Circuits For Analog System Design

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Lecture No. # 04
Some Applications of Transistor - II

Last class, we were discussing about relay drive using a MOSFET. So, we were discussing about what is the use of these diodes, in this connection we had shown that if the relay is switched off, then that current that is flowing through the inductor produce a noise pack of this voltage 5000 volt. Because when the transistor switched off the current flowing through this abruptly stop, then this one into d i by d t is induced here and induced voltage is 5000 volt and this 5000 volt is so high, that it destroys the transistor by using this diode, that cannot tracking the current to stop abruptly.

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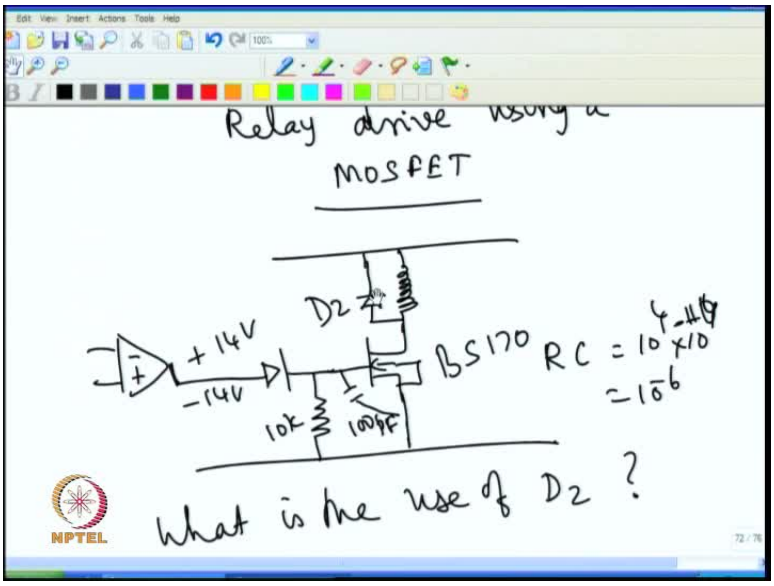

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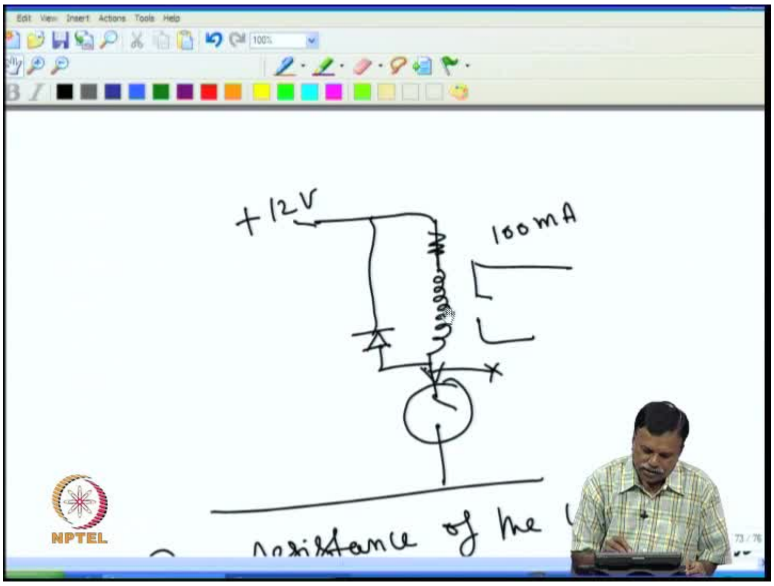

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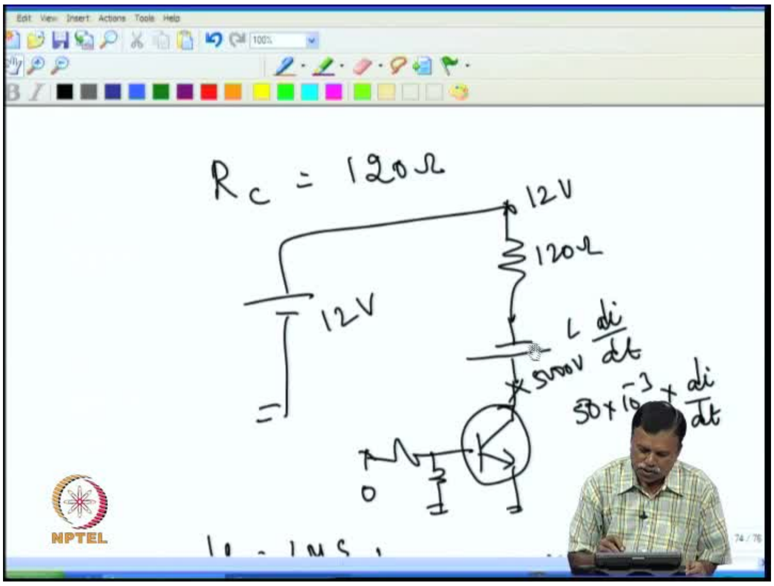

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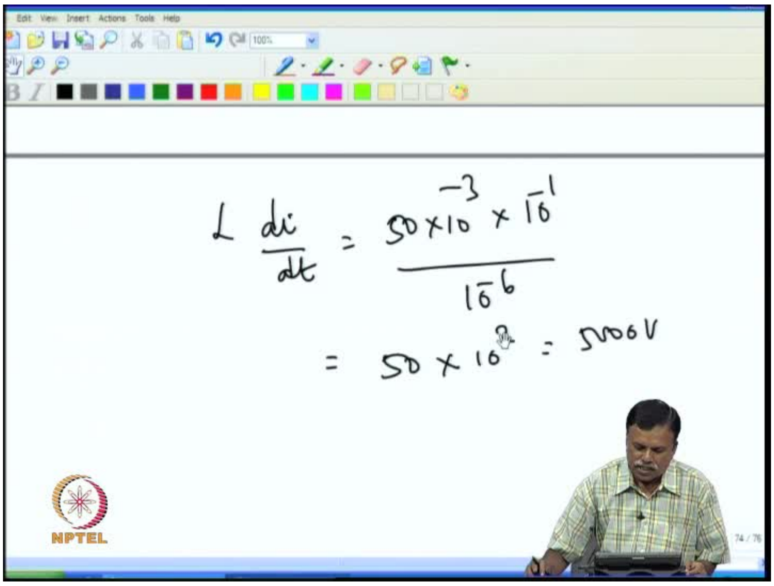

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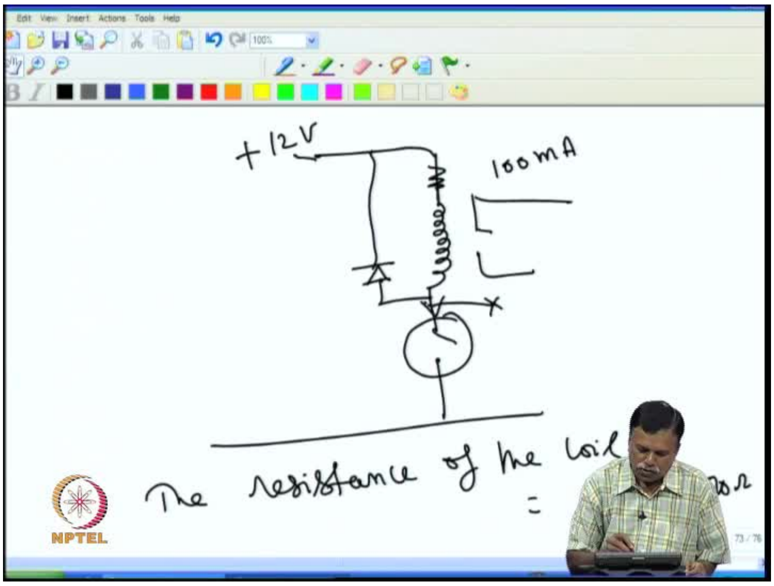

So, when this diode is used whatever, current that is flowing is actually returned back through this and it is dissipated as heat so that, the transistor does not see more voltage if this is 12 volt at the maximum this goes only 12.6 that is the use of the diode. Now, next we see other applications of the transistors. Now, this we see for example, how to switch the relay using the transistor? Now, we will also, we can also use the transistor to switch on and off another transistor with the particular at a particular voltage. For example, this used as is in power electronics for constant for current limiting.

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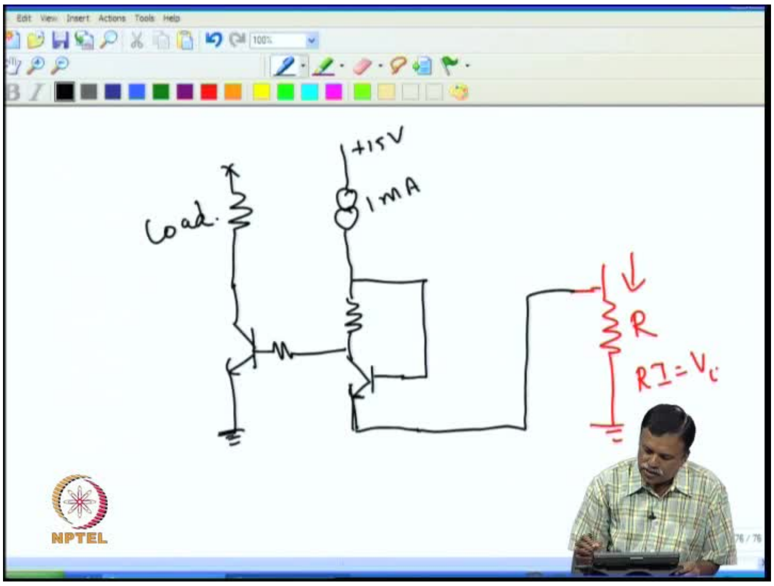

For example, if the current is going very high then we at since the current and if the current is more than the particular amount we want switch off the transistor for that application also we can use the transistor. For example, we have a resistance assume some current i is flowing through this it may be due to transistor or some other device that current is flowing through this. So, the voltage at this point thus the ground would be r into i is the voltage that we get across this, and if the voltage is same more than particular amount we want activate the transistor. In that case we have a reference and then we have say another transistor to be switched off.

Now, this function can be achieved easily using a transistor without reverting back to the operational amplifier the circuit is like this for example, if I have a constant current source, then I connect one transistor and then I will connect this transistor. I connect the base to this assume that I connect this current is a very small say one milli ampere then I connect this to this. Then assume that another transistor is the transistor, which is to be switched off, so I connect this here.

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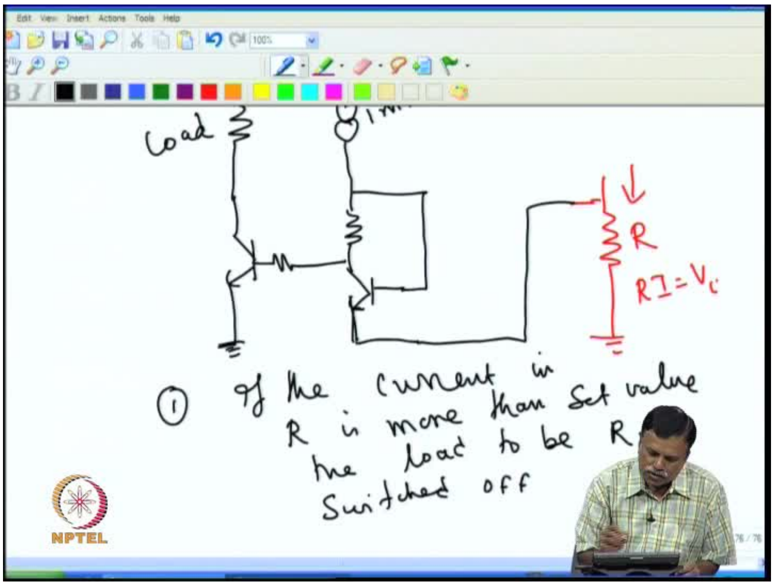

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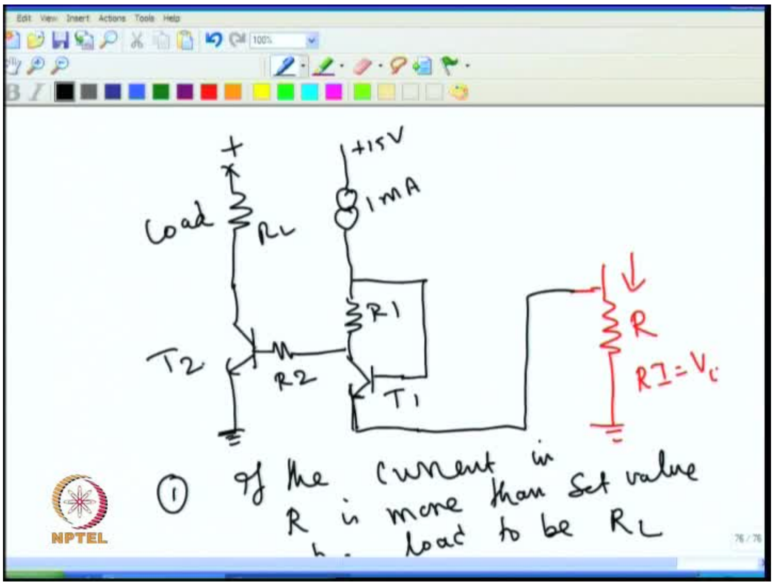

Now, this is our transistor may be it is a relay or it can be any other load. So, (( )) material all that we want this current that is flowing through this current flowing through this is more than particular amount. We want switch on this transistor that is our aim for that we are using this so assume that we have a current say a plus supply in our current source, then this we can consider as another load. So, all that need it is if the current in R is more than particular amount more than set value the load R, the load to be switched off. The load call it is R l, call it has call it is R l so this is R l in fact this is R l that is also assume that connected to plus.

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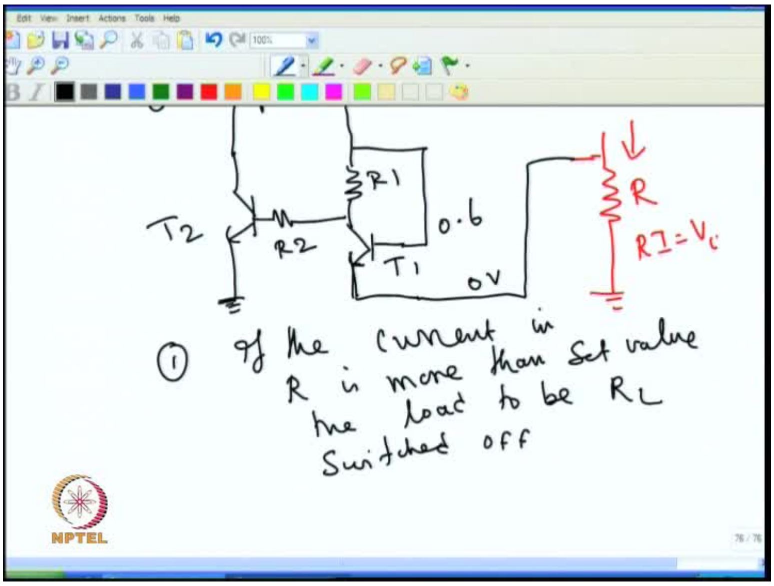

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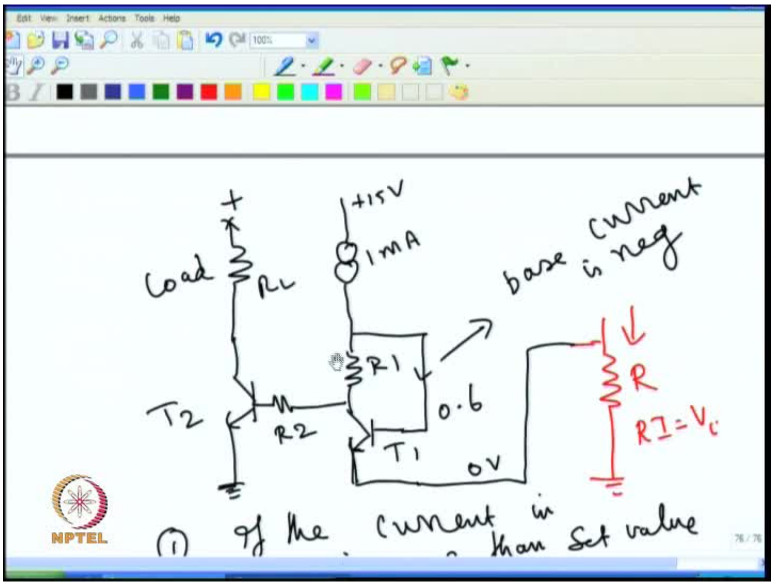

We name this resistor is R 1, this is R 2 so this is transistor T 1, this is transistor T 2. Now, we see how the transistor working assume that you have at any given point this is say start with for example, if this is 0 volt then this will be at 0.6 volt, then if assume that the current flowing through this the base current is negligible assume this is negligible current base current is negligible. If assume the base current is negligible then the entire current that is coming here actually goes through the resistance R 1.

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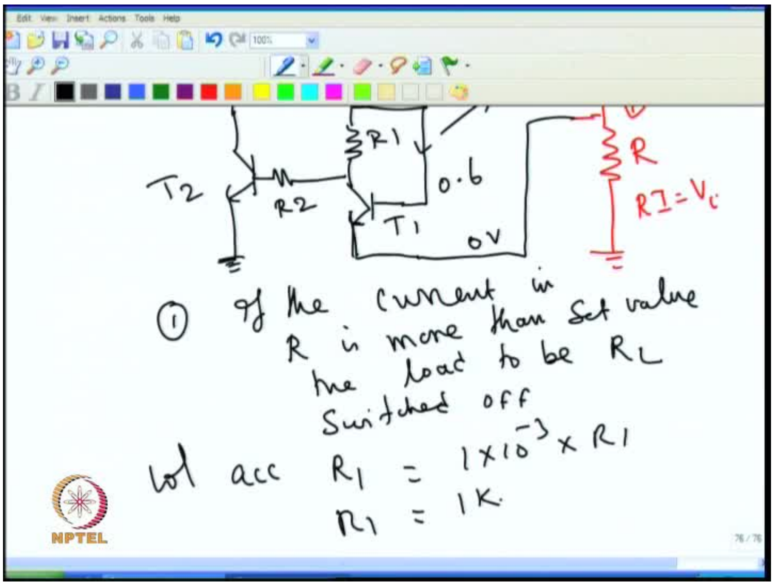

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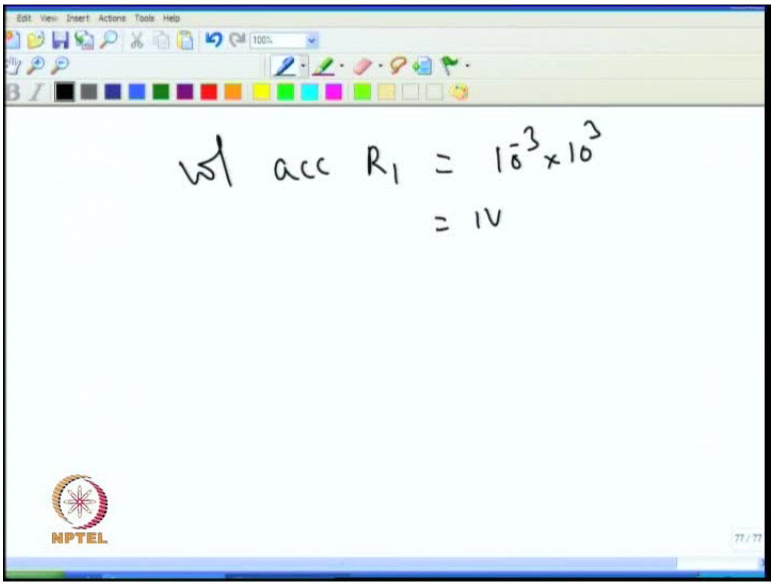

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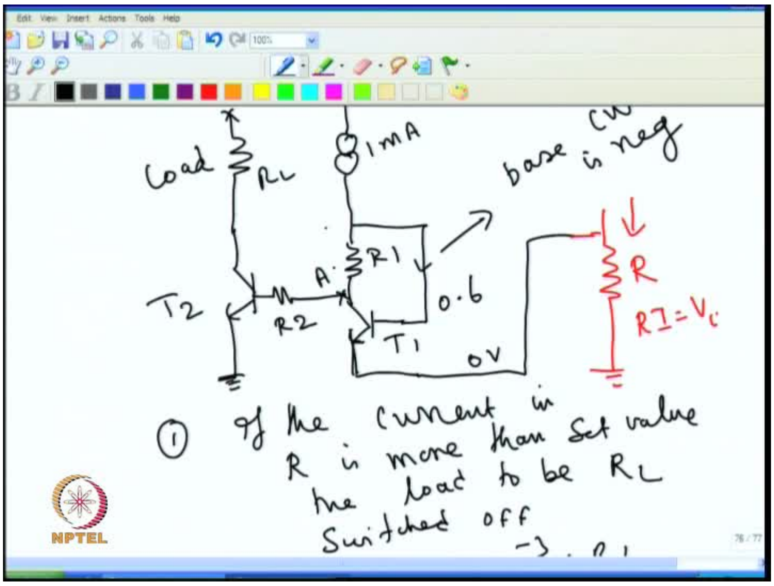

So, voltage across R 1 will be, voltage across R 1 is equal to the constant current source which is 1 milli ampere into R 1 assume that R 1 equal to 1 k, then voltage across R 1, R 1 is equal to 1 milli ampere into 1 k that is equal to 1 volt. So, if 1 volt any given time voltage across R 1 will be 1 volt so this is for decided first voltage across this is fixed as 1 volt. And we know that to switch on the transistor T 2, we need base voltage as 0.6 that is we need 0.6 volt at this point to make this switch on assume the base current is negligible, that means I can assume that the voltage required at this point is also 0.6 if I want switch on this.

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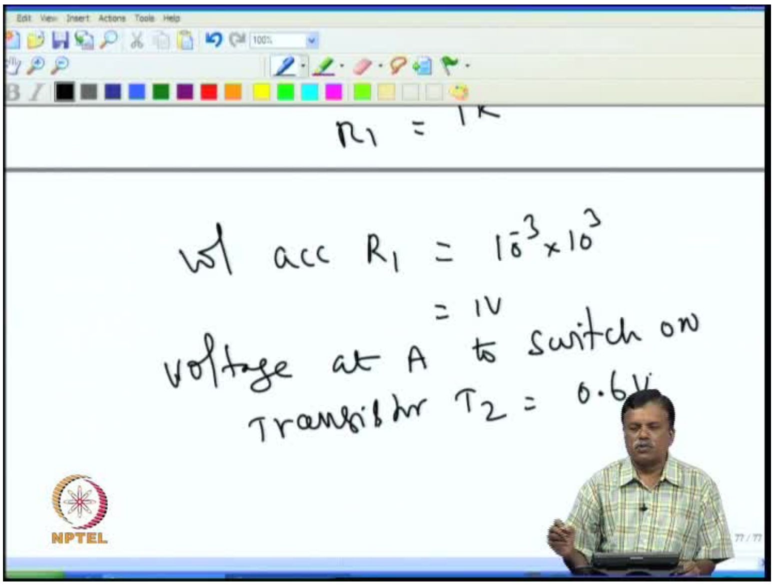

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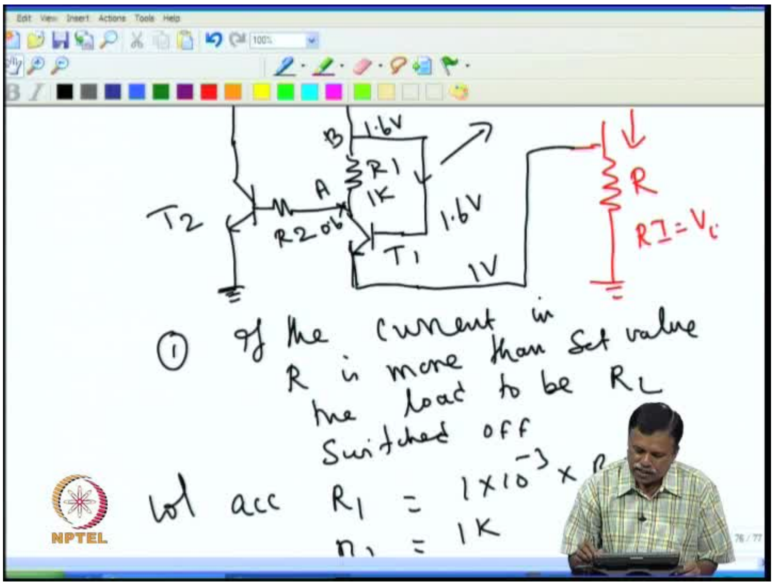

So, the voltage at this collector, I will put it as this point as A so I will need voltage required at A it switch on T 2 is 0.6 voltage at A to switch on transistor T 2, T 2 is equal to 0.6 volt this assuming there is no base current is negligible. So, we need the remains voltage at A is to be 0.6 volt then only the transistor will be on, but if we are taken as this as 0 volt and this automatically comes 0.6 and if this is 0.6 this will be definitely less than 0.6. Because the current if I assume that all the current is flowing you need actually 1volt drop on that 1 volt is not there right now, because if this voltage comes if this is 0.6 then automatically some current will flow through this and voltage across this will not be 1 volt whether you, what you got is only 0.6.

So, in effect the current what is coming is actually going through this, on this current is small compared to this current. So, eventually, totally this is at if this voltage is a 0.6 and then A is going to be less than 0. 6 and the transistor will not be on that means at 0 volt the transistor will not be on. If I want here at A 0.6 then I call this as point B and the point B must be 1.6, if the current is flowing through this and the current flowing through the base is negligible then if the entire 1 milli ampere flows through this and if I take this is 1 k this is 1 k. If the entire current flows through this then if this requirement is 0.6 volt at this point and then 1 volt across this will go to 1.6 volt. So, that means the basis at 1.6 volt the basis at 1.6 means emitter must be at 1 volt.

This calls for one volt; that means only when the emitter of T 2, T 1 goes to 1 volt or the current flowing through this current that is flowing through this produce the 1 volt here.

Then 1 volt will become 1.6 here that will become 0.6 here and transistor will be switched on. Other way around the voltage through this when the voltage across this is more than one only the transistor T 2 will be on, if it is less than voltage at this point less than 1 volt transistor will not come on.

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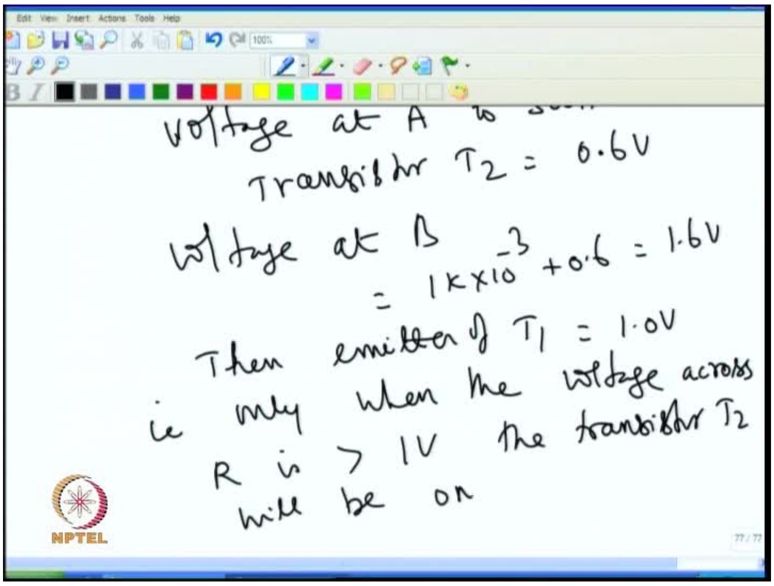

So, effectively speaking that if you write the equation, then we can write voltage at B would be 1 k into 1 milli ampere plus 0.6 that will be 1.6 volt. So, I need B should be 1.6 volt b is 1.6 then emitter of T 2 1 will be then emitter of T 2, then emitter of T 1 will be 1 volt, that is only when the voltage across R is 1 volt voltage across R is 1 volt the transistor R 2 T will be T 2 will be on.

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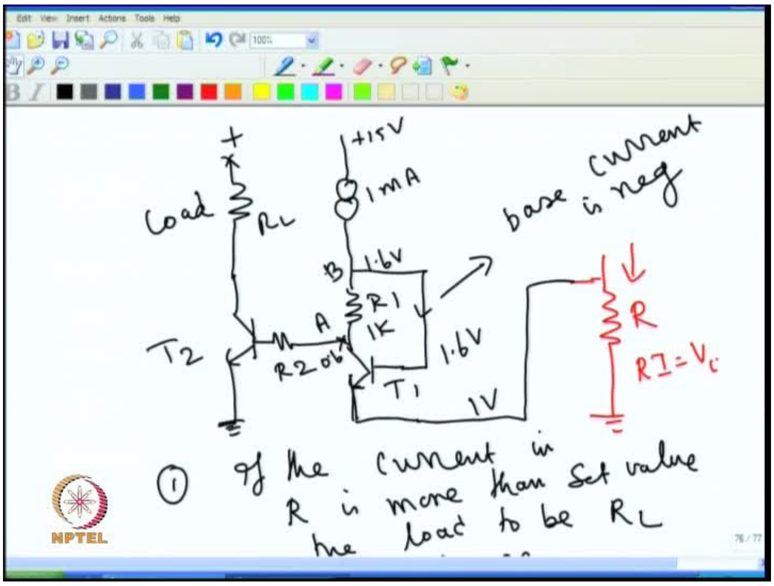

So, only when the voltage across R is greater than 1 volt the transistor T 2 will be on. So, the transistor acts like a comparator, we got switching that is if the voltage at this point goes more than 1 volt this transistor will be on. When the voltage at this point goes less than 1 volt the transistor will be off and thereby doing this we got, we are done this one particularly for one important advantage that is this switching voltage. We see, we say now 1 volt is our switching voltage, this 1 volt is independent of the temperature. For example, if we are not done this arrangement when temperature changes then the required voltage to switch will change.

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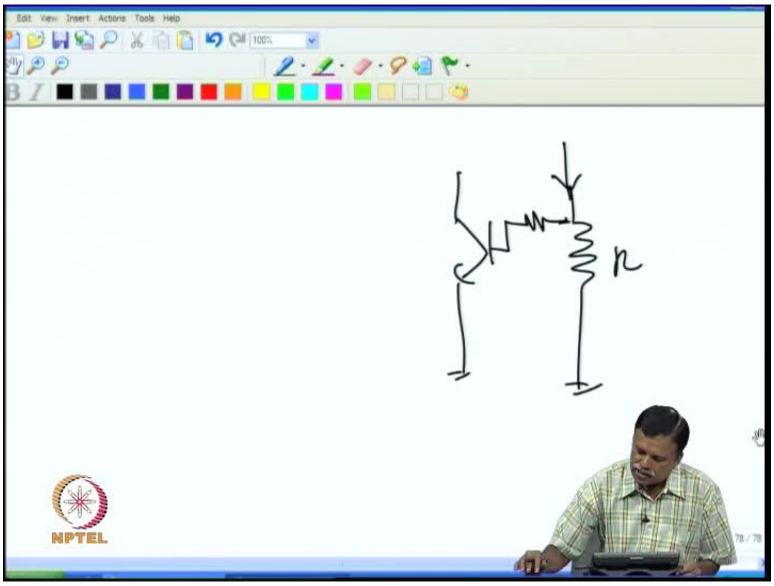

So, this is a series which because if I connect directly the R 2 T 2 then you do not get that benefit for example, if I connect like this so I have resistance here, and this is R and if the current is flowing through this, and if I connect directly the transistor here to switch on. Now, at room temperature what is required the voltage difference required is 0.6 volt.

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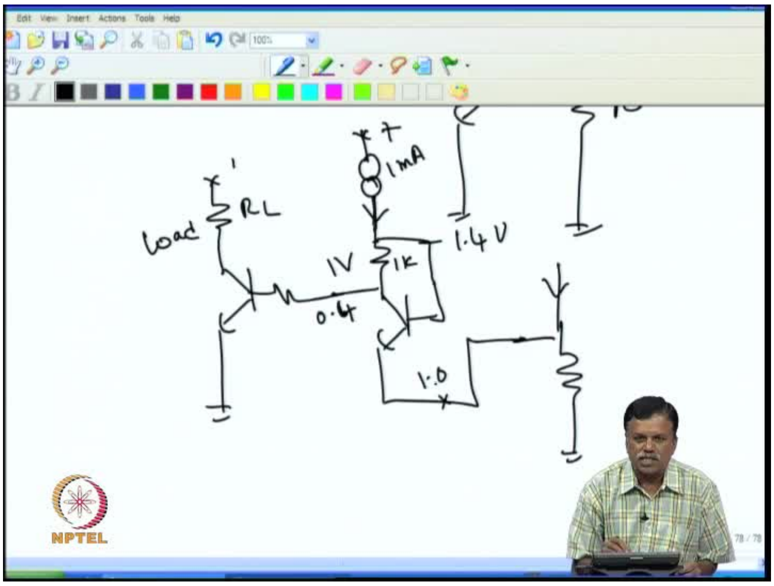

So, when the voltage at this point is more than 0.6 then this will be on, but if the temperature changes for example, if the temperature goes up then the required base emitter voltage decreases 2.2 milli volt per degree c. That means the higher temperature need only less voltage, that means at lower voltage only it will be switch on for example, 100 degree if you switch on roughly around 0.4 volt itself. This problem is not there in the circuit which we are discussed so far, because if we look at the circuit very carefully what we have done is we are taken the load current and then this one is connected to the emitter of the transistor, and the base we are connected through this and this is connect to a constant current source. Then this one only connect to the switching then the transistor which is to be switched on so we had this transistor and then this is our load R l.

So, now if we see when temperature changes it not room temperature we need switch on this 0.6 volt. But then at high temperature the temperature goes up we do not need 0.6 for example, we need only 0.4, then assume that we need only 0.4 volt here at high temperature. Then what happen the switching voltage also this voltage will not change, because this also needs 0.4 only for example, if this is 0.4 this whatever current that is flowing also will flow through this and there it will 1 volt assume this is 1 k, then we need 1 volt drop across this and this point goes to 1.4 volt, because the current is 1 milli ampere.

So, 1 milli ampere flowing through this produces 1 volt so if this switches at 0.4 automatically this goes to 1.4 then if it is 1.4 this also, this and this are this and this is the same temperature. So, this also needs only 0.4 volt difference that means again if it is more than 1 volt if it goes more than 1 volt, then this will not be conducting and all the current will be flowing through this and then this transistor will be switched on. So, you see that even when temperature changes the switching voltage does not change, is the greatest advantage of this circuit.

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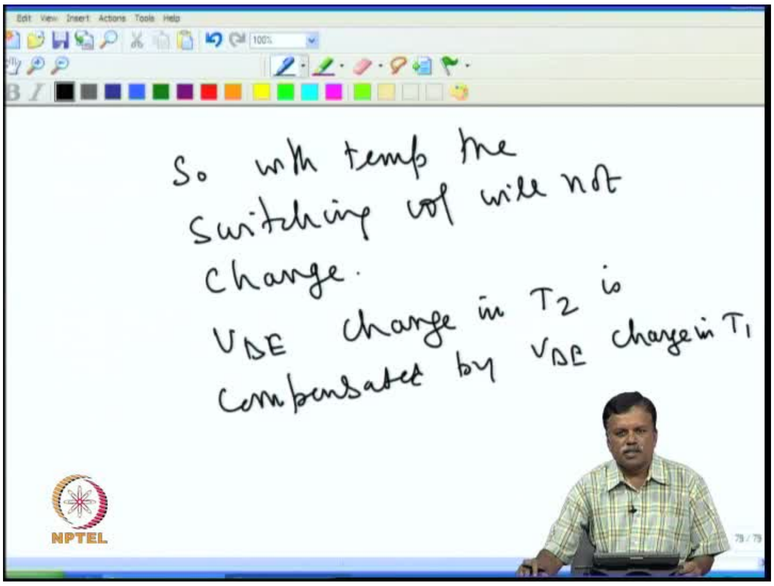

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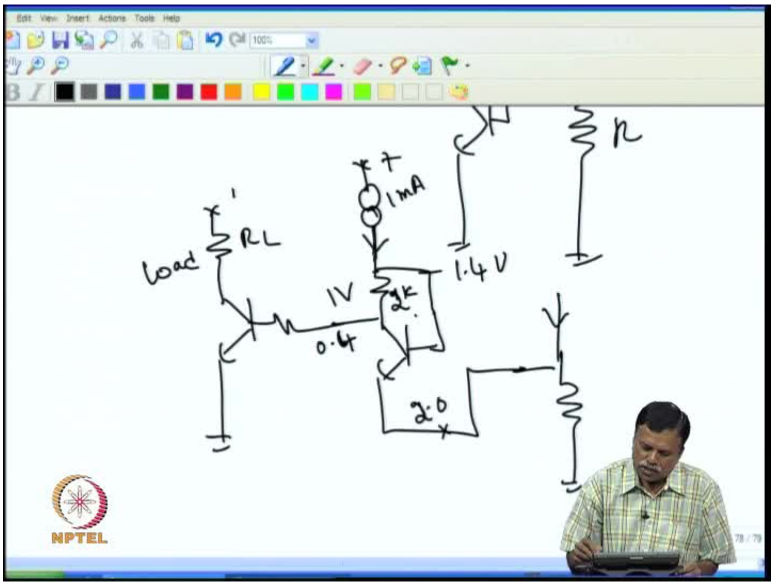

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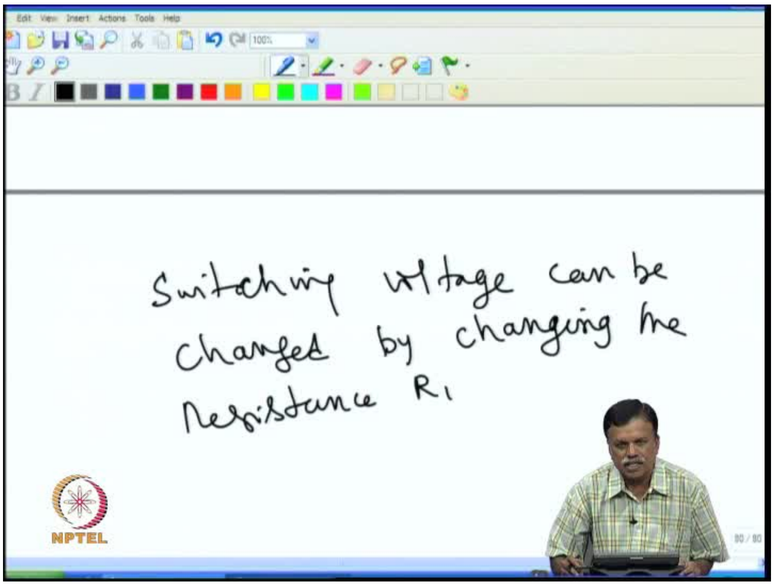

So, with temperature the switching voltage will not change, so V B E change in T 2 is compensated by V B E change in T 1. So, this can be used the great advantage, because the switching voltage is not changing with temperature we added to that, if I want switch at different voltages for example, if the switching voltage take it as 1 volt. If I want to change the switching voltage all that I need to is a change this resistance for if I put 2 k, then the switching voltage will go to 2 volt. So, switching voltage also can be easily changed by change the resistance value. Then second advantage is switching voltage can be changed, by changing the resistance change the resistance R, I think that is the kept as R 2 that is R 1, so switching voltage can be changed by change that is resistance R 1.

So, the transistor can be used easily as a comparator to switch at the required voltage and that resistance to temperature change of course, constant current source needs the reference voltage of course, now the switching voltage is the with respect to ground and the constant current source reference need not be at the ground potential. So, this circuit is utilized at many places for switching purpose; now, we also see other applications of the transistor, because it is essential to understand the analog circuit properly how to use the transistor in different situations effectively.

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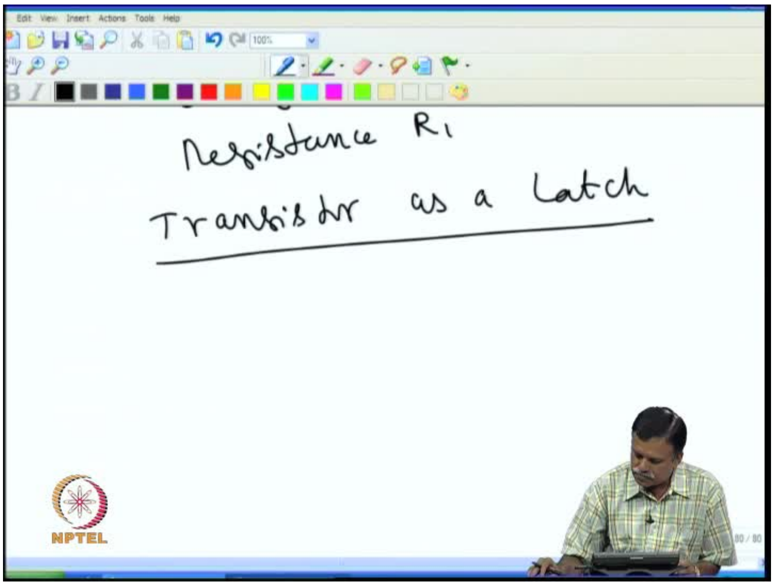

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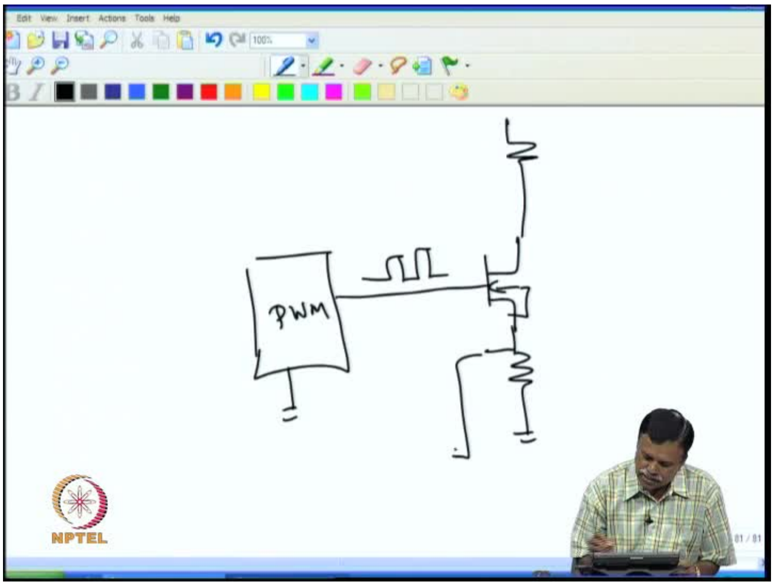

Now, let us see, how to use the latching function using a transistor? Now, I can take an example from power electronics for this description. So, we next see transistor as a latch (No audio from 18:58 to 19:10) for example, we want switch on the transistor, but then once on if the load is switched off then the current will not be there and the transistor should continue to be latch this kind of application is there in power electronics. For example, if I have a MOSFET switching. For example, power switching is there then we will have a switching device here say P W M I C is there, which gives you the P W M pulses to the gate of the MOSFET and we have a load here.

And if the current is more than the level that we like to more than the level what is allowed then we want to switch off this P W M, and that should once it switched off condition, for switched off condition even if this current is not there. For example, once I remove the gate pulse this current will be zero, but then once current zero, whatever logic that I wish into switch off that should not again allow the pulse to appear here.

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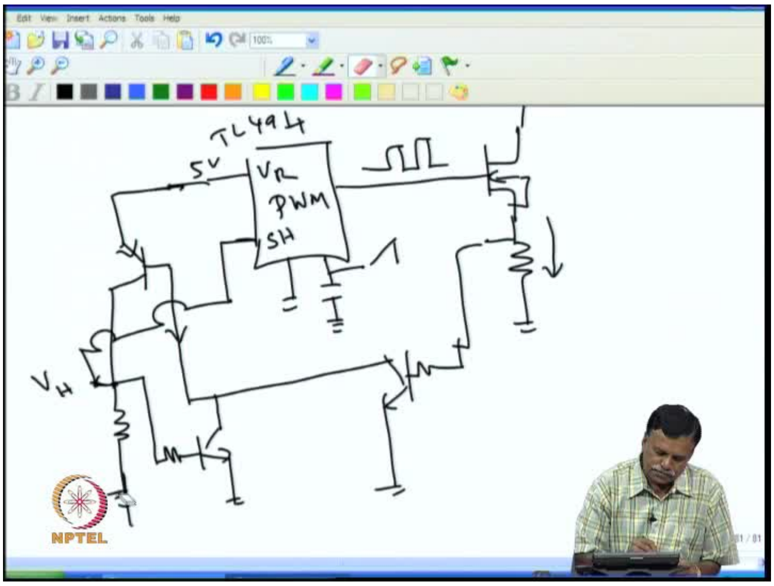

So, what I do is for example, I put the switch here then I have take this I connect to transistor here for example, to switch, and if I take for example, P M W I C as T l 494 we have and this one has a reference output V reference a 5 volt is available. So, I can connect this 5 volt through transistor and this can be connected to this. So, when the current goes high here, then this transistor will be switched on once this transistor on whatever emitter current that will flow through this.

Now, if the current flows through the, current will flows through this now that will make the current appear here. Now, I can make it getting latch for example, I can put another transistor here then connect this then this voltage can be given back to this. So, as soon as the voltage goes as soon as the voltage at this point goes high say higher than 0.6, then this transistor will be conducting. Then the current will flow like this that will make the current flow through this that means as soon as this voltage goes high then you will get high voltage here, because this transistor on first that will make this transistor on and then voltage appears here.

If the voltage goes high again this will be on and that will make this to continuously conducting and make this transistor on, and you will get the voltage at this point that means now you will get a voltage at this point high. Once the current goes high this voltage will be high, but then once the current goes high if this voltage goes high we can give for example, shutdown terminal of this so we have a shutdown terminal of this can be given to this we will shutdown terminal of this.

So, this as soon as current goes high this will go high and then the shutdown terminal of this will be pulled high and then pulses will be terminated. Now, to remove to make this transistor to go off again, because once current goes off this will be going off, this transistor will be going off. But nevertheless this will not go off, because this already triggered and it got the voltage here and this will continue to be conducting and this will be continuous to be high.

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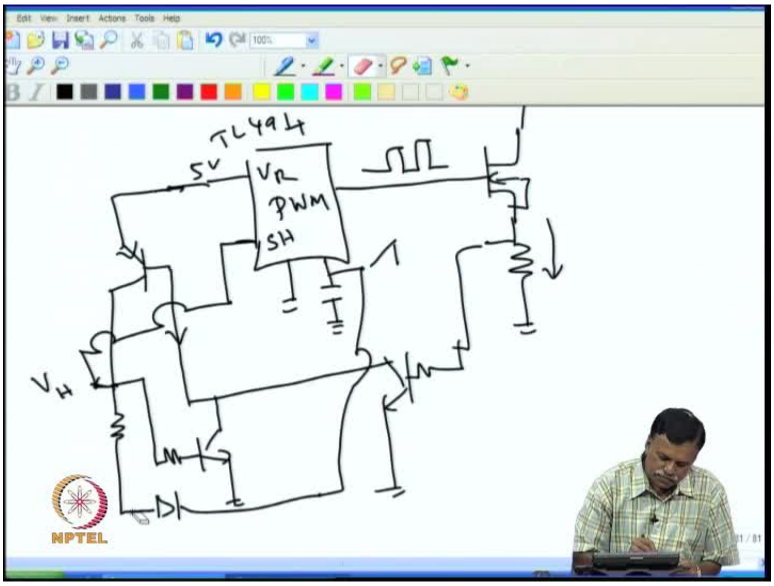

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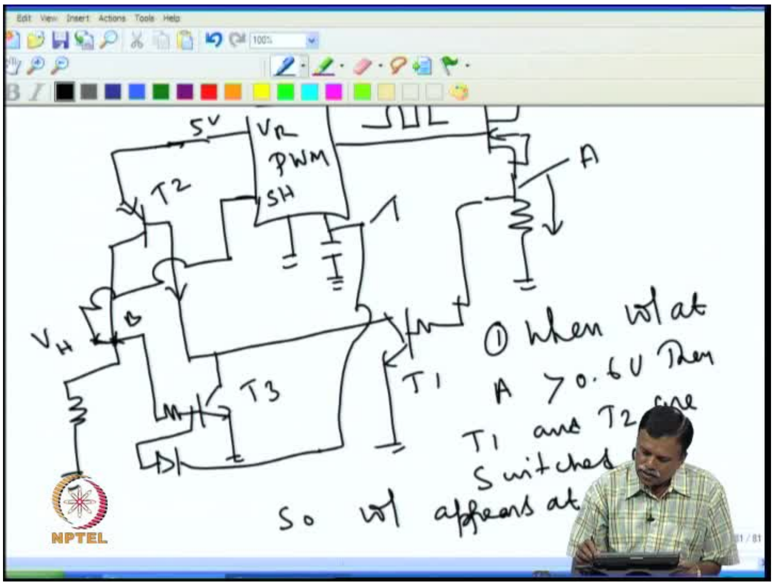

So, the pulse at disappear current at disappear, but then the triggering voltage that is the voltage which at which switched off the controller still will be there. So, when the next pulse comes we want reset this, because we reset then only the next pulse will appear. Now, this is normally done using a provision here for example, we have a capacitor here you will get a saw tooth wave and the saw tooth wave is the one which actually triggers the next pulse. So, normally what they do is I will connect this to the saw tooth wave here for example, one can connect is of grounding it, I can put this and then I can connect to saw tooth wave.

So, when the voltage is high then that is no problem that this there would not be any voltage, because when the current is low there would not be this would not be conducting and this voltage also zero and this is not interfering at all. Once the voltage current goes high and if this voltage goes more than 0.6 then this transistor conducts then that current actually goes through this and that will make this voltage to go high. Then if this voltage is going high of course, we can limit the current by putting a lower resistance so that, it will not disturb this and once this voltage goes high this will be shut down. But then once it is shut down then next then once the voltage are gone high this will be reset, and will go to zero at that time this voltage also will be going through this and we at make this voltage drop to zero, that actually can be done by actually removing this. For example, I can connect this diode instead of here; for example, I will put the this diode here.

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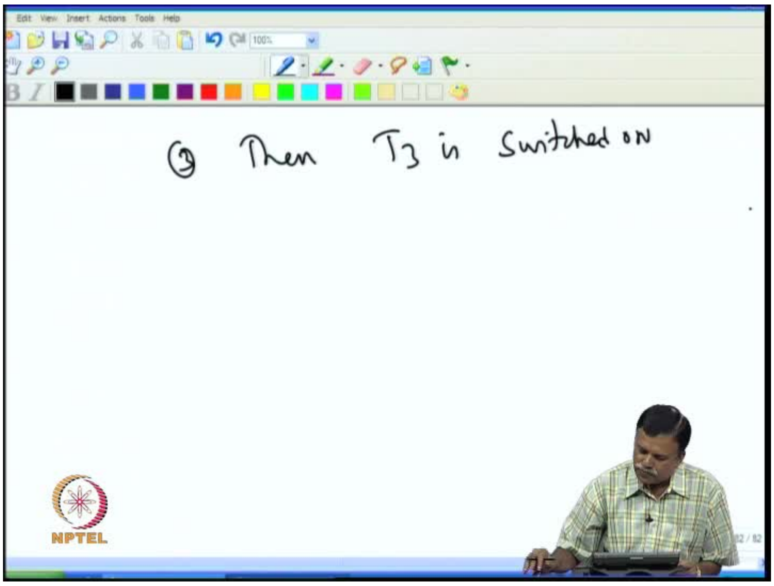

So, I put this now, once the voltage at this point drop to zero this voltage will be drop to zero and this transistor will go out of conduction and this voltage also will disappear, that means a reality when the current goes when the voltage at this point i name it as A. So, first step is when voltage goes at a high when voltage at a greater than 0.6 volt then T 1 T 2 then T 1 and T 2 are switched on. So, T 1 and T 2 are switched on and we named as T 3 so this we call it as point B once T 2 is on then you will get a voltage at point B. So, voltage appears at point B at B this switch as the then T 3 is switched on.

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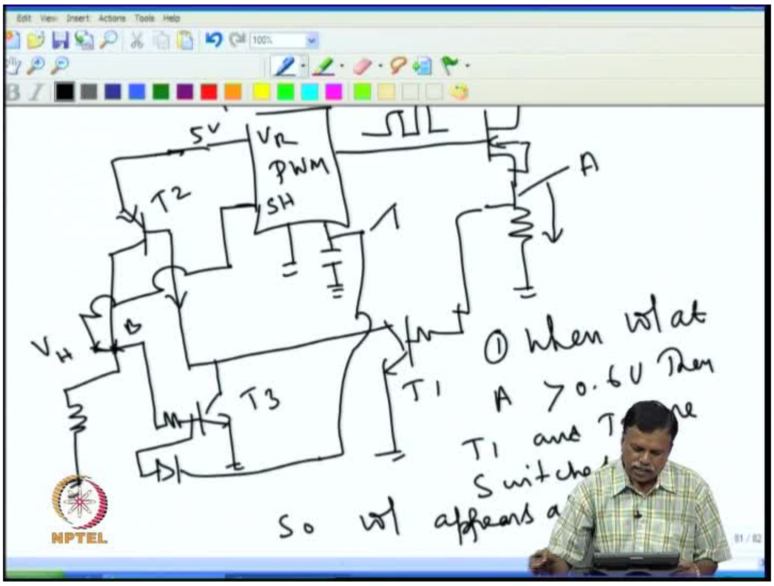

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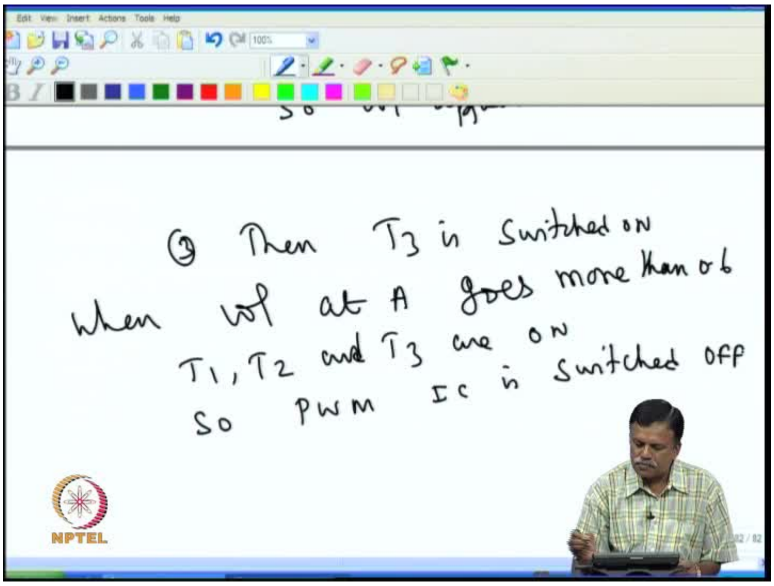

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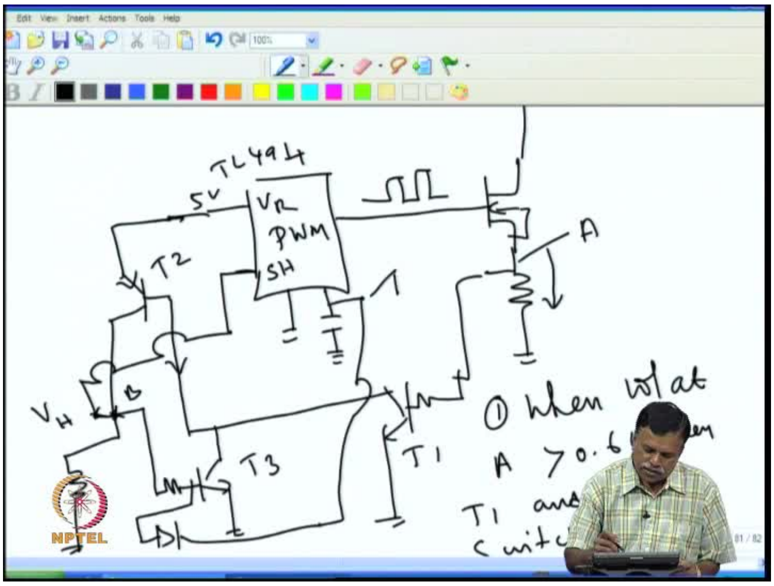

So, effectively when the voltage at A goes more than 0.6 T 1 T 2 T 3 all are switched on and then at B you will get a voltage. So, once voltage at B appears then the P W M I C is switched off, because we are connected the B to shutdown terminal. So, effectively when voltage at A goes more than point 6. So, when voltage at A goes more than 0.6 T 1 T 2 and T 3 are on so P W M I C is switched off. This makes voltage at A to disappear because once P W M I C goes off so you will find you know P W M I C goes off then voltage at A disappears. Even a voltage at A disappears is does not matter since, T 3 is on T 2 continued to conduct and B will remain there so switched off.

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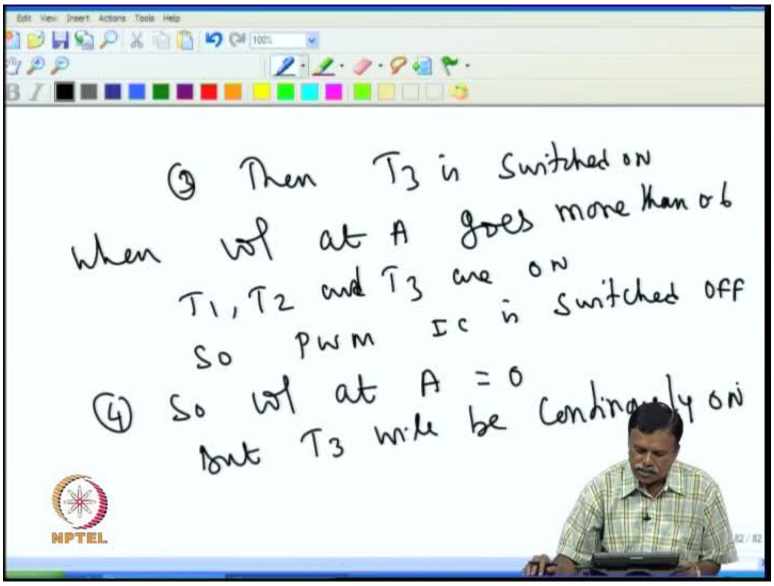

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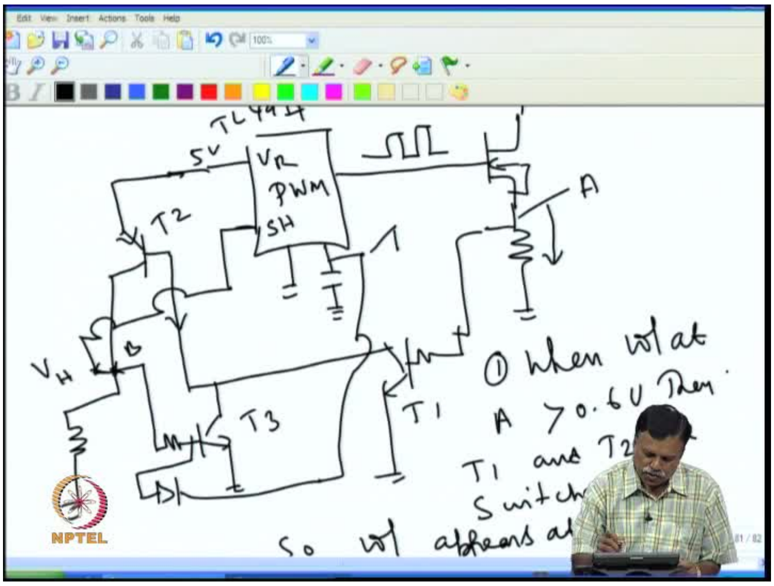

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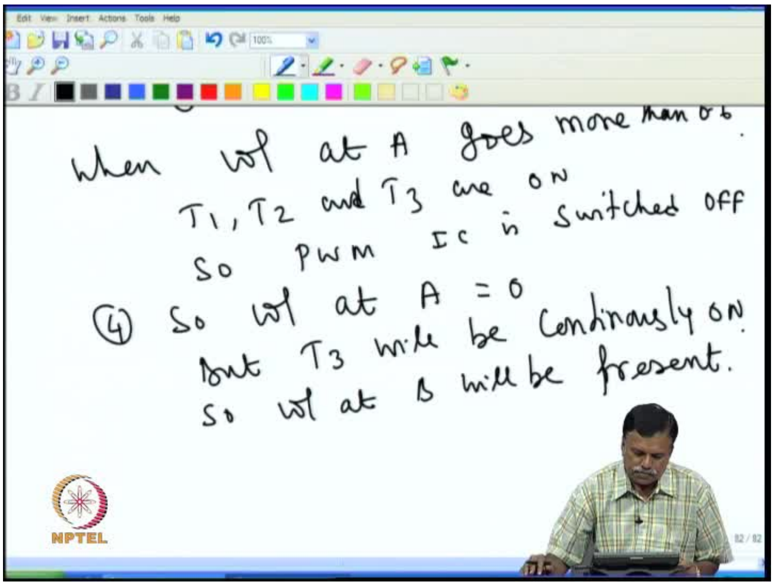

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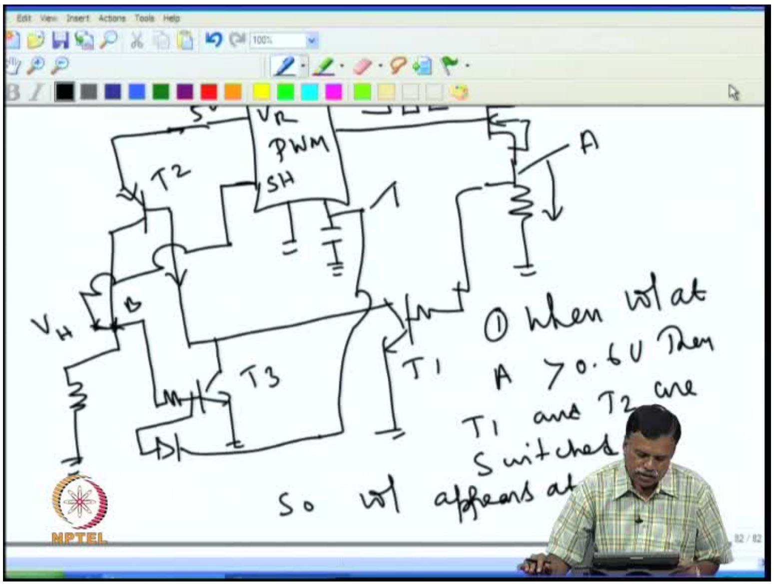

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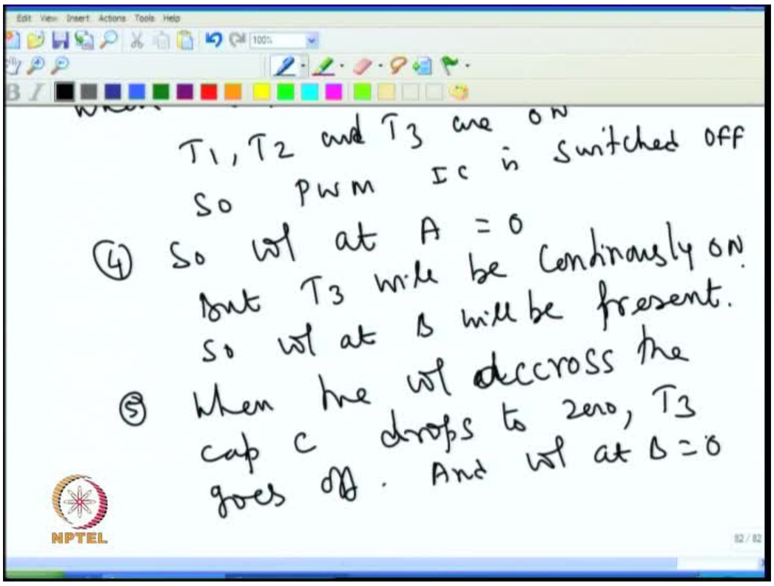

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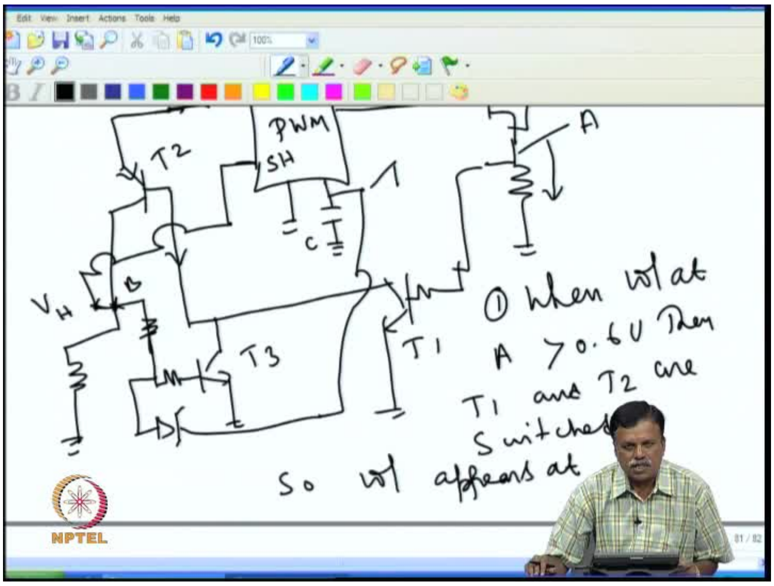

So, voltage at fourth point is voltage at A equals 0, but T 3 will be continuously on that this is the latch function. So, even though the input original voltage disappears, but then T 3 will be continuously on and voltage at B will still be there. So, voltage at B will be present, voltage at B will be there even now, but when the saw tooth voltage goes down to 0 that is one voltage at the capacitor make, I will make it is c in the voltage at c drops to 0, then t 3 goes off. And then the fifth point would be when the voltage at across the capacitor across the cap c drops to zero, T 3 goes off and voltage at B becomes 0. So, the voltage across the capacitor c drops to 0 then automatically this voltage decreases and then this transistor stop conducting and then B volt this also stop conducting and B becomes 0.

Now, the next pulse can appear so this way, it can act as a latch that mean the pulse once voltage goes high it this can be latched and the latch function can be easily obtained using this process. Of course, to practically make this circuit work you need to make the small change, because what happens when this diode is conducting. When this diode is conducting this needs 0.6 volt at 0.6 this may still conduct to make it you know full proof, what can be done is I can shift this, I can make a change like this put this and shift this on like this a small resistance can be added. So, that this is 0 this is 0.6 definitely this is not 0.6 and transistor will not conduct and then also we can use a Schottky key diode such that the voltage of across this is small.

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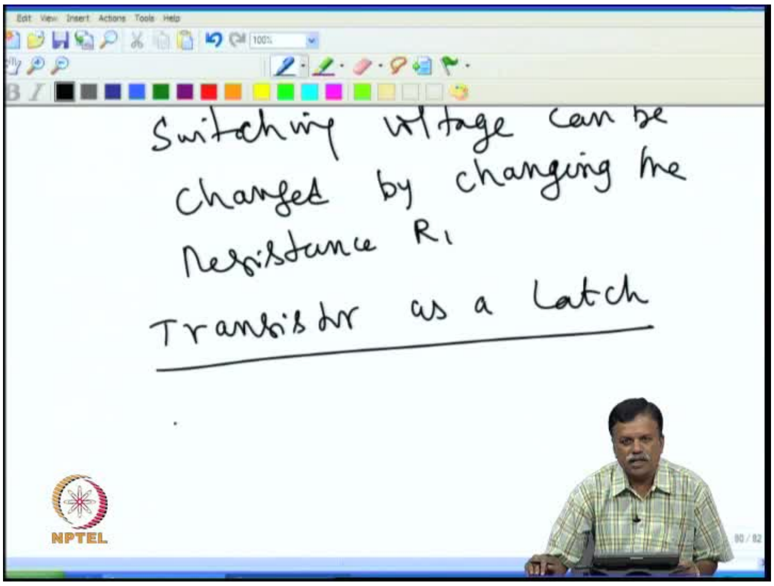

So, by doing that we can by using a schottky diode also we can improve the performance of this. So, you can see the transistor can be used at will for various applications, so we are shown how to use a latch in a P M W control I C, we also shown how to use a transistor to switch off and on at a required voltage, and how to do the temperature compensation for the switching of voltage that is what we are seeing the first example. In this example we had shown how to use the transistor as the latch.

Now, the transistor also can be used as a temperature compensating element, because when many cases for example, many transducers when temperature changes the property of the transducers changes, and we want make a temperature compensation. So, we can use transistor effectively for this, because base emitter voltage of the transistor changes with temperature that can be used to compensate temperature as some other transducer.

For example, have we taken some transducer assuming changing with temperature, then how to do the temperature compensation we see in this example.

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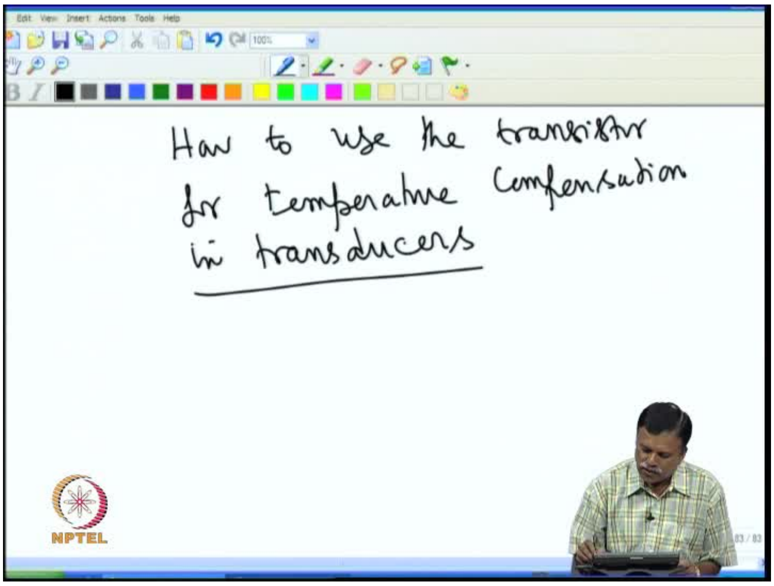

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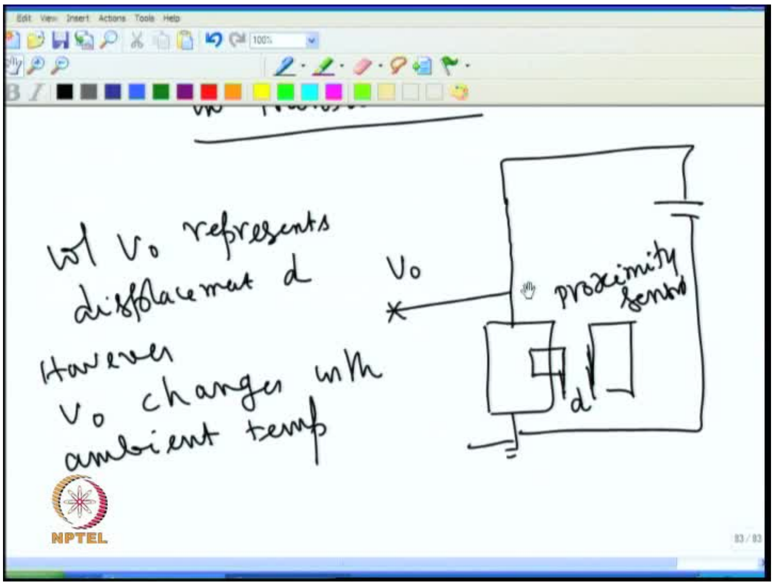

So, how to use the transistor for temperature compensation?

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For example, if we have a transducer if that property changes with temperature, how to use this transistor effectively for compensating their temperature drift off the transducer? Assume that I have a transducer here and then some property changing for example, proximity sensor we have a metal here then we have a core kept here and assume that we know we have a sensor here, and that is energies and we have a supply voltage here, this assumes proximity sensor. So, voltage at this point gives me the displacement for example, this is the distance we want to see so voltage V 0 represents displacement d, d is the gap between these two the distance between these two.

If varies for example, if this is moved for away then d increases then v 0 also assume it increasing so assume we have a transistor like this. So, then d is more then you will get this voltage also more, but then we know that with temperature this voltage whatever is there will be changing even though d is constant this is the major problem for example, V 0 is changes V 0 depends on the temperature. So, effectively however V 0 changes with temperature of the ambient temperature, because this transducer is in the ambient whatever changing in the ambient temperature that is affect this one.

So, even though forgiven if the distance d is not changing, but voltage v 0 will be changing this is the major challenge in analog circuit now, because the temperature drifts is a real issue in most of the circuit particularly the transducers. So, how to make you know this, how to compensate this change for example, I can send this change and then do this for example, one of the application would be driving the sensor with the constant current source for example, what can be done is I can have a transducer.

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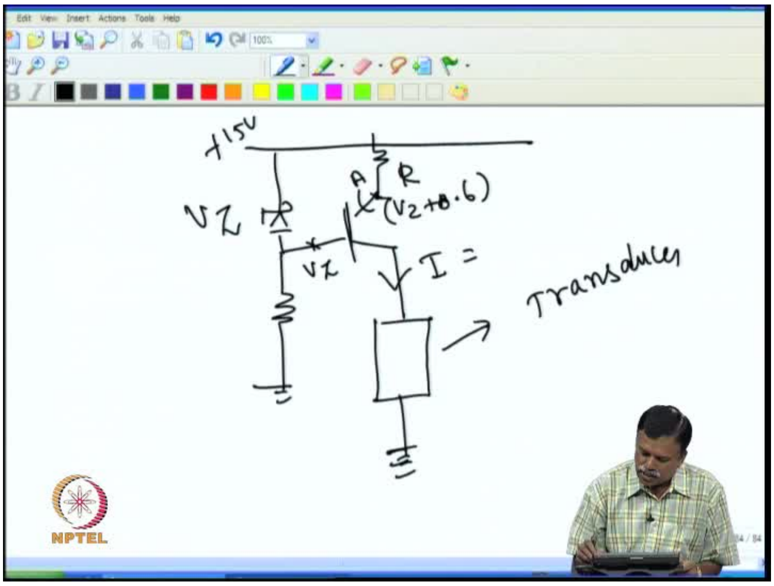

For example, I put the circuit like this. So, you have a transducer, transistor assume this is supply voltage then I have a (( )) diode connected this then I have the resistance here for example, this is plus 15 volt and then this is a load. If I take this load can be now transducer, this can be a transducer essentially there is a current that is flowing through this transducer. because this is I, I is nothing but this is V Z this is R. So, if this is V Z we know that this will be V Z plus R plus point 6 because this is V Z, so this has higher than V Z by 0.6.

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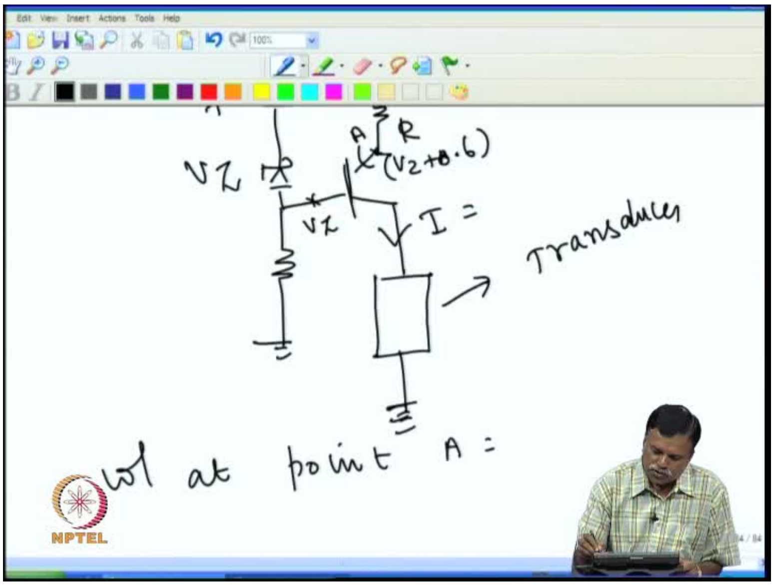

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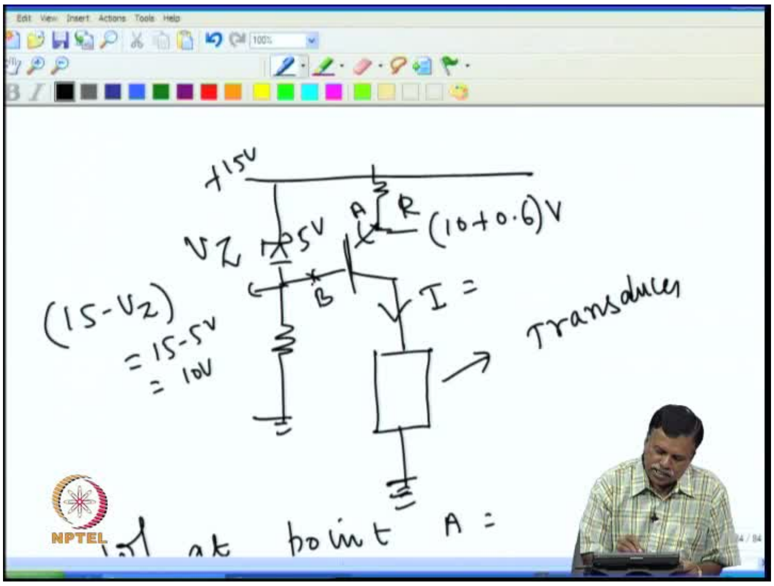

So, voltage at I call this is the point a, this is A, so voltage at point A is assume this is a zener voltage at point A we had find out. So, this is zener voltage assume this is 5 volt, this will be is not zener voltage actually this voltage at this point is I call it as B. So, voltage at this point will be 15 minus V Z, because this is 15 and voltage across is 5 voltage at this point will be 15 minus V Z that will be 15 minus 5 that will be 10 volt.

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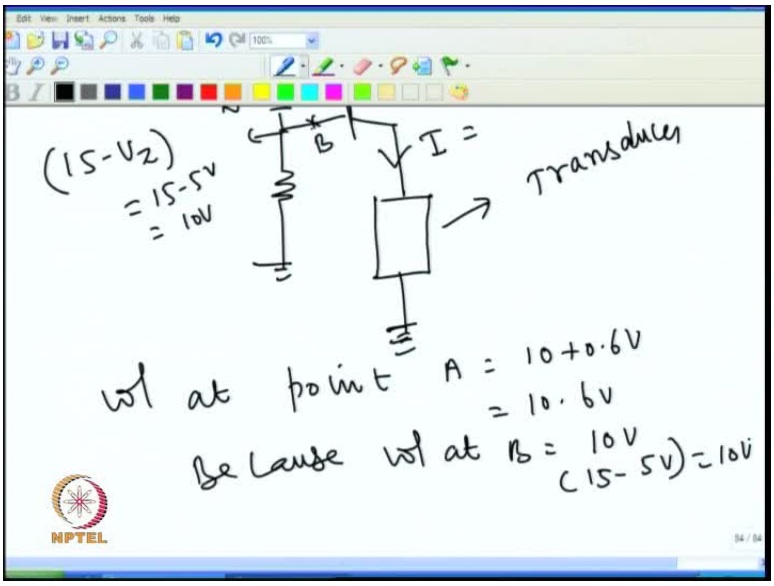

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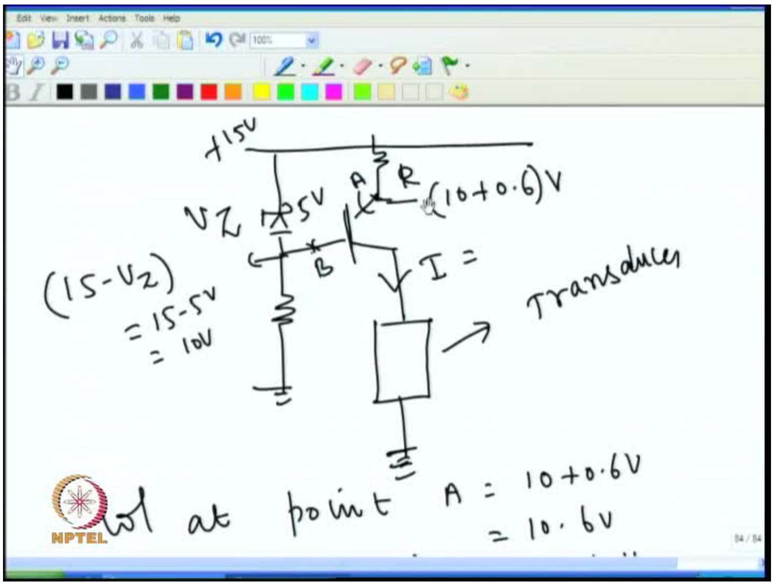

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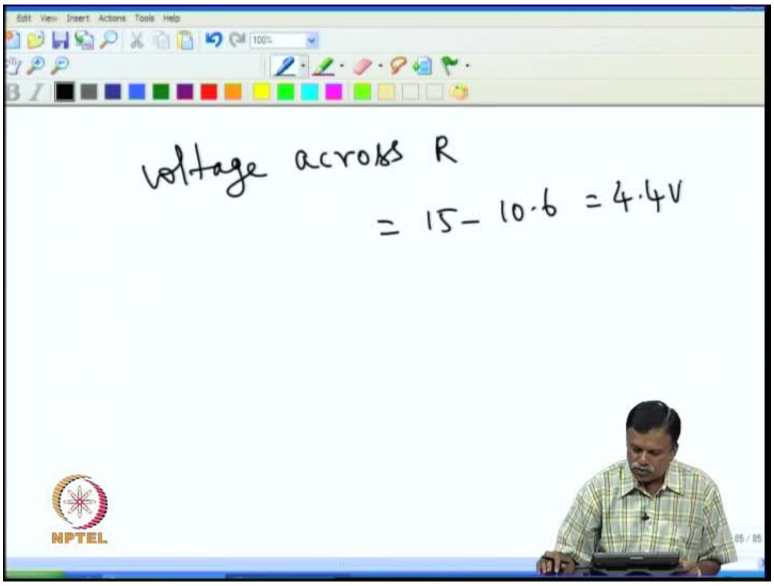

So, voltage at B will be 10 volt, voltage at a will be 0.5, 0.5 is not V Z, but actually voltage at A would be 10 plus point 6 volt, because this is 10 so this has been 10 plus 0.6 volt. So, that means voltage at point a will be 10 plus 0.6 volt, that will be 10.6 volt these are come because voltage at B equal to equal to 10 volt, that are come 15 minus 5 volt zener voltage that become 10 volt. So, from this circuit we see the voltage at B is at 10 volt and voltage at A is 10.6 so voltage across this R voltage across R would be if this is sitting at 15 this is 10.6 then 15 minus 10.6 is the voltage across R. So, voltage across the resistance R would be across R would be, 15 minus 10.6 that will be 4.4 volt.

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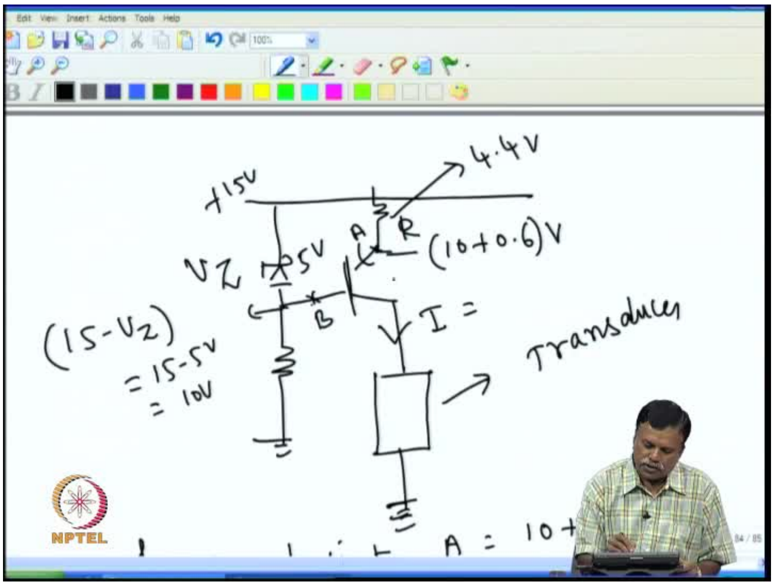

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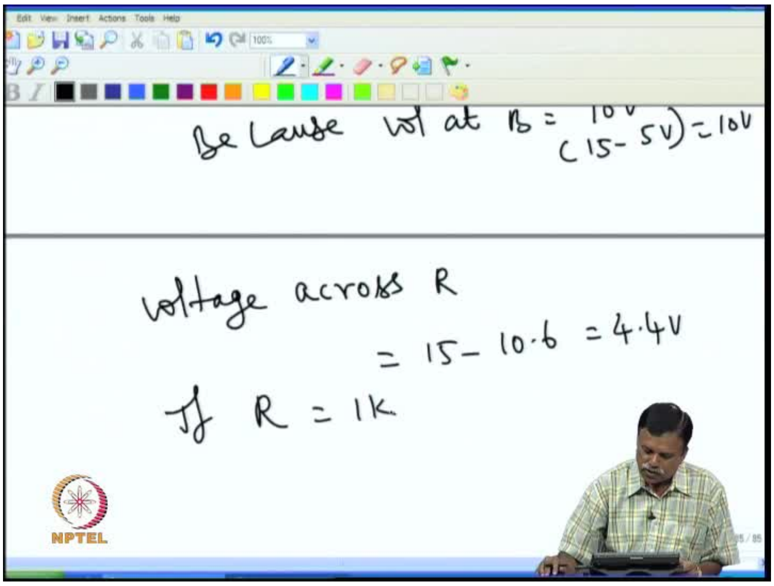

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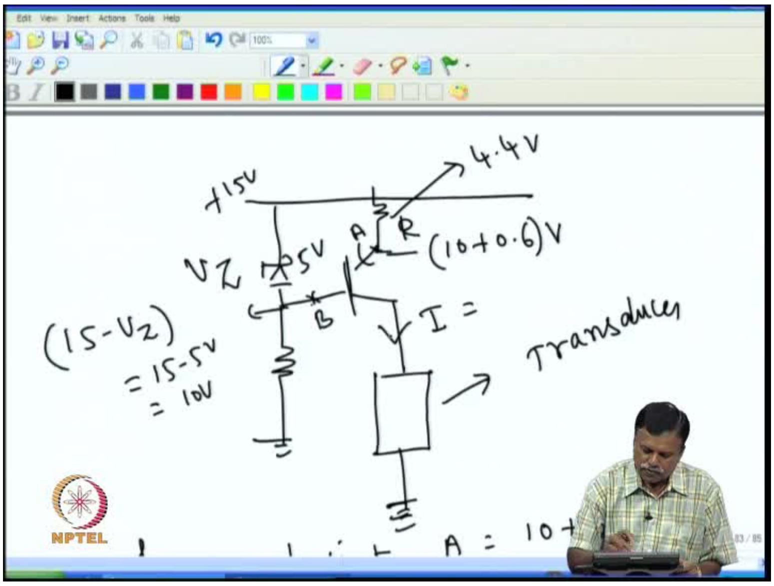

So, we got the voltage across this resistance R has 4.4 volt, so we know that base current is negligible then voltage across this is known and if I know the resistance value then I know the current flowing through this. So, assuming R has 1 k, if R is 1 k if R equal to 1 k then current through R would be that is this resistance we had find out current through this R. So, voltage across is 4.4 and the resistance value is 1 k, so if I take 1 k then current through R would be 4.4 milli ampere.

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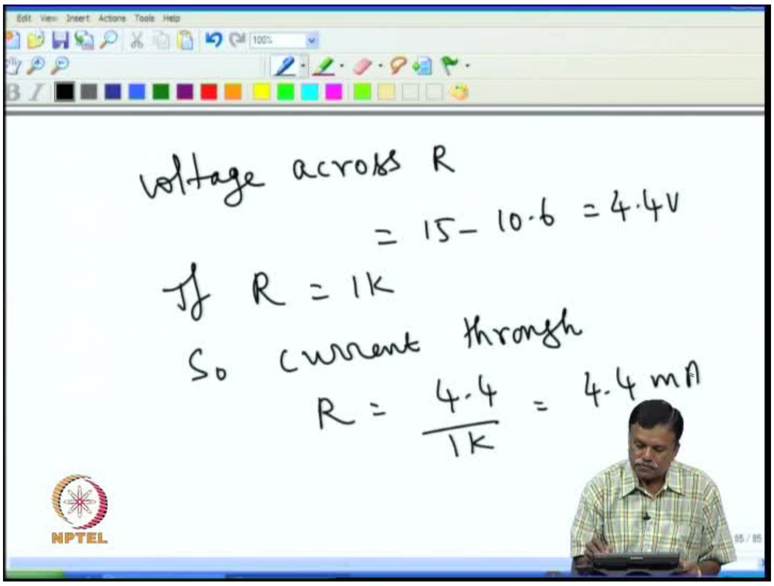

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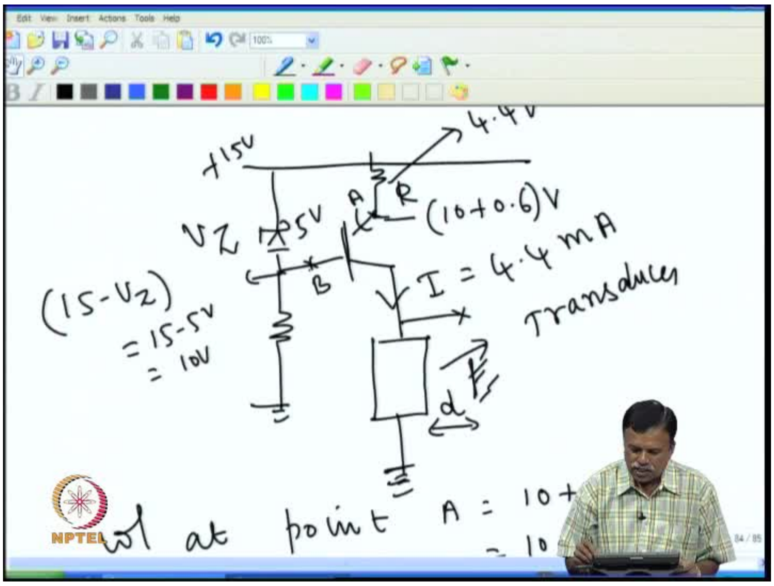

So, current through R would be 4.4 volt divided by 1 k that will be 4.4 milli amps. So, effectively it is a constant current source and the current that is flowing through this is 4.4 milli ampere, because I had taken this resistance has 1 k so voltage across this is 4.4 volt and the resistance value is 1 k. So, current flowing through this is 4.4 milli ampere, that current entirely flows through this assuming the base current is negligible so the current i will be effectively 4.4 milli ampere. So, current flowing through the transducer is 4.4 milli ampere and correspondingly you will have a voltage developed at this point.

So, you will have voltage at this point depends upon this current and assuming that this has a resistance depending upon the sensor you have and depending upon the displacement d. So, you have a distance d and because of this variation d you will have the resistance of this effectively changes. Since, the current is constant you will have voltage at this point that will be constant so when d changes effectively when d changes you will find that voltage at this point changing.

So, the d change will give a voltage change, but then when temperature changes then this voltage also will change, that was the issue we want to solve so when temperature changes we do not want this voltage to change. So, only when d changes this voltage has to change that is how the transistor is made so when d increases this voltage will increase the d decrease this voltage will decrease, but then with temperature even for a fixed d this voltage will be changing. So, you want to compensate that in this case that is what happens when current which is set here is 4.4 milli ampere is constant as long as temperature of the transistor is constant.

The temperature of the transistor changes, then this current 4.4 milli ampere also changes, because when temperature changes the base emitter voltage it is changing and then available voltage across this changing and net result is current flowing through the changing.

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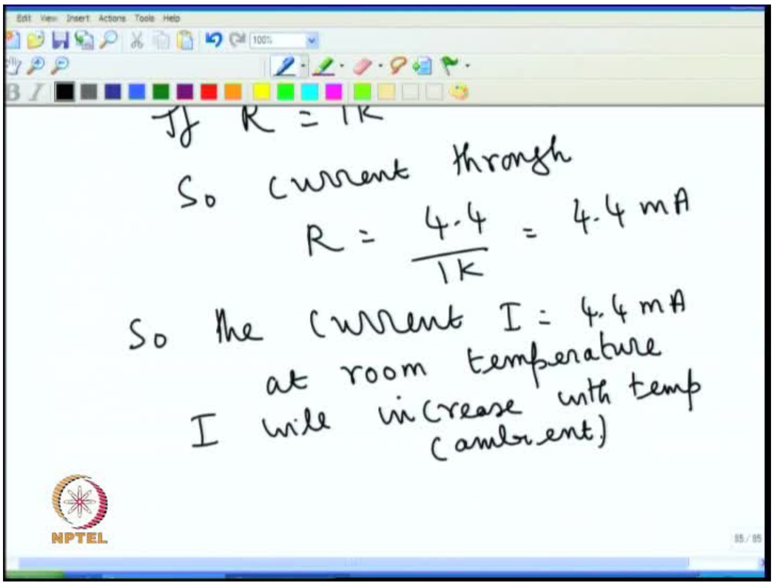

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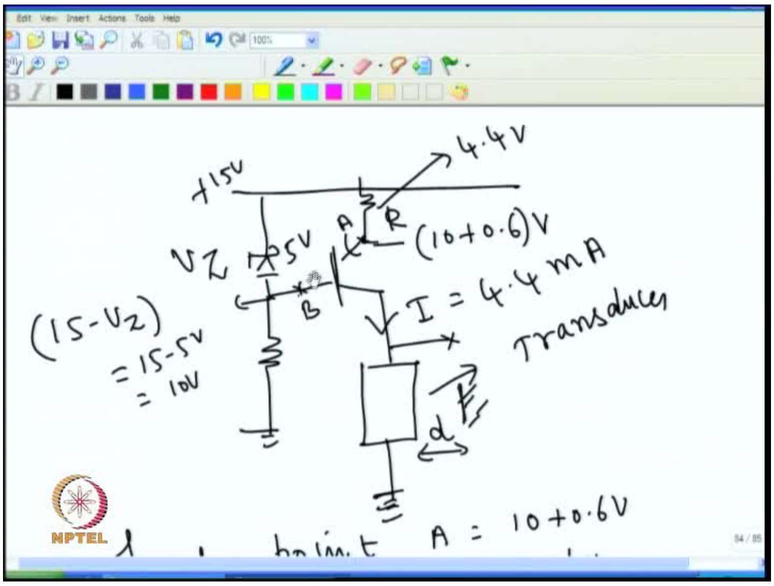

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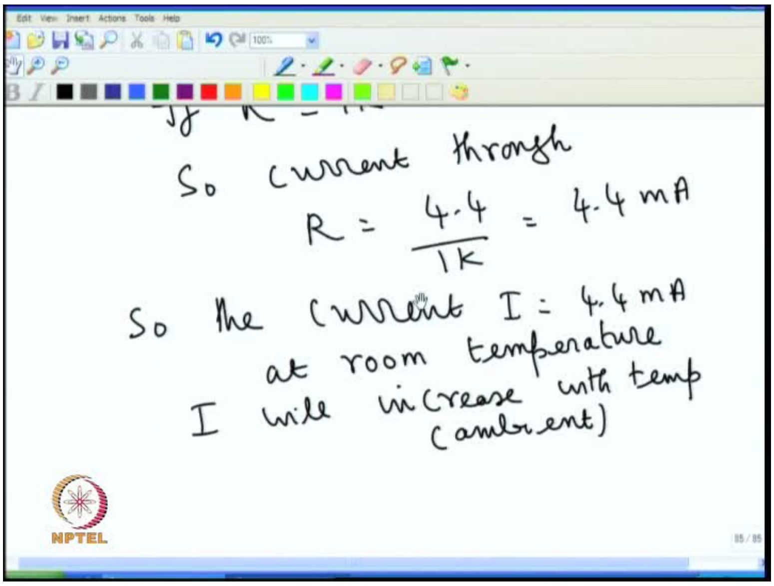

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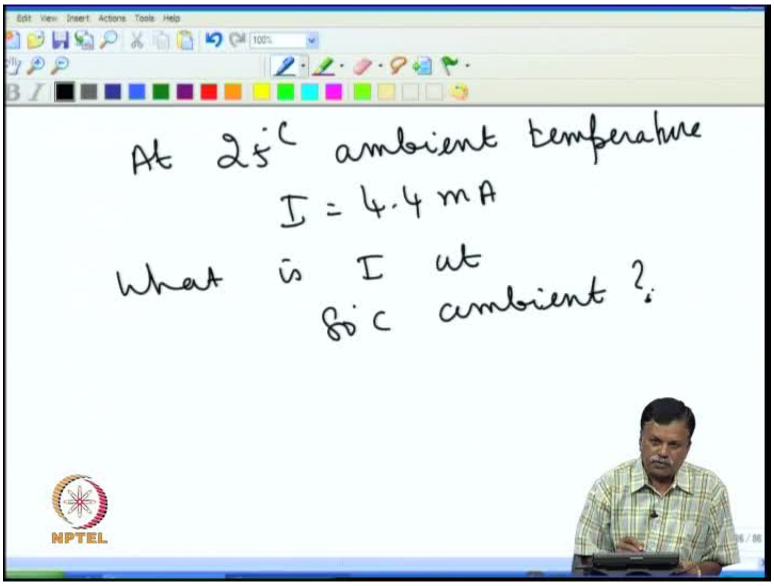

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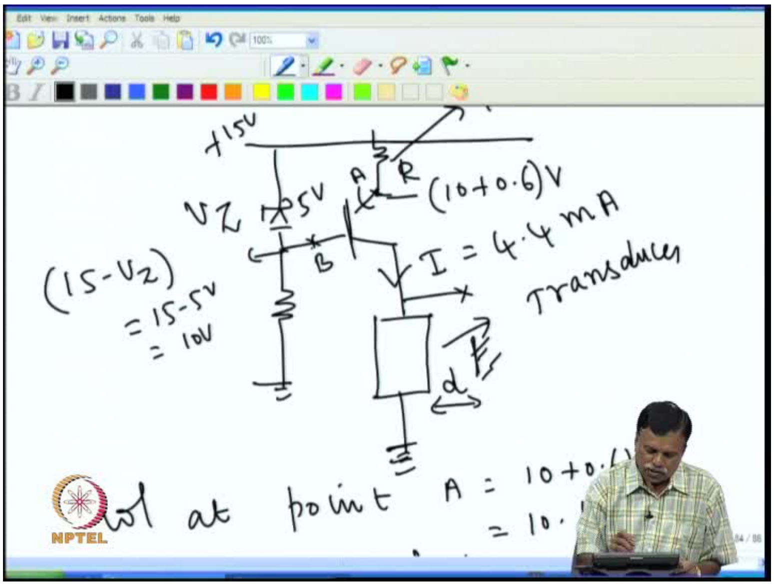

So, effectively when temperature changes base emitter voltage changes that will produce the change in current and that will compensate the temperature drift off this is the method, which is used expensively, you see this now in detail so assume the current I is 4.4 milli ampere at room temperature. So, the current I equal to 4.4 milli ampere at room temperature, but this current will increase with temperature, I will increase with temperature that is temperature means ambient temperature. When ambient temperature changes this current I also will increase, because when ambient temperature changes the transistor the temperature of the transistor also changes.

So, when temperature of this transistor changes this current increase that is because the base emitter voltage decreases with increasing temperature. So, if you now see assume that this 4.4 milli ampere is 25 degree ambient temperature. Let at 25 degree c at 25 degree c ambient temperature, c ambient temperature, I is equal to 4.4 milli amps. Now, find out what will be the current what is I at 80 degree c ambient now, that we can find out by this equation, because the base voltage remains same, because the voltage at b voltage at b is always 10 volt.

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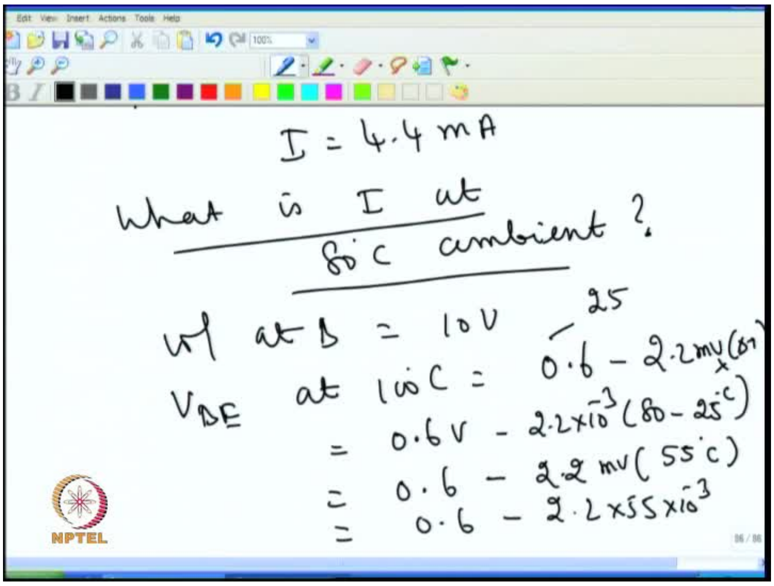

So, voltage at b is 10 volt what is, this is what we are to calculate so voltage at B equal to 10 volt then V B E at 100 degree c would be 25 degree c we had 0.6 volt minus 2.2 milli volt into delta t that is equal to 0.6. This is a 25 degree c 0.6 volt minus 2.2, 2.2 into 10 power minus 3 into change that is now we want at 80 degree, so what will be 80 minus 25? So that, conserve to be V B E at 100 degree would be 0.6 minus the difference will be 2.2 milli volts, so milli volt into 30 55 degree into 55.

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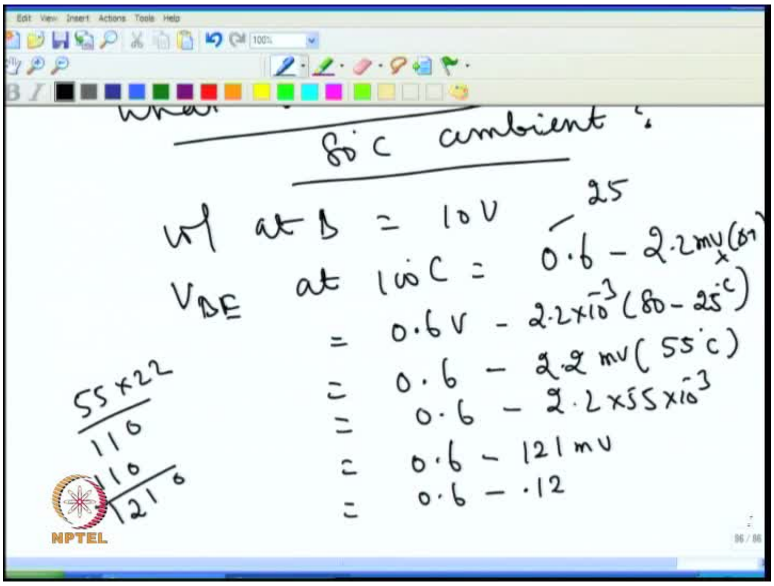

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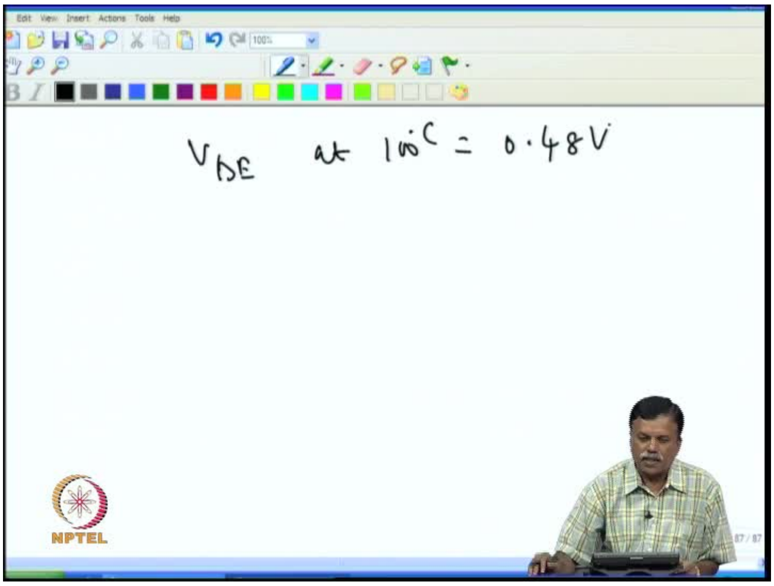

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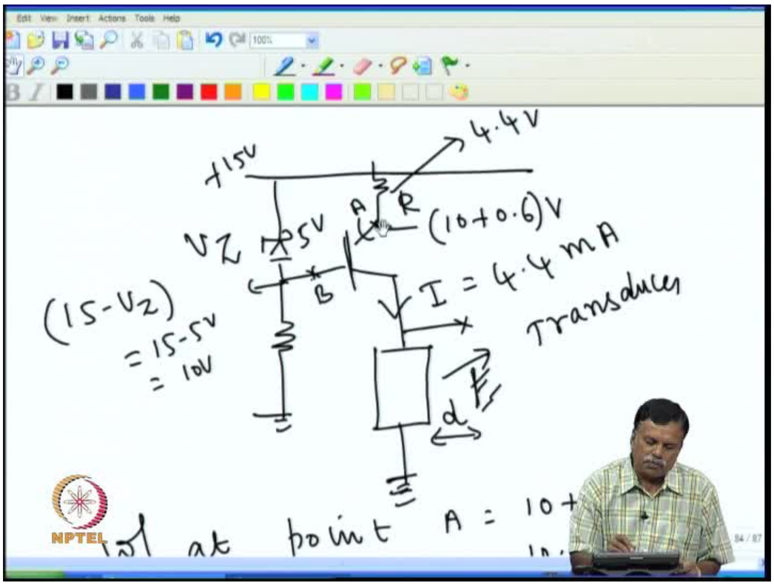

So, that comes out to be 0.6 minus 2.2 into 55 into 10 power minus 3, that comes 0.6 minus 2.2 into 55 that comes out to be 55 into 2. 2, that comes out to be 121 milli volt that is 0.6 minus point 1.2 that will be 0.48 volt so V B E at 100 degree c would be 0.48 volt. So that, makes what is the voltage at point A, because this voltage at b is at 10 volt and voltage at B is at 10 volt and then V B E is 0.48 then A will be 10.48 volt so voltage at A will 10.48 volt.

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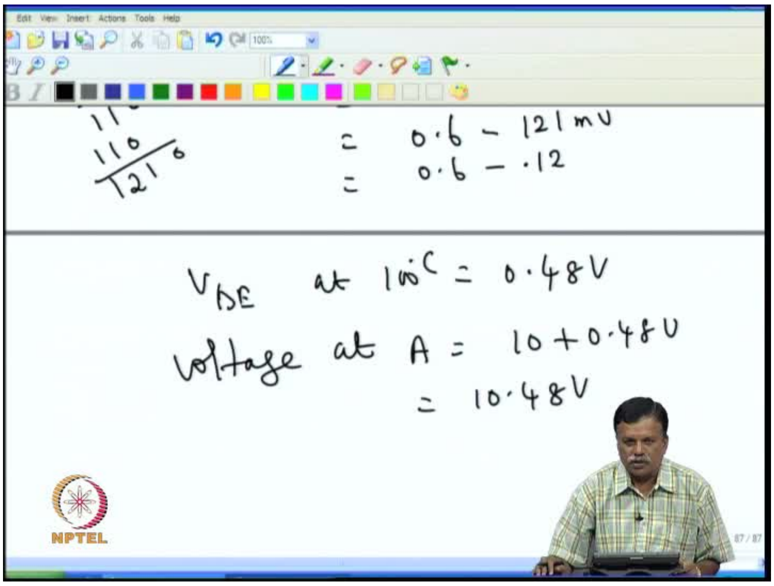

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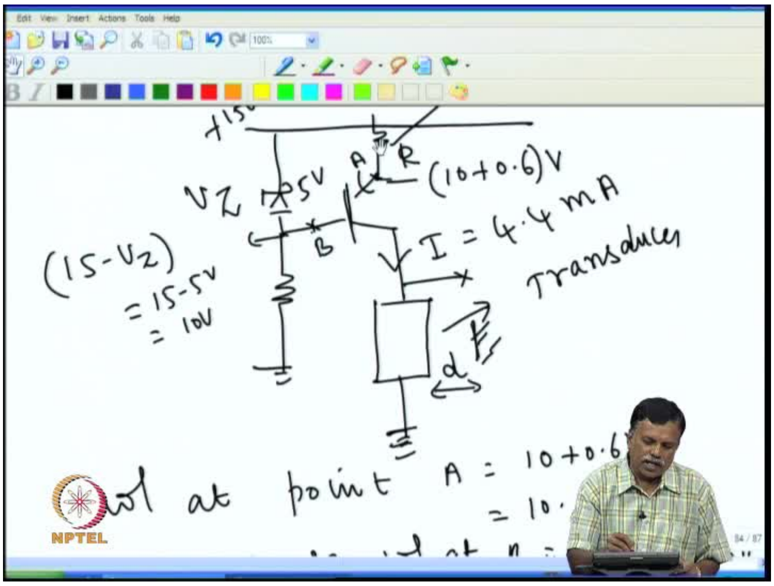

So, voltage at A would be 10 plus 0.48 volt that is 10.48 volt so at 100 degree c the voltage is 10.48 volt at A, at 25 degree c the voltage was 10.6 volt. So, effectively at high temperature the voltage at A had decrease now, we have find out what is the current flowing through the resistance R 1, because now we know voltage across voltage at A is 10.48. So, this is 15 you know voltage at A is 10.48 and this is 15, the voltage at R is now 15 minus 10.48 and divided by R will give me the new current.

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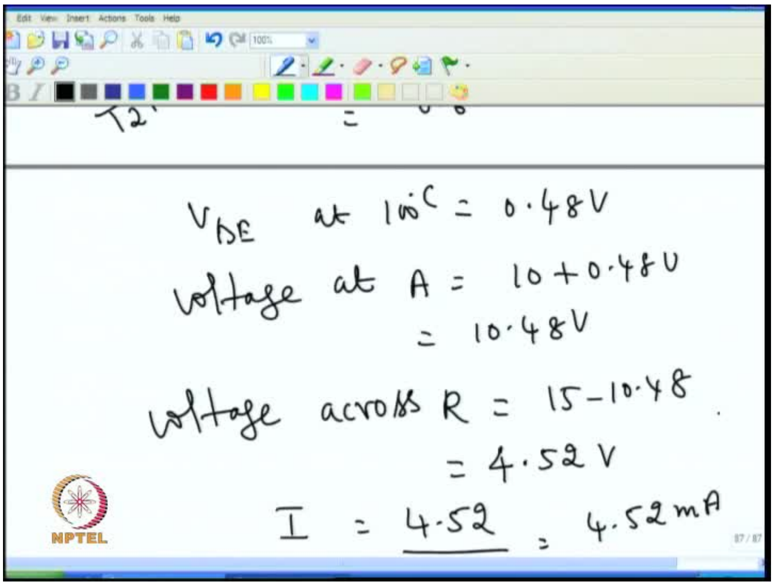

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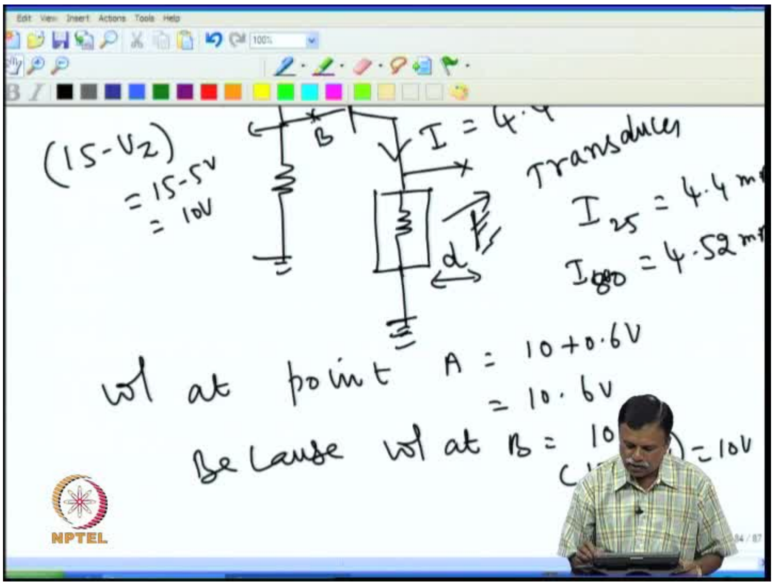

So, voltage across R we had find out next so we can find the voltage across R voltage across R will be 15 minus 10.48 that will be 4.52 volt. So, you have 4.52 volt across R so the new I will be 4.52 divided by 1 k that will be 4.52 milli ampere. So, at 100 degree c the current is 4.52 milli ampere, so current at 100 degree c become 4.52 that means I at 25 degree was 4.4 milli ampere, I at 100 degree c, 80 degree c is 4.52 milli amperes. So, temperature this current at increased effectively so if the current increases then if then the current flows through the voltage across this also will increase.

So, in case you know if the transducer is a negative temperature coefficient for example, with temperature the voltage at this point decreasing means this increasing current will compensate, assume that this is effectively a resistance. Assume that this is effectively a resistance and this resistance for example, decreases with temperature respecting of this distance. The distance remaining constant, but assume that this resistance is decreasing with temperature it should decrease only due to the resistance only due to the distance. If the distance increases effective resistance of this suppose to decrease, but then this assume that you know this resistance changes with temperature also assume here it is decreasing with temperature, then the voltage at this point will decreasing with temperature.

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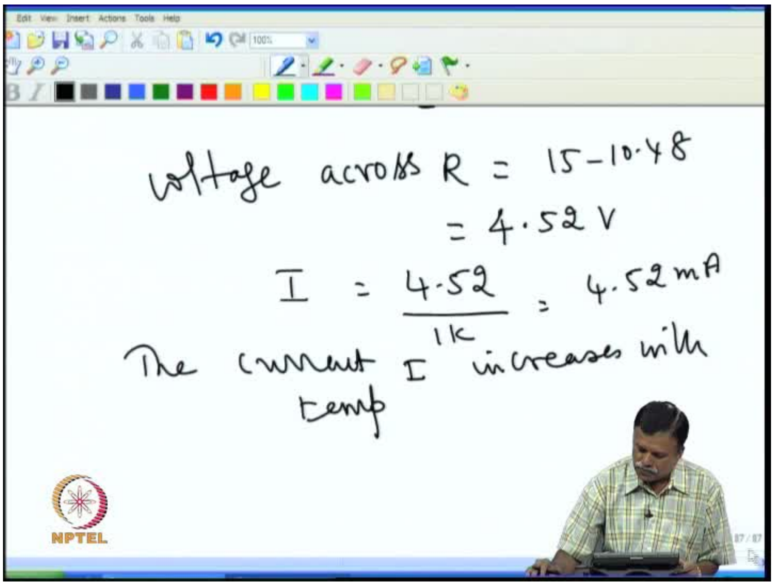

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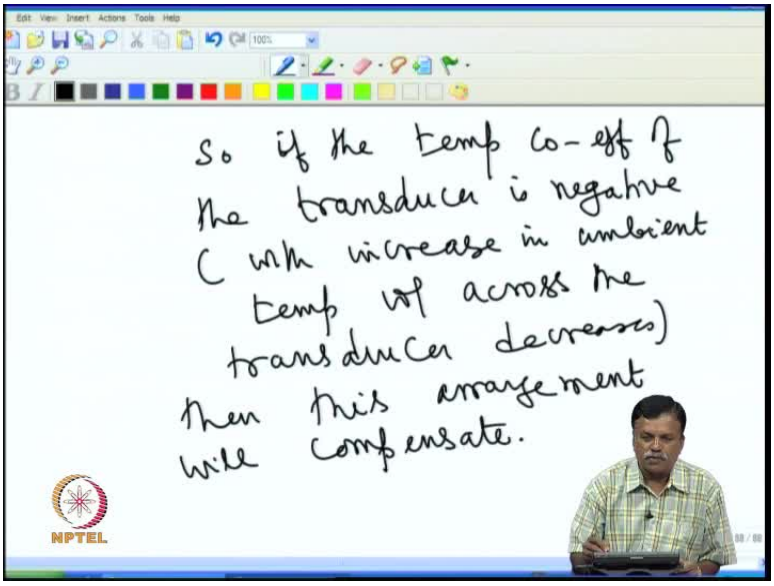

Now, the increasing current will compensate that loss one can select the proper values of R to get whatever compensation required. So, effectively it means effectively this means the increasing current, the current I increases with temperature so if this means, if the temperature coefficient of, the transducer is negative meaning with increasing temperature with increasing temperature increasing. The ambient temperature voltage across A decreases across the transducer decreases voltage across the transducer decreases. That is the meaning of negative temperature coefficient.

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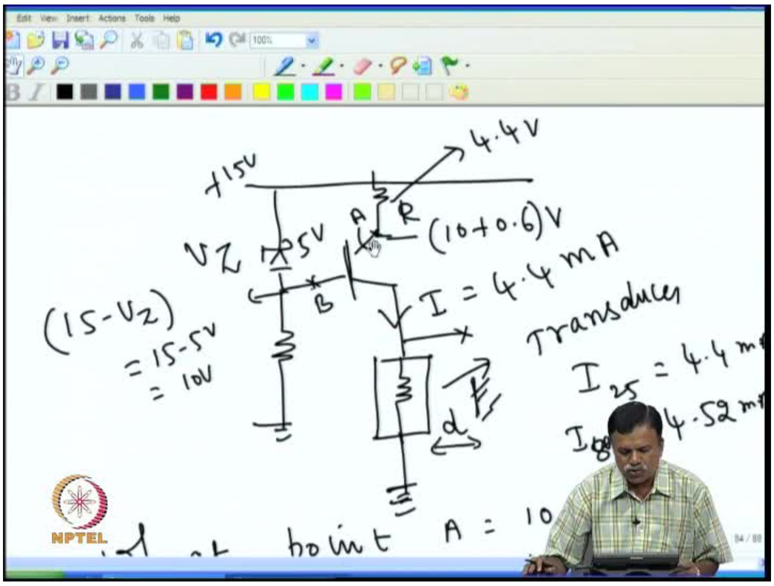

So, if the temperature coefficient of the transducer is negative then this arrangement will compensate will compensate, because as transducer voltage decreasing with temperature, but the current applied to the transducer increases with temperature. So, the decreases will be compensate by the increasing current so the one can select the values correctly such that the decreases at your getting across the transducer will exactly compensated by the increasing current, that is for example, if I select different values of R different values of R. And then if I select for example, the different values of the zener diode one can tailor made what is the percentage of current have to rise for a given temperature change.

So, for different combination of zener voltage and the value of this resistance one can get the required rate at which the current has to rise with temperature and we know if the transistor will drift with the certain amount, if that matches with this then one can make it the transducer is not changing with temperature. So, this is another transducer that is we can use the base emitter voltage change, the base emitter voltage changes with temperature that can be used for positive advantage that is uses advantage to compensate the temperature changes of the transducer and so on.

This is an very important application actually we have constructed constant current source and those current is not really constant, and those current is really changing with temperature and that change we are used here as an advantage in this circuit. So, in this case the transistor is used the transistor drift is used for a advantage and this kind of application this many in the real world, because if transistor is very dependable temperature drift when, because base emitter voltage changes accurately 2.2 milli volt per degree c.

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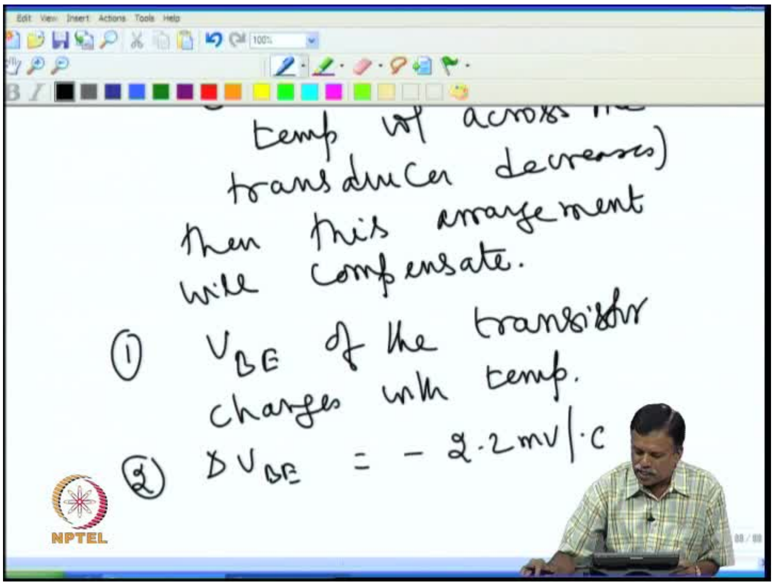

So, this can be utilized at many places for our advantage, because this kind of accuracy you will not get it in thermistor and so on. Because earlier the use thermistor is temperature compensating element, but thermistor also has a good temperature coefficient in the sense reproducible temperature coefficient, but use of thermistor is not as comfortable as the transistor. So, one can use the transistor for a temperature compensation vary many applications. So, the important property that is used here is V B E of the transistor changes with temperature and the change is that is the one and the second point here is V B E delta V B E, that is the V B E changes equal to minus 2.2 milli volt per degree c and this is highly reproducible.

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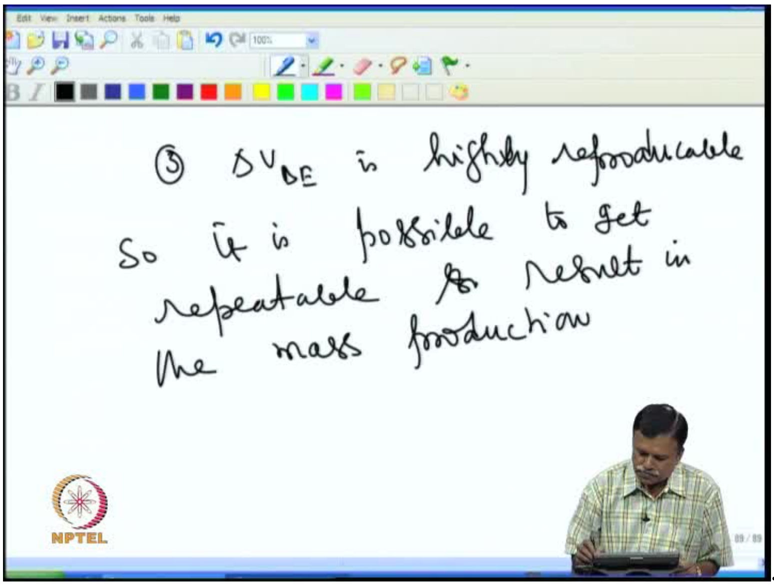

If the transistor does not change, the delta V B E third point is delta V B E is highly reproducible. So, one will get a repeatable result, so it is possible to get repeatable result in the mass production, that is why transistor is used extensively for temperature compensation, compare to the thermistor transistor used as a temperature compensating element is very common. Because of this reproducibility when thermistor also it is possible to get a reproducible, but however the thermistor if you want reliable thermistor we have to pay lot more money then what you spend for the transistor. So, we see the other applications of the few more application of the transistor in the next class, with this, I will stop this class lecture. Thank you.