Circuits for Analog System Design

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Lecture No. # 05

Transformer Design and Heat Sink Design

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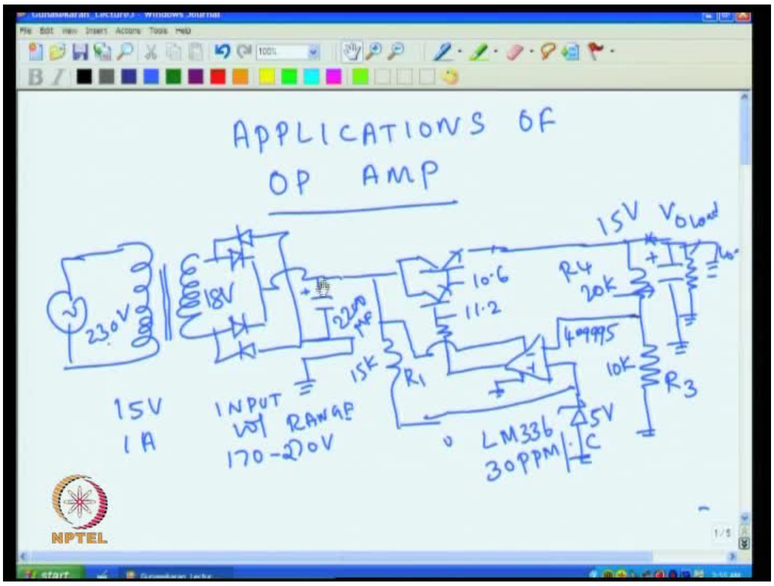

Good morning students in the previous class, we are studied about how to use the operational amplifier for voltage regulation. So, you can see this is the circuit that we are used in the previous class, that is we have the transformer is the step down transformer. And then we are used 18 volt secondary winding and then we are rectified that a c voltage and we got the d c here. Across this capacitor you get the d c voltage there is a 18 volt into 1.414 is the d c voltage that will get here and then this is a series pass transistor and then this the error amplifier so this the output voltage.

So, output voltage is divided using this two resistor so, you get the 15 voltage is there and part of the 15 voltage appears here and this is the reference voltage and this reference voltage is compared with this output voltage. So, you get some output voltage that output voltage appears here and then 0.6 less appears emitter and another 0.6 less appears here.

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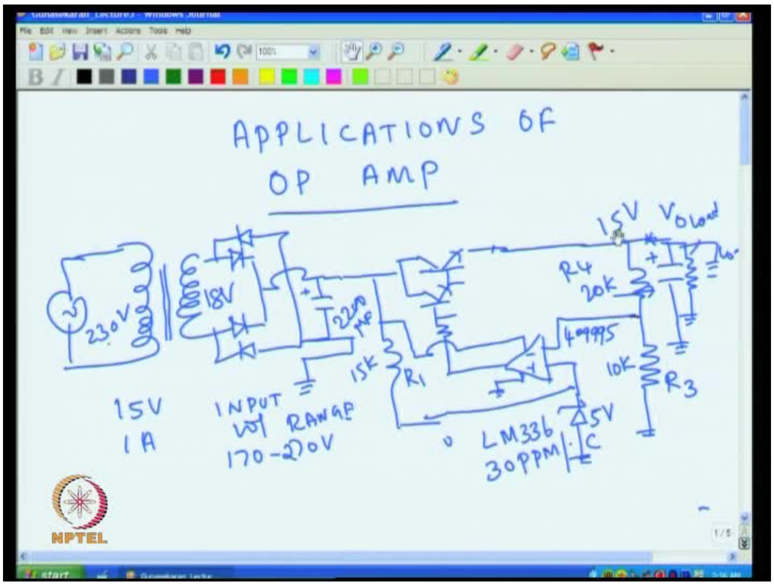

Now, this is how the circuit is working? Now, if you see if it is 15 volts then if this is 5 volts you obviously, see it is comes to close to 5 volt. Because difference between these two this voltage and this voltage amplified by the open loop you know the operational amplifier and put it here. So essentially, if this voltage is 5 this will come very close to 5 and then that voltage is put here and if this 15. I know this will be 15.6 and this will be if this is if this is 15 and then you will get at this point 15.6 and 16.2 and this is almost 16.2 and then 16.2 divided by the open loop gain is difference you will get.

So essentially, this is how the voltage regulator is working? So essentially, if this voltage goes up this will go up the difference between these two comes down and that makes output reduce and that reduce this also. Suppose, if this goes lower than the difference between this to increases the output increases and again that possess the output go high. So eventually, this settles at close to 15 volts. So, this how the voltage regulator as working and we are discussed this in the previous class. And also explain that how to select this resistance value and how to select this secondary relating for the transformer.

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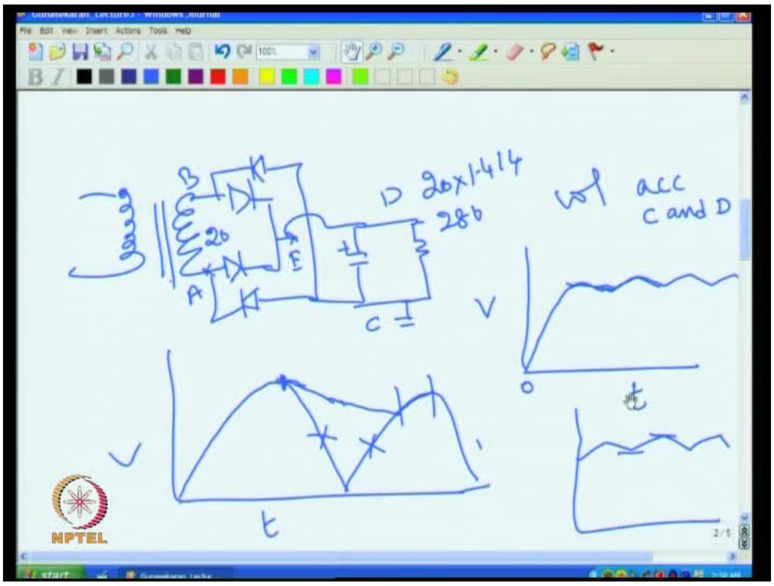

Let us discuss I think that you can see in the so I show you by considering this how much voltage that is coming here. And then I also show you that these diodes are not conducting throughout of cycle they conduct only during this time there is a fraction of half cycle only the diodes are conducting. So, that means the current drawn by the current current through the diode during this time will be obviously much more than the load current. That is flowing through this roughly it is about three times and also told we that as long as transformer is there for a particular transformer. If increase the capacitor value is not their conduction angle going to decrease this is because this has the equivalent resistance and that at any way charge of the capacitor.

So, in practice you find that per quite large value of the capacitor value the conduction angle are all remains almost same. For example, if you put very large value one parade capacitor does it mean the conduction angle will be very small? So, in a practical well that we will find this conduction angle is about 3 milli second for 3 milli second only it conduct remaining 7 milli second of the half cycle. The diode is not conducting and then I also shown you how the repulse is coming how to select the value of the capacitor and so on in the previous class.

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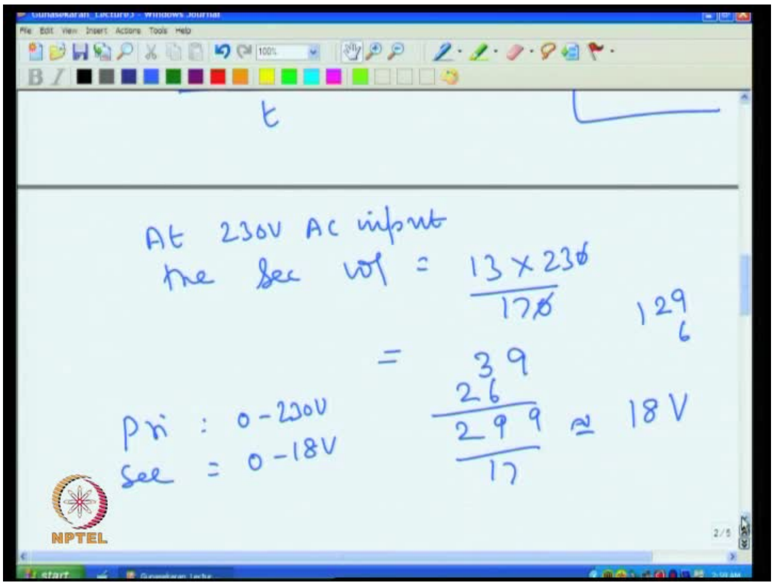

Than I had show new how to compute the secondary voltage for example, what is required is here primary 0 to 230 volts secondary you need 0 to 18volts.

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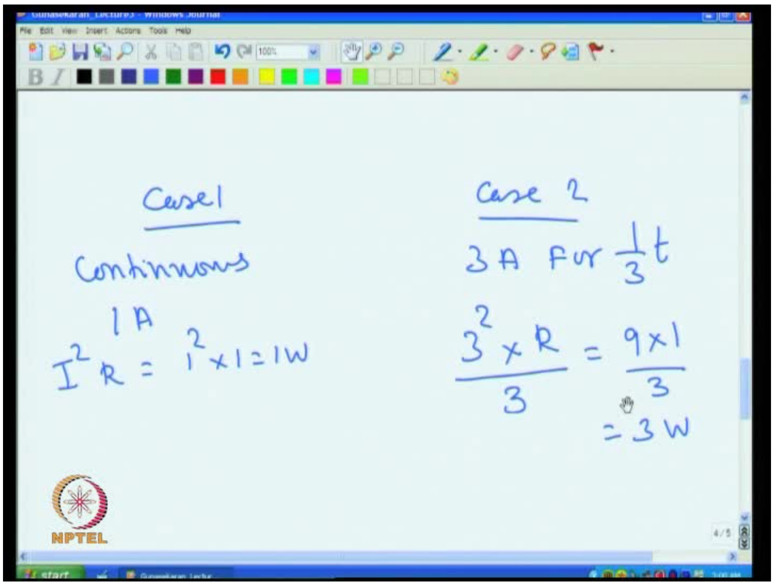

So, I also showed you that because the conduction if the conduction angle is small for example, for 1 ampere current the conduction is continuous you will have 1 watt loss in the transformer here. We are taken 1 ohm secondary equivalent resistance of the transformer and for 1 ampere the loss will be 1 watt. But if I take 3 ampere for 1 third of this conduction time there is 3 milli second is the conduction time in that case the total loss will be 3 square into R by 3 for the same transformer. We will have 3 watt loss that means if I draw the power continuously the heating is less, but if I draw the same power, but very short time with high current then the heating is more this what really happens in the transformer actually?

So, when you are using a linear supply it is obvious that we are to go for a much higher capacitive transformer then normally. What is if I use only resistive load right at the secondary. Now, we will discuss the new topics that is namely how to design the transformer because we at given the transformer rating that is I need 0 to 18 volts and then I need you know if it is 1 ampere output that. So, I need 1.8 ampere rating to be given to compensate the excess loss there is coming because of the 3 milli second conduction angle conduction time.

So, to compensate the excess the loss it increases the transformer winding and transformer rating so that the heating is normal. Now, we it is also important an analog circuit one should learn how to design the transformer because we will be using transformer at very many places and then also will be using inductor. So, it is very much essential to learn about transformer. So, you know one need not too much worried at so many parameters that is comes in designing the transformer in fact transformer can be very easily they no need of any computer or any calculator for that.

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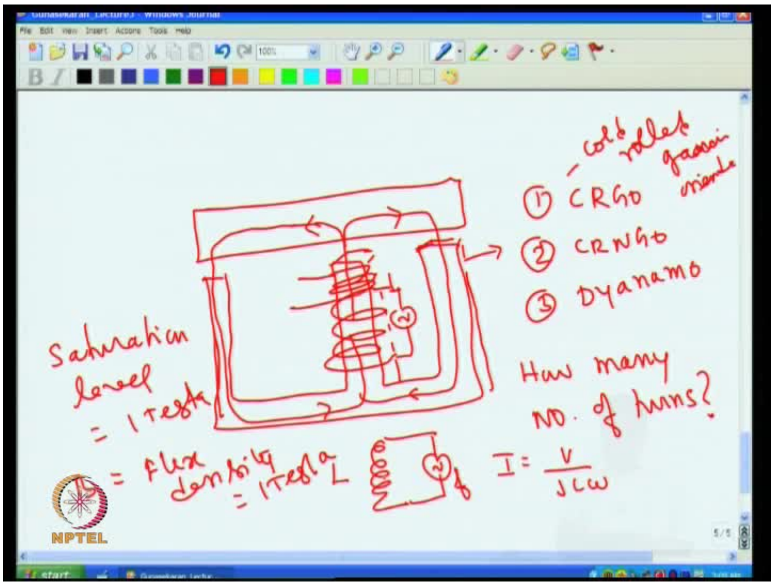

Now, if you see you know that general generally how the transformer looks like you know you have the so call core you know if you see the core this we call e core. You know you will have transformer looks like this core actually you have the core you know you have this one then you will have bobbin in fact you will wind wires in fact here this is how the wire is wound and then to close the magnetic path. You have I so if I put a c here for example, the a c is applied here then magnetic field actually complete the path it comes like this then other half actually goes like this and then goes through this and then complete the path like this and this half actually comes like this and completes the path.

So, if you see a general structure of the transformer this was happened. So, we will wind here and then magnetic field actually goes like this and other half it goes like this. Now, new winding a transformer then officially two question will coming namely how many turns I have to put? Then what is the thickness of the wire that I have to use? These are the two things when are to design in the transformer design because if you see our regular power transformer the structure of e i core is the standard one. And then this is the silly the material all so three different types of materials available the core material.

Say for example, you have one C R G O is there the second type is a C R N G O type core is there and third type is called dynamo break. So, you have the three types of cores are available in the commercial world that is see this is cold rolled grain oriented. You know C R G O means cold rolled, this cold rolled grain oriented this is cold rolled non grain oriented this is you know there is no cold rolled in normal silica steel actually core. Now, this is actually superior quality the core loss is less and then you have little more core loss and this has much higher core loss.

So, if you take these three gates of cores are available. So, any of them can be used only the heating will be slightly different like. Now, undertakes for example, C R G O cores we take and then if I put the turn correct number of turns and thickness of the wire correct then you act as a transformer. But if you look at the core in three dimension then this looks like this you know I will normally this is one and then you will stack them. You know we will put the many is one after another is put and then you get three dimensional view of that you will get and normally the transformer is made such a way that you know there is no air gap in filling this here.

In the figure air gap are come, but in actual case there is the very small air gap comes it is a stacked such a way that this and this perfectly jointed. Now, how many number of turns I have to put that is the main question? So, the question is how many number of a turn (No audio from 10:47 to 10:52) that is the question. Now, if I apply a voltage you know if I have a coil you know if I apply a voltage to that then there is the flow of current through the coil and that actually determine by what is the inductance of this coil.

So, if I have inductance L, then I know that current through that is nothing, but v by j L omega l omega is the endurance and F is the frequency and then two phi F comes omega. So, the current flowing through this is given by this if the L is more obviously, small current will be flowing then then there will be a current flowing through this that produce a magnetic field. That means, if I connect this then current is flowing through that produce the magnetic field. And that magnetic field goes through this in fact it is mu r time it is multiplied and you will have the magnetic field.

So, if I put for example, very low L that is less number of turns I will get the very low value of L then you will have too much magnetic field that will generate that together to much current. And then you will find too much magnetic field is flowing through that this core as one problem that sense the magnetic field if increase the current here. The magnetic field will increase for then if you continuously increase the current after some value the magnetic field will not increase. The core cannot take more than the particular amount of flux that is for example, if I take C R G O core that say it can accept only flux instead of 1 tesla.

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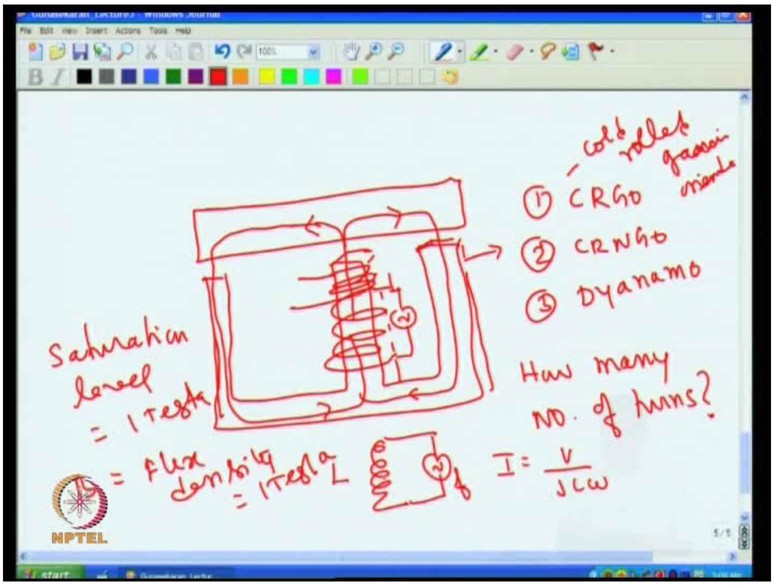

So, we call the saturation flux density what is the saturation level. So, saturation level is 1 tesla that is the B should be less than one tesla flux density B should be is 1 tesla. So, if the current is large then the magnetic field will not increase after 1 tesla so that we called saturation saturation of the core. And we should never allow the core to saturate because if we allow the core to saturate the voltage may be changing. But then the magnetic flux in the core will not change if there no change in magnetic flux then to get the secondary voltage we will wind in this secondary here and we try to get the voltage here.

If there is no change in the magnetic field the no induced voltage will come and this and also if there is no change in flux here. This coil itself will have no self induced voltage will not come in this coil. And that will make large current flow even in the primary and that will actually make that large current flowing through that short the voltage source itself. So, we should never allow the core to saturate if once the core saturates then the voltage source will be short circuited and then the large current will flow through that in fact the coil burns up and you will also get no induced voltage in the secondary.

So, it is very important that I should select the number of turns such that I will get the flux density which is less than saturated flux and if I exactly design for example, if the core can take 1 tesla maximum. The saturation flux density level is 1 tesla than it is good if I design such a way that maximum flux that I will get in the core is 1 tesla that means I will be using the core very effectively and that is the best way to design the transformer.

So for example, if I fix L and then look at then I go back to calculate the core saturating are not that is the round off have doing and then it is not it is also very difficult to cut to arrive at the correct number of turns. And then also we at again check flux is saturating if it is not saturating again you to come back and design change the L. So, if have doing that way so the basic basically what is done in the transformer design.

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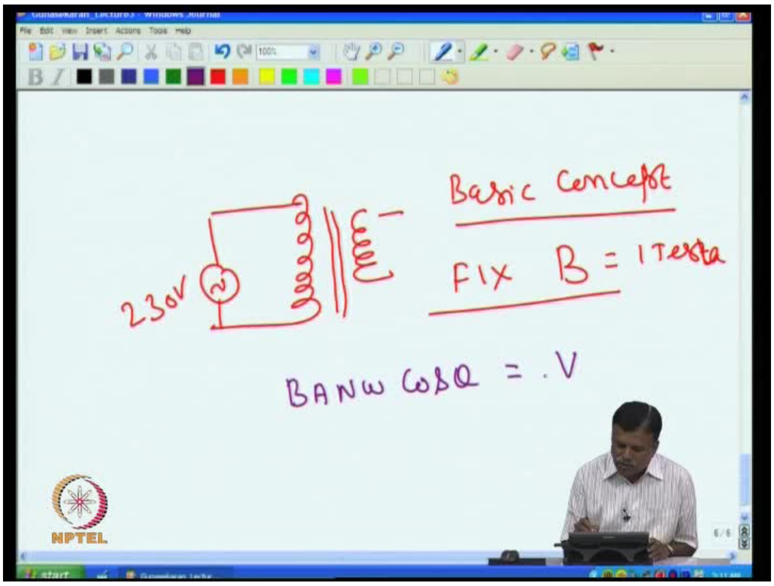

I will wind the number of turns I will put the number of turns such that if I connect the applied voltage say in this case 230 volts. I am going to connect the primary if I connect 230 volt then assume there is the whether the load is there or not in the secondary. I will first make sure that the flux generated by this coil in the core is exactly 1 tesla that is the saturation level of the core.

So that is the basis of designing the transformer you should not fix L and design the value of N. So, the basic concept basic concept is fix B there is that is equal to 1 tesla there select N number of select the required number of turns such that when it is connected 230 volts for example, it produces 1 tesla field on the core. So that is the basic ideas of design in the transformer that means I have to select N so that it produce 1 tesla now what is the formula that to be used we know that this classic V so for example, B A N omega cos theta if I take.

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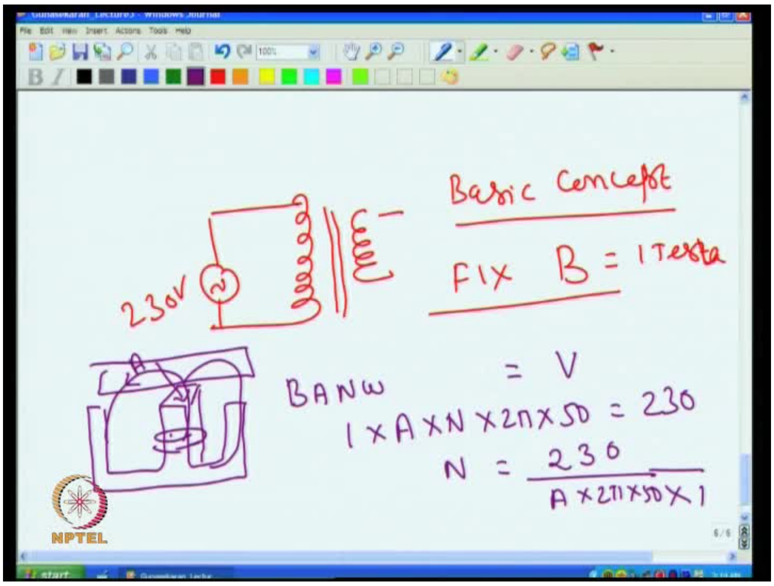

So, for example, the basic formula is B A N omega cos theta is equal to V the induced voltage in any coil is given by this formulae. Now, at at the maximum then we can take cos theta is 1. So, I can remove this term so this is the basic relation cover in the voltage induced that is if I have a coil of N number of turns then if I apply frequency of omega and then frequency says 230 volts then what is the B? That is generated here that is given by this background this case I want 1 tesla.

So, B is taken as one and area of the core that depends on the core size also you that then this N number of turns I have to put this case 2 phi omega is 2 phi F which is 50 hertz and applied voltage is 230 here. So, I applying 230 volts 50 hertz fields then I want to 1 tesla V to be generated. Now, I have left to the two quantities A and N that is N is the number of turns that I have to input and a is the area of the core now. What is the area of the core? Now, area of the core if you see carefully that our actual core what we used e core. (No audio from 18:16 to 18:22)

You know we are winding is here that core this is the area of the core here only the magnetic field is generated and this is the area of the core that that actually fixed in this. So, we know the if I know the area of the core then I know all the parameters. So, N can be determine so that means number of turns is required is actually you have this divided by that area into 2 phi into 50 and that the field B is 1 tesla. So, one can depending upon the area of the core you had select the number of turns are required. That means if I put that many number turns here and if I give 230 volts 50 hertz then I am sure that 1 tesla field only will be setup in this core.

That we at seen our earlier this thing that you know the magnetic field goes like this and we will find that here 1 tesla field that the flux should be only 1 tesla here also one tesla and the core will not get saturated. And we are also utilize in the core fully because if I do not setup 1 tesla field that may I am not utilize in the core fully. So this is the first principle that we are to look in to that to in design in the transformer then once the number of turns are decided then I should see what is the thickness of the wire that I have to used so, the next question is that what is the thickness of the wire to be used.

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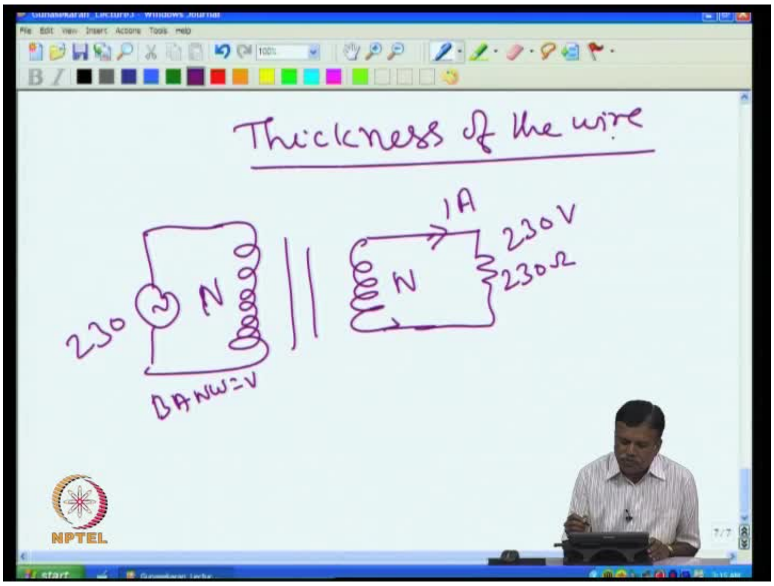

So, (No audio from 19:52 to 20:00) now going to that we should see little about the secondary circuit because this is the primary. And you have the core and then you have the secondary voltage assume it is 1 is to 1 transformer. We have N number of turns here if I put N number of turns here so N number of turns is decided as a set using these formulae. So, you know you are selected the N number of turns. So, if there is secondary one is to one and here also put N number of turns suppose, if I connect the load if I connect the load then what happens we can because now if I applied the voltage here that actually produce the magnetic field. That is the current, that produce the magnetic field that magnetic field is changing magnetic field so that induced the voltage here.

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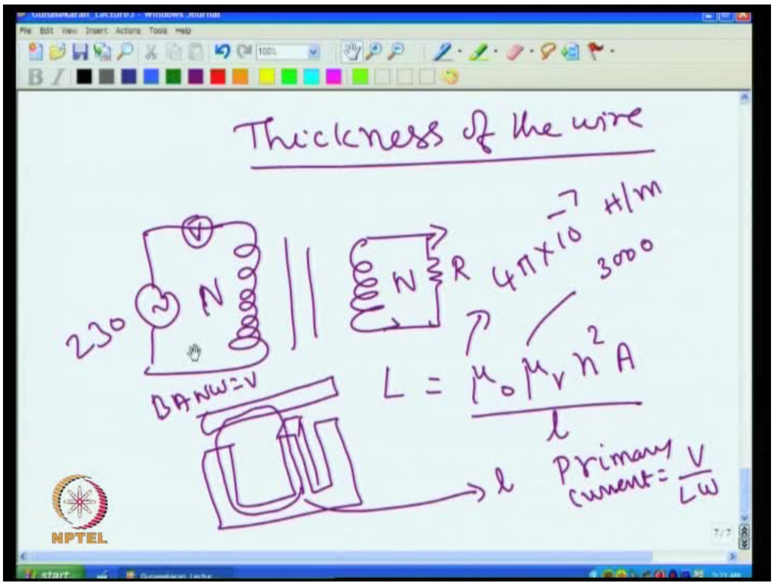

Now, the induced voltage it is one is to one transformer so if it is is 230 volt I know that I will get again 230 volt here. Now for example, if I put 230 ohms then I will have a 1 ampere current here. Now, secondary current is known the next question is what is the primary current? Because depending upon the current only we are to select the thickness of the wire that is what we are seeing now one important thing in transformer is for example, if there is no load in the secondary. For example, I will put nothing is there you know I keep it to open here you know the secondary is open there is no current here then only primary is connected.

Now, there will be a current what is the current that current is the one which produces the magnetic field in the core. Now, why that current is coming because if I two ways of looking at it if I have N number of turns then I know the inductance of the primary is given by this. That is the you know a a is the area of the core because I had shown you in the what is the area actually? So, you have this is the area of the core now here the L path length L is actually this you know you start here go like this and go like this and enter that is the L.

So, you know the two rounds so one of them to be taken so that is the L that is where a that is path length of the magnetic field. So that is the value L and mu r invariably for this core around 3000 for the C R N G O core or C R G O core. If we take this is actually coming as the 3000 the mu not is known that is 4 phi into 10 power minus 7 Hendry per meter. So, we know already your site at N and we know L all the quantities are known so one can one we can find out what is L.

So, if L is known then primary current will be the primary current can be determine primary current current actually is given by V by L omega. So, since L is known the frequency known one can find the primary current. So, if the secondary is open there will be a current flowing through this that we called as a magnetizing current and that current is given by V by L omega this current is invariably very small that is the one which produces 1 tesla flux.

In this now you may be wondering you know why only that much current is flowing if I have connect the inductor you know why only is small current. For example, if the inductor is few entry in the normal transformer is 230 volt a c fine only few milli ampere current is going through this. This is happening because of the self induction because when current is flowing through this and then this is a c current so this current flowing through this this a c voltage.

So, current flowing through this you know the current flowing through this is also a c so the magnetic field setup by this is a c that change in magnetic field induces voltage l as well as induced in the here itself. So, this is the self induced voltage this actually mutual induced voltage. So, when magnetic field changes it induce the voltage here and as well as here, but this voltage will always equal to the applied voltage. And this is this initially always oppose is that of operate voltage and always it will be equal to the applied voltage. And this is the one which are opposes this that is the why you know current flowing through the primary is very small when there is no load in the secondary.

Of course, when you load the secondary for example, if I connect load here resistance r then there will be a current here this current will produce a magnetic field in the secondary. Now, the secondary magnetic field is opposed that of primary magnetic field. So what really happening is if I connect load in the secondary then there is a current in the you know now there is a current in the secondary coil. So this current in this produce a magnetic field since this and this are coupled. So, if more current flows here then you get more magnetic field generated because of this and magnetic field generated by this and magnetic field generate by this due to this you know this when the primary have already some magnetic field generated.

Now, because of this primary current there is the magnetic field generated by this and this magnetic field is opposite of this. So, this magnetic field cancels of primary magnetic field and net result is since reduce the magnetic field. Then again more current try in to flow through this and the more currents flowing through that producing again more induced voltage and which always is trying to match with this.

So, net result is when I load this then you will have magnetic field cancellation and then to get back the original field more current now goes through that. So, other way around if I load here more then I will find more current is flowing in the primary also, primary current consist of two currents one is the magnetizing current that is when there is no load here. What is the current that is flowing then second one is if I put a load then the load current also reflected in to the primary. So, you have two components one is the magnetizing current other one is the secondary reflected current. So this should be understood clearly because (No audio from 26:55 to 27:13)

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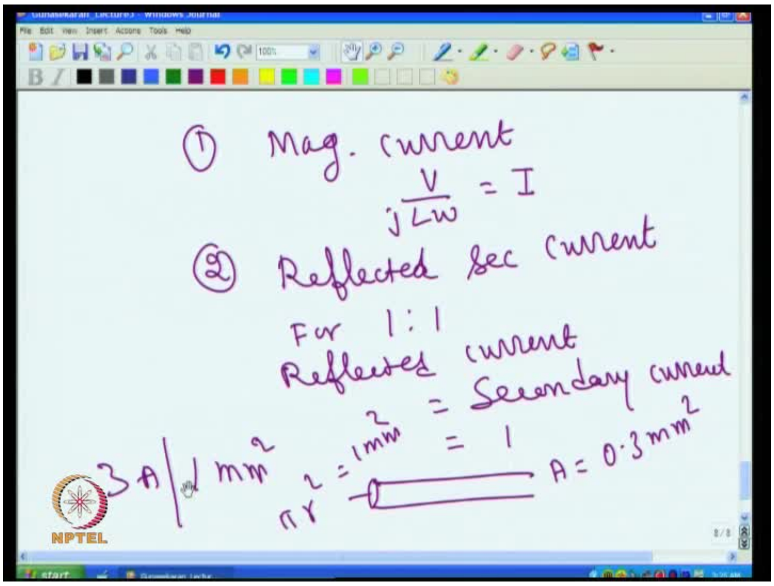

The two point that is primary current consist of two parts one is magnetizing current, magnetizing current that is nothing, but V by L omega in fact j L omega indicating that the current is 90 degree phase shifted with respect to the applied voltage. And the second component is reflected secondary current. So, the two components now the reflected secondary current for example, if it is 1 is to 1 for 1 is to 1 transformer for secondary or primary are 1 is to 1. Then the secondary reflected current equal to the reflected current equal to secondary current for example, if it is secondary current is 1 ampere, then the primary reflected primary current also 1 ampere.

So, you will have this 1 ampere that is if the secondary current is 1 ampere then the primary currents consists of the reflected current of 1 ampere plus. The magnetizing current which is normally very small may be around point 1 ampere. So, the total current will be secondary current plus this one normally, we can neglect this current in considering the transformer because this will be invariably very small. So, in this case I had to design I had to in this transformer. I have to see that primary turns; Primary turns turns are taking at least 1 ampere plus this 0.1 ampere neglect this. 0.1 the primary wires it able to carry 1 ampere current of course, the secondary wires also at carry 1 ampere because this one is to one transformer.

So, I have to select the current the thickness of the wire corresponding to 1 ampere. So, the look normally for the to avoid over heating how we take for 1 mm square 1 mm square 3 ampere current. We take that is if I have a wire you know we are winding the wire then we have cross sectional wire if I take if this phi r square is 1 mm square then I have pass 3 ampere current it is for 1 ampere. I need 0.3 mm square cross sectional area so that is the area of the wire that I need.

So, I have to select the thickness of the wire such that the cross sectional 0.3 mm square then it carry 1 ampere current and transformer will not get heat it up too much. Now, this 0.3 ampere per mm mm square the practical value because we know that the transformer can go only above the certain temperature based on that we are fixed this this also can be seen in detail a impossible, but later time.

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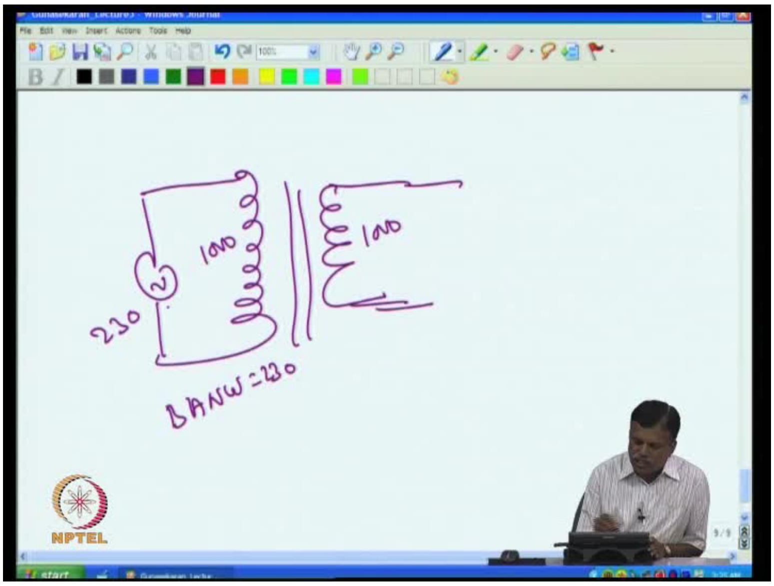

So, this is how the thickness of the wire and the number of turns to be selected. So, in some if you see that if I am designing a transformer then I will select the primary number of turns N and then I will select the secondary number of turns. Of course, one primary selected secondary automatically decided because if the if this is 1 is to 1. For example, if I end it up with 1000 turns here and if you want 1 is to 1 then I put here also 1000 turns. And if I want to step down half here are 230 volts I want 115 volts then 1000 turns here arrived at that N arrived at using this formulae B A N omega equal to 230 using this. We arrived at N for a given a and then if the step down of half required then I will reduce this to 500 turns then if here 230 I will get you know if I put 500 turns here.

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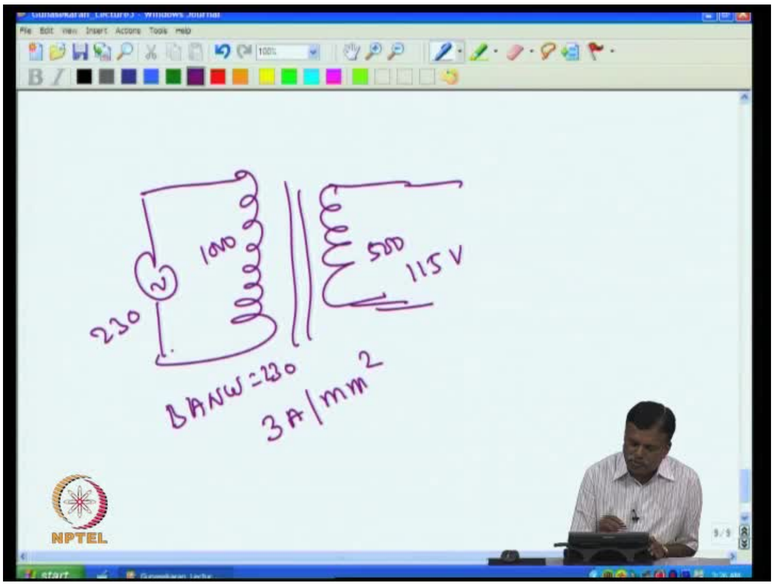

Then if I put 500 turns and I will get 115 volts here. So, N number of turns of this decided then automatically depending on the requirement of secondary voltage this turns is decide then the thickness of the wire. So, thickness of the wire is decided by taking 3 ampere per mm square. That means I should estimate what is the primary current? What is the secondary current? If it is for example, in the previous example we arrived at 1 ampere primary current that 1 ampere means I need 0.3 mm square of wire to be put. The secondary also if it is for example, in even our earlier case we are taken this also thousand turns.

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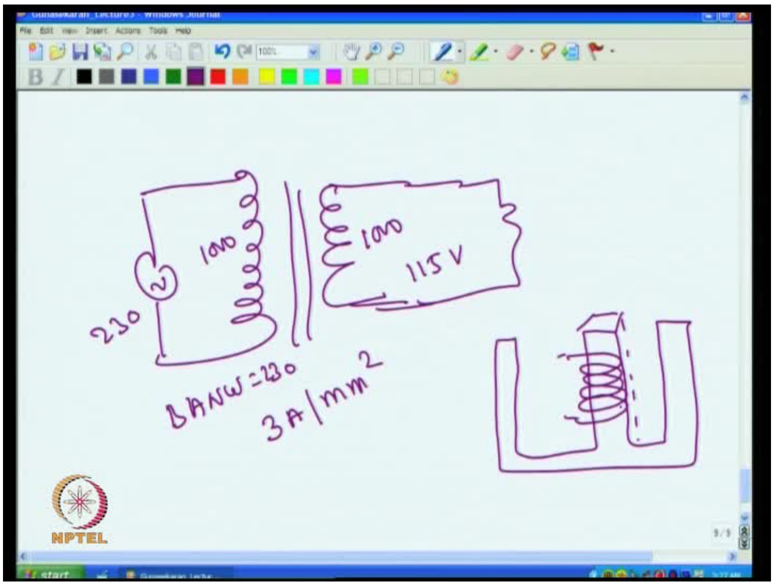

In that case if one ampere load is there, then here also 1 ampere. So, here also needs 0.3 mm square so that is having the number of turns are selected. Now, one question arise that if I you arrived at this N number of turns on the thickness will the core hold that number of that turns because you know when your winding you know we are winding. The you know if you see the how the core looks like this I said we are winding it here. So, this core must able to take this many number of turns of that much thickness that one can find because I know the diameter of the wire. So, I will know how many turns that it can take for example, if i carefully draw this you know see for example, take the core.

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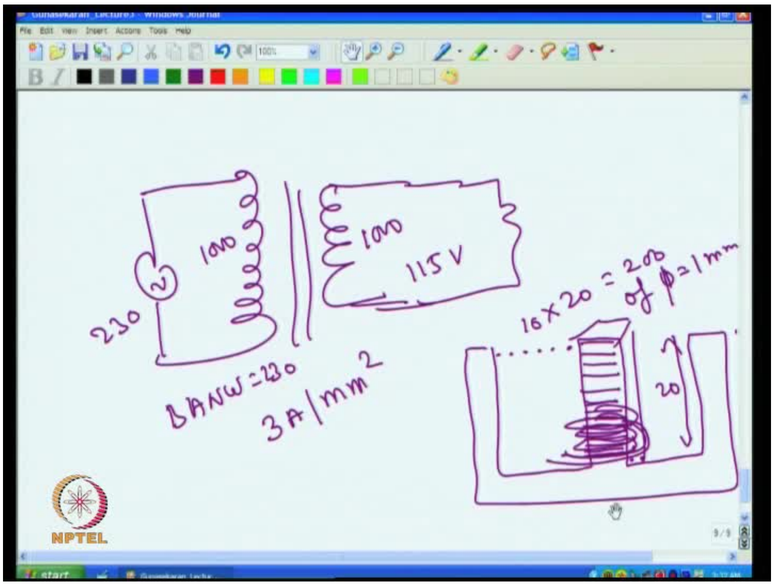

And draw this one can easily verify at the number of turns that we can take (No audio from 33:22 to 33:37) for example, if I putting you know one turn then it occupies one diameter length so if you I can ask how many turns at one layer can take. So, if this length is take 20 mm then if the diameter diameter is 1 mm then it can take 20 turns in one layer. So, we are winding like this. So, it start 1 then you will able to put 20 turns because this length is 20 mm if this is 20 mm diameter diameter of the wire is 1 mm then it can take 20 turns.

Then next question is next layer I will wind the next layer is here, the next layer will be wound, then third layer will be wound, then fourth layer will be wound that means if i see how many layer it is can take. So, if this is each one is 1 mm then each layer it can take. So for example, if this is 10 mm then it can take 10 layers that means 10 layers on the each one each layer can take 20 turns 10 into 20 that means it can takes 200 turns of 1 phi is equal to 1 mm. The diameter diameter of 1 mm wire it can handle 200 turns.

So, one can always verify whether the given core will take that number of turns or not because we at we know that half the transformer half the transformer is occupied by the primary other half we are allot it for secondary. Because the total you know the area occupied the secondary is equal to total area occupied by the primary. So, normally we allotted half the area for primary other half for secondary. So, one can always verify from this whether the transformer can take this number of turns or not if this not taking then we are go to next higher size.

So, once we go to next higher size the area will change and then turns also will come down then this this your this distance and this height will be different accordingly it can again verify whether it takes. So, this is the easier way of doing this in the academic environmental, then actually in real world what they do is they know the core size. And once you know the core size then you knows how much wattage it can handle and connect to the wattage select this that is what you will see the text book and all other design books.

And there is no compulsory role are to follow that route only it is easier to follow the route at I had shown to you because you have the core in the academic environmental in your hand. And further core you can always find out whether the given wattage can be obtained and other ways you can go to next core or if you want go academicals in the commercial way. Then also you know if you have different size of core one can always find out. How many turns it can we handle and how much power it can because you know if for example, in this case it is the 200 turns it is handling and then I know the current rating off how much by you taking 3 ampere per mm square how much current. The wire can take in that case I know the current rating and then the voltage rating I can decide how power the core can take.

So it is only just think about this apply your mind and you will immediately see that the transformer can be designing in both ways. So, the way I had discuss shown to you is good for the beginner and then particularly good in the academic environmental. So, follow this and if you have a if you look at the text book or the transformer design books invariably follow the reverse of what I have told you. And in fact that not help and we found that understanding is more difficult going the text book route.

So, you can kindly follow this route and then if you want the reverse work and see whether it fits in, but nevertheless both will give you the same result. So, need not worry about that this is have the transformer to be design and I will explain this transformer design at this point of time. Because we will be using this at very many places in analog course because for example, we will be using l v d t there we are to wind the coil. We will be using current transformer to sense the current there we are to wind the coil and we will be using a filters there we need a inductor there will be designing this.

So, all along the same formulas will be used and as an analog circuit designer in fact as electronic engineer it is the must that one should know how to design the transformer otherwise you will not became a good electronic designer. The reason is that you will be using at very many places and it will be like your half the hand is cut if you are not knowing how to design the transformer that is why I had spend this much of time in explaining how to design the transformer.

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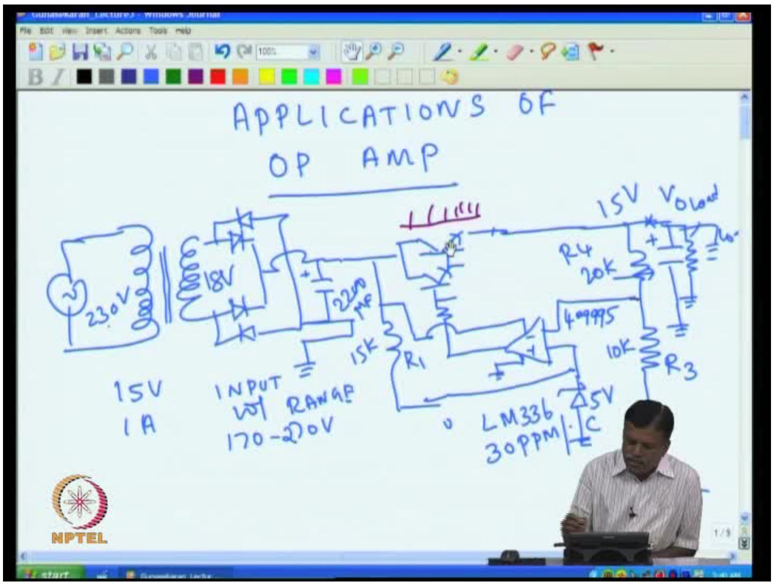

So, once you know that design the transformer then of course, you can either design are get it done by given by the aspect nevertheless for a regulator to work ,we are to fix the transformer first that you can do it either way you are design it or you buy it. Now, if you go back our actual design of regulator, then another issue that we are see would be how to select the heat sink here because you know we have a this transistor here. And now this transistor invariably heats up for example, this heats up and then once it heats up the temperature of the junction will go up. And we know that in transistors if the junction temperature goes more than 150 degree the transistor goes bad.

So, we at make sure that this transistor works as we like and because of you know heating this transistor will not go bad. And there another issue that you know the if I take this transistor for example, when I load this then it is heats up if there is no load then the very small current is flowing through this and transistor does not heat up. Because in normal case for example, if the input voltage you know if the input voltage here is a 25 volts the output is 15, then you will have 10 volts across this. And if 1 ampere current is flowing through this then you will have 10 watt of heat dissipation on this transistor.

If 10 watt heat is there then it will be heating up of course, if the load current is not 1 ampere if I increase the resistance the load currents comes down then the heating comes down. So, depending upon the load the transistor heats up, but what are the case it make sure that the transistor will not to go bad or the life of the transistor not getting reduced because of the heating. Now, I introduce the term life of the transistor because if the heating is more than the life of the transistor less this is because you know when assume that this is here using it for a t v in the t v what happens? You will be switching on the t v and watching program in the morning, in after sometime it switch it off at that time you know this would heat it up the junction would have gone some temperature may be 100 and 120 degree.

Then you switch it off and go back and noon time you may be switch on the t v again and watch the program again the noon time this again will go back 120 degree. And then switch of this also comes back after sometimes to room temperature, then night again you will switch on and see the program and again this temperature will go high say 120 degree and come back to room temperature. So, if you see t v typically there will be a 3 thermal cycles the temperature goes up and comes back and noon again goes up and comes back and again in the night goes up and comes back. That means, 3 times it heated and cool in a day that means in a year roughly 1000 times heated up and cooled.

When these times heated up then inside you know the connection who connecting wires and then the silicon everything heated up and there are stretched and cools down. It is comes back every time in heating and cooling there is thermal Fedics develop inside then after several cycle the wire bonding actually breaks inside. So, how much the thermal cycle the transistor can withstand depends upon how much temperature it went and how much it comes back.

So, the delta t is very important so if it is morning it went to 120 degree and come back 20 degree means the thermal cycle 100 degree temperature change occur and it bonding wire inside expanded and contracted. So, if it is for example, if I operate the transistor say a junction temperature 150 degree so that is what maximum allowed then you will find the transistor goes bad in above 200 to 300 thermal cycles. Where is if he operates the transistor at 100 degree c there is limit the junction temperature 100 degree c, then this comes even more than 10,000 thermal cycles if I operated 80 degree it goes even more than 1 lakhs thermal cycles.

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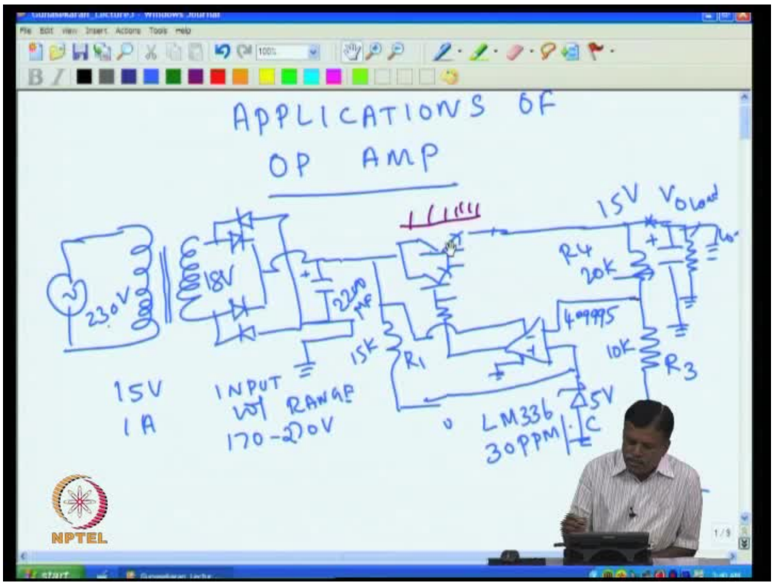

So, it explantially, life increases if I reduce the temperature. So, I should never try to I should never attempt to operate this at 150 degree. In that case the life will be less for example, if you design this this transistor such that every time it switch on the temperature junction goes 150 degree. Then probably if you are using in t v in three months time your t v had go to for servicing because this transistor would blown up.

So, depending the because this transistor that voltage regulator decides mainly design the life of the equipment very critically. So, one have to think what is the life of the equipment and how much the junction temperature that I to keep and then if I reduce the junction temperature. What I have to do? For example, if I want to keep it too much cooler then what I do is I have to put it in the heat sink. So that the heat goes out and the junction is kept at much lower temperature and the heat sink place very crucial role in designing the life of the equipment. For example, if it is the defense equipment where only ones it for example, if it is a missile then you fire the missile it is goes and heats get destroyed once for all.

So, the life is only once. So, there I need not design the junction too much lower temperature that will if I if I have to design per much lower temperature I know I have to put a heat sink and the heat sink size is bigger then will the equipment size will go up. So, depending upon the life that is required for the equipment I have to decide on the heat sink and then the junction temperature because heat sink ultimate decides the junction temperature.

This is the very important thing for any circuit designer particularly the for voltage regulator is very important because the voltage regulator is the critical path equipment where most of the heating is taking place. And that decides the life of the equipment because if the voltage regulator fails then the whole equipment fails. So, depending upon the junction temperature higher to design the heat sink assume that I want life of say one like 1 lakhs thermal cycle then I want to keep the junction at say 100 degree c then assuming that let us design the heat sink now.

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So, heat sink design you will look into that little carefully because

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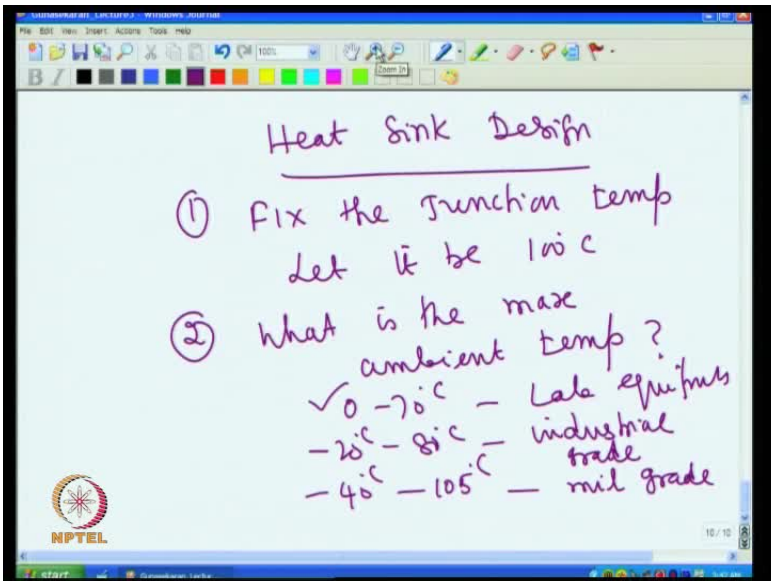

Heat sink design is very important for an analog circuit you will have to use the heat sink at very many places. So, first fix the first fix the junction temperature (No audio from 46:30 to 46:36) explain to you that depending upon the usage and what is the life of the equipment? We had decided on the in this case let us assume let it be 100 degree c then the second step is what is the maximum ambient temperature. (No audio from 46:54 to 47:04) What is the maximum ambient temperature?

Because you know the equipment are to work in ambient and then if I put a heat sink, the heat sink basically radiation to the ambient and depending upon the ambient temperature only you will have the heat sink size. For example, if it is laboratory equipment is the ambient expect ambient temperature is 0 to 70 degree for lab equipment. Is then for industrial grade equipment is minus 20 degree c to 80 degree c for industrial grade equipment. Is then for mills that we have minus 40 degree c to 105 degree c, they are mil grade equipment for military application we need a much higher temperature.

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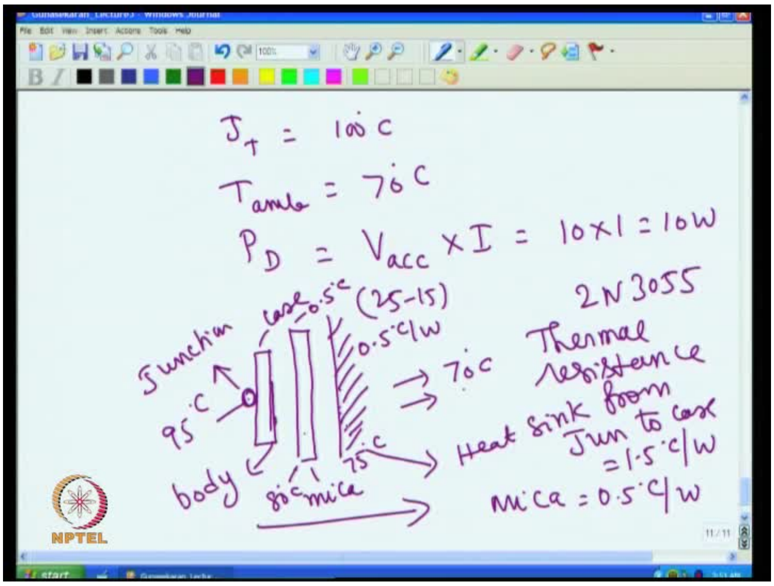

So, we are to select which what is the operating ambient temperature? Let us take in this case we are working with the lab grade equipments 0 to 70 degree c. That means by maximum temperature ambient temperature going to be only 70 degree. Now, if I take that is the case then that means we are now fixed the two things that is junction temperature supposed to be not more than 100 degree c then the second one is ambient T, T ambient is actually 70 degree c.

So, when the ambient is 70 degree c the junction temperature should not go more than 100 degree c. Then next thing I should to design what is the power dissipation on the transistor power dissipation power dissipation is voltage across the device voltage across the series pass transistor into current. So, in this case if the input is 25 twenty five output is 15, 25 minus 15 there is the 10 and if it is the 1 ampere current and then it is 10 watts. So, I have to desired on what is the power dissipation that is the that we are taken as ten watts.

Now, we had to see how the transistor mounted in the real world. So normally, what is done is we have the transistor and all the power transistor invariably you have a junction here you know the this is the junction here this is the case of the transistor. Then so whatever heat that is dissipated here the 10 watts is dissipated here and that has to come to case. Now, from the case what normally we do is we will a put mica actually insulation to insulate the heat sink we put mica here then we will put the heat sink. (No audio from 50:06 to 50:16)

So, basically what really happens is in the junction heat is develop for the junction heat comes to the body of the transistor. So, this is the body of the transistor which is invariably collector in case of power transistor from the body it goes through actually that be a small gap here. The small gap here this is normally filled with heat sink components. So, this why I will just showing here, but normally filled with heat sink components so the heat was comes from here to here, then here to heat sink and then heat sink to ambient so ambient is sitting at 70 degree c.

So, heat dissipation is eventually, from the heat sink, but then we know that heat has comes from here to here through these things and from here has to the radiated out to the ambient. The heat had to go means that means of temperature difference that means if this is 70 degree the heat was to be radiated by the heat sink. Heat sink will be more than 70 degree the heat sink then this mica has be more than heat sink then the case must be more than the mica then junction must be more than the case because the heat is flowing like this. That means this is higher and the case is little lower, then this is little lower, this is little lower, this is little lower, than that that means officially junction will be that is the heat sink will be more than 70 and this fellow will be if it is 80 degree.

Then this will be more than 80 and if this is 85 then this will be more than 85 and if this is a 90 and this will be go more than 90. So, all that we need to use that we at make sure the junction is not more than 100 degree c for that what is the heat sink size I have to select. Now, if I look at the data sheet for example, if i take data transistor say 3055, 2 n 3055 is the I power transistor general purpose transistor which available for the normal use very easily. Now, if I take this look at the data sheet it gives one data that is thermal resistance between thermal resistance resistance from junction to case is it 1.5 degree c per watt. That is what is the thermal junction took at that is if I dissipate 1 watt of heat in junction then that 1 watts has to come here. You will find the case and junction will differ by 1.5 degree that is the case will be 1.5 degree higher than the junction.

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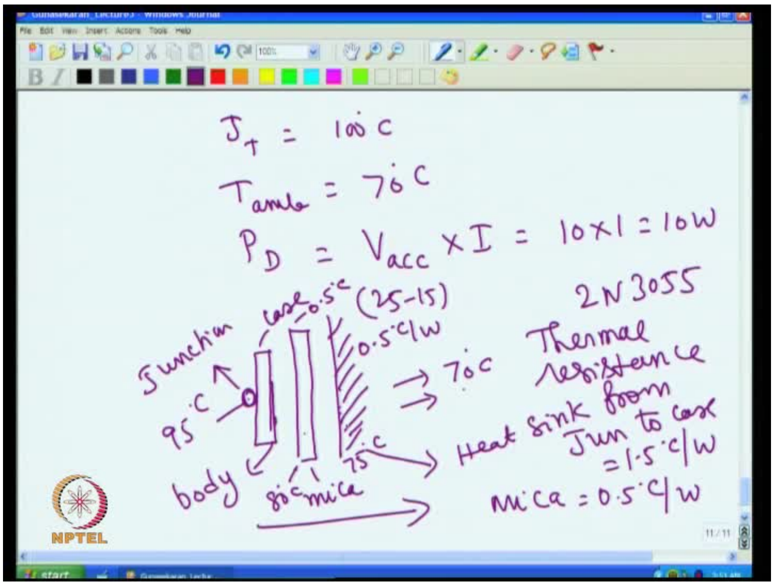

So, if it is dissipate 10 watts then the case will be 15 degree higher than the junction then similarly, I have to find out. What is the thermal resistance of the mica that is the insulated? So, mica thermal resistance is 0.5 degree c per watt, then similarly, that means this is 1.5 this is 0.5 that means 2 degree temperature difference will be there. If it is junction and the mica for 1 watt of heat to go if 10 watt heat had to come then you will find this. And this differ by that is 10 watt heat is coming then you will find this and this differing by 20 degree c then from here you know that is this and this are at the same contact.

So, if I take the for example, if then here the heat what go to ambient. Now, if I put bigger heat sink bigger heat sink then thermal resistance from heat sink to ambient will be smaller assume I have to a put bigger heat sink because of heat sink size you can find out the thermal resistance from the data sheet of the heat sink. Suppose, if the thermal resistance of the heat sink is say 0.5 degree c per watt and this thermal resistance is 0.5 degree this is 1.5 degree. That means, total thermal resistance from here to ambient if I take 1.5 and another 0.5 for mica 2 degree and then another 0.5 for heat sink 2.5 degree is the thermal resistance from junction to ambient. That means, for 1 watt dissipation of heat here you need 2.5 degree difference between ambient and the junction.

So, if it 10 watt is dissipated here then you will find 25 degree difference between the ambient and the junction. That means, if this ambient is 70 degree then the junction will be 95 degree. So, here for example, 10 watt dissipation case this is 0.5 degree this is 70. So, 10 watts dissipate this has to go for every 1 watt 0.5 degree that means for 10 watt will be 0.5 degree higher than this will go to 75 degree. That is you know then only 10 watt will go because this dissipation is 0.5 degree c per watts. So, 10 watt dissipate you need to 5 degree higher than ambient then this has to 5 degree here again 0.5 degree temperature difference. So, 10 watt is going so this will go to 80 degree then from anyway this two are actually there is no gap here filled with the heat sink component.

So, this is case is at eighty degree then junction will be again 10 watt has to come this is 1.5 degree so for10 watt 15 degree difference required. So, if this is 18 degree this fellow will go to 95 degree. So, this is at 95 junction case is at 80 and mica is at case is at 85 the case is at 80 degree sorry because for10 watt 1.5 degree case is at 80. That is same as mica 80 then the from mica then it heat has go to this and this this fellow will be sitting at 75 degree and ambient is 70 degree.

So, we are to decide on the heat sink depending upon the junction where that we need I will discuss more about this in the next class. So, we are seen in this class two important thing how to design the transformer and how to design on the heat sink. Because unless you design the heat sink correctly the junction temperature will go high and the life of the equipment may come down. So, we have one or two more issues that we are discuss about the regulator before going to the other topic. So, thank you.