

Circuits for Analog System Design
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Module No. # 05

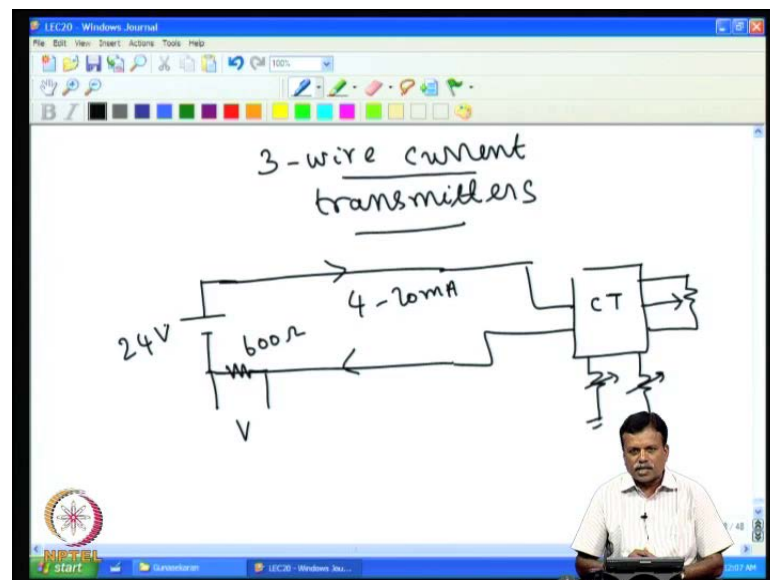
Lecture No. # 28

3-Wire Current Transmitter

In the previous class, we have discussed how to use resistance sensor for current transmitters. So, there we are discussed how to design a 4-20 milliampere current transmitter for pattern resistance thermometer.

Now, this current transmitters are very popular in the process (()) industry. There are two types of current transmitters, that is one is 4-20 milliampere, 2-wire based current transmitter, other one is 3-wire current transmitter where 0 to 20 milliampere is used. So, let us familiarize how to design a circuit, which is suitable for 3-wire system.

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So, we will discuss about 3-wire current transmitters in this class (No audio from 01:01 to 01:13). Essentially, we should first understand, what is the difference between 2-wire current transmitters and 3-wire current transmitters? Now, the 2-wire current transmitters

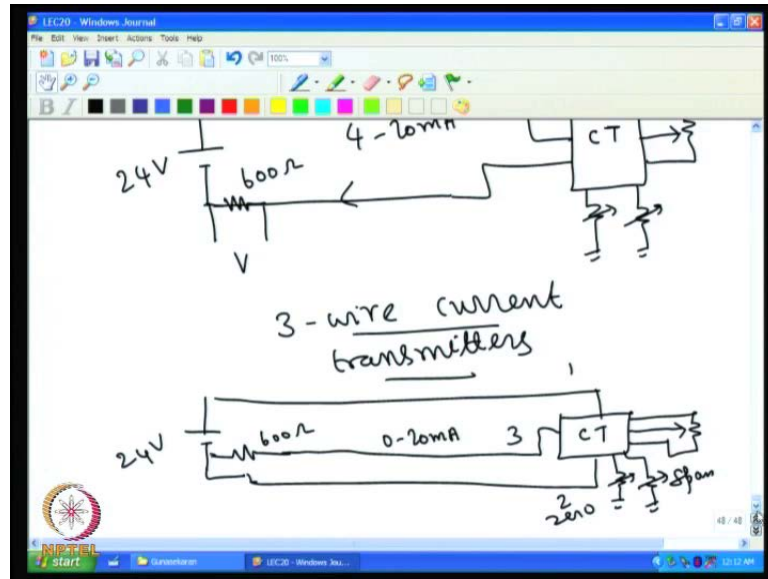
we had a source and then there two wires are running and then we had a current transmitter, current transmitter is here and then, that has linked to, for example, it is a potentiometer based, then we have a potentiometer is connected to the system and then we have zero adjustment and span adjustment is provided like this.

And then, the current through this is actually 4-20 milliampere, so the current will be 4 milliampere when the potentiometer is at one end, and when the potentiometer is at the, when this potentiometer is at one end, then current will be 4 milliampere in this, and the potentiometer is other extreme, the current will be 20 milliampere, and that adjustment is done using this zero and span adjust pots.

So, keep it at one end, adjust the current for 4 milliampere, keep it at the other end, and adjust the span for 20 milliampere. This is repeatedly done few times such that potentiometer is at one end, you get 4 milliampere, other end 20 milliampere, and then the measurement is carried out by adding a resistance here. So, voltage across this gives you the current information that, indirectly gives you the position information of this potentiometer. So, this voltage measurement is utilized for taking the data out essentially.

So, this is, this resistance will up to 600 ohms and the typical values 24 volt. This is actually called 2-wire current transmitters, because we are using only two wires, which carries both the power and then carries back the signal as well. And this is quite popular, but the accuracy achievable in this is about only 1 percent, because this current whatever is flowing here, that is should get have only by this, and thus temperature change extra, this circuit should have contribute any current for the, in this circuit. But eventually, this temperature drift use to contribute some amount of current change here. So, that puts an ultimate accuracy limit for this circuit. So, to get 1 accuracy, we need to go for 3-wire system, that is what we have finally discuss in this lecture.

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So, 3-wire system looks like this, so this is called 3-wire current transmitters. a 3-wire current transmitter essentially looks like this, that you have potentiometer, the voltage source and then it has given to the system, the 3-wire current transmitter. So, this is, then one more wire comes out, and that carries the current back to the system and whatever measurement you want, you put a resistance and measure, there is this is one wire, this is second wire, this is third wire, this is current transmitter. Of course, the parameter which is should measured, for example potentiometer, then it is connected like this (Refer Slide Time: 4:50). So, this is a model of a 3-wire current transmitter.

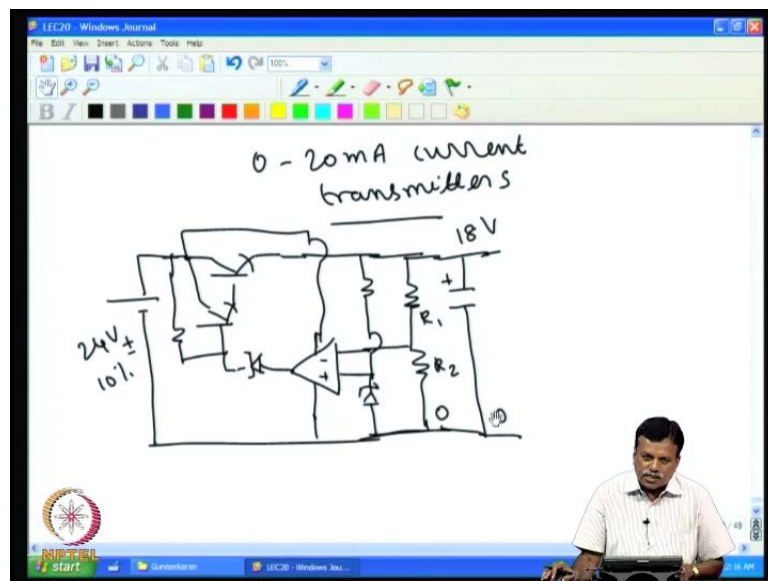
In this signal, is now coming in this terminal, the third terminal and that current is convert into voltage by adding a resistance here, and this also typically around 600 ohms and this also 24 volt, look out this also has the two potential, zero and span, adjusting potentiometers are there.

For example, we have here zero pot and then span pot. So, normally what is done is that, you keep the potentiometer at one end and adjust the zero, to get 0 milliampere in this, then take it to the other extreme and adjust the span to get 20 milliampere in this line. So, this is not repeatedly three, four times; one end, zero milliampere at other end, 20 milliampere, that is adjusted using zero and span pot.

So, eventually when this is moved, at one end you will get zero milliamperes, here in this wire and at the other end, you will get 20 milliamperes here. So, this is actually 0-20 milliamperes current transmitter.

So, unlike their 2-wire system, we have 4 and 20, here we have 0 and 20, this is because the current consumed by the circuit is not coming in this signal wire, because even if the current consumed by the circuit changes, it has no effect on the signal. So, even if the current consumed by the circuit changes, you will have no error on the measured quantity, that is the advantage of 3-wire current transmitters, 3-wire current transmitters are more accurate than 2-wire current transmitters; because of this elimination of this varying current problem, because the **circuit current about the** circuit current need not vary in this case, so these 3-wire current transmitters also popular.

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Let us see, how to design these 3-wire current transmitters. So, 3-wire current transmitters made for 0 and 20 milliamperes. So, one end it will be 0 milliamperes, other end is 20 milliamperes, so we call 0-20 milliamperes current transmitters (No audio from 07:31 to 07:45). Now, the design of the circuit is slightly easier compared to the 2-wire system, for example, the power supply what is required can be easily designed without worrying about the current consumed by the power supply; for example, in a 2-wire, 3-wire system we can have a input power supply design (Refer Slide Time: 8:08).

One can use a conventional power supply itself and the power input to this power input to this can be directly from the supply itself. We need not struggle like what you had in the earlier case; **you know** the power supply should be from the regulated voltage, because the, even if the input voltage changes, this has to be changing to a D C supply, **to a D C supply.**

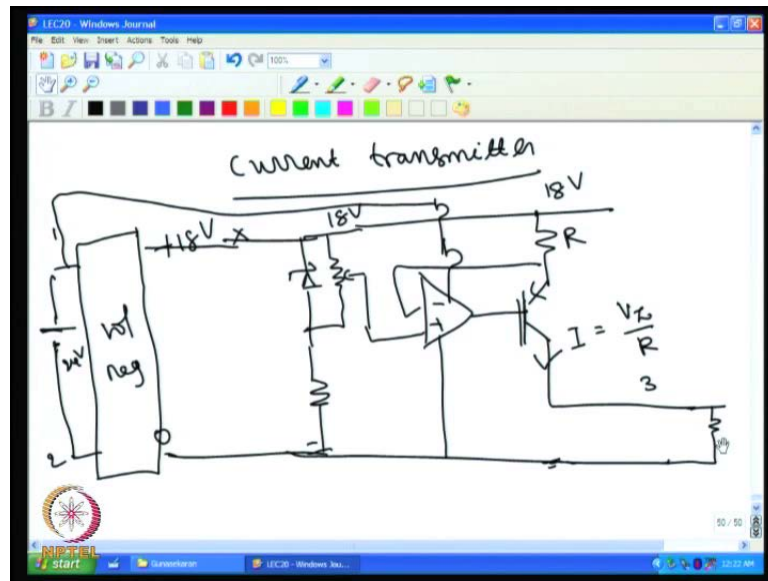
So, one gets a D C supply straight away and **even if this voltage changes** even if this voltage changes the current, obviously the current will change, but that current is no more issue, because we are not measuring current flowing through this in 3-wire system. So, the design of this become slightly easier, now what normally done is that, **you can have the...** but still here the zener is required to start the voltage regulation process.

So, this we already discussed in the earlier lecture, what is the function of this zener and then at the output, we can have the voltage divider **voltage divider** and then the reference zener can be put here. This is one possible regulator design, but this zener be the only circuit, because it is a 3-wire system, even the conventional voltage regulator chip can be used for this purpose, all that required is one has to get a steady voltage across this two points. Of course, we need to have a capacitor and this capacitor also can be **(())**, because even the leakage that develops is not a serious issue.

So, one can have the regulated voltage and this can be even the conventional regulator. So, all that needed to be done is you get, for example, the required regulated voltage and this has to be slightly higher, for example, if it is a 24 volt supply and if it is having plus or minus 10 percent variation, then the voltage can be even kept at 18 or 19 volt regulated voltage, because we need to drive a 600 ohms, 20 milliamperes later in the current transmitter.

So, we need to have this kind of voltage at this point. So, we will not discuss much about the voltage regulator part which we are already done in the earlier case. So, and the, this regulated design is not a critical issue in the 3-wire system. So, we assume that we have a regulated voltage of 18 volt coming to the circuit. So, next step would be we have to go for 3-wire current transmitter circuit design.

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So, the current transmitter partly at design, now, if we look at the current transmitter design, now one easiest thing that two possible circuit topology can be used, and one could be this (Refer Slide Time: 12:13). In a current transmitter of this type, and then we can have, for example, in this case if I have a voltage here, then you have a current that is coming here.

So, now the current actually flowing through this is given by this is V_z , and this is supply voltage say that plus 18 volt, assume that is what we got taking the other case. So, this is 0 and 18 volt and the, if this is R , then I actually will be equal to V_z by R , so in this case, if I can use this model for 3-wire system. In this case, the third wire will be this one, that is instead of putting this resistance here, what we do is, we will give this is output terminal third wire.

So, we have in this model, we will have a voltage regulator coming here, and this is 24 volt, this is a voltage regulator, this is a 24 volt which we, this voltage we are discuss and then this is acting as a first wire, this acting as a second wire, and then this is acting as a third wire and the user can connect the resistance here, at the receiving end and then see the current.

This is one possible model, we can use for current transmitter, this has disadvantage mainly because, we have to generate the variable voltage, where the current is to be varied, then this voltage has to be varied, then only the current can be varied.

So, in the case of potentiometer based system, then one can do this. For example, I can have, I can add the potentiometer here across this, then connect the **connect the** potentiometer like this. For example, potentiometer changes suppose to produce a current change here, then this model can be employed. When the **when the** potentiometer is have to one end, that will have 0 milliampere current, because of this voltage and this voltage would be at the same potential.

For example, if this is going and sitting here, then this is going and sitting here. Then, you will have for example, if this is 18 volt and if this also sitting at 18 volt, then no voltage difference and current will be zero. So, I will have a zero current and when the potentiometer comes to other end, then if this is 18, if this is says 1.2 volt zener, if I use then it will be 1.2 volt, then 1.2 divided by the resistance will be the current.

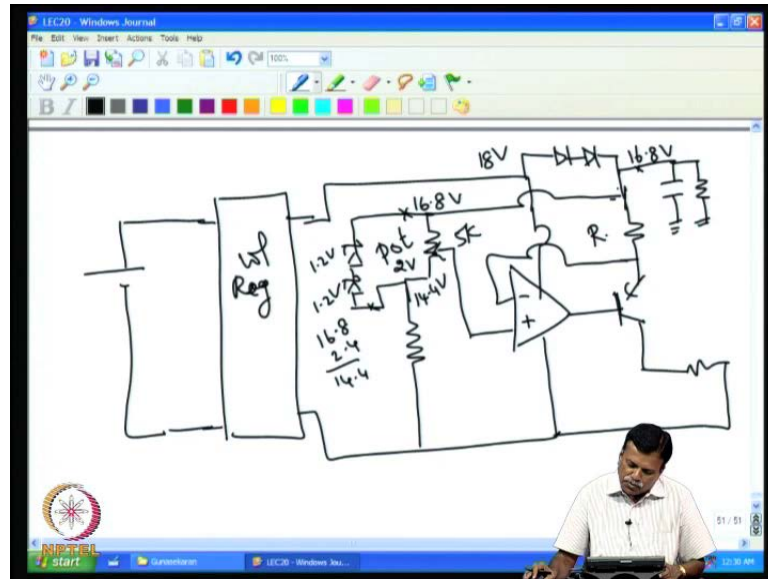
One can adjust this voltage and this resistance should get the required current for this moment. So, when it is at one end, we can have 0 milliampere, when this potentiometer at the other extreme, we can make it 20 milliampere. It is quite possible to scale this resistance and this zener correctly to get for 20 milliampere, but this has one drawback namely, that the supply is 18 and we know that we have to give power supply for this also to be made 18, that if this power supply also 18, then it will not work up to 18 volt, because supply itself 18 and this calls for little less than 18, this also calls for little less than 18.

But if this is supplied directly from 24 volt like this, for example I can have this power supply connect it ground here and then, this directly connected to the input, then this circuit works well. And then one can get 0 to 20 milliampere in the 3-wire system, because this supply this, then supply for this is definitely more than this, and in that case, we will have 0 to 20 milliampere coming properly without any problem.

But there is one drawback of connecting this directly to the mains, that is whatever noise that is present here, that will directly coming to this without any regulation, and the output also this noise voltage is influences the output current, the output current also will have noise. So, normally this is not preferred circuit, so one can modify this slightly to get the, to get it off this regulation, the noise problem.

So, normally what is done this that instead of connecting it here instead of connecting it here, we can connect it in a slightly different way, we can see in the next circuit.

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What we can do is, we can have a regulator that can be in the conventional form that we have discussed earlier. So, we have a regulator, voltage regulator. So, we have the input voltage coming to this and the regulated output coming in. So, we feed the regulated supply only to the, this is ground, and regulated supply only we feed to this and then, we connect similar to what we are discussed, the current transmitter pot. Then, this regulated output only we connect to the potentiometer. Of course, we limit the voltage across that, we can have this zener even if the regulated voltage even the zener is not required, one can scale directly even without zener also, it works (()) this no problem.

So, one can have this directly connect it here, and then one can have this potentiometer connected like this, then only issue would be we had that this, and this you know the when zero current is there, this voltage, voltage at this point would be equal to voltage at this point, and the supply also at same potential that is this and this (Refer Slide Time: 19:25). For example, in the earlier case, we have connected all these three together and 2-wire, 3-wire system, we will have this going out separately, then it is connected back.

So, in this case our original issue was that, the supply of this is same as this potential, no current is there, and then there is no voltage drop at zero current. So, this also goes up to the supply voltage and the potentiometer is move to one end and this end goes to the supply voltage and (()) input will not accept, exactly the equal to the supply voltage, the input has to be little lower than the supply voltage.

So, this was the problem that we are discussed in the previous circuit. Now, we can modify this to get rid of that problem, what normally done is you remove this, and this supply to this, you can give to directly to this, and these two can be forward using a slightly lower two diode drop, less than **less than** what is actually at this point and then to make this point stable, we can have one capacitor and very small current can go in this to make sure that, the diodes are biased and some 1.2 volt drop is there.

So, now 1.2 volt reduction in voltage is achieved by this arrangement. So, the earlier issue of the inputs going up to the supply voltage terminal is resolved by adding these two diodes. But still we have to add now, we have to add zero and span adjusting potentiometers to this circuit, then only **it is,** it will be commercially viable circuit. This is because, this is the part that actually controls the 0 and 20 milliamperes; when at one end, it will be 0 milliamperes at the other end, it will be 20 milliamperes.

Unfortunately, what happens, this part will be mechanically linked, normally this part is mechanically linked the system, whose position to be measured. But this when they connect mechanically, when the wiper most one end it may not reach the potentiometer, it may not reach the **end of the** physical end of the potentiometer. So, mechanically the system might have moved to one end, but the potentiometer might not moved to the one end. Similarly, the potentiometer might not have moved to the other end, when the system is driven to the other extreme, this happens because of mechanical misalignment.

So, one has to take care of that; that is, I should get even if this is not reaching the one end of the potentiometer, current should be 0 milliamperes. And the achieving that is a trick issue, so that we have to, and then similarly, when other end is there and the current **you know** the voltage may not have reached full value, the potentiometer may stop little away from the end of the potentiometer. For example, if this is 5 k part **if this is 5 k part,** if I take this as my one end of the point, then when the potentiometer is moved to this end, then, if I try to see the volt resistance between the, this point and this point, that is the resistance between this point and this point or voltage across this, when the potentiometer move to the one extreme, this extreme, it should get 0 volt, that may not be exactly 0 (Refer Slide Time: 23:10).

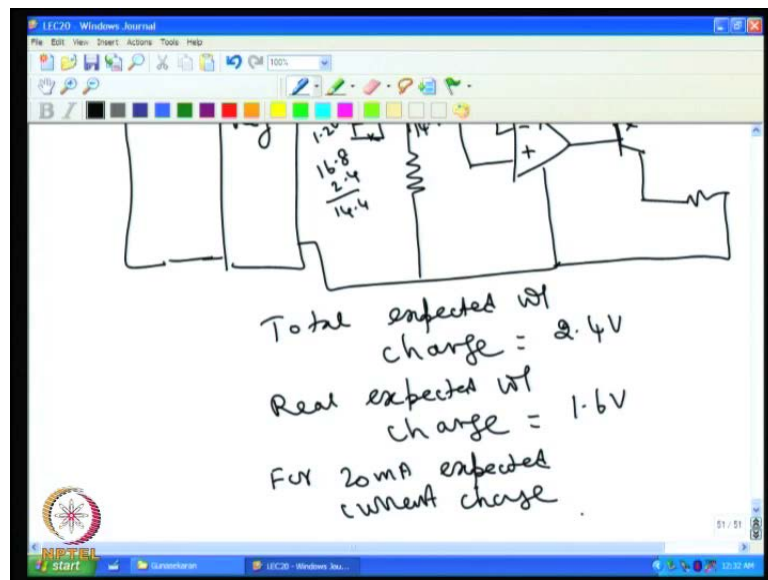
Similarly, if I had design around 2 volt across this, then when potentiometer move to this extreme, I should get 2 volt across this, you may not get 2 volt, you may get only less

point less than 2 volt. So, this problem to be handled and for that, we have to provide zero and span adjustment. Now, one can do that for example, if I want 20 milliamperes I can have 2 volt drop across this I can have 2 volt drop across this, now that I can exactly achieve this by putting a for example, I can have 2.4 volt zener here.

So, one will get 2.4 volt across this, only thing is that, it may not go and it goes to one end. For example, if this is if we write the values that it is 18 volt and this is expected to get 1.2 volt drop you may get 16.8 volt, and this will be 16.8 volt and 2.4 volt, each one is 1.2 volt diode zener diode. So, 2.4 down, so 16.8 minus 2.4 will give you 14.4 volt. So, once when the potentiometer is moved to this extreme end, and the potentiometer is move to this extreme end, the voltage should be 14.4, when the potentiometer is move to this extreme end, it supposed to 16.8, which may not happen, because of the physical limitation.

So, we have to deal with this, by adding zero and span pot. For example, if I want 20 milliamperes, then in this case, I we have to fix this value. So, I will fix this resistance R, so 2.4 volt supposed to give me 20 milliamperes.

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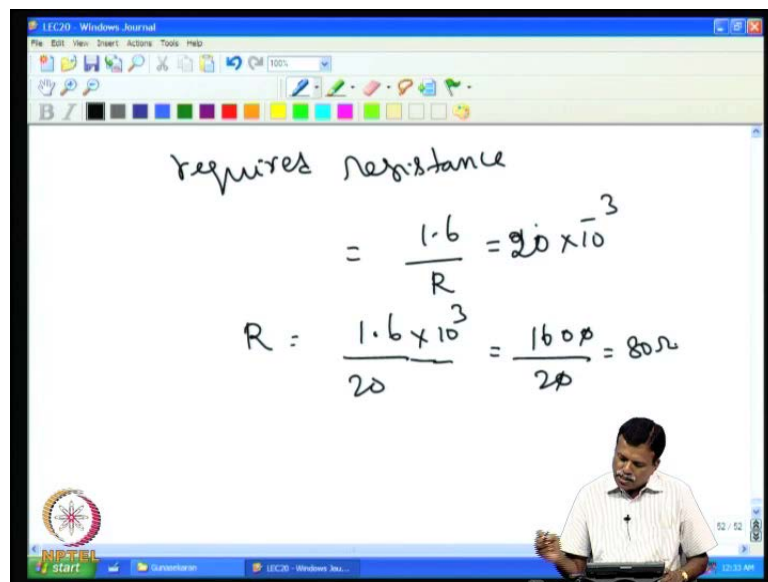


So, total voltage change, total expected voltage change, change is 2.4 volt, it will be definitely less than 2.4. So, we can take normally 20 percent both sides going off. So, real voltage real voltage change real expected voltage change, that is it will theoretically we expect 2.4 volt change here. When this point is moved across this, we expect 2.4 volt

change, but reality it may not be 2.4 volt, both sides normally expected to have about 20 percent error, that is mechanically not able to move very close to the end. So, if I take 20 percent change, that means, each point I can give 0.4 volt that means, I can have only 1.6 volt change is only expected to a real life.

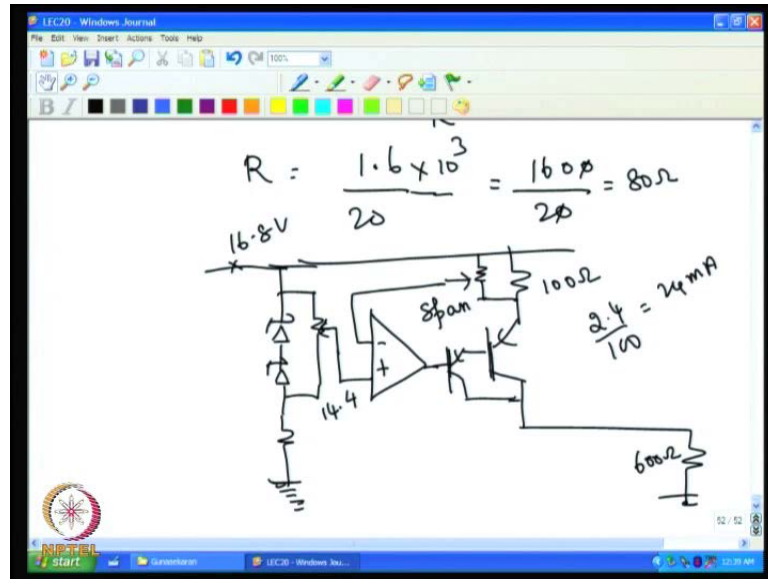
So, we may expect only 1.6 volt change; in that case, for 1.6 volt change should give me current of 20 milliampere. So, change of current, change of 20 milliampere, because this voltage **you know** the voltage change here, this voltage change divided by this resistance is the current, which we have discussed in the earlier circuit design. So, the current change the expected real current change for 20 milliampere expected real current change, expected **current change** current change.

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$$\begin{aligned} \text{Required Resistance} &= \frac{1.6}{R} = 20 \times 10^{-3} \\ R &= \frac{1.6 \times 10^3}{20} = \frac{1600}{20} = 80 \Omega \end{aligned}$$

Required resistance values, required **required** resistance change, required resistance is actually 1.6 divided by R that is, supposed to be equal to 20 milliampere. So, that comes R works out to be 1.6 divided by 20 milli amps, that comes out to be thousands, you will have 80 ohms resistance is what is actually required to get that change. So, if I put 80 ohms here, then if 1.6 volt change occurs, then I will have 16 milliampere current. But we know that some potentiometer can go more than 1.6 also, but none will we assume, none will go below 1.6. So, when **when** some potentiometer goes to the extreme end, then the current can go higher. So, we have to solve that issue, so we have to have a variable resistance R.

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So, normally variable resistance part is achieved in the following manner. So, what is done is, if we look at the, but current transmission part alone, it will be like this, we can have and this is the 1.2 volt zener and potentiometer to go with that, and there 3-wire resistance is coming here (Refer Slide Time: 29:04). So, normally what is done is, we had a potentiometer here and then terminates this with another potentiometer like this. So, this is taken as a span pot, so for example, when this is take it as a span potentiometer.

And of course, we also have to add a darlington here to make sure that the current actually, whatever that current is flowing, the same current is flowing here and we want to make this base current negligible, then only the current that is coming here is same as this, because we are sensing this current, and this current is taken as a output current. So, whatever current that is flowing into the I C will be loss, so we have to make sure that this base current is negligible. So, we normally add a Darlington to this, so we can add a Darlington to this, we can add a Darlington to this that will make base current negligible and this will get a, this span will get adjusted with this.

Now, that adjustment to be to happen properly, then one, we has to calculate the values correctly. So, normally what is done is that, we will have resistance here, for example, we need 80 ohms resistance here to 80 ohm is put, when the potentiometer comes to one end, then it is 1.6 volt is there, when there here, if this point is less by 1.6. Then, if it is at

this extreme, then you will have exactly 20 milliamperes flowing, but sometime this difference can go even more.

So, if it goes more, say for example, 2 volt, then 2 volt by even this at other end, when 2 volt by 80 ohm will give more than 20 milliamperes. And if you want to reduce, then you have no way of reducing. So, normally what is done is that, we can have this resistance little higher so that we have some adjustability. So, for example I can have 100 ohm resistance here, so when it one point when the voltage here, this point is **you know** compared to this point, if it is less by 1.6, then one can always move this upward to make it equal. So, now **we can** we can adjust this and get 1.6, get 20 milliamperes even more than 1.6 volt. For example, and the case 1, we take for case 1, if this is for example, if this is 16.8 volt and this is sitting at **14 point** our earlier case we have design this one 14.4 volt, as 14.4, then we got exactly **1 point** exactly 2.4 volt difference.

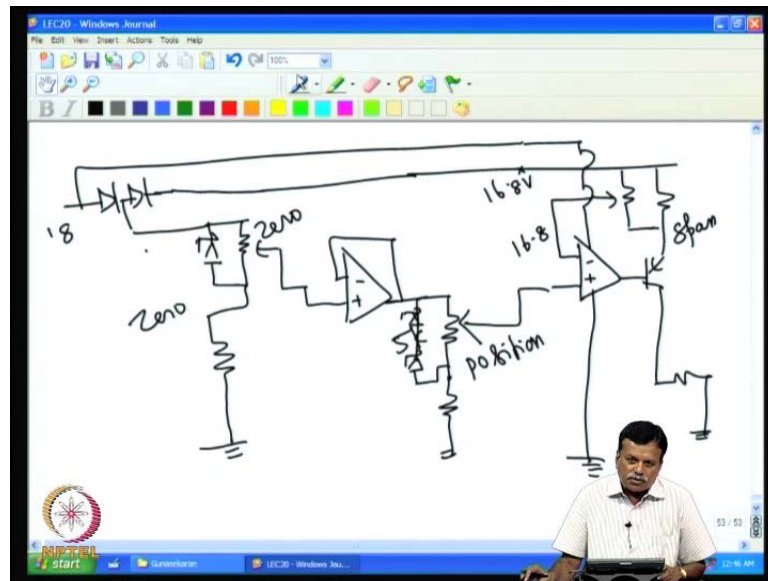
So, 2.4 volt difference if the potentiometer is at this extreme, this the extreme, then we have the current have 2.4 volt divided by 100 ohm, which will be 24 milliamperes, which is actually coming higher.

Now, to reduce the current, what we can do is, we can move the part little closed, need not go up to the end, we can go here and keep it **you know** for with **with** the 100 ohm, we need only 20 milliamperes. So, one can move this away such that the voltage difference is only reduced, because if this voltage and this voltage try to reach the same point. So, one can adjust this potentiometer and this resistance such that whatever combination we want, we can achieve.

So, one can have this span adjustment such that, when it mechanical end of the, when the potentiometer is mechanical end, one can get 20 milliamperes. Similarly, when potentiometer at other end, we have to make it is 0 milliamperes. To get 0 milliamperes is the only issue, because the potentiometer may not go one end, some voltage will be still left and you may have an issue with that. So, to get a zero adjustment, we have to do this circuit that we modified.

So, how to get a zero adjustment, so span adjustment can be achieved by selecting a suitable value for, suitable value of this, suitable value for this resistance and then this one can achieve the span adjustment. So, now we modify the circuit to include the zero adjustment.

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Now, one can get the zero adjustment by adding another operational amplifier, for example, I can have a one more potentiometer. Of course, if you want I can also add another zener to this, and this supposed to be connected through the voltage follower, then our regular circuit. This 2-wire system comes in, then we can have our potentiometer can be connected in this version. So, this is the potentiometer, for example, 5 k which determines the position of the mechanical system.

Now, for example, if the potentiometer is not going to one end, physically not going to one end, then one can adjust this as a zero. So, we keep this as a zero pot, and this is actually is what it is coming through the regulated voltage. And supply for this is actually coming directly from the, so this is acting as a span pot, this is acting as a zero pot, this is actually the position measuring potentiometer (Refer Slide Time: 37:13). So, now for example, if this not going to one end, one need not worry, because if the voltage is not equal to the supply voltage, then I can increase this by adjusting this. Of course, this in that case we have to have a provision that this course little higher, so that it reaches this point. Now, that also can be achieved by slightly feeding different voltage to this, that actually can be done by set a modifying this part.

What I do is, I will have this, and for example, I can have slightly higher voltage to this, so that they able to get little higher voltage, and this voltage also can be increased a little higher or even we can go down by moving it, lowering this point. So, we can now, we

have flexibility to vary this voltage so that we are able to adjust the zero by even if this potentiometer is not going to the one physical end. So, this gives a provision to adjust zero and span. So, we call this is a zero pot, this is actually the span pot, this is the position pot actually.

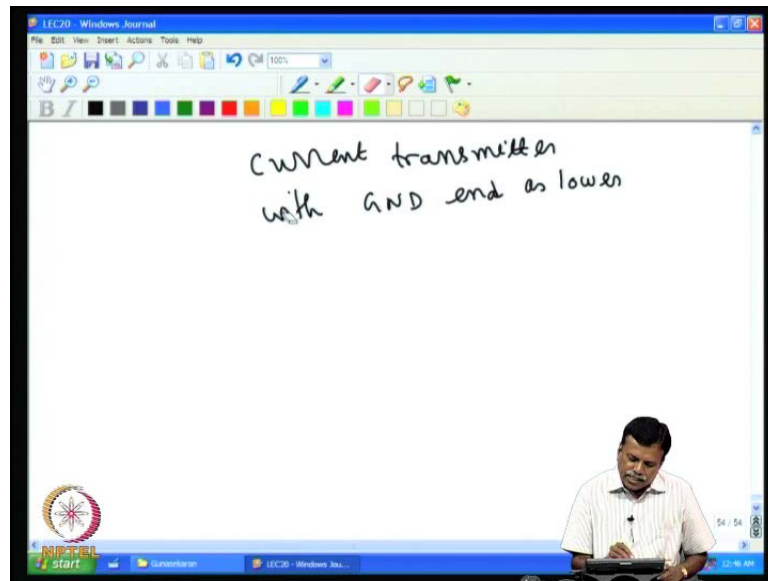
So, by this method, one can even if the potentiometer is not reaching full, for example, if this is 18 volt, you can go up to 17 point, this point goes to 18 minus 1 point into 16.8. So, even if the, even if there is 0 current is there, and then this will be sitting at 16.8. And since, this voltage is little more than 16.8, even if there is a small gap is there, and reaching the maximum end, one can easily move, adjusts this to lift this voltage higher.

So, that provision is possible, of course we have to limit the available voltage across this. So, that can be achieved by adding a zener, so we need not give too much **you know**, 1.2 volt can be the total variation that can be planned, or even 2.4 volt also can be planned depending on the selection of this resistance that we have planned.

So, we have planned for 2.4 volt, we can retain this 2.4 volt, and then do this. So, this way zero and span adjustment can be provided for 3-wire system. Now, you could have quickly understood that designing a 3-wire system is little complex than designing a 2-wire system. This is because we have to make sure that, **you know** this voltage, the current flowing through this **current flowing through this** is actually maintain 0 and 20 according to the position of this.

So, now practical terms, these issues to be consider if you want to maintain the current. Now, quickly you would understood that designing this circuit looks little cumbersome, that we have to plan various voltages at various points. So, one can think of another simpler circuit than this, to get this 3-wire system, that current transmitter part will be like this.

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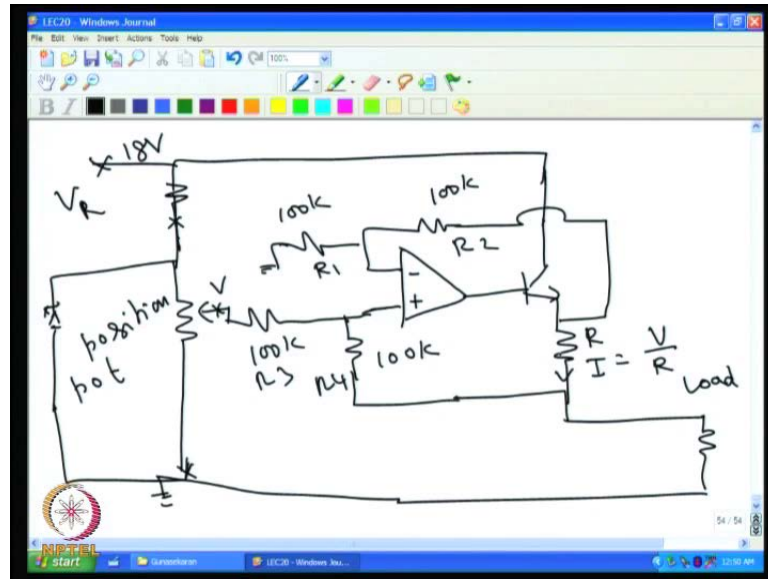


So, one can use this, we call it is a current transmitter **current transmitter** **current transmitter** with **with** ground side, ground end **ground end** has lower potential, because we are now or other way around, we say that this is a current transmitter without referring the, reference to the supply.

Because in the, if we look at the earlier transmitter, current transmitter, we take supply as a reference point and then lowering this voltage, **you know** we are take supply as the reference point and then we are lowering this to get the required current.

So, this is supply referenced current transmitter, instead of that, we go for ground reference current transmitter, then we will have slightly different problem, not the same problem, current transmitter with ground reference with ground side reference (No Audio from 42:33 to 42:47).

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Now, that actually we can do the following general circuit like, for example, if I have this kind of current transmitter. And this can be supply and then, this can be have at load, this goes back to ground, this is reference resistance. What we do is, for example, I put equal values here, then normally what is done is, I give for example, if the potentiometer voltage to be varied by the current, then I put the potentiometer here, this is the position potentiometer.

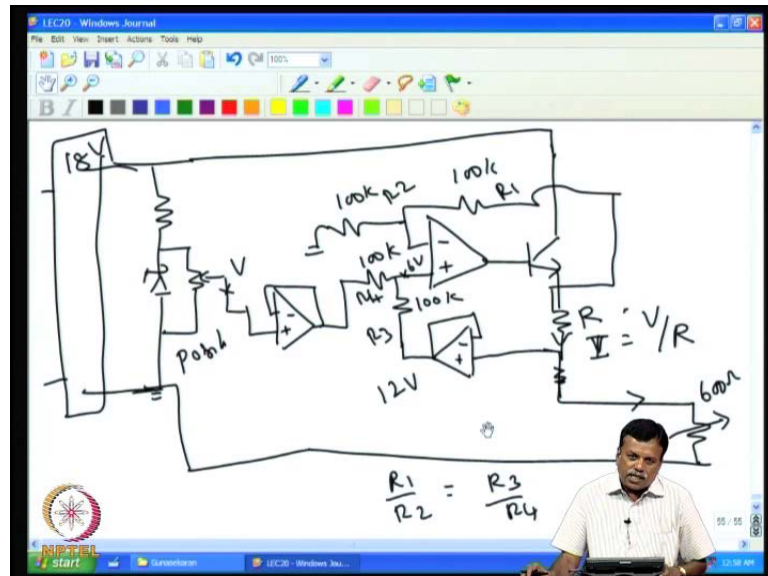
Then, to maintain the current constant, we go to this circuit, for example, if this also 100 k and this also 100 k. Then, assume this is come into V supply and of course, we can make it stable by adding a zener to this, and have this, that is V regulator, for example, V regulator, that is may be 18 volt.

This is one possible way of designing, in this what we are trying is that we have these 2 these resistances, which we are already discussed for example, R 1, R 2, R 3, R 4 are equal. Then, if this is say V with respect to ground, then the current I actually is given by V divided by R.

If provided this, all four resistance are equal, if this all four are equal and this resistance is negligibly small, then what happen, that loading effect would not be there, and then this also small. In that case, this relation is true, that current that is flowing is actually depends on this V and R, other way around when we increase the V, current will be increasing; decreasing, then current decreases. But then, this assumption to be valid, if

the assumption to be valid, then I has to make sure that I add up voltage flow here, as well as here.

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So, if I modify the next level of circuit looks like this, in the what we can do is, we will have, so we have the reference voltage coming in. So, I have 100 k and the same 100 k here, then what I do is, I will have the supply voltage, from the supply I have the zener diode, then **then** I the position part. So, this is the position part, this is the regulated supply is 18 volt, and then I connect this as usual (Refer Slide Time: 46:18). Now, here this one I feed through a voltage follower so that **this resistance** this resistance has no effect and the working of the circuit.

So, this I feed to this, where we are actually your **2-wire** 3-wire system is actually connected to this back, and this is what the input our regulator here, and then given to the input. Now, here this voltage again fed through a voltage follower, so we have this 100 k and a 100 k is kept. So, all four resistances are equal, but now we have added this, if you compare our earlier circuit, that now we are added these two voltage followers, because this voltage follower, does not load this resistance. Similarly, this voltage follower does not load this potentiometer, because of that, now the accuracy of the circuit is improved, because the input events given by the, using by the voltage follower is very high.

So, first improvement is this, but still we have to worry that, how will you make sure that these four resistors; 1, 2, 3, 4 are equal, because if they are not equal, then the current

will not be any more, if they take this as V and the current through this V , I will be equal to V by R .

The current I is equal to V by R is not strictly valid, if these two are not equal, and the worst is, if they are not equal, when this resistance changes. For example, if the current may be constant, the current may depend upon only these V when by R , in first order approximation that you have this V by R as a current, but then, that current what is flowing here will vary little bit with this resistance, because the load resistance is not in your control, this is given to the customer, you may connect 600 ohm or even less.

Now, but not more than 600 ohm, when we connect very small resistance here, when we connects a very small resistance, then 20 milliamperes current flowing through that will produce only very small voltage. And other extreme, when we puts 600 ohms, then 20 milliamperes will produce a 12 volt here across this, and this point will be sitting at 12 volt, and the 12 volt has to be reproduced at this point, and 12 volt will come as 12 volt at this point, and the 12 volt will make its 6 volt.

But when, if the whatever voltage that is coming here, that is also to be equally divided by half, for example, for low current, for 0 current, if this is a 12, if this is a 0 volt, then this also will be 0 volt. Then, if whatever voltage extra is there, that will come by half, then if whatever voltage there, half of that will come here, and here whatever voltage there that also half of that have to come. If this ratio **ratio** is not equal to this ratio, then the difference is not correctly reproduced at this end. So, we have to make sure that this ratio and this ratio are equal (Refer Slide Time: 49:51). So, essentially making calling that we call this ratio, they say R_1 and R_2 and this is say R_3 and R_4 . So, if the circuit has work independent of this resistance value, that is the accuracy to be maintained means, then have to make sure that the ratio R_1 by R_2 , is exactly maintained as R_3 by R_4 .

I really speaking 1 is to 1 is ok, but nevertheless the ratio to be maintained, the ratio is not maintained, then the, when the resistance changes, the current also will change. For example, if the **if the** user changes as this resistance, then voltage developed across this will change.

That voltage will produce a different error at this point and at this point, because this voltage is applied at this point by this ratio of this resistance, whatever voltage is here,

that is applied by the ratio of these two resistance, if this ratio and this ratio is not equal, the **voltage at this point** voltage at this point transferred to this point will be something and voltage at this point transferred to this, will be something else.

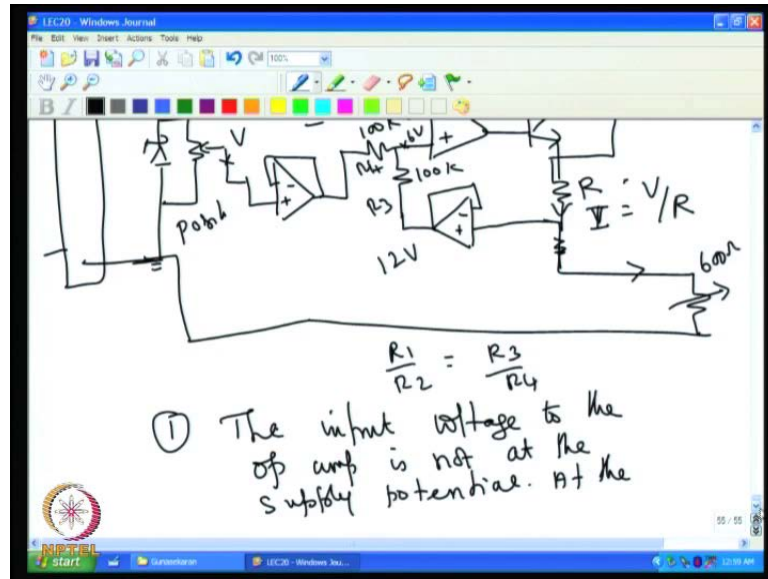
And that will make that, this voltage we call common mode voltage will have effect on the current. So, we have to make sure that this ratio is maintained constant, this is one of the major problems in this circuit, other way this circuit is much easier compared to the other circuit which we have discussed, because here we need not struggle with various voltages that we had faced that problem, we had faced in our earlier circuit. Because if you see carefully, if this is 18 volt and even if this is close to 18, we have 1 is to 2 ratio, So, this point never goes to 18, it is only half of that at the maximum, so it will be always below 9.

Similarly, whatever voltage that is coming here, that **you know** you have this is, if the resistance is zero of course, will have close to zero, assume the resistance not zero, then this is also not zero, but even if it is goes to 8 k, 12 volt, then here what is coming is only 6 volt. So, at the, as far as higher voltage is concerned, these, this op amp is safe.

Of course, you may have worry that **you know** what happens if the user puts 0 ohms and if this goes 0, then the op amp will not work properly, because close to the ground reference point single supply op amps do not work properly, so this is the problem that we face. So, for that **that** problem can be easily solved by adding a small resistance wantedly from our side.

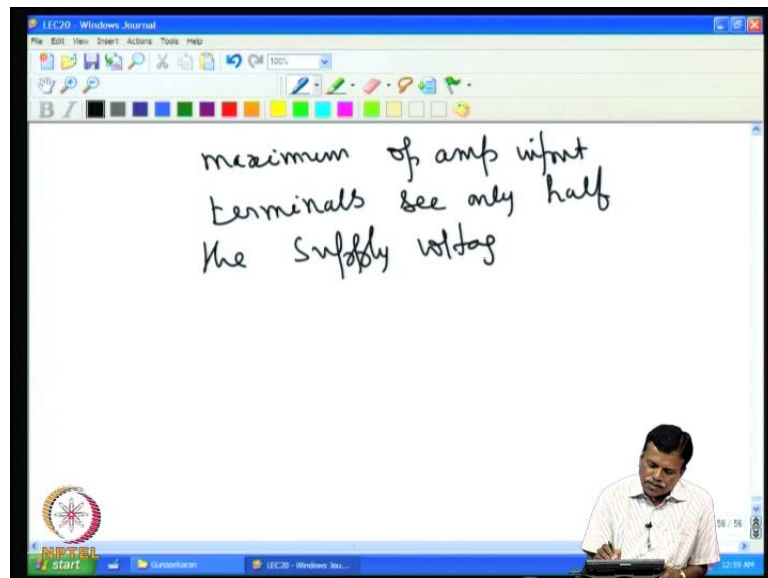
So, I can add a small resistance 47 ohms or so, so that even the user grounds this voltage at this point will not go to 0. So, that can be tackled and similarly, the high voltage say 12 volt is not a serious issue, it can go up to the maximum supply voltage easily, because even at 18 volt, this goes only 9 volt and this also goes only 9 volt. So, the circuit works properly even 9, at 9 volt, because supply is at 18 volt. So, that 0 and supply voltage what we are faced there, is not the issue in this circuit.

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So, if you look at advantage of this circuit is that; 1, supply op amp inputs voltages, the input voltage op amp is not **not** at the **not at the** supply potential.

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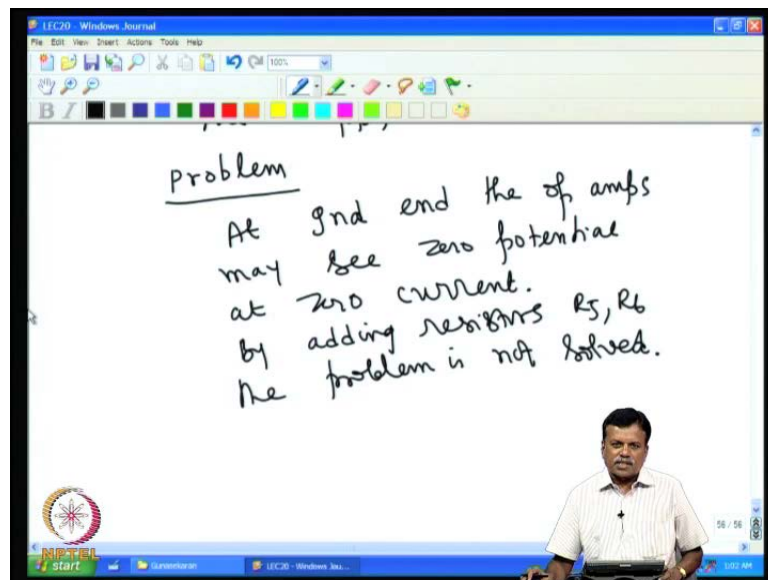
At the maximum, there only half the supply potential, at the maximum, there only at the maximum **maximum** op amp input terminals are seen, input terminals see only half the supply voltage. This is one of the main advantages to the circuit.

And then, so this makes our working simpler. So, this avoids too many complications that had come, because of the supply and then, input that is our position potentiometer, if we look at the position potentiometer, there at the ground side.

So, the voltage **the voltage** can go down to 0. Now, that we can solve, because if the potentiometer goes down to 0, then this voltage will go 0, and the op amp may not work properly this also can be solved by adding a resistance here so that it does not go to 0.

And if of course, now soon we find that when this is not going 0, if this is not to going 0, if this is not **if this is not going** to 0 and this also will not go to 0, the output current also will not go to 0, that problem will soon we will have. So, that problem to be addressed, because we have to take that **you know** the op amp is not will not go to 0, then here of course, this side the op amp voltage now going to 0 can be addressed by adding a resistance here. Of course, when the current to 0, then there would not be any voltage drop and this also will post go to 0, at the time this will not also work properly. So, we had additional two issues now coming, that supply I say, supply point problem is solved, but the ground sides have potential which is going to 0 is not solved.

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So, the second issue is actual problem is at ground end **at ground end**, the op amps may see zero potential **potential** at zero current **current**. Similarly, zero current, solving by adding **adding**, I call the resistors. For example, R 5 and R 6 having R 5 and R 6, the problem is not completely solved by adding resistors R 5, R 6, the problem is not solved

not solved, so not find a solution for this, but nevertheless we are better off compared to our earlier circuit.

So, we have to see how to resolve these issues, of course, one can resolve this issue by adding additional voltage at this point. For example, even this 0, that we can add some additional voltage to this, because if the problem comes when this is when it is not going to 0, then this also will not go to 0, but then we want for 0 current 0 volt, that can be achieved by only adding some additional voltage at this point.

So, we have not find a solution, how to add a additional voltage without disturbing the balance, unless this issues are solved, this may not work for 0 and 20 milliamperes. So, now we have to explore this and see how to solve this ground side problem, nevertheless we have solved the major issue that is supply related issue that is op amp terminals which are op amp terminals, which we are going very close to the supply voltage that has been solved.

So, we see how to modify this circuit to take, to solve this ground, you know the ground potential that is the op amp going close to zero potential, how to solve that, we will see in the next class, thank you.