Circuits for Analog System Design
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Lecture No. # 25
LVDT Based Current Transmitters

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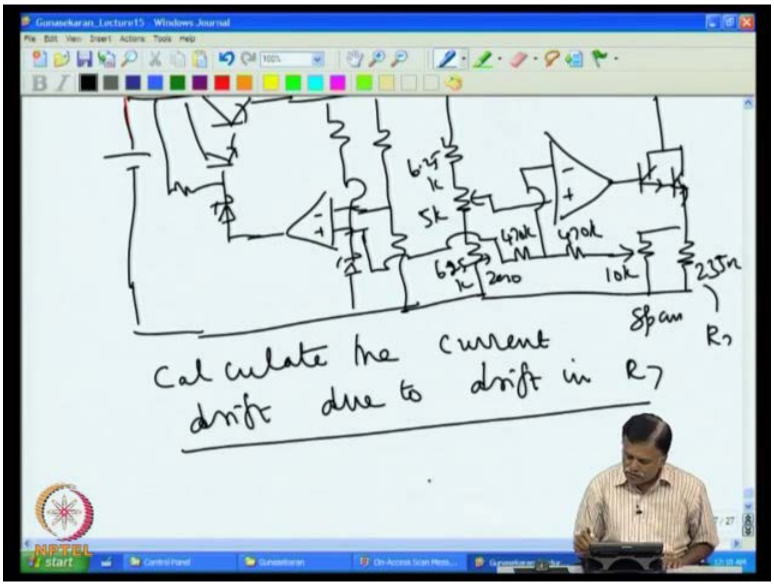

Good morning, in the last class we were discussing about error involved in the current transmitter stage of 420 milliampere current transmitter. So, the, if you recollect, basically what we are trying to is, we are trying to transmit the signal in the form of current. So, for that we had the input stage as, the input stage as voltage regulator. So, we had a voltage regulator at the input, then we had a, followed by that we had a current transmitter. So, we had our voltage regulator like this and then we had to start, we had the zeno diode like this, then followed by this we had the current transmitter here. So, this was, we had shown as 6.25 k and this was 6.25 k and then 5 k (( )) was used, then this was actually connected to this, then we had the output current converter stage. So, this is actually given as a feedback and this was used as a 0 adjustment, this used as a span adjustment. So, this is the current transmitter, which we were discussing and then we also calculated various error, error that used to come because of temperature drift.

So, we calculate what is the error due to the offset voltage drift of this (( )), then this resistance change, then what is the error, that you will get in the voltage regulator? Then, similarly, if the (( )) trips, then this output voltage changes, then what was the error that is coming because of that you have calculated and then we also calculated what is the error, that comes because of offset voltage drift of this (( )).

Now, we (( )), calculate what is the error due to this and then other errors, that is, was the error due to drift of this resistance? Now, we can do many things, but I will calculate only one case, that what is the error, that comes due to this resistance drift, the rest that you can do it yourself. So, if you take this example, that we had taken this has a 235 ohms resistance, this 235 ohms resistance we had taken, let us see, and this was normally around 10k and this is actually 470k and then 470k.

Now, let us assume that this resistance is drifting due to temperature and then, what is the current drift that you can expect because of drift of this resistance. So, we calculate, calculate the, calculate the current drift, current drift due to drift in, say, this resistance R 7, drift in R 7.

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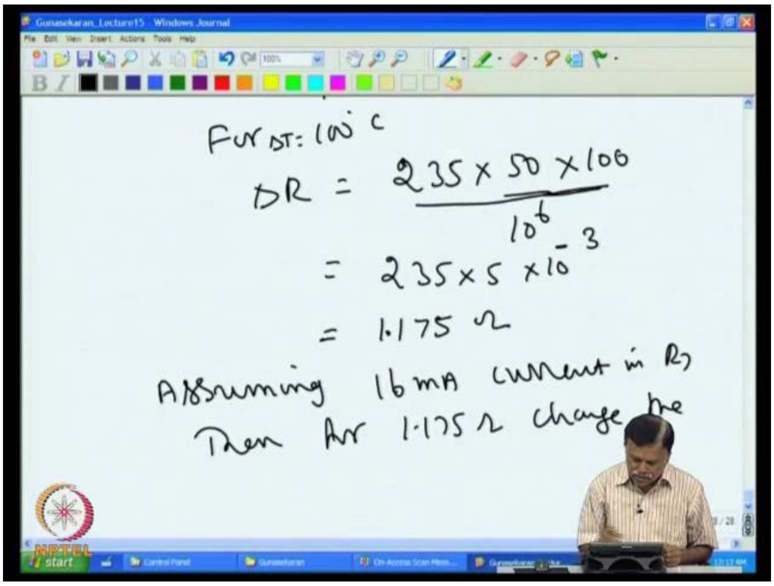

Let the, let the temperature coefficient of R 7 is equal to 50 PPM. Assume, that we have used 50 PPM per degree C resistance, then for 100 degree C and delta r will be, this is 235 ohms, so 235 and a 50 PPM and then, for delta T is equal to 100, 100 degree change, then that has to be 100. So, that is the resistance change expected, that will give you 235 into 5 into 10 power minus 3, that is for, that, because this, that amounts to 1.15 ohms. Actually, that is, the total change will be 1.175 ohms resistance change expected in 230 ohms resistance when temperature change of 100 degree occurs.

So, what is the corresponding current change? Now, the 1.175 ohms change in resistance here, we take this if the, for example, if the resistance in this case if it goes up, then this voltage will go up and then this goes up, then all, automatically, the current will go up, then that may current have to come down because if this voltage goes up, this voltage will come down. The current had to come down such that the original values maintained because essentially, this, this voltage at this point and voltage at this point and have to be same all the time.

So, eventually, if 1 millivolt, 1 ohm resistance changes here, then that will be a change in voltage and that voltage, half of that will be appearing here. So, it has to correct it back such that again the current decreases, so that the original voltage is retained back. So, we can calculate the current, changing on that depends upon what is the actual current that is flowing. So, easiest way of doing this should be assuming that around 16 milliampere current is flowing at the maximum. So, 235 ohms gives you 16 milliampere current, then 1 ohm. What is the current, that it gives, that would be easier route to find out the error due to the resistance change?

So, what you do is, we will take, assuming, assuming 216 milliampere current is flowing because normally, you have 20 milliampere current of which 4 milliampere current comes from the other part of the circuit. Normally, the current through this will be around 16 to 17 mill ampere, so we assume here it is 16 milliampere current.

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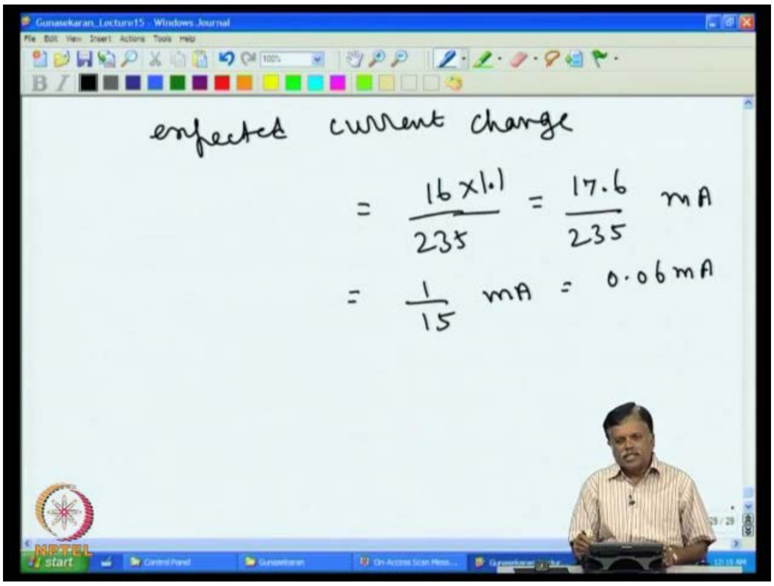

Assuming 16 milliampere current, current in R 7, then for 1.175 ohm change the expected current change is, that would be 16 divided by 235 into 1.1 ohms, that will be roughly about 17.6 divided by 235, that actually if you take percentage wise, that will be current in milliamps, it will be in milliamps. So, that will be fifty, 1 by 15, that you will get approximately milliamps, that will be 0.06 milliampere current.

So, because of that resistance change, the R 7 change, you would have a current drift of 0.06 milliampere like this. The various errors in the circuit can be computed, I (( )) the rest of the error calculations to you, so that you can practice that and arrive at total error involved in the circuit.

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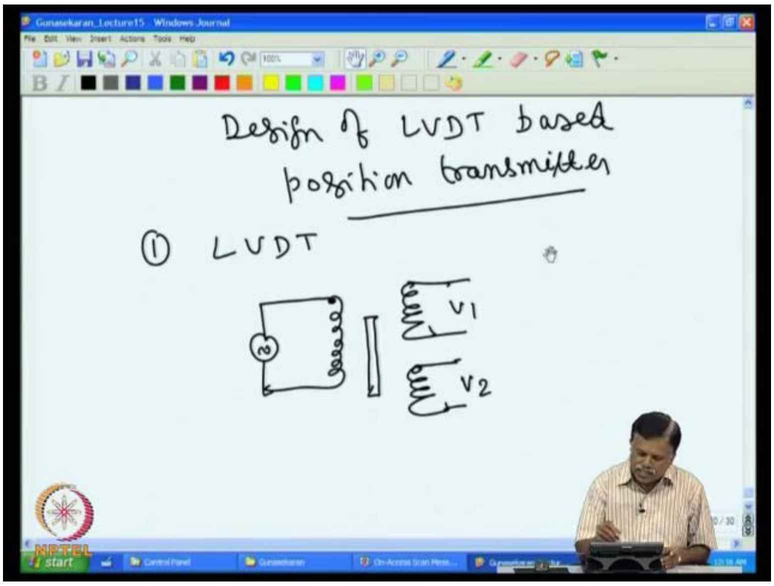

Now, let us see at another design, namely, how to use LVDT for displacement measurement. So, we will pick up another example, that is, design of a LVDT based position transmitter. So, so if you, first we explain what is LVDT. So, if you take LVDT, this is actually linear variable differential transformer, it looks like this, that is, you have a primary and then you have a two secondary (( )) associated with that and then you have a core, which is a moving core, is there. So, the idea is that if energy is the primary with AC voltage, then you will get a voltage here V 1 and then V 2.

Now, if the, if this core is in the middle at, is linking half of this coil and then other half is linked to this coil, then this voltage V 1 and V 2 will be equal. In case if the core moves up and if the core occupies more, more of this and then less of this coil, then you will have V 1 more and V 2 less. Similarly, if the core moved downwards, then it will have V 2 more and V 1 less.

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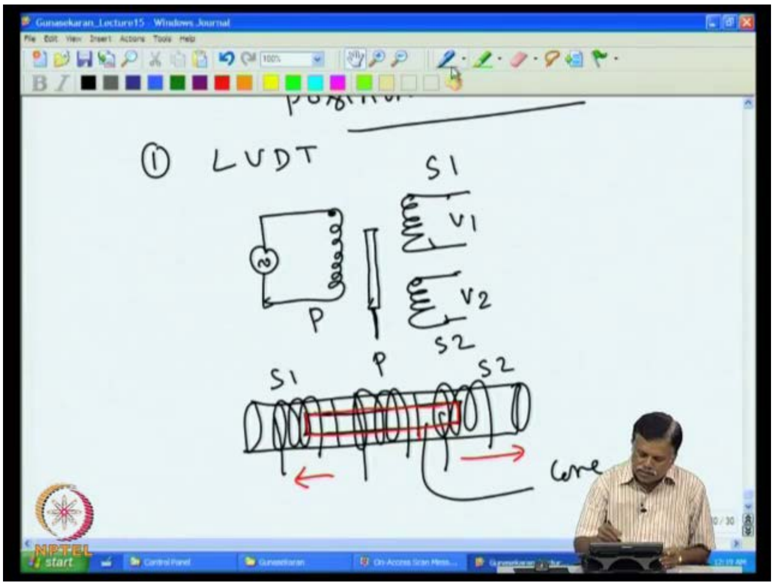

So, if we see, want to realize in the three-dimension, then this look like this, that normally there are LVDT as a core; bobbin is there and then you have three segments in this. Actually, one secondary is wound and in this another secondary is wound and primary is wound in the middle, so this is the primary. So, here it comes primary and then S 1, rest as two secondary. So, this is coming S 1 and this is S 2 and the core is actually, normally, moves inside, so you will have the core inside. If you see it will be like this. So, that is the core that it comes.

So, the movements of this core, if I take another color and show you, see the core will be this. So, now, for example, it, normally when the core moves, the, the core moves, you will have all the time, you know, primary will be linked to the core. If the core moves, for example, towards this, then you will get, the core will be mostly occupying S 1 and then, the primary and secondary will have very little link to the core, or if the core moves this way, then you will have the S 2 links the entire core and then primary, there is no linkage to the S 2. So, that is what it happens in this case.

So, we had shown semantically like this, you can, physically the LVDT looks like this. So, essentially, what is done is that the link, this one for the displacement, that is to be measured, that is, mechanically connect this to the system where the displacement to be measured. So, when the, when there is displacement, then core moves accordingly and accordingly, you will get more voltage in V 1 or V 2. If that links both the coils equally, say, if the core is at the middle, then you will get V 1 and V 2 equal. So, by measuring V 1 and V 2 one can, I determine the position of the core. This is the purpose of LVDT, that is, that is why it is called linear variable differential transformer.

So, now, mostly the V 1 minus V 2 difference, linear for the displacement up to a certain range, for example, if we take 3 mm LVDT in, for the 3 mm displacement of, 3 mm displacement of this core, you will find V 1 V 2 difference is linear. So, this is the basic principle of the LVDT. Now, we see how to use this for position information and then what are the errors associated with this and then, how to take care in the circuit design.

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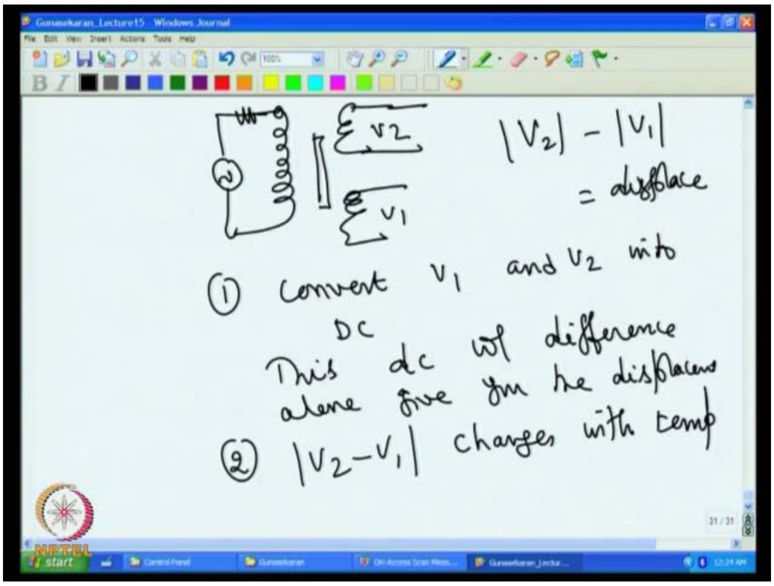

So, if you look at this, if you look at the basic LVDT, then what are the problems associated with this? First thing is I had it energized with the AC source and then I have to pick up these voltages, V 1 and V 2, the two voltages. Now, the problem is that when the core moves the amplitude in V 1 and V 2 changes, but in addition to the phase relation between the primary and secondary also changes.

So, actually, if you want to really see the difference, only have to see the magnitude of V 2 and the magnitude of V 1 is the difference, that we have to measure, that gives you the displacement. That means, I had rectifier, make it DC; this also has rectifier, make it DC. And then, that difference between these two DC voltages you will give me the displacement, that means, what I do is I had to convert, convert V 1 and V 2 into DC.

This DC voltage difference, this DC voltage difference, difference alone give you the displacement, not the AC voltage difference. So, this is one problem.

Then, second problem is when the LVDT is used in the actual, in the field, invariably you will find, that temperature of the entire unit changes. Now, we have issue, that because if the temperature of this changes, then the coil resistance also change because this primary, for example if you take this is having resistance because LVDT wound in smaller size and they use a very thin wire. So, the resistance of this coil matters lot because whatever voltage is there or whatever applied voltage is there, that is partly applied on the, that is partly lost on the resistance of this wire.

So, if I take LVDT that it has the resistance in the primary and as well as inductance, only whatever voltage is there on the inductive part alone transfer to this and this. So, whatever voltage there on the resistance is not transferred, it is a loss. So, as temperature increases this resistance increases and consequently, that you have less voltage across this, even if the applied voltage constant and you will get reduced voltage on V 2 and V 1 proportionally and that makes V 2 minus V 1, difference also changes with temperature.

So, essentially, if you see for a given position you will find, even if this is constant the difference between V 2 minus V 1 changes with temperature. This is because, as I said, because of the temperature change mostly the resistance of the wire changes and that creates problem. So, this is a second major problem that one has to solve, that is, essentially V 2 minus V 1. V 2 minus V 1 changes with temperature, also changes with temperature. So, these two problems have to be solved if it is to be practically used for displacement measurement.

Now, let us see how to tackle first the temperature. Because of temperature change we are losing some voltage on this, how to tackle this problem we see first. That means, we have to make V 2 minus V 1 independent of temperature change, then only displacement measurement is possible. So, we solve this problem first, then we go and see how to make V 1 minus V 2 DC and then the DC voltage must drive a current source. The more, more likely 420 milliampere current transmitter also needs to be built along with a LVDT.

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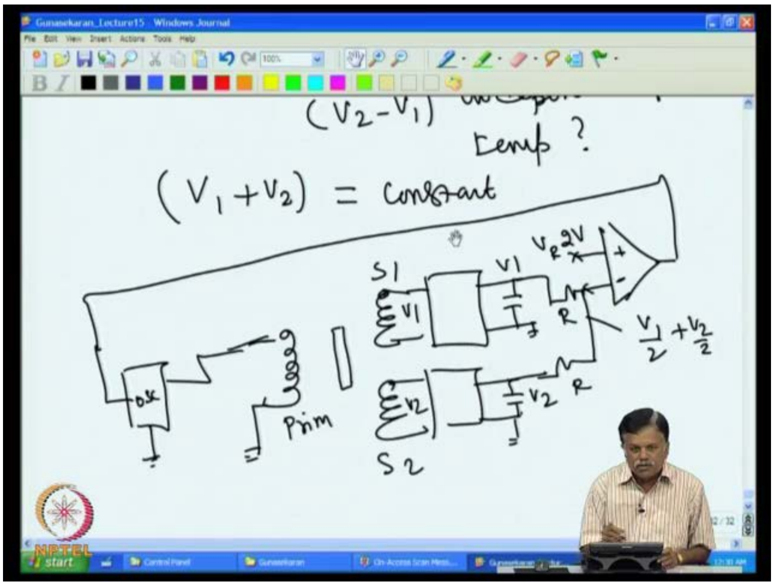

So, first step would be how to make, how to make V 2 minus V 1 independent of temperature, independent of temperature. Now, because of temperature the resistance of the wire changes, because of that we are getting error.

Now, to solve this problem normally what is done is, we know, that if V 1 plus V 2, because suppose if I take V 1 and then we add with V 2, so the total voltage V 1 plus V 2 is supposed to be constant in the LVDT. This is because when we are moving the core, if we see our original discussion, when we are moving the core V 1 is increasing and V 2 is decreasing. For example, if I move in the core upwards, then V 1 increasing V 2 decreasing. But if I find V 1 plus V 2, that will be always constant. Similarly, if I move downwards, then V 1 will decrease, V 2 will increase and again, V 1 plus V 2 will be constant. So, if I make V 1 plus V 2 constant all the time, then that will, I need not worry about the temperature drift at all.

So, what is done is that you take V 1 and find DC and V 2 you take and find DC value. We add these two and compare it to the reference such that by varying this voltage, for example, if I, if the temperature is going up, then the resistance of this goes up and then I will get V 1 less and V 2 also less.

Now, to get back old value, then I increase the excitation voltage of this, increase this voltage. If you find V 1 plus V 2 is reduced because of temperature, increase in temperature, so I can alter the excitation voltage. If the voltage here V 1 plus V 2 comes down, then I increase the excitation voltage. If V 1 plus V 2 goes up, then I decrease the excitation voltage, so that always V 1 plus V 2 will be kept constant.

So, essentially what we now do is we will rectify and convert V 1 into DC, V 2 into DC and then add these two voltages, so that we will get V 1 plus V 2 and then we compare it with reference to get (( )), rather block diagram of our proposed scheme, it look like this, that is, what I do is I will take the two voltages V 1 and then I make it DC rectifier, I put, then I will get a DC voltage here. Then, I take V 1 here and this is the core, then this is the primary. Similarly, I rectify this V 2, then again get a DC voltage.

Now, I take these two voltages, then add these two voltages and then I can add these two voltages here and I put this, add this two voltages, then I compare it with reference here. For example, this is a, this is supposed to be minus, we have minus, so this I compare it with reference voltage. So, this I give you to V, reference fixed voltage, this output I connect to oscillator, here is oscillator circuit, oscillator drives this LVDT primary, this primary of the LVDT and this is a S 1, secondary 1, secondary 2.

Now, this will control oscillator output, so that the amplitude of the sine wave oscillation changes depending upon the output of this error, this comparator. So, what is done is, here we get V 1, here we get V 2. So, at this point I will get V 1 by 2 plus V 2 by 2. If I put this equal resistance here, then I will get, at this point I will get this, that is nothing, but we added the two voltages, of course, we have divided by 2, does not matter.

So, we will, now we compare with the fixed voltage. Suppose if this is a two volt, if the amplitude of the oscillation is less than this and this is lower than 2, then output will go high, the output goes high, then it will increase amplitude of the oscillation here. So, if the voltage increases here, this also increase and the oscillator, oscillation will be more and you will get increased V1, V 2 and again this and this will increase and that will make this voltage to go high.

So, in case if this is lower than 2 volt, if it is less, more than 2 volt and if it is goes more 2 volt, then output will reduce and then amplitude will reduce and then this and this will reduce and then eventually, this also will come down. So, any given time if I do this, this voltage will be equal to this voltage. So, it maintains voltage at this point, V 1 plus V 2 constant, that means, even if temperature changes, if the resistance increases, then what happens? If this voltage will decrease, this also will decrease, that will make, should go high and oscillator voltage will increase to commensurate the loss that took place under the resistance. So, by this action always V 1 will, V 2 will be constant. So, this is how the loop is maintained.

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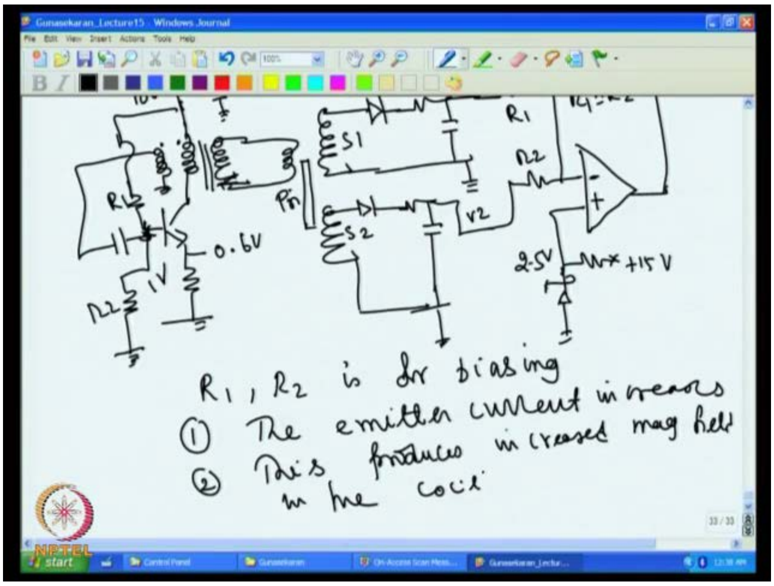

Now, if you want to build the exact circuit for this we can do like this, we will start from the oscillator because we have to design oscillator and then, that should energize the LVDT. So, use a transistor based (( )) oscillator, for example, we can have this, then we have the output here, that is actually one transformer we can have that can be primary of the LVDT, that is secondary here, secondary here. So, this is a primary of the LVDT and then and that is the core and this is S 1, secondary 1, secondary 2 and this is the transformer and that we have, and in this we will also wound one more winding and then connect this.

So, this is the basic circuit of the (( )) oscillator, I will explain this now. Now, we complete the circuit, so that you know, it becomes a working circuit. To make the circuit to work what you do is we will have to rectify into DC. So, I do this, I will also do rectification of this voltage. Now, I want to filter it, so I do the filtering here, similarly I do the filtering here. So, if this is grounded and this is grounded and then, I will get V 1 here, V 1 here and then V 2 here, now I have to add this V 1 plus V 2, so the comparator I can use here. So, I have these two voltages and we add it here. This I can connect through the, I here only have one RC to filter the oscillations, so I will have this, this is given to the, to be given to the reference voltage.

Now, this is the basic circuit. What we are trying to doing is that we are rectifying this and getting a DC voltage here, rectifying this and getting a DC voltage here. Now, there is one issue in this rectification, mainly, because this, we are using a diode here. If we are using a diode here, then this will drop 0.6 volt all the time and then this 0.6 volt also changes with temperature. So, it is 0.6 at 25 degree C. As temperature increases, the voltage of appliance decreases by 2.2 millivolt per degree C. So, higher temperature need, you will have only smaller voltage across this and smaller voltage across this. So, the simple circuit, what you are aiming we ask this drawback, so we address this issue little later.

Now, if you take this voltage what you are trying to do is I will try to compare this voltage is say, R 1 here, R 2 here, they are equals, R 1 is equal to R 2 and assume, that this is kept at, say, 2.5 volt, R 5 volt. So, in case if some of the voltages increases, then this will increase, that will make output decrease. If the output decreases, then we know, that voltage at this point will decrease and then once voltage at this point decreases, the amplitude of the oscillation, that is coming here also will decrease and the same voltage is applied to the primary of the transformer. So, the amplitude applies the excitation voltage of the LVDT primary also decreases.

So, by this action, that is, if the voltage decreases here, then automatically this voltage increased and then, that increased the amplitude of the oscillation and the energy is excitation voltage also increases. In case if the V 1 plus V 2 decreases, then this is less, this is more. So, output goes high and then the amplitude of the oscillation increases and further, that will increase this. So, like that the loop can stabilize and work except that it is, you know, the issue with this diode that is to be solved, that we will do it little later.

Now, let us concentrate how to design this oscillator circuit, which is a (( )) oscillator. Now, if you see the actual circuit you have these two resistances, which are used, say it is R 1 and R 2; R 1 and R 2 for biasing, actually. So, assume that I had kept this point, say this point, let us say 1 volt, then I know, that this point at say, 0.6 volt because I can select R 1, R 2 such that at some voltage, for example, at, at 10 volt here, at 10 volt here

I want to get here 1 volt. So, I can select R 1, R 2 to get 1 volt corresponding when the input voltage is 10 and if it is, then will you have 0.6.

So, S 1 is switched on, then the voltage at this point increases, that increases the current through this that current is flowing through this. So, as the current increase, the magnetic field across this increase. So, increase in magnetic field produce a positive voltage here because we adjusted the dot polarity like this. Then, magnetic field increases, then the current increases, the magnetic field increases and that produce the positive voltage here. When the positive voltage comes here, that voltage added along with the DC, whatever voltage is coming here, from here that is added to the DC voltage. So, you get an increased voltage, the voltage increases, then this voltage also increase, then this current increases here and then, further increase in magnetic field is expected.

So, the first step is that upon switching on the, switching on, first step is that the emitter current increases, emitter current increases. Because of that increase in current this produce in increase in magnetic field and the on this coil this produces increased magnetic field, magnetic field in the coil.

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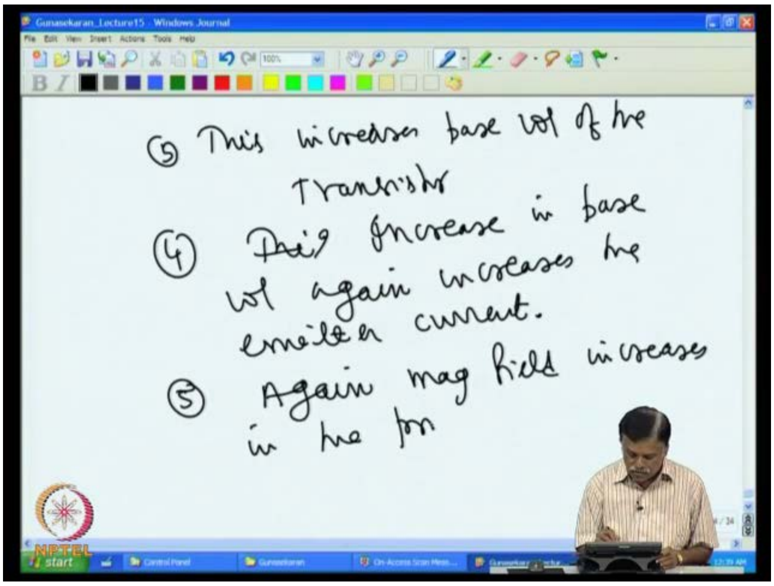

So, this induces this, this increases, increases base voltage of the transistor, transistor. Then, once base voltage increases, this increases, next increase in base voltage, increase in base voltage again increases the emitter current, again increases the, increases the emitter current. Once that emitter current increases, again magnetic field increases on the primary, again, again magnetic field increases in the primary. So, increase in the, that is the, what, it is the cyclic effect.

So, first (( )) switch on some voltage appears here, that increase the current through this, that current flows through this. So, you have a increasing magnetic field, increasing magnetic field increase a positive voltage here, that increase in this voltage, that increase the current further, that increases magnetic field here. Again, more voltage comes and then, again current increases, more magnetic field, more increased voltage, like that it will be keep going one after another in the cyclic equation. After some time you will find, that this voltage increased and then this current also an increased sufficiently large and no more increase in voltage possible. That can happen either due to saturation of the core or saturation of the transistor itself.

So, in that case in the, when, when it reaches that stage, then further increase in current will not produce any magnetic field change. In case if the core saturated, the amplifier saturated, this voltage will increase, but current will not increase. So, whatever may be the case, the moment the increase in magnetic field stops, then there would not be any induced voltage here. Then this, whatever the, this voltage started decreasing and this voltage started decreasing, then this current started decreasing, then magnetic field will decrease, decreasing magnetic field will produce minus voltage here now and that will reduce this voltage further and that will reduce the current further and that it produce more minus. Then, like that, then it will reduce here and further current will come down, like that keep reducing still it goes completely cutoff, that when it to finally, goes to zero and this current become zero, magnetic field also will stop.

Then, again all over it will (( )) because it, because 10 volt is there, again the voltage will appear here and then again it start that current from the positive, like that it will keep moving around and then the oscillation will be occurring, and we can control the frequency, also the oscillation may be putting the capacitor here and this, the effective l and c decides the frequency of the oscillation, that is, f is equal to 2 pi l c is the frequency of the oscillation. So, you will get the oscillation.

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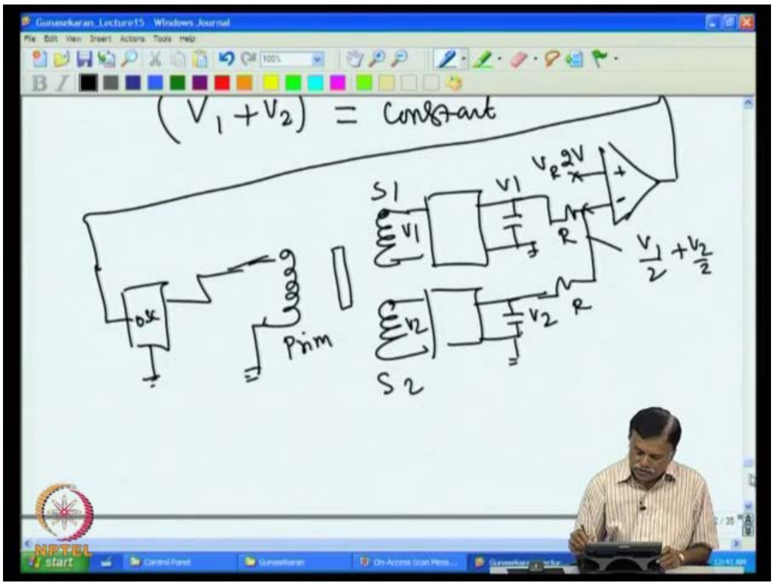

Now, interestingly if you see, if the, if you have more voltage here, if you have more voltage at the, at this point, then obviously, more voltage will come here and the more bias voltage and then, the unit also will produce more oscillation (( )) the amplitude also will increase. So, if I increase the voltage here, you will find the amplitude of the oscillation is increasing and you will get more voltage here and the more voltage across primary of the LVDT. So, that is what you are trying to do. So, here, actually the DC voltage convert into AC voltage using this amplifier, that AC voltage is applied across this and when this voltage is more you will get more AC voltage here; if this voltage is less, you get less voltage, less AC voltage here. Now, so that way the primary is energized using this oscillator.

Now, we, as we said, the errors associated with this diode problem have to be solved. So, this part of the circuit can be modified in the following manner to remove the diode related error. So, the diode draws the so called 0.6 voltage and then that 0.6 voltage also not constant, changed with temperature. So, you will get as if rectified voltage is changing with temperature. So, to solve that problem we can modify the rectifier in the following manner.

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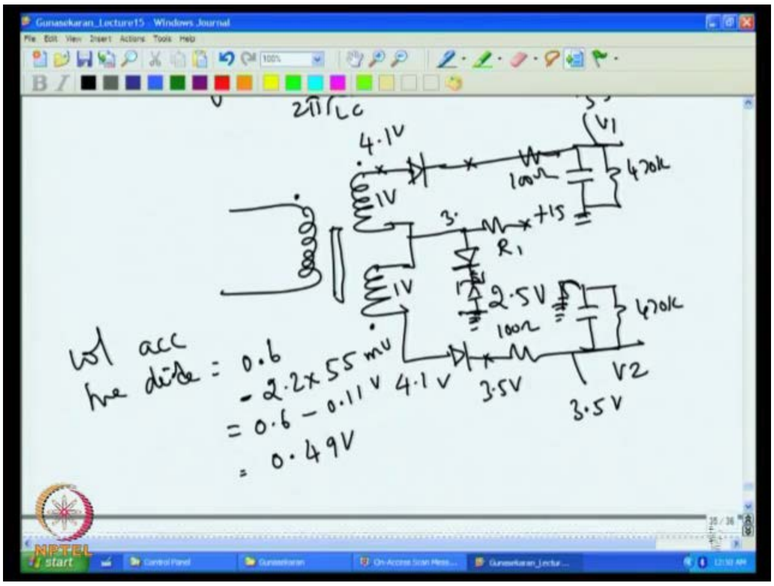

So, you will start from the LVDT. So, if this is LVDT primary and then two secondary voltages are here and the core is here, now I rectify this, then I join these two, then both are actually reverse connected. You have, this is here for, this, it is, sorry, for this the dot polarity, this is the dot polarity is here, this dot polarity is here. Essentially, when this is positive and at that time this is negative. So, that is what we wanted.

Now, take this, now I, what I do is since I am grounding this I will actually connect this to a diode and then, one zener diode, diode, then I bias this using the resistance. So, I put one resistance here to bias this. We see how much bias current we have to send through this. So, we also connecting this to ground and keeping it at some potential here and that potential, actually there is error here, that potential, this is a diode not a zener. So, it has a diode and then zener, say 2.5 volt zener and diode is connected like this. Now, to rectify this is what I do is I will put diode like this, filtering I do this, similarly I do this. So, that is coming as V 1 that is coming as V 2.

So, instead of directly instead of simply rectifying this diode, now we have added this diode and zener and then these two diodes are rectifiers (( )), which were there earlier only. But then, now what we have done is we have made this diode, this diode and this diode are actually in the same package and are supposed to be identical. So, if that is the case, then due to temperature voltage of this also will drift, voltage of this also will drift, voltage of this also will drift, all will have almost equal drift. In that case, we will show you, that the drift due to diode gets cancelled. So, that is our aim, that for doing this.

So, for example, this is actually 2.5 volt at room temperature, then you will find this is sitting at 3.1 volt because this is 2.5 here and 0.6 volt and this will be 3.1. If this is 1 volt AC, this is also 1 volt AC peak, then you will get at this point 3.1, all the positive side. This will go to 3.1 plus 1, 4.1 volt, so 4.1 come. Then, you will get here 3.5 volt, 0.6 is across this. So, if point, if it is 3.1, you will get 4.1, then minus 0.6, you will get a 3.5 volt. Similarly here, and the positive side, this will go to 4.1 volt because you get 3.1 and 1 volt across this, assuming both are, both are producing equal voltage here, 1 volt and 1 volt here. Then, you will get 4.1 volt here and this also will give you 3.5 volt and if the resistance of this, resistance of this very high and this is small, say for example, I put here 470 k and here about 100 ohms, this is 100 ohms and I put 470 k here, then you will find same 3.5 volt is coming here and same 3.5 volt is coming here. So, what you got is you got 3.5 here, 3.5 here corresponding to 1 volt and 1 volt here, this is at room temperature.

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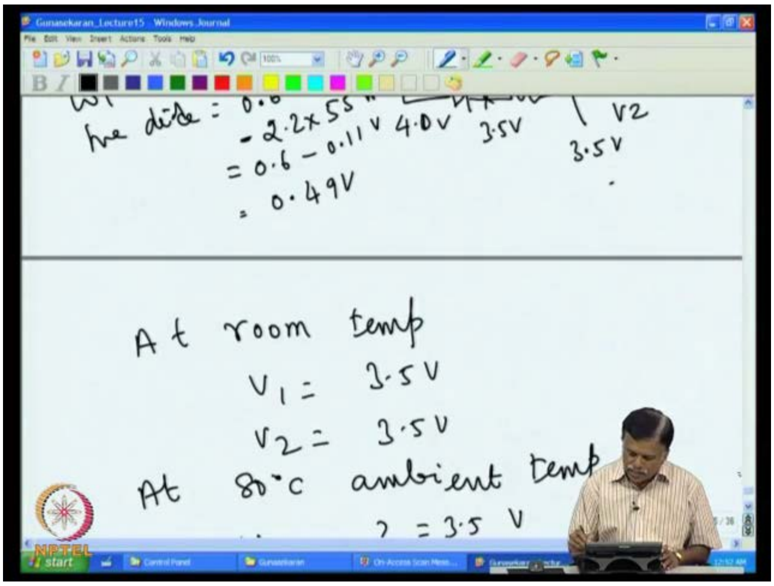

If so, at room temperature V 1 is equal to 3.5 volt, V 2 is equal to 3.5 volt. Now, see at 100 degree C, then the temperature of, you know, then why we are going up to for, for industrial use we go up 80 degree c. So, I will take at 80 degree C because industrial guide equipment is supposed to work in the open air and the temperature in open air can go up to 80 degree C. So, all industrial grade equipments are manufactured for minus 20 degree to 80 degree working. So, if the, in case the ambient temperature goes to 80 degree, 80 degree ambient temperature, then what is V 1, what is V 2?

So, if you go back and calculate at 80 degree, now at 80 degree what is the voltage that is expected at this point? Now, you will see, that if I remove this, this is 2.5, that remains constant, but then voltage across this what we assume is 0.6 is not at 80 degree, is at 25 degree C. At 80 degree we have what will be the voltage across this diode. So, voltage across the diode would be, there will be 0.6 minus 2.2 into temperature difference. So, temperature difference is 55 degree, so that will give 0.6 minus 0.11, 11 volt because 2.2 millivolt into 55 will give you 110 millivolt. So, you have a 0.11 volt, that appears, that the voltage will be 0.249 volt. So, at 80 degree C the voltage at this point would be 2 point plus, plus 0.49. So, roughly 3 volt only, roughly, roughly 3 volt, roughly 3 volt you will get.

No audio 44:39 to 45:04

Where did I do this, let us go, yeah.

So, you get about, this one will come about 3 volt. Then, you will find, that this is voltage across, this is 1 volt, so this will come to 4 volt at this point. Then, again, this also would be only 0.5, then again this will come 3.5 and same thing happens here, this is 4 and it comes 3.5. That means, even though temperature at changed voltage drop across this, voltage drop across this, voltage drop across this, across this, all at changed, net result is, voltage at this point remains constant as long as this voltage and this voltage is constant.

So, you will get here 3.5 volt, here also 3.5 volt, even at 70 here, even at any other temperature the voltage will be 3.5 only. So, this will be again 3.5, this will be again 3.5 volt. So, at any other temperature also it will be same. That means, V 1, V 2 will not change with temperature. The temperature drift problem is compensated by adding this, adding the diodes to, adding the compensation diode, that is, this diode, by adding this diode we have removed the temperature drift problem.

Now, the zener is mainly added to push the voltage to one side because by adding this 2.5 is already gone to 4 and you will not get minus voltage and that is good because most of these diodes have a low voltage capacity. So, that, that is also good plus we also need the zener for other purpose. So, we have put even without this zener. Also, it can be done, you know, by directly grounding. Also, one can remove the voltage, but (( )) positive completely gives a better result. So, we have done this, I will show you the usage of this duality later.

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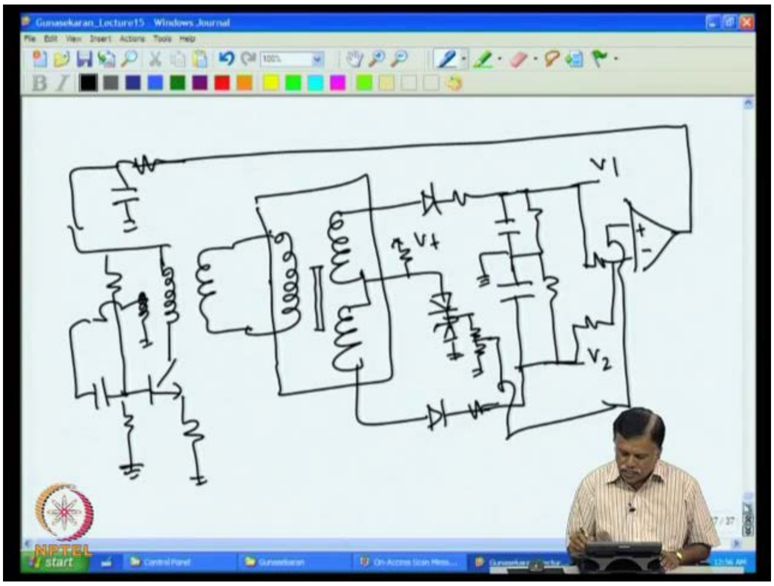

So, this voltage now can be summed up as a set in the comparator amplifier. So, what you do is, now I will take the, now I will take the two secondarys here. So, if you look at this, at this and I have the zener voltage, then we had this, the bias voltage, then I had these two voltages, the comparator. So, it is, to recharge higher resistance is put here, then these two voltages can be summed up at this point minus, then V reference we need, that resistor can be utilized for the V reference. So, I put a divider here and then I connect the V reference to this point and this can be connected to the oscillator, that is, actually the oscillator, we already discussed about this. So, you get the…

So, that solves the both problems, that is we have solved now the, the temperature problem of this diode rectifier diodes and then, we also solved by giving the feedback, maintaining V 1 plus V 2 constant. The temperature change, the temperature in induced error due to the resistance drift of the LVDT, we take this is, this is LVDT. So, we have, this is the LVDT, now V 1 is the temperature of this change, you will not get any change in V 1 and V 2, V 1 plus V 2 will be constant.

Now, if I see this V 1 here and V 2 here, if I see the difference between V 1 and V 2 that will truly represent the displacement given by the core because you have a core here. If the core moves now, you will find V 1 and V 2 are changing. For example, if I move the core upwards V 1 will increase and V 2 will decrease. If I go downwards, then V 1 will decrease, V 2 will increase and this V 1 minus V 2 now depends only on the movement not due to temperature change of this or temperature change of this diodes. So, this is, this is how the LVDT to be energized first.

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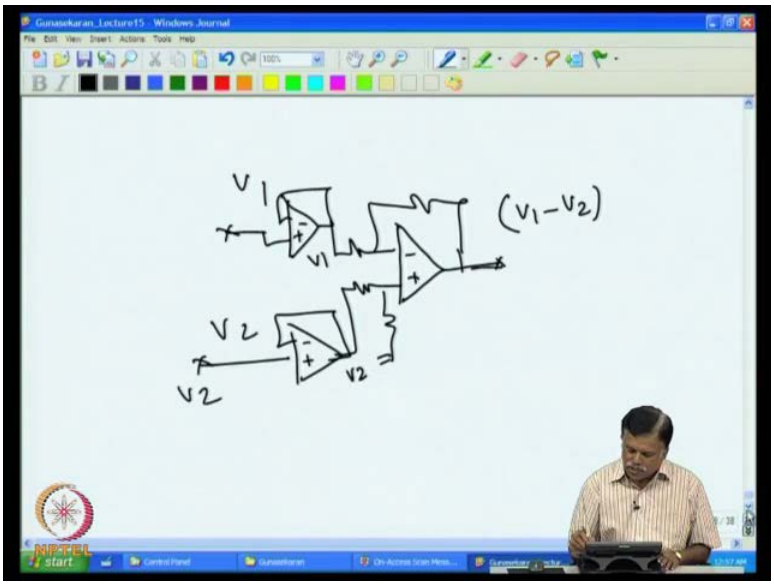

Now, the V 1, V2 can be utilized to produce the current, that can be done by a simple circuit. What we can do is we can put up a current transmitter or even convert your voltage into current. For example, we have this V 1 here and V 2 here. If you want we can even put a (( )). So, this is V 1 and then I have V 2, so this is V 2. So, the V 1, V 2, for example, I can convert into a differential voltage, that can be done with the differential amplifier. So, you will get here V 1 minus V 2. So, this voltage represents the displacement. So, this also can be done or we can convert this into current V 1 minus V 2, that is here, also getting here V 1, here V 2. This also can be converted into current that can be done using a current transmitter.

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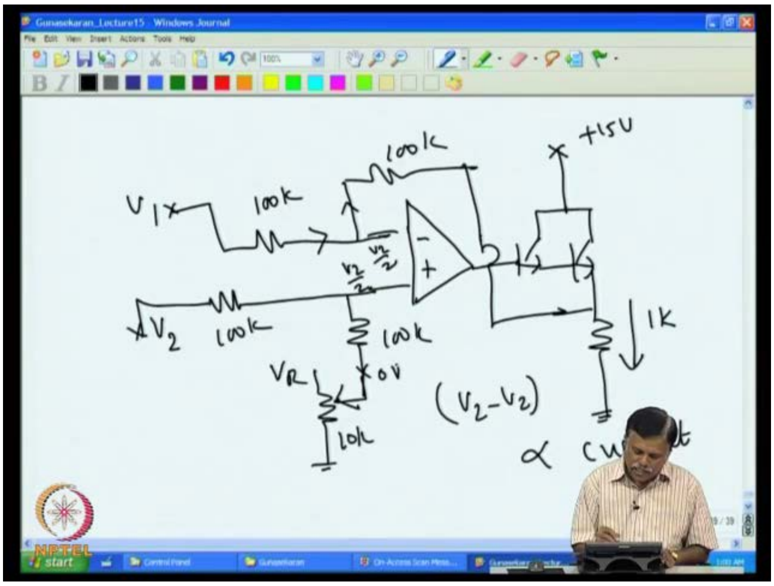

So, I can have a current transmitter here, I can have a current transmitter like this, I can put this, then all that I do is that I have V 1 here and V 2 at this point. Now, that actually should be converted into, the difference will be converted into current. Now, one possibility is I can apply this. For example, I can have V 2, V 2 increases, then I can also put, for example, 0 adjustment (( )) here. So, have V reference here, this can be connected to this, then the V 1 can be connected here and then the output feedback can be given from here.

Now, this gives you the current. Current through this now depends on the difference between V 1 and V 2, say V 2 minus V 1; V 2 minus V 1 gives you the current. So, this is for, you can use for current transmitter. If we look at this how it is working we can explain this by putting the values. For example, I can put here, say, 100 k, 100 k here, 100 k here. For example, if I have here same 1 volt now for simplicity, for example, I assume, that this is kept at 0 volt. If this is kept at 0 volt, then you will get at this point V 2 by 2 and this has to be V 2 by 2 and that has to follow this one.

So, obviously, if the, this more, then you will have the current from here, current flowing here. If both of them are equal, V 2 minus V 1 are equal, then you will find this is V 2 by 2, this is V 2 by 2. Then, the voltage across this have to be equal to this because the same current is flowing and you will find V 2 minus V 1 is equal. Then, if this contribution is not there, for example, I connect this simply here, then this, because differential amplifier you will get 0 volt at the output.

Now, R we can explain like this, that is, if you have, first I will go to a differential amplifier and explain, then come back to this and explain how this is converted in the current.

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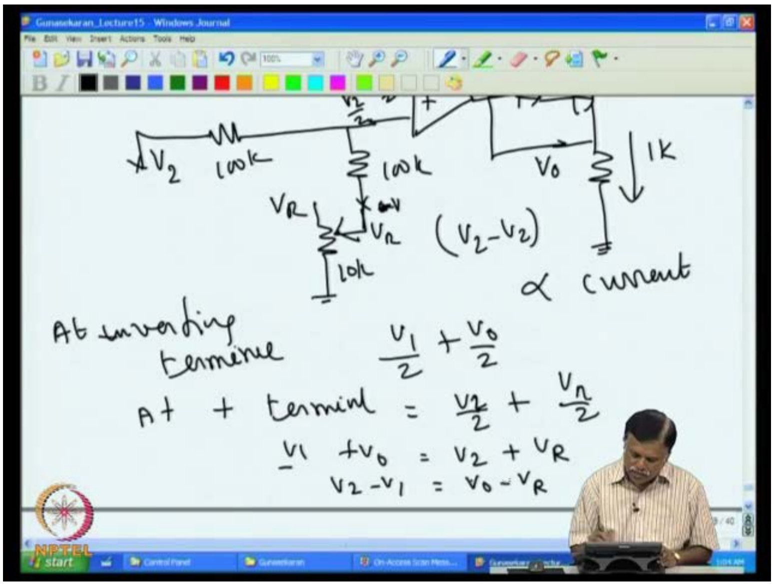

Now, if I take a simple differential amplifier, a simple differential amplifier, this is grounded and then this is V 1 and this is V 2. If they are equal values, then I get here V 2 minus V 1 here at the output. Now, if I add this here, say for example, I put a potentiometer and add the voltage here, if this is V reference and if this is V 0, then this V 0 is, as it is coming the output that will be V 0. So, whatever the voltage given here, that come as it is without amplifying and difference between these two also appearing. If I give a gain, then this also multiplied by the gain, but this will be not multiplied, this will come as it is, that is the function of this one.

Now, instead of connecting it to this here if I connect to output somewhere, see as we did in this case for example, we have connected the minus, instead of connected the output we have connected to this point. So, now, voltage at this point, voltage at this point actually applied to this divided by 2 because whatever voltage is there, say V 0 here, that V 0 is actually coming as half of that. So, V 0 by 2 will come in case if the current increases. In this case V 0 will increase and that will increase this voltage because V 0, half of V 0 is appearing here. Similarly, V 1 is there, V 1 also will have, assuming this resistance very small; V 1 also will apply voltage at this point, that also again half.

So, voltage at this point is V 1 by 2 and V 0 by 2. So, voltage at minus terminal is at V minus, at V minus terminal, at inverting terminal, inverting terminal, the voltage equations is V 1 by 2 plus V 0 by 2 and that supposed to be equal to voltage at plus terminal. So, voltage at plus terminal is V 2 by 2 and the constant voltage, so by 2. So, at plus terminal the voltage V 2 by 2 plus V R by 2, that is, if I assume this is V R, this is, assume that I have kept full voltage, then you get this is V 2 by 2 and this. So, these two must be, both must be equal.

So, essentially if you find, that V 1 by V 1 plus V 0 to be equal to V 2 plus V R. So, if I take this outside, then you will get V 2 minus V 1, that would be equal to, I, I bring V 1 this side and keep V 0 minus V R actually. So, since V R is fixed, so V 0 is proportionally V 2 minus V 1. So, you will get the difference, will produce a voltage V 0. So, the current would be V 0 by R. Suppose the current is, if the resistance r, so the current would be V 0 by R. So, that way V 2 minus V 1 can be converted into here current.

So, with this I will stop today’s class. So, we will discuss more about this tomorrow, how to use LVDT and so on in the next class.

Thank you.