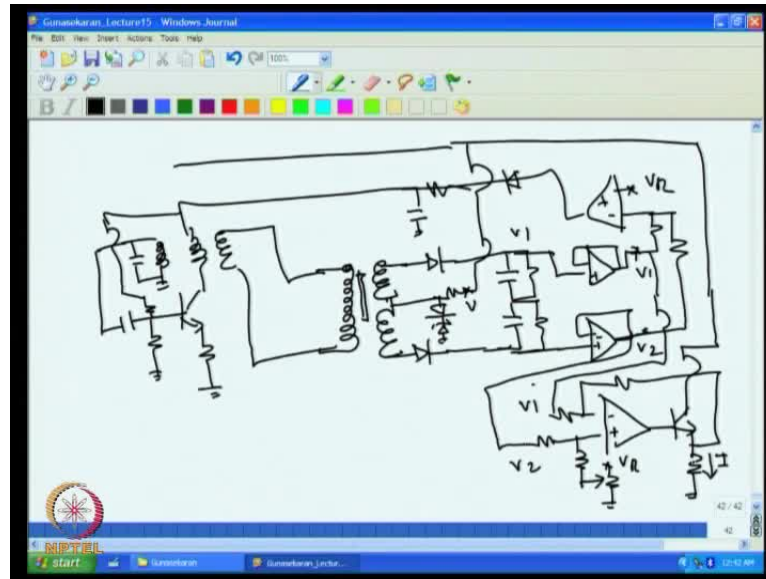
Constant Current Source Design

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Today, we will continue the L V D T based position transmitter design and then see totality how this position transmitter looks like. So, far we are discussed about L V D T excitation that is we are shown how to excite the L V D T using sine wave. Then, we have discussed about temperature compensation for L V D T, then we are discussed about V_1 minus V_2 is proportional to displacement and then how to convert V_1 minus V_2 is converted into proportional current. (No audio from 01:25 to 01:32)

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So, today we had the power supply to this and then that becomes complete towards system for L V D T. so, first I show what we done up to now without involving the power supply, then I had the power supply. So, what is done, so for that we had the L V D T here primary of the L V D T and then we had the secondary's, two secondary's there. Then we had the rectifiers here, then to this center tap we are put the voltage lifting up using a Zener diode, we done this. Then this voltage actually rectified and filters.

So, this is taken as V_1 and V_2 and then this actually V_1 plus V_2 was add it up so, what we had done was, we have added up plus minus. In the minus input we have added up these two voltages, then this is given to V reference and this was fed back to the oscillator circuit. Oscillator circuit consists of Hartley oscillator. Essentially, you had the inductor transformer for Hartley oscillator. So, you had the generalize this one and this was fit to this the DC voltage fit to the oscillator and then you had the secondary and resonating capacitor input and then this was connected to that and this biasing resistors. So, this is again connected to the supply of inputs apply to this.

So, essentially the core actually moves here so, essentially this voltage is fixed. So, if the take the L V D T and then the L V D T core moves, then you know that V_1 and V_2 will change then we are adding this and finding V_1 plus V_2 here and comparing it with reference. V_1 will as V_2 goes more than the reference, then the output voltage comes

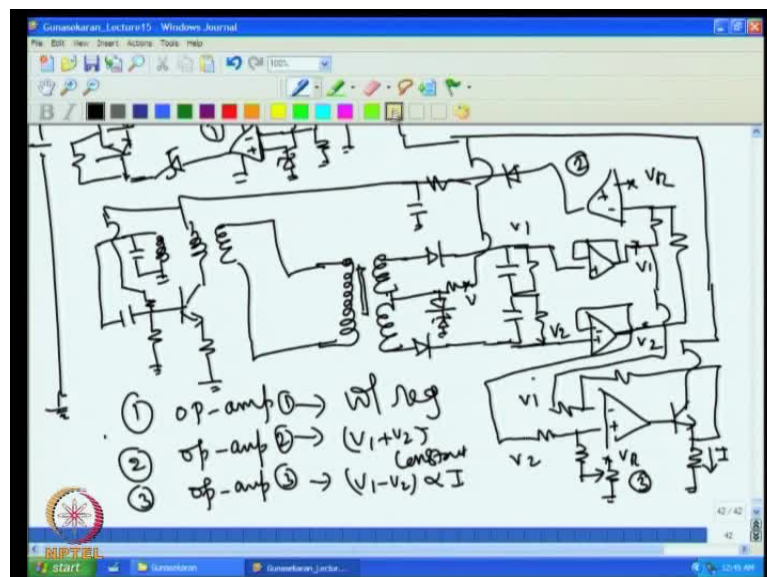
down. That reduce the this voltage that reduces the amplitude of the oscillation and that makes again V_1 and V_2 to come down to make it V_1 plus V_2 always equal to V_R .

So, by this arrangement we and made V_1 V_2 always constant. And then now we are taken V_1 and V_2 that is difference between these two should be used retrieved the current. That we done like this so, we had taken V_1 here. And V_2 if necessary this can be even voltage follower can be put here to remove so, I can had the voltage follower here. So that this voltage will not create any voltage drop due to the so I can had regulator the voltage follower here.

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So, now this becomes V_1 and V_2 , this was used to convert into current. So, you had fed this one to the current convert here, the current convert was made like this and this is the power supply point of course, this is to be bias also to the power supply. We so, this is connected to V , you have this also connected to V and then we had this input voltage to V_2 and then to offset the voltage we had done this, this going to be V reference and then connected to this. So, this is connected to V_1 and the other input is connected is to V_2 . So, we have V_2 here and then so V_1 can be connected from here so, if have V_1 here, V_2 here and the difference drives the current through this. So, this current I is proportional to displacement eventually and the that can be made 4 to 20 milliamperes. By suitable adjust in this and even the adjustment can be given, here using a potential meter.

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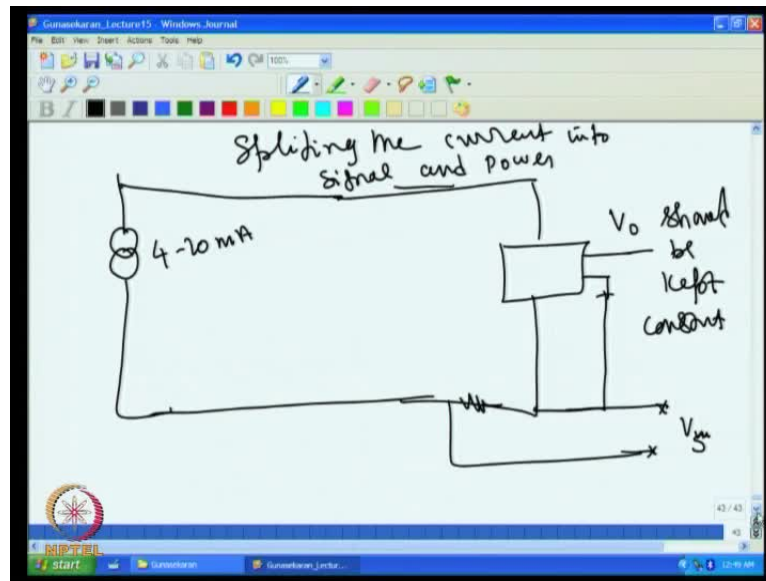
And then now we add the regulator for this to make it a two-way system. So, what you do is, that we provide regulator supply. This we already discuss in the earlier current transfer design, but nevertheless we can do it again that you can have this and then put the regulator at this point. So, what can this? We can have a follower here and then the error amplifier can be added at this point. The error amplifier actually this is the output, we also explained about this using the Zener. The voltage can be boosted out here and this supply is connected to this and then this minus and plus and we have the divider arrangement here. And the plus can have reference voltage like this. That regulator output can be given to this so, you will have the input connect at here and the output to the ground.

So, eventually that this gives you fixed regulator voltage say 8 volt and entire circuit works on 8 volt. And then the amplitude of the L V D T is stabilized, such that $V_1 + V_2$ that you have the V_2 here at this point $V_1 + V_2$ is kept constant and then $V_1 - V_2$ gives you the displacement. So that you see the full circuit of this so, what is done is one input is regulator using this op-amps, that is op-amp 1. So, op-amp 1 used to regulate the input voltage and gives the regulator voltage op-amp 2 is actually makes $V_1 + V_2$ constant. And then this operation amplifier 3 converts $V_1 - V_2$ difference into current.

So, the op-amp 1 is a voltage regulator, op-amp 2 makes $V_1 + V_2$ constant. Then that is op-amp 2, op-amp 1 does this op-amp 2. So, the op-amp 2 makes $V_1 + V_2$ constant, then op-amp 3 makes $V_1 - V_2$ proportional to I . So that way the displacement eventually convert into current variation as the displace. The core moves then the this current as the core moves here and this current varies that is eventual net result. And we at shown how to bias this one to avoid the temperature drift, that we had explained in the previous class using this because this diode, this diode and this diode are match so that temperature drift is compensated at in the circuit. So, this op-amp and this op-amp are only use as a voltage follower, to avoid the loading and this transistor is used to produce the oscillation in the circuit.

So, this is how the current transmitter design works. We can now see the reverse of this current transmitter because now we at seen in how to use L V D T as and then how to consent a current transmitter.

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Now, in the industry what they do is, they also send the current and expects as to convert into a signal and then also use the same current to power the device. So, what is normally done is like we have current transfer for example, if I have constant current source, this constant current source is transmitter, then it is over the long distance and at that receiving end, we will have an instrument. That instrument should produce output voltage, that mostly it is respective to this ground. This produce the output voltage, this voltage will be constant, this V_0 as to be constant, this V_0 should be kept constant. (No audio from 13:03 to 13:10)

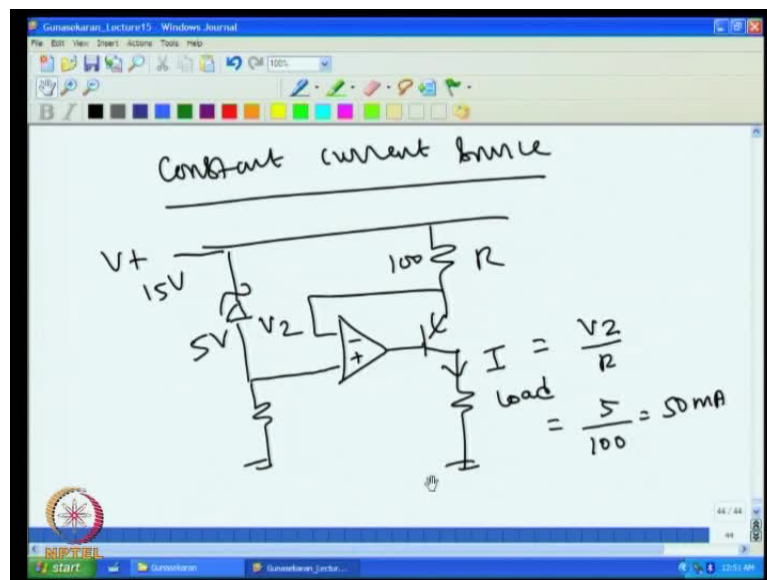
Even this current varies, this current normally varies from 4 to 20 milliamperes so, this 4 to 20 milliamperes current transmitter and even this current varies, this voltage should be kept constant, that is one requirement. The second one is, the current that is flowing through this is sense invariably using a resistance and this voltage is actually V input that is or V signal we call. So, this V signal gives you the current information you know, the current is 4 milliamperes, you will get some voltage. The current is 20 milliamperes, you will get some other voltage.

So, this voltage will be used to activate various signal. This signal is use to activate the control valve. According to the this current if the current is 20 milliamperes, then the valve will be moved fully. The current is 4 milliamperes, the valve will be shut down. And for that we for that operation we need electronic circuit, power for that that electronic

circuit should come from this V_0 . So, eventually it looks like this, that this voltage will be used to power the circuit. And this will be used as a signal, to activate the actuator or anything else. So, this is actually the conversion of the current to splitting the voltage, splitting the current into signal and power. This another application which is essentially used in the process control industry.

So, we see how that can be done. Because before doing that, we that understand, what is the current source, how the current source is useful? We already discussed. If we use a current source that the noise pick up is low. Now, we explain what is the current source, and then what is the property of that, and we can design this converter, which converts current into signal and power.

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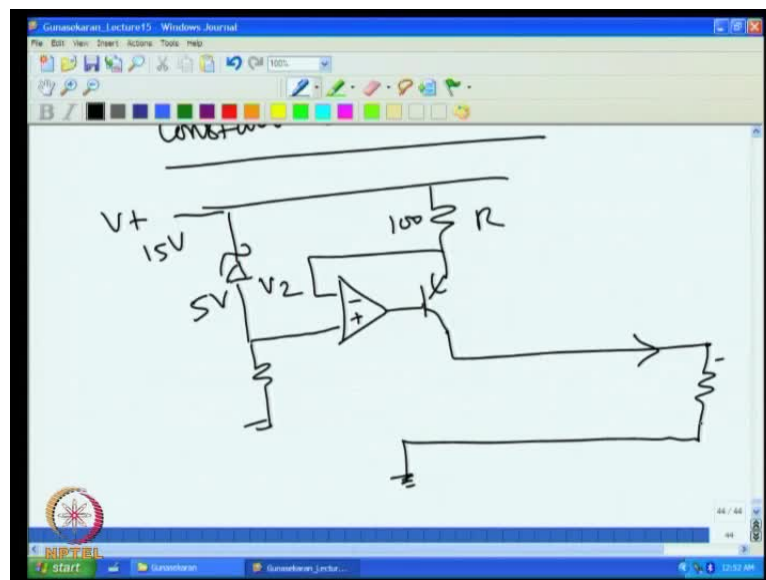
So, basically we already discussed about once the current source so, if we look at the constant current source for example, a typical constant current source looks like this. (No audio from 15:59 to 16:10) This is a load and this is the supply V plus save 15 volt will give here and then ground is given here, and this load slow if you find the current through is actually given by V_Z by R , that V_Z is Zener voltage. For example, if I put 5 volt Zener here and I puts 100 ohms here, then the current I would be 5 volt divided by 100 ohms, that will be 50 milliamper current.

So, this is the constant current source of 50 milliamper, that is actually the current flowing through this is always constant given by this. And it is independent of this

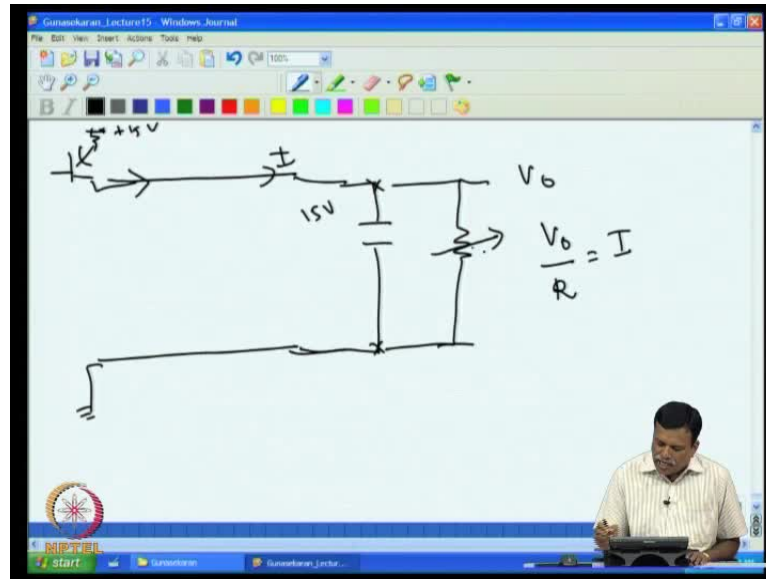
resistance for even if I change this resistance value, the current will not change that will be always constant. That is the exact meaning of the constant current source. We will also be discussing more about this little later.

Now, let us see how we can do this. Now, if I use this current source, I transmit this for the long distance and I want convert this current into signal and the power. Because the same current source should power the remote device and also the current information also to be carried, taken and that should be used to control the valve etcetera. So, normally what is done is for example, I remove this load, now what I do is I will just convert this; I transmit this for a long distance. Then I have a load here and then bring back to the ground.

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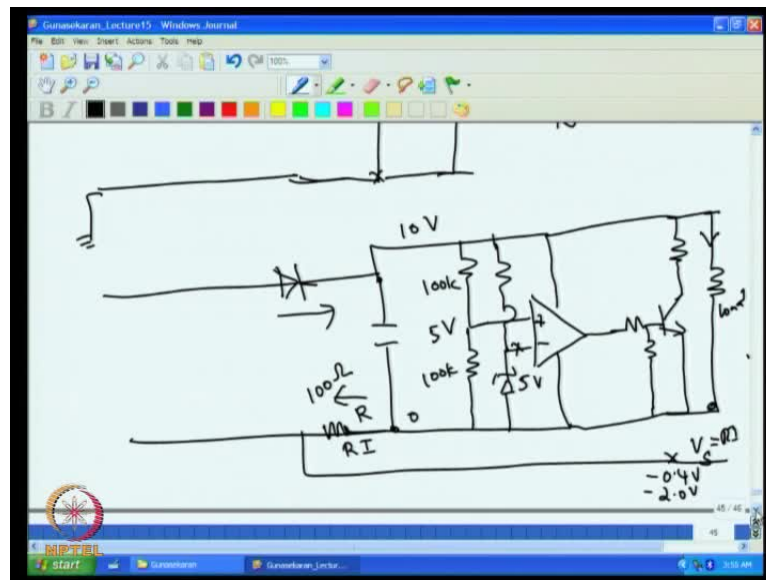
Now, this current will vary if I vary this resistance. Now, to convert this into power what I do is whatever current that is coming from the long distance. You want convert in first a power, that is the convert in to a constant voltage so further what I will do? I put the capacitor here. So, if look at this, this current transmitter that you have this, the constant current is coming and that is grounded. So, you put a capacitor here, whatever current that coming here will be charging this capacitor continuously. And voltage across this will be a continuously will be increasing.

Now, how much voltage it will reach? Eventually, it will reach 15 volt because this constant current source is driven through a 15 volt supply here. So, it cannot go beyond 15 volt so this will go 15 volt eventually, whatever may be the current here. Now, I have to use this for powering the various devices. So, if I connect this to a resistance here and if this resistance changes, then what will happening is, depending upon this load the voltage across this will be varying. Because if the load resistance small, then you will find the most of the current is going here and then voltage small current is going even that is the time passes, the voltage will increase and then more current will flow across this.

So, eventually voltage across this is given by this resistance on the current. So, what actually happens is the V_0 here, what you get would be? V_0 by R that would be input current I . So, if this is current I , then if the voltage at this point is determine by R . In fact

if I varies if this current you know this current can varies 40 to 20 milliampere so, this I varies, eventually you will find this V_0 also changes. Similarly, R changes also V_0 will change. But we do not want this to happen, we want V_0 to be constant irrespective of this current and irrespective of this resistance change.

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So, how to get that? So that we can do it in following manner, what I do this, I will take now this current source, take this current source, now I put the capacitor here, then I connect the operation amplifier here and then high power the operation amplifier also. And, to avoid the capacitor being discharge I put one diode, so that the current cannot go back. So, high power this operation amplifier using this, then I take output of the operation amplifier, I have the two inputs. Now, the output of the operation amplifier I connect to a transistor which is again connected to this it is biased. Using these to resistance I will explain more about this shortly, then I will connect this through a small resistance connect to the collector.

So, what happens is, if the voltage at this point is more than the transistor will conducts more and more current will flow through this. So, more current flow through this, then the voltage across the capacitor will decrease. Similarly, if the this voltage is low, then this transistor will conduct lightly and less current will flow. The less current flows the voltage will increase that means if more voltage here, then you will find less voltage at this point, if the voltage is less here, then will find more voltage here. So, to maintain this

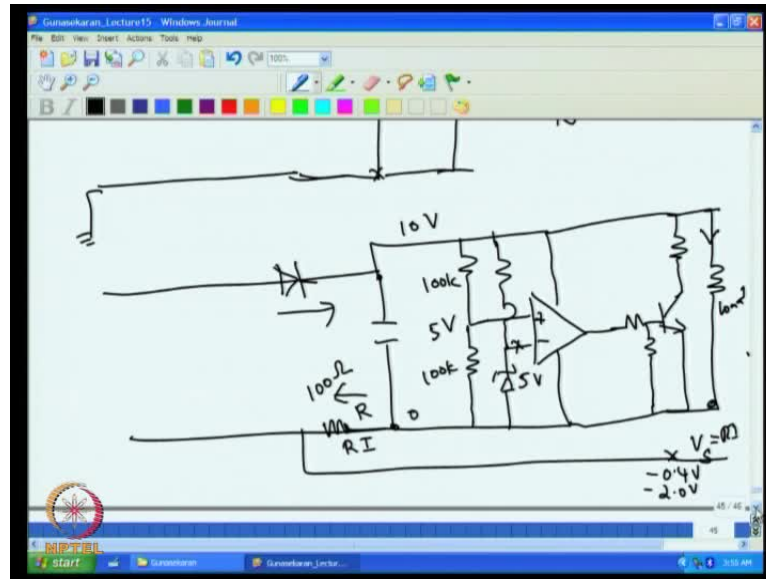
at constant voltage, we at configures this comparator correctly. So, this I can do one thing that I can connect this to output sensing. So, I connect this to the output, then this I connect to the reference voltage. (No audio from 22:17 to 22:24)

So, this point is sitting at V reference say 5 volt, this 5 volt. So, this is sitting as V reference, then if I take for example, equal values for this 100 k, then if this has to be 5 because if this is sitting at 5 volt, this also has sit at 5 volt that is know other go. Suppose, if this is 5 and less than 5, then output will go high, then this will conduct more, then this voltage will come down. And in fact this voltage comes down too much, then this will come below 5. If it will come below 5 and if this is 5, that output will go high, then it will conduct more and this voltage will decrease. If it goes actually I reverse the think if it is go lower, it is so this polarity is to be reverse. So, what I do is I will change this polarity then it comes.

So, if put this one plus this one to minus. So, if the voltage is 5 and if this is less than 5, then output will decrease here because this is 5 and this is lower than 5 so, output will decrease, that will make low current here. And that will increase this voltage, and if this voltage increases and if it is goes more than 5, then output will go high and more current will go and this reduce. So, eventually by this mechanism if I keep this one at 5, this will also remain at 5. And since these two resistances are equal and the current flowing through this is negligible. So, voltage at this point is 5 means this has to be 10 because the voltage across this and this has to be same the voltage across this 5 and this another 5 so, you will get 10 volt.

So, in fact we can adjust this resistance to get whatever voltage that you want. But now whatever may be the case that, voltage at this point will be always 10 volt. So, by this process, we are now regulated the voltage to get 10 volt. Now, we can add whatever load that you want that here. So, this is actual load. If the load is taking more current, then the load is taking more current through this, then never what really happen is if the voltage, if the load is more current flows through this, then the regulated reduces the current that is flowing through this. Because if the voltage decrease because of more current, then automatically this voltage will decrease and this current flowing through this will decrease.

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So, large current flows through this, current flowing through this is reduced. If less current flows through this, current through this is increase, such that the voltage at this point is maintained at say 10 volt. So, this can be maintaining the any voltage as you like by varying this. So, by this way the current flowing through this, produces now the fixed DC voltage. Now, all that we at do is we at convert this current, whatever that is flowing through that, anyway return through this and this current information will provided signal. So, this signal to be obtain a signal what we do is will add resistance here.

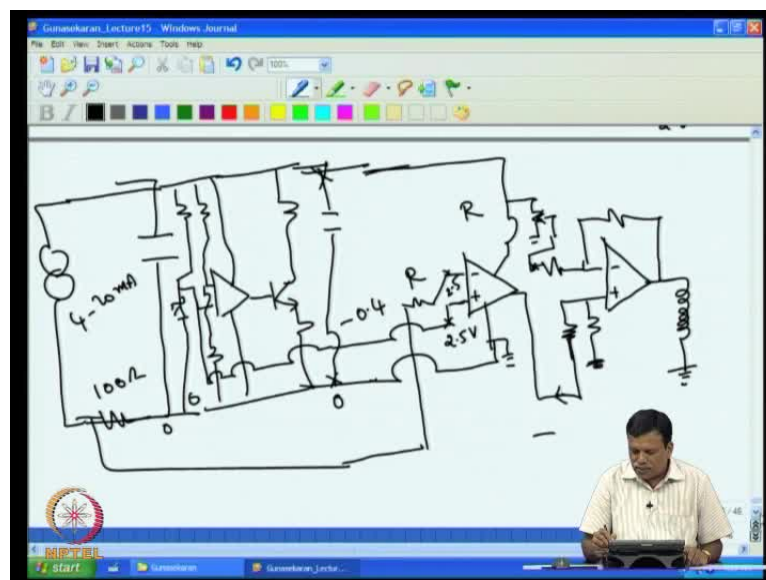
So, the current entire current whatever is coming here actually flows through this. Now, this is our reference 0 volt, voltage at this point gives you the signal so that is V signal. So, the V signal is this R is known so this R into I is the V signal. So, we get this as 0 so this V signal which is equal to R into I. So, we will see how to use this to control temperature controller or some other system now because this is another instrument which is used essentially in the field.

So, next we see, how to use this voltage this regulated voltage and this signal to control the system that we are interested. So for we had discussed about how to convert this current, this 4-20 milliampere current that is coming here into a regulated voltage. And then this gives you the voltage this voltage across this is nothing but is proportional to the current that is flowing. So, we at now use this power supply regulated voltage and this signal to activate some process. So, first step would be converting this signal voltage

into a usable positive voltage. Because if you see carefully, voltage across this is negative because this our ground point and current is flowing like this.

So, as current increases, you will have more and more negative voltage here say at 4 milliampere. For example, if I put here 100 ohms, at 4 milliampere I will get minus 0.4 volt, at 20 milliampere I will get minus 2 volt. So, the signal V varying from minus 0.4 volt to minus 2 volt, then voltage the power for power the voltage will remain at 10 volt. So, now we at convert this minus voltage into plus voltage, that we can do it like this.

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So, the next what I do is I will take this 10 volt supply, I redraw this from this point. So, we have that capacitor here which is holding the voltage and then this is the resistance which is having so this our ground and then this voltage is minus voltage. And we have here that operation amplifier and that resistance and so on. What you have discussed there? So, this and then we have one more capacitor one to avoid the oscillation we can use this. So, this is your 4-20 milliampere current so, 4 to 20 milliampere current is here and this is resistance here we have 100 ohms so, this our ground.

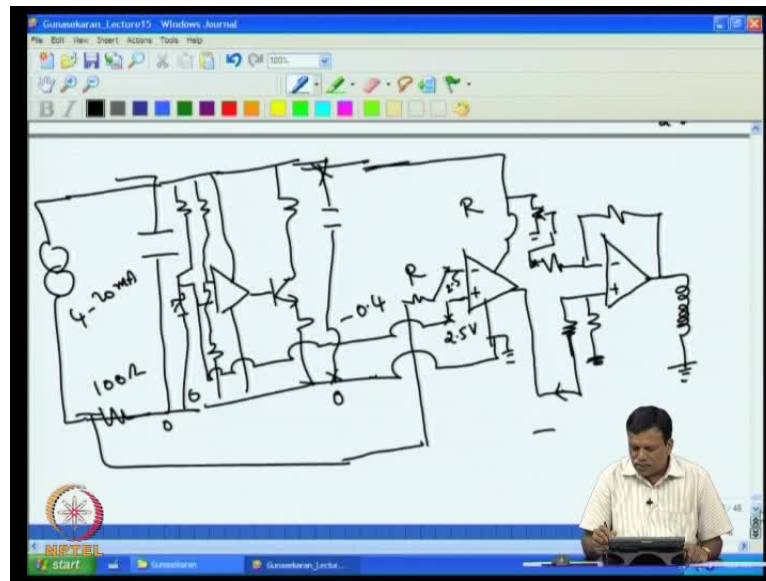
So, this first we convert into positive voltage by applying this one to the minus terminal. So, we can do this, then I can have this voltage, I can had this to this minus voltage because the op-amp is working only an single supply because we do not other dual supply. So, we at work this op-amp also single supply mode only so, minus cannot be given to the input so, input should see always positive voltage. And then the plus can be

given to V reference because here we have the V reference is there. I have the V reference at this point which is given to this and output is compared here. So, this V reference voltage it also can be used for this purpose. So, take this voltage can be given here so if this is says 2.5 volt. And also can be given some voltage say 2.5 volt.

So, this is 0 if this is say minus 1 volt. Then this is 2.5 you have, 2.5 for simplicity first what I do is I remove this even I remove this, I connect this 2.5 only to this sorry, so we have this 2.5 is connected this. So, if this is 2.5 if this minus 1, we know this as sit at plus 2.5 then we have 1.5 volt difference. So, this as to have 1.5 volt difference that means this is will go to 4 volt. So, at minus 1 it is plus 4 volt then it goes to minus 0.4, then you will have here minus 0.4 then current is low so, you have minus 0.4. So, you will get 2.9 volt difference that is one small mistake actually, if you have earlier case, I just change this earlier case assume we had minus 1 volt, then the difference is 3.5 volt. So, we at have 3.5 volt across this that will give 3.5 plus 2.5 so that is the output voltage will be 2.5 plus 3.5 volt. That is assume this resistance and this resistance are equal, then you have 3.5 volt difference across this, then you will have 3.5 volt difference across this. So that output will stay at 6 volt this is for minus 1 volt input for minus 0.4 volt input.

If the input drops to minus 0.4, then output will be 2.5 plus a difference between these two 2.9. So, you will have 2.9, that will be 5.4 volt that is V 0, this is for minus 0.4 volt. So, as the current increases here, you find these voltages also increasing. This a that means, but this output voltage is positive now, we can use this to drive the some other device here because now we got a signal which is positive. Because what you done is the signal at this point was negative and we have no way of passing negative because we do not have negative power supply. So, we reduced now the we are converted the negative voltage into positive by feeding it to this and keeping this one or 2.5 volt.

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Now, this can be used to provide saw a whatever other functions that we want for example, I want operate actuator depending upon this signal. For example, if it is 20 milliamper current in this, you will have minus 2 volt at this point. So, corresponding you will have minus 2 volt will give here actually 4.5 volt difference. 4.5 into plus 2.5 you will get 7 volt at the output. So, we can use this one to operate some valve or some other or temperature controller or whatever we want we can control. So, we take one example that is assume that we want control amps actuator, then what you do is we will compared this output voltage with the reference voltage.

So, if this reference is given to positive, which can be this itself. So, I can have reference that is this is our ground so, I connect this to ground and then I can set this whatever really I want. And then this voltage if it is very high I can put a divider and suitably scale it down, so that it matches with the reference. Then this can be used to for example, if it is a pneumatic actuator, then we use flopper nozzle mechanism to control the mechanical valve. In that case flopper nozzle is operated at using very small current flowing through the coil. So, we have a coil that the current flowing through that produce a magnetic field. That is enough to activate the small flopper nozzle and I can eventually that will control the valve.

Now, this also this is acting like a more like on off controller, we can reduce the again and make it proportional controller by adding a different amplifier to this. Even this

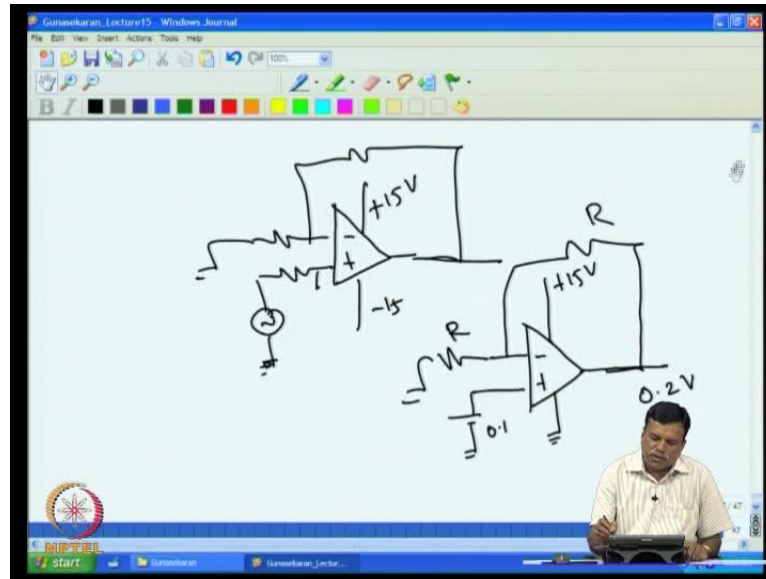
device also can be done very slow, you can have set the again whatever that we want and accordingly we can modify this as well little bit here to have the different amplifier here. (No audio from 36:40 to 36:48) Even the gain in this can be varied, such that you get the enough voltage. The voltage is not enough this itself can be need not be connected at here, this can be even connected to a high voltage supply that is the mains voltage itself. (No audio from 37:02 to 37:11)

So that the difference between these two voltages will drive the current in the flopper nozzle mechanism so that current flowing through this will able to control the actuator. So, in this example we at design a circuit starting from this 4 to 20 milliamperes so, what you done is 4-20 milliamperes current that is flowing here? In this is convert into a regulated voltage, so that is what you had done here so, you got a regulated voltage across this point say that is 10 volt. Now, then this is the one which gives you the signal because this represent what is the total current is flowing.

If they want to the actuator will be at 15 percentage level that will be sending 12 milliamperes current. Even at 12 milliamperes you will have 10 volt. And then corresponding 12 milliamperes you have minus 1.2 volt, that will converted into plus. And then the difference between these two it actually controls the actuator if this current is more than obviously, the error voltage will be more because we have said this one. And if the actually if the current is more, we want actuator to move positive then I can modify this. For example, even we can do this way. (No audio from 38:41 to 38:50)

So, you got this. We can connect if the more current if you want more actuator more then I give this one to the plus input. And then I can use this to be reference or it can also be connected to supply or it can be divided and to connected to supply. So that you will get the difference between these two as error and error will drive the actuator. So, if the current is more, obviously you will have more error voltage and the valve also be moved more. So, this an example I had shown you how to use this 4-20 milliamperes, 5-20 milliamperes current source, such that you will get the power and signal and signal can be used for whatever purpose that we need to have.

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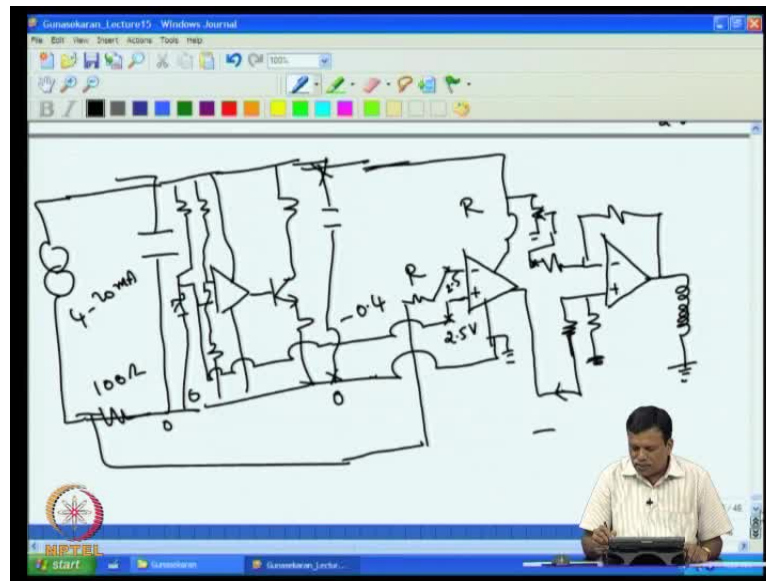


Now, in this example we reduced single power supply. And single power supply usage is very important in the process control industry. Because normally can we use dual supply for the op-amps like we put plus 15 and minus 15. And then we of apply a voltage 2 plus terminal and the minus terminal. For example, if I want amplifier, then I feed this and give the feedback to this output. Some in many times we may not have a dual supply, we at work with the single supply only. That is what we had done in the previous example like for example, at current transmitters and then voltage regulator all these things, we are using only a single supply.

Now, here using the op-amps in single supply certain precautions should be taken, that is if I have supply single supply like this then I plus I give the plus 15 and minus voltage I have connect to ground. Then the operational amplifier have to work in a single supply mode, we at make sure that input level. For example, in this case suppose if I give the input like this I give 0.1 volt per 741. If I want amplify like this amplify say where factor of 2 then I will have here for example, R and R then gain is 2. So, you supposed you will expect 0.2 volt at the output.

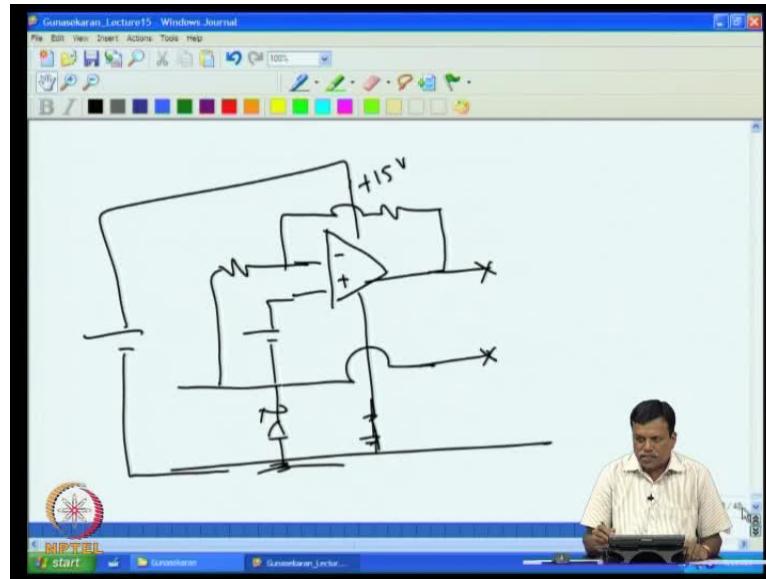
But actually if you do this for single supply with 741, you will not get 0.2 that is 0.1 into 2 k in supposed to come as 0.2, this will not happen for 741. Even LM 324 which is given for single supply operation also gives some errors. The point is that we using a single supply we at see for that op amp what is the minimum acceptable voltage.

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For example, 741 will not work, if you give below 2 volt in single supply. And output also will not go below 2 volt whatever you do. So, if it is for example, LM 324 it works up to input goes up to 0.1 volt, output goes down up to 0.2 volt. So, in all our examples if you see whenever went the input terminal close to 0, we maintain always some voltage at the input as well as the output also we at make sure certain minimum voltage is there. Otherwise, the circuit will not work. So, for example, in this case there will be some output voltage, if the output voltage you do not want that output voltage then we at do one thing we at make sure that the extra voltage whatever is coming not drive. This one popular way of solving that issues put 1 Zener. So that the minimum voltage whatever is coming the op-amps is drop across this Zener.

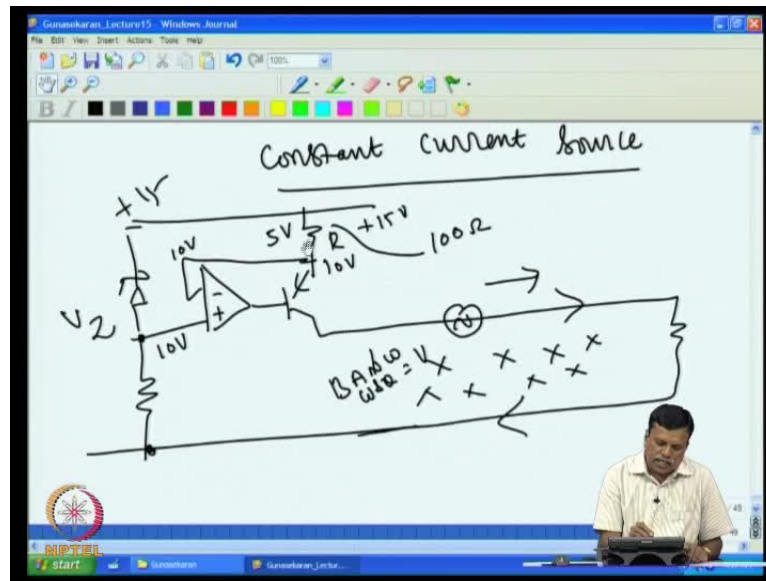
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So, this is one of the important observations we have to make in terms of uses of operational amplifier with single supply. So that is what we are done in this case. For example, many time if you want otherwise if want using single supply, we can also make a floating ground like see, we have plus supply alone is there and then you have a ground. For example, if I want amplifier very small voltage, they amplify through this then you put one Zener diode here to the actual ground. This is the signal then all your voltages can amplifier with respect to this ground, then output also you must with respect this. Whereas, input supply is respect to this ground, this is the two ground plus 15 volt ground.

The output is between these two points. That is you will get the your measurement signal is respect this. So, we are artificially created one local ground with respect to that, we are floating all our signals. This is one way of during with input, output voltage limitation when are using a single supply. So, we are seen in last two classes how to make a current transmitter to transmit the signal for a long distance. The current transmitters are used extensively in the industry to transmit the signal as a set. Initially, this is to avoid the noise pick up because magnetic field in the loop will not induce the will induce the voltage. For then the as long as the frequency response of the current transmitter is good they will not response for the magnetic field. So that is why the current transmitters are used. So, we will see what are the different kinds of current sources are there and how they can be utilized for this purpose.

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So, let us spend some times and constant current sources. (No audio from 45:16 to 45:28)
So, one of them we already seen and constant current source for example, we have.

(No audio from 45:33 to 45:51)

So, this is ground, this is plus 15 so current flowing through this, this is V_z , this is R , this is V_z by R so this is the load. So, current flowing through this load is always constant, that given by a this relation and even if you change the load, this current will not change. Now, this is one type of current source. Then very many different types of there and each one will behave differently for a different noise frequencies actually. Now, to understand the this pneumonia, we should carefully look at the actual design of this circuit. If you see the actual design we have the V_z across this say 5 volt we have assume this is 5 volt, if this is plus 15 then this is sitting at 10 volt with respect to 0, then this is 10 volt and this is 15 volt. If this is 10 volt then this also has to be 10 volt because plus and minus terminal should be same. So, if this is 10 then this also automatically comes 10, that makes voltage across this is 5 volt.

Suppose, if this is not 10 because the current flowing through this determines what is the voltage, if this 15 if I put here 100 ohms, then 50 milliamper current that is flowing through there, it will make 5 volt drop here and at will be 10. Suppose, if 50 milliamper cannot current is flowing, if more than 50 milliamper flows then we will have more than 5 volt drop across this. Then this will come less than 10 if this comes less than 10 then

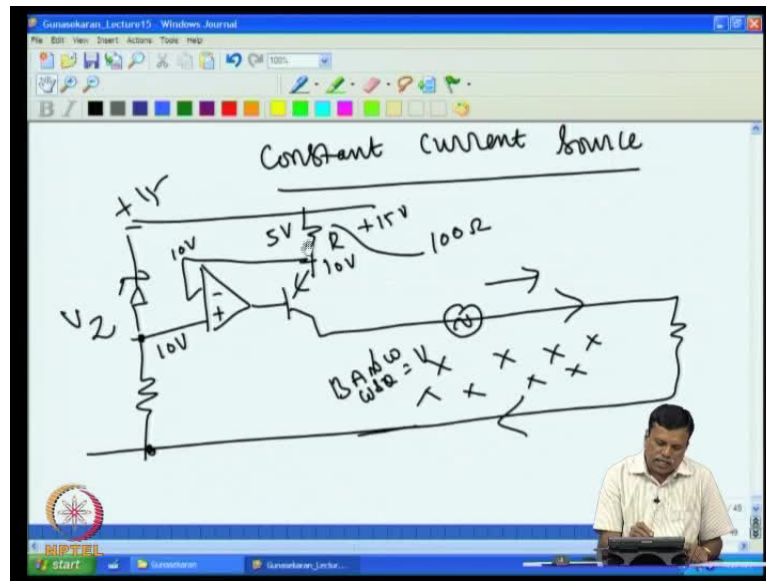
this is 10 and this is less than 10 then automatically output will go high. And the difference between base into voltage will decrease and that will make less current flow.

So, then current flowing through this will reduce. The current flowing in through this reduces, the voltage at this point increase because if this is 15 and voltage of across this, this voltage minus voltage drop across this is only the voltage that are getting here. So, if less current flows you will have less voltage drop. So, this voltage will up to go towards 15. For example, 0 current flows this is 15 this also 15, current increases this voltage decreases. So, current decreases mean this voltage will increase. So, if the current is low then this voltage will give more than 10. In that case this voltage will decrease because this is more than 10, this is 10, this will decrease. Then difference between base emitter will increase and you will have more current flowing here.

So that way this will make sure that this always sitting at 10 if this is 10 is always sitting at 10 and the voltage drop across this will be equal to 5 volt that is nothing but Zener voltage. So, then the assuming that this base current is small, then this entire current is flowing through this so, voltage across this so, the current flowing through this. The current flowing through this will be V_z by R that is what this current source is giving. Now, if this by use this a current transmitter, then what happens? For example, I do not put this, I connect this to a long distance and then put the load here and connect it back now, the current is flowing like this.

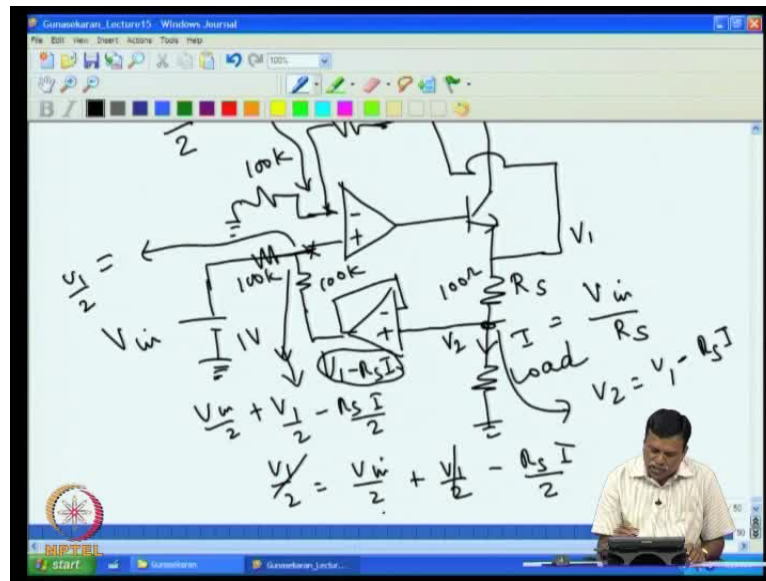
Now, if there is a changing magnetic field in these loop, that two induce the voltage here, it will induce the voltage in the in this loop. This voltage it is a AC voltage because that we know that $B A N \omega \cos \theta$ is the individual voltage and here N is 1 so, the magnetic field is use the voltage here. And this AC voltage will not drive any current through this because if this voltage drives a current through this, that current have to come from the supply only. And that current have to go through this, there is no way this current source can this in this voltage is can complete the path.

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If that current flows through that then that will develop the AC voltage across this, if AC voltage will develop, then automatically this voltage is vary and correct it, to make this current always constant because AC current appears as a changing a current. And the property of the this current source is want to make the current always constant. So, you may the AC current flows here, it automatically corrects it and make sure that is only DC current is flowing and if the load is only DC current. So, this magnetically individual voltage as no effect on the load, this the basic philosophy behind the use of current source to avoid the noise pick up. That is why in process control industry, they transmit the signal for long distance using 4 to 20 milliampere current transmitters.

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We have different types of current source, we can see one more type of current source. Because another celebrate current source is this. (No audio from 51:12 to 51:21) This is load, this I connect to plus 15 volt. Now, to make at a current source, it depend on the voltage what I do is I will pick up the voltage across this resistance, this is my sense resistance, this is the load. So, I pick up this voltage and apply to inverting input this I connect to ground. (No audio from 51:51 to 51:06) Then I pick up the voltage across the at this point the follower and connect this one to this, this I connect to ground.

Now, this has become a constant current source. Now, the current that is flowing through this, this I we are study this is V_{in} , V_{in} divided by R_s . There if I change the load resistance, the current through this will not change that will remains constant that is given by this. For this to happen we at design the values and I will put the values for example, I put here 100 k I will put this also 100 k and also put this 100 k, this also 100 k so I put here 100 ohms, if I example 1 volt. Now, if we analyze the circuit, see this is plus analyze circuit whatever be the voltage here that voltage actually coming here.

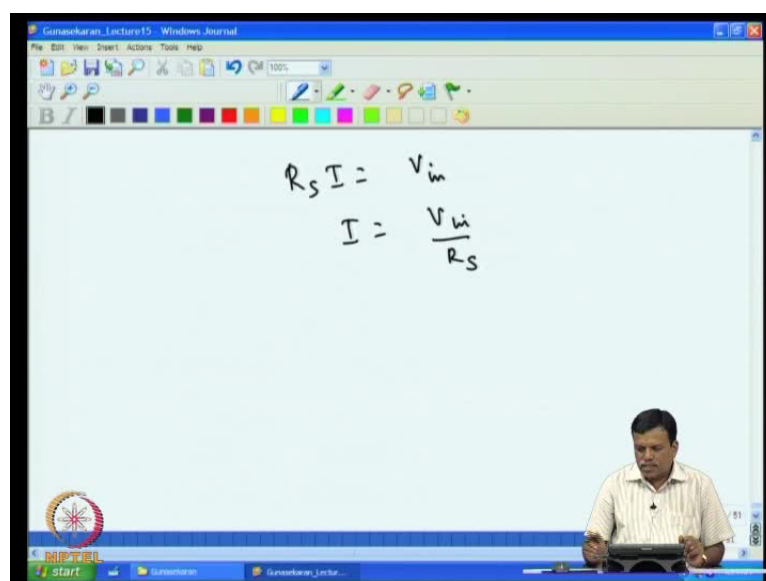
Now, voltage at this point whatever is there is actually apply to the inverting a input terminal. So, this is the external voltage that we are applying. Now, if you see say for right what is the voltage at this point, if I take it this as the V_1 and this is V_2 . Now, this voltage at this point is actually V_1 by 2 because you have V_1 here and this resistance

divides these two. You have one resistance here, one resistance here, it acts as the this V output voltage is divided by 2. So, voltage at this point is actually given by V_1 by 2.

So, obviously voltage at this point also should be V_1 by 2. So, this voltage also must be equal to V_1 by 2, but then what is the voltage at this point? Because two contributions for voltage at this point, one is from this input, another is from voltage at this point. So, if current some current is flowing through this, then you will say voltage V_2 . So, what is the voltage V_2 ? We can write, we can say V_2 is V_1 plus $R_s V_1$ minus sorry, V_1 minus R_s into I because R_s in I is the current that is flowing through this so voltage drop across this is R_s into I .

So that means voltage at this point will be this is V_1 so this is lower so lower by voltage drop across this. That is why we write V_2 is nothing but V_1 minus R_s into I so this point, that means I can write this is voltage follower. So, this also equal to V_1 minus R_s into I . So, voltage at this point is V_1 minus R_s by I and voltage at this point is V_1 . So, we can write what is the voltage at will get at this point. That will be half of this plus half of this so, voltage at this point is V_{in} , we can write in another way V_{in} by 2 plus this by 2, V_1 by 2 minus $R_s I$ by 2. That is the voltage that will get at this point because V_1 by 2 at this volt contribution by this then because of this of the contribution comes from here. So, this voltage is output is V_1 minus R_s by I so half that V_1 by 2 minus R_s by 2. So, voltage at this point is this and voltage at this point is V_1 by 2.

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So, $V_1/2$ must be equal to this. so, I can equate this and then find out what is the current that will give as I equal to V_{in}/R_s . This I can do it next class. I can also explain you how this circuit works. So, eventually what you want do is we want so that $V_1/2$ that is equal to $V_{in}/2 + V_1/2 - R_s I$. So, actually, you will get this, this and this getting canceled. So, you will find $R_s I$ equal to $V_{in}/2$ that will make it, that will give $R_s I$ is equal to V_{in} . So that is why the current through that is I actually given by V_{in}/R_s . So that is why the current maintains constant. I will explain working of this more in the next class. Thank you.