Electronics Enclosures Thermal Issues
Prof. N. V. Chalapathi Rao
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture – 15

Jensen model

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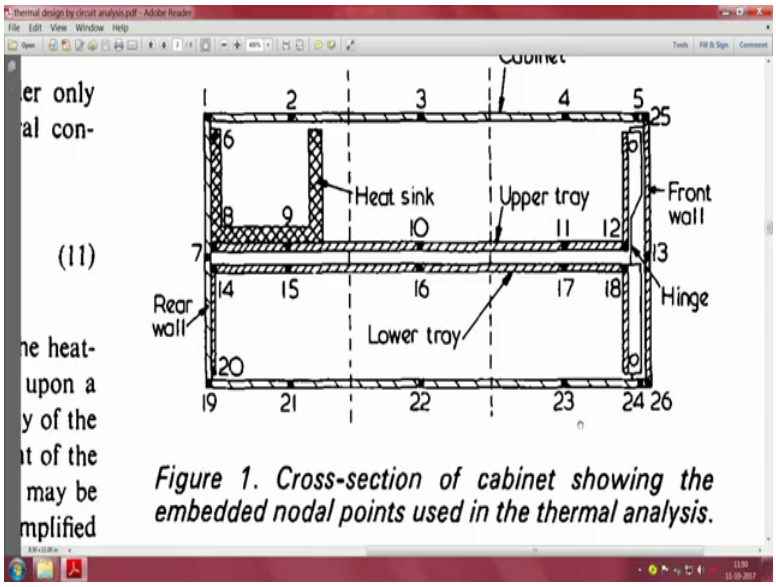

So, they have a small heat sink and we have a there is a front wall, then you know we have a what do you call trays and you know way have all the this is the enclosed cabinet inside. So, how things are attached to the thing, so we have a hinge which helps in you know probably lifting the heat sink, this door can be lifted and then this can be lifted out and we can see how things work. And on the upper tray, you have heat what do you call generating components and the lower tray we have other things mounted here and using this they have tried to make, you see here everywhere need sections are there. So, each point nodes are kept here saying that 19 starting at this all these points you know, total 26 nodes have been evaluated.

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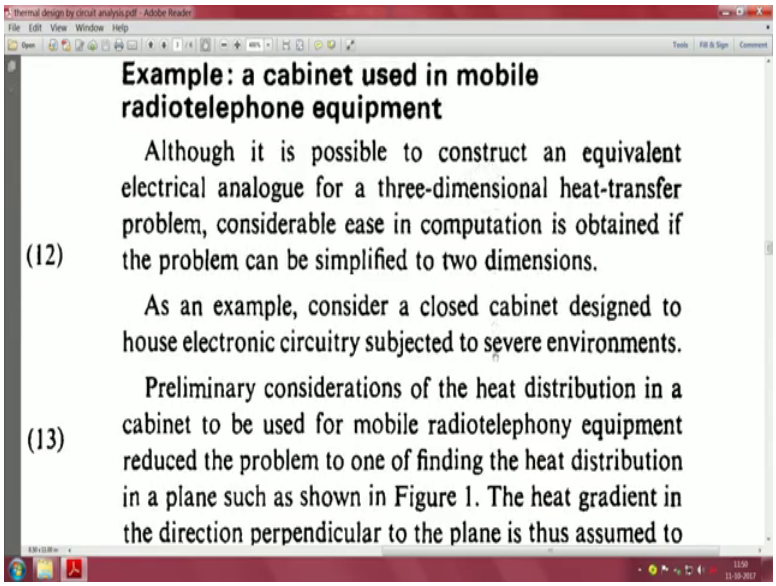

All that is possible to construct an equivalent electric analogue for a 3 dimensional heat transfer, if the problem can be simplified into 2 dimensions; can we read it again read it a second. This is, remember these are all early analysis way back 45 years back or even it may have been 50 years back when they are started the analysis ah, it was not easy. Right now, full 3 dimensional q f t type of things are possible to be solved perfectly ah. Next I have, may be in the next slot I will show you things from another what do you call, a commercial company. So, they said heat gradient in the direction perpendicular to the plane is assumed to be 0; it is not a very good approximation.

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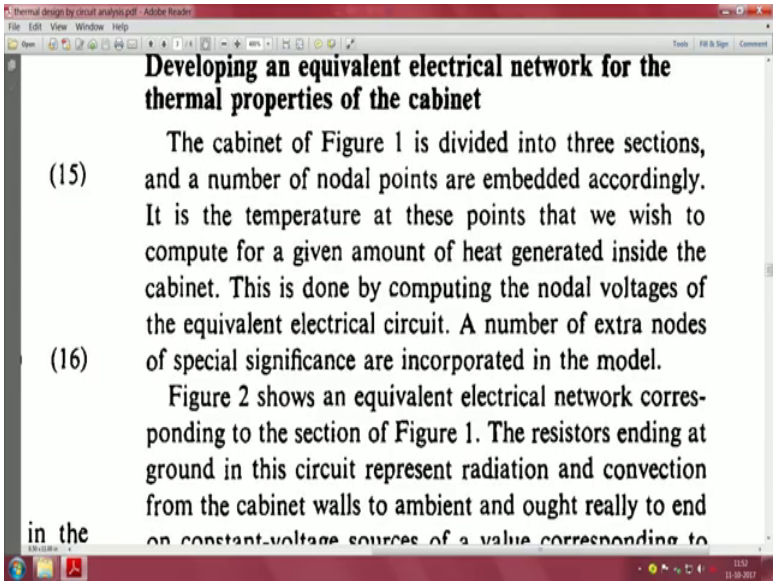

Oh sorry ah, just same thing which I had read out divided into 3 sections and a number of nodal points are embedded accordingly. It is the temperature at these point that we wish to compute for a given amount of heat generated inside, done by completing the nodal voltages of the equivalent electrical circuit number of extra nodes as special significance are incorporated in the model.

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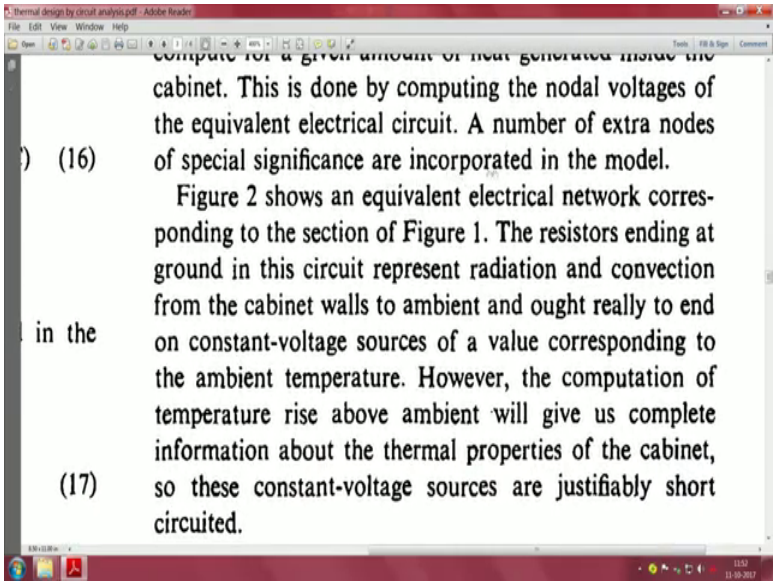
cabinet. This is done by computing the nodal voltages of the equivalent electrical circuit. A number of extra nodes of special significance are incorporated in the model.

(16)

Figure 2 shows an equivalent electrical network corresponding to the section of Figure 1. The resistors ending at ground in this circuit represent radiation and convection from the cabinet walls to ambient and ought really to end on constant-voltage sources of a value corresponding to the ambient temperature. However, the computation of temperature rise above ambient will give us complete information about the thermal properties of the cabinet, so these constant-voltage sources are justifiably short circuited.

(17)

So, I will now try to jump and I will try to come back, resistors ending at ground in the circuit represent radiation and convection from the cabinet walls to ambient really to end on constant voltage sources of a value corresponding to the ambient temperature.

The competition temperature above ambient will give us complete for information about the thermal properties of the cabinet; constant voltage are justifiably short circuit or not. Here we end up with a very peculiar this thing.

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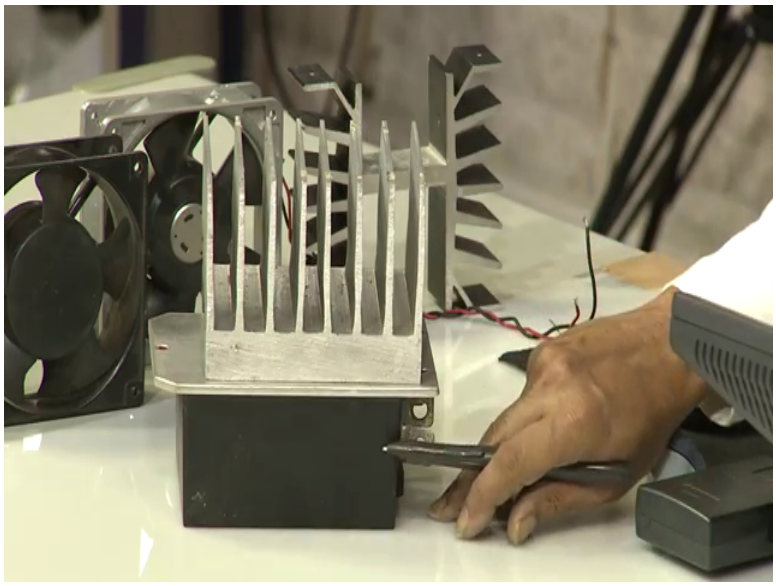

So, if you can kindly show me this, we have some source inside mounted here and then we have a heat sink unless the this spreader is above the ambient temperature, it cannot transfer any heat to the ambient and unless this spreader is much lower voltage than these, it cannot absorb heat from there.

So, the optimum temperature of this, what do you call convector is also very very critical. This is where no we need to do a bit of optimization if you make it very big and all that it is waste of material and increasing weight and cost whole thing. If you make it very small, they well this temperature is high and it can transfer effectively to the ambient. It does not the temperature differential here for you know heat transfer by conduction reduces. So, coming back to this again you see here, next one we will see the competition of the temperature rise above ambient will give us complete information about thermal properties of the cabinet. So, this constant voltages justifiably right now no short circuited.

So, assuming, this is not what do you call while it is not impossible ah, maybe I should make it a little smaller. I am not able to what do you call.

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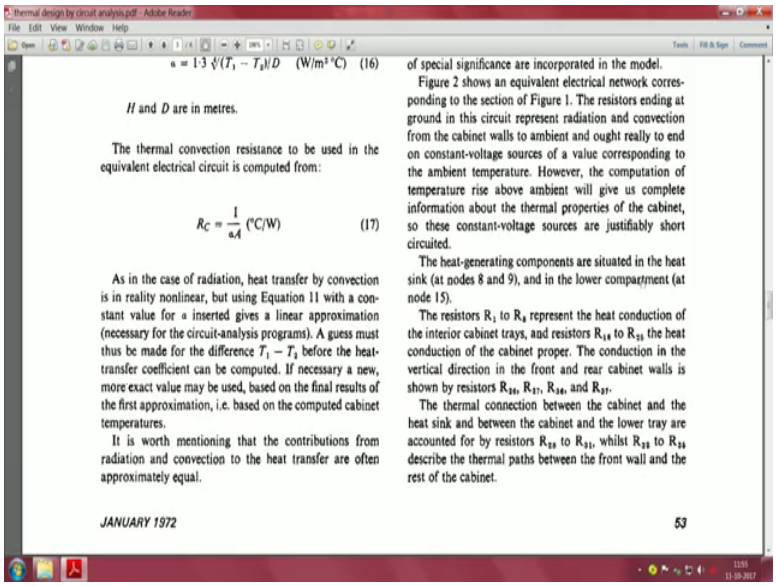

$$\alpha = 1{\cdot}3\sqrt[4]{(T_1 - T_2)/D} \quad (\mathrm{W/m^2\,^\circ C}) \quad (16)$$

H and D are in metres.

The thermal convection resistance to be used in the equivalent electrical circuit is computed from:

$$R_C = \frac{1}{\alpha A} \quad (^\circ\mathrm{C/W}) \quad (17)$$

As in the case of radiation, heat transfer by convection is in reality nonlinear, but using Equation 11 with a constant value for α inserted gives a linear approximation (necessary for the circuit-analysis programs). A guess must thus be made for the difference $T_1 - T_2$ before the heat-transfer coefficient can be computed. If necessary a new, more exact value may be used, based on the final results of the first approximation, i.e. based on the computed cabinet temperatures.

It is worth mentioning that the contributions from radiation and convection to the heat transfer are often approximately equal.

of special significance are incorporated in the model.

Figure 2 shows an equivalent electrical network corresponding to the section of Figure 1. The resistors ending at ground in this circuit represent radiation and convection from the cabinet walls to ambient and ought really to end on constant-voltage sources of a value corresponding to the ambient temperature. However, the computation of temperature rise above ambient will give us complete information about the thermal properties of the cabinet, so these constant-voltage sources are justifiably short circuited.

The heat-generating components are situated in the heat sink (at nodes 8 and 9), and in the lower compartment (at node 15).

The resistors R_1 to R_8 represent the heat conduction of the interior cabinet trays, and resistors R_{18} to R_{25} the heat conduction of the cabinet proper. The conduction in the vertical direction in the front and rear cabinet walls is shown by resistors R_{26}, R_{27}, R_{34}, and R_{37}.

The thermal connection between the cabinet and the heat sink and between the cabinet and the lower tray are accounted for by resistors R_{28} to R_{31}, whilst R_{32} to R_{36} describe the thermal paths between the front wall and the rest of the cabinet.

Heat generating components are situated in the heat sink and in the lower compartment. Resistors R 1 to R 8 represents the heat conduction of the interior cabinet trays, R 8 into the heat conduction of the cabinet proper itself. Conduction in the vertical direction at the front and the rear cabinets are shown by and so on. Connection between the cabinet and the heat sink and between the cabinet and the lower tray accounted by resistors describe the thermal baths between the front wall and the this thing.

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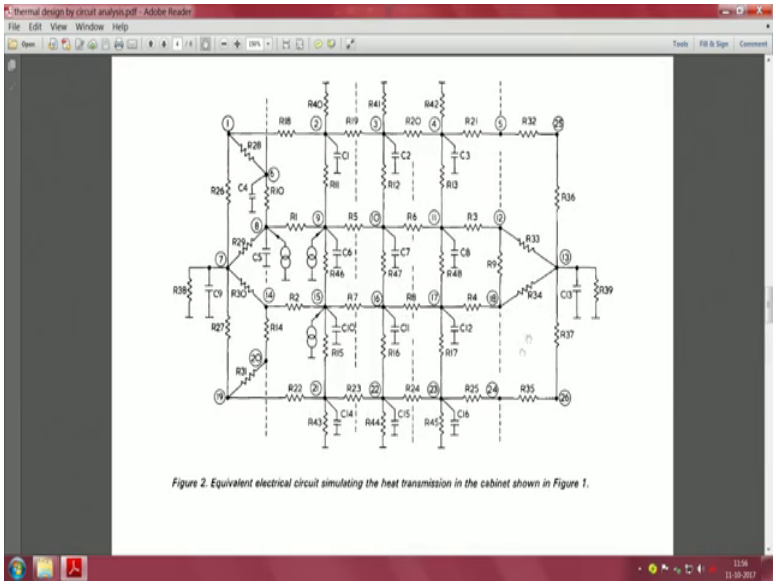

Figure 2. Equivalent electrical circuit simulating the heat transmission in the cabinet shown in Figure 1.

Now, coming here this is what he was talking about. So, I will give you a link. I suggest you take a printout and try to read carefully, equivalent electrical circuit you see here know this what you are starting. What you shown is ground are the things which are transferred to the ambient. So, if you remember in the old thing no, we had 26 and then we had 1 and then all these things no represent various types of what do you call conductions and so on. So, we have here no large number of sources which generate heat and they are transferred to the heat sink at the bottom. So, you have the capacitance and then you have various things which are related to this here. And from here onwards you know these are all much smaller. And then there is no heat generation you seen this no, these are all the heat generators inside the cabinet.

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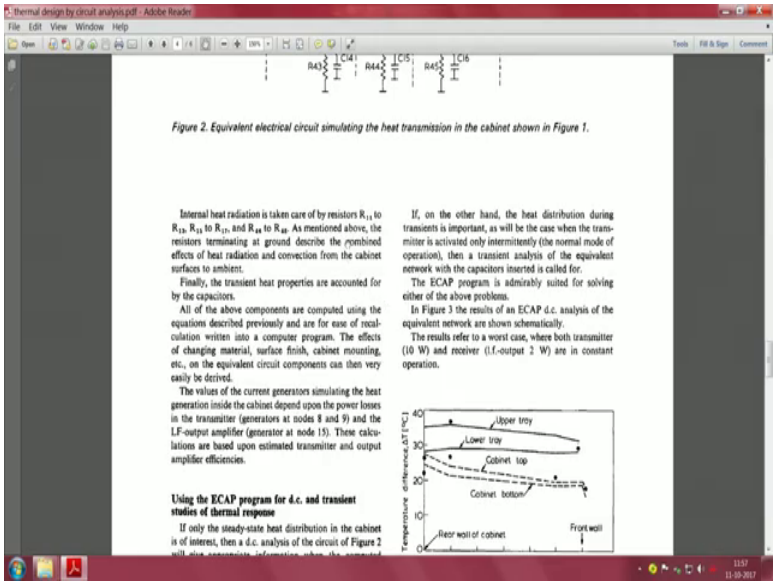

Having gone through this, resistors at ground describe the combined effects of radiation and convection of the cabinet, transient heat properties are accounted for by the probe capacitors are computed using the equations described previously and for ease of re-calculation written in to computer program. The effects of changing material surface finish cabinet mounting on the equivalent circuit components can then very easily be derived means, you can check keep checking the variables, values of the current generators simulating the heat generation inside the cabinet depend on the power losses in the transmitter and the output amplifier.

This calculations are based upon estimated transmitter in output amplifier efficiencies. This is what I had mentioned to you in passing in my vocal this thing, every circuit has a inefficiency. So, in my case I will try to see.

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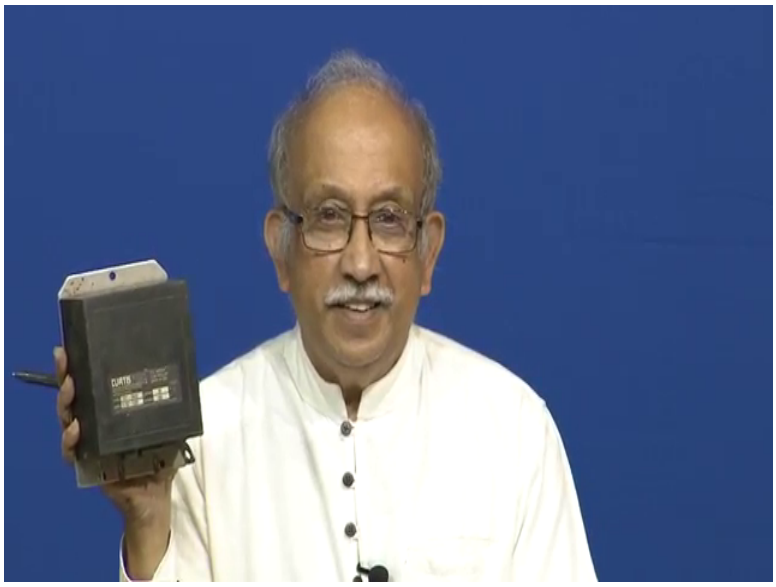

Now, just see here, it says it has a voltage of 160 amperes and then I am sorry current 160 amperes and the voltage of 36 volts. If I around it of let us say thirty volts at about 100 amps, this is supposed to be a 3 kilowatt, nominal you know, actually if you multiply 160 into 36 almost a 5 kilo watt device. So, we had actually used it you know something about 3 kilo watt. They have to they thing is what is the efficiency of it at all conditions, typically part load efficiencies.

We are still trying to see whether it during part loads which is the most efficient configuration electrical configuration by which you know, not long ago we are worried about power and we are worried over all about the other effects including current voltage and all right now, a lot depends on not just power, but the total energy efficiency of it. So, we are trying to complete it and hence the device here. So, I will notice here the power losses in the a transmitter section and the LF audio what do you call output amplifier, this calculations are based upon transmitter in output amplifier inefficiencies.

So, that is where actually the problem starts and the reason also why if you take a switched mode power supply, these days in the smaller and smaller packages we get specifications like 19 volts and 10 amps and so on like that because specification also has

changed a little, maybe the analogy may being a mechanical engineer, I can draw the analogy to the engines that are mounted in cars and the engines that are amount in motor bikes. So, if you take a 600 cc motorbike and you see the b h p they it shows the ridiculous figures same 600 cc in a car which is typically what the Jidoushi small car thing we have, the power put a small. So, it is partly due to convenient you know new shampoo and snack oil type of advertisement, but everything is measurable. The conditions are correct, it is correct.

Smaller engines mounted on open charges in motorbike seem to be producing a lot more power than the other things. Typically one liter engine can probably generate about 75 bhp and the same 1 liter engine on a motorbike, you check it up; I will not deliver the punch lime. If you read along with me on this, the heat distribution during transitions is important as well be the case when the transmitter is activated only instrumentally normal mode of operation then a transient analysis of the equivalent network with capacitors is called for the ECAP program admiralty suited for solving. Results of the ECAP d.c analysis of the equivalent networkers are shown refer to worst case were both transmitter and the receiver are in constant operation, probably have a look at it.

Temperature difference in the upper tray with the distance from the rear wall and then the rear wall of the cabinet, the various types of temperature differences have been plotted here. So, in the succeeding what do you call write up, seen that no this dots seem to be nicely very close to the computed things.

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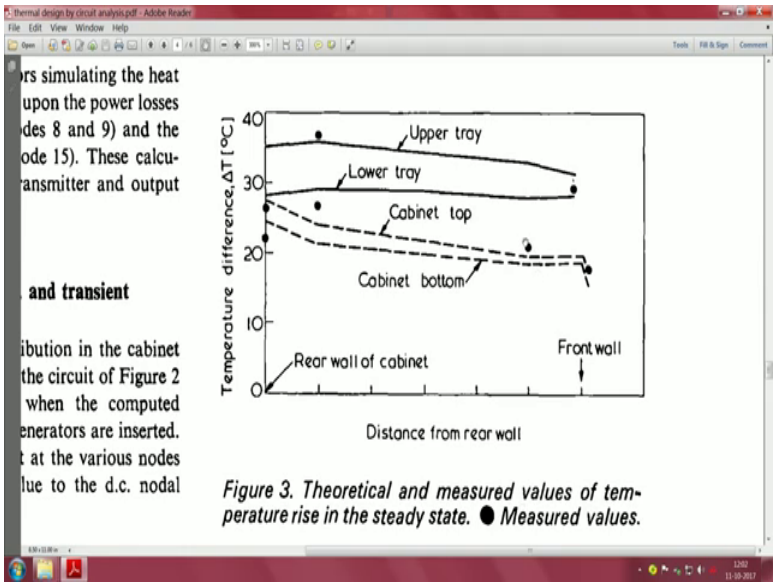

So, in this case once upon a time, it is difficult case when our chance came when we wanted to do this analysis, what we did is we made huge printed circuit boards typically which are 10 inches high that is approximately 25 centimeters and between 30 to 35 inches deep end made it into a grid mounted standoffs that is a small what do you call brass, I mean copper pins and resistors physically we knew the profile of each of the what do you call printed circuit board where hot things are there. We simulated them were mounting resistors across each of these things and the whole thing had a bus structure here. You had a positive voltage at one end and then a negative voltage and the whole thing was put into the racks.

Now, this is where we end ended up with a beautiful thing. Then we had a probe at the back ah. The whole you know rack was covered. There were small openings in which no probes could be inserted. So, some of you may remember old transistors 33, I do not remember the number now. It is a small compensated absolute temperature sensor which is inserted you know the depth could be controlled and vertically could move it a little with the back closed. So, we use this what do you call temperature sensors and physically scan the cabinet which had some 14 pcb s horizontally and total 6 what do you call rows of it. So, you get columns and rows and the depth full 3D and plotted everything manually. That is the only way things could be done way back when we started and while this people have, only few of the points here we had a full grid of all

the 3 dimensional thing which we could do. This is one of the reasons why I have been asked to talk about this.

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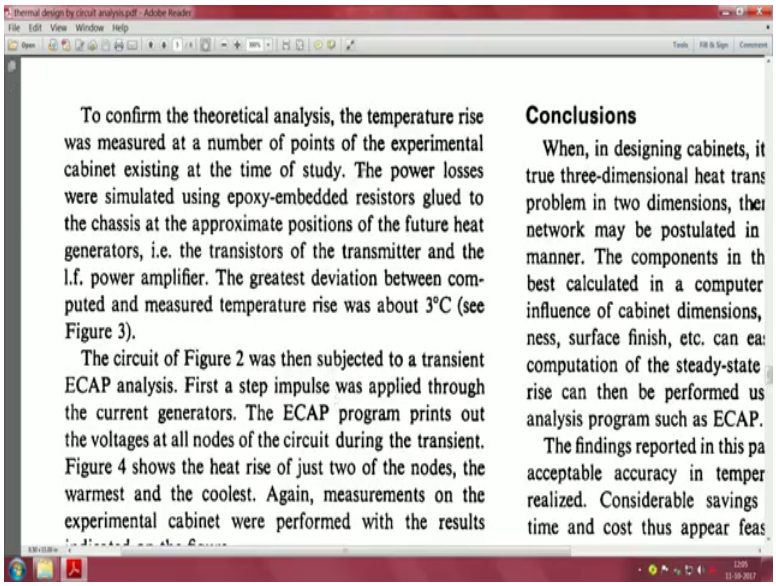

To confirm the theoretical analysis, the temperature rise was measured at a number of points of the experimental cabinet existing at the time of study. The power losses were simulated using epoxy-embedded resistors glued to the chassis at the approximate positions of the future heat generators, i.e. the transistors of the transmitter and the l.f. power amplifier. The greatest deviation between computed and measured temperature rise was about 3°C (see Figure 3).

The circuit of Figure 2 was then subjected to a transient ECAP analysis. First a step impulse was applied through the current generators. The ECAP program prints out the voltages at all nodes of the circuit during the transient. Figure 4 shows the heat rise of just two of the nodes, the warmest and the coolest. Again, measurements on the experimental cabinet were performed with the results

Conclusions

When, in designing cabinets, it true three-dimensional heat trans problem in two dimensions, ther network may be postulated in manner. The components in th best calculated in a computer influence of cabinet dimensions, ness, surface finish, etc. can ea computation of the steady-state rise can then be performed us analysis program such as ECAP.

The findings reported in this pa acceptable accuracy in temper realized. Considerable savings time and cost thus appear feas

You have seen this here, to confirm the theoretical analysis temperature rise was measured in number of points in the experimental cabinet exists existing at the time of study. The power losses where simulated using epoxy embedded resistors glued to the chancery at the approximate positions of the future heat generators, this was the way everybody was working at that time. Can you see it, the only way is you take a small area.

And in the case we were you know it was possible, you are trying to simulate point things by skipping the what do you call that resistor directly into another small case and if you know that is going to be a small tran I mean heat generating device, we use to take a 30 mm by 30 mm plate and then use resistors which can be a directly bolted onto it. You would have seen that the upper resistors where and then we were giving separate voltages to them to ensure that in a small area of 30 mm by 30 mm ah; if something is genuine, you know likely to dissipate one and half watts that is will be very different from something which is heating up there in general.

Which is exactly the same thing, glued to the chancery at the same positions of the future heat generator, transistor as a transmitter in the power amplifier greatest deviation between completed measure temperatures was only about 3 degrees centigrade.

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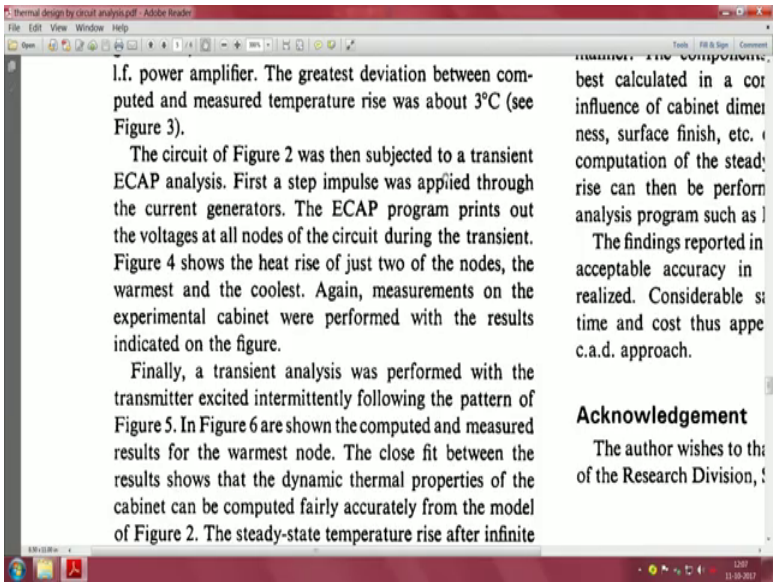
l.f. power amplifier. The greatest deviation between computed and measured temperature rise was about 3°C (see Figure 3).

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Finally, a transient analysis was performed with the transmitter excited intermittently following the pattern of Figure 5. In Figure 6 are shown the computed and measured results for the warmest node. The close fit between the results shows that the dynamic thermal properties of the cabinet can be computed fairly accurately from the model of Figure 2. The steady-state temperature rise after infinite

Then it comes to the circuit which I had shown earlier the I was put through this ECAP program and then impulse was applied through the current generators ECAP program print out voltages at all nodes using transient shows the heat rise of just 2 of the nodes warmest and the coolest. Again measurements on the experimental cabinet were performed with the result indicated in the figure.

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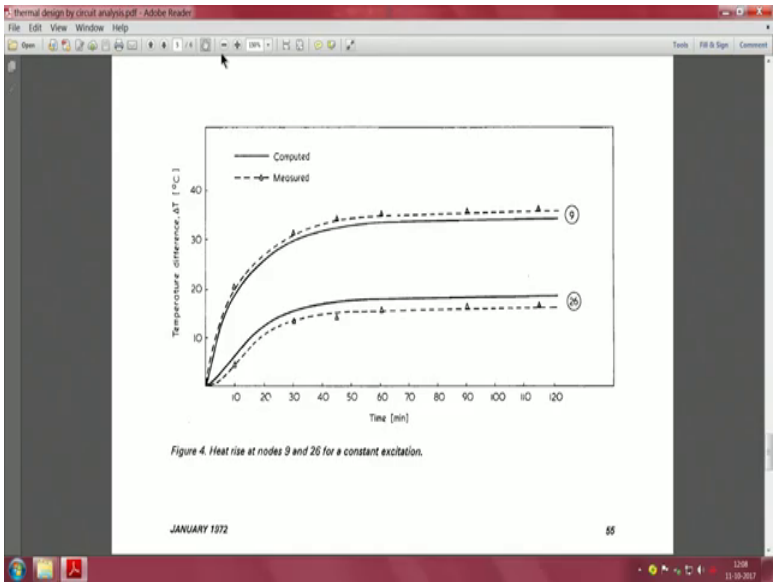

So, nodes 9 and 26 for a constant excitation, you see here one very important thing with that time, there is a stabilization that is required. In our own analysis, what we found out is that when we exited the racks and kept and things are because we wanted to use a natural ambience which fortunately for us in the place where we live in Bangalore and inside this beautiful wooded hallmarks like a park; things were cool, but the thing is at the peak of summer, maybe the temperature should come to with 32 degrees at the first sign of any clouds any passing cloud also, all that whole cabinet will become cool down significantly as a order of you know at one point may be 7 or 8 degrees things have come down which is you know a very very good and at that point, we tried to add lose circulating fans at the bottom.

Unlike this fans which they are all made such that you have seen that maximum amount of area is covered, but if you see a propeller of a normal turbo proper airplane, very little areas has covered by the propeller because that that is the detrimental to other things. The fans which look like that turboprop things, but large diameter all of them they probably smallest was about 35 mm diameter. 30 is so much and 35 is so much and 2 any of the thing at the bottom running a teddy rated speed. And again you would have noticed here a very important thing, if you were to mount something as an exhaust fan or something sucking at the bottom, it will see the high temperature produced here, but if it have use it as a blower from the bottom, you have the advantage that the fan itself will see lower temperatures.

Having done that, we have found out that is very much possible for us, in spite of it the top prober getting hot. So, in between one more self was crated external cool air was you know fed through it from the bottom. So, if you see if this was the rack, cool air, hot air existed then we decided to put a horizontal input separately and cool air again goes up and this hot air which goes here was taken out like this, so which will come to the next level of system design. Do we fit air conditioning to the whole room? I will see if I get a chance to take a picture of the air conditioning what we have all, air conditioning seems to be very effective in freezing the operators and students inside the room while the equipment no randomly cubes getting hot.

To avoid all this separately, not acting as you know suggested saying you provide the ducts where the input is there and most important give filtered air. Anywhere you have any of this forced cooling, we have the issue of this fans were quite a lot like your vacuum cleaners, I do not know whether you use the word Hoover and now or Dizen or any of the trade names, but their vacuum cleaners and vacuum cleaners, they provide more section then we have a need. So, you see here that transient alliances was circuit of figure was then subjected to trans transient analysis.

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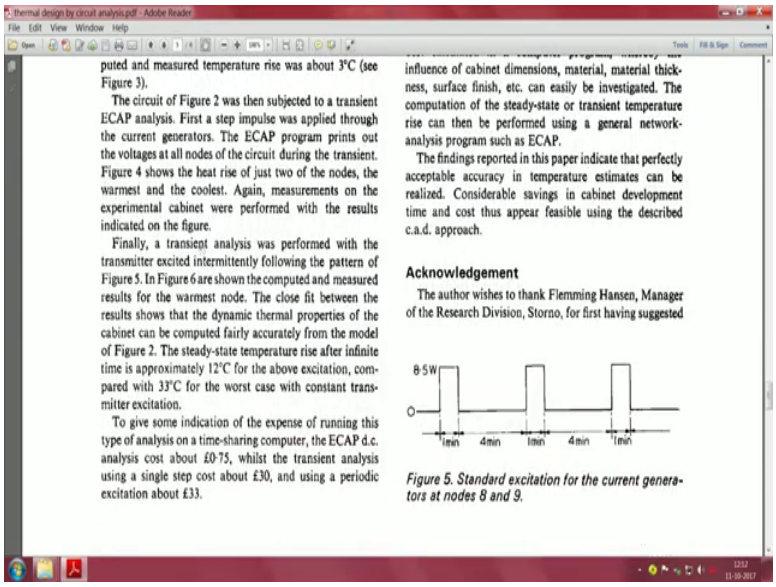
puted and measured temperature rise was about 3°C (see Figure 3).

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Finally, a transient analysis was performed with the transmitter excited intermittently following the pattern of Figure 5. In Figure 6 are shown the computed and measured results for the warmest node. The close fit between the results shows that the dynamic thermal properties of the cabinet can be computed fairly accurately from the model of Figure 2. The steady-state temperature rise after infinite time is approximately 12°C for the above excitation, compared with 33°C for the worst case with constant transmitter excitation.

To give some indication of the expense of running this type of analysis on a time-sharing computer, the ECAP d.c. analysis cost about £0·75, whilst the transient analysis using a single step cost about £30, and using a periodic excitation about £33.

influence of cabinet dimensions, material, material thickness, surface finish, etc. can easily be investigated. The computation of the steady-state or transient temperature rise can then be performed using a general network-analysis program such as ECAP.

The findings reported in this paper indicate that perfectly acceptable accuracy in temperature estimates can be realized. Considerable savings in cabinet development time and cost thus appear feasible using the described c.a.d. approach.

Acknowledgement

The author wishes to thank Flemming Hansen, Manager of the Research Division, Storno, for first having suggested

Figure 5. Standard excitation for the current generators at nodes 8 and 9.

Close and what do you call, measurements on the experimental cabinet where performed in the results indicated. A transient analysis are performed by the transmitted exide intermittently following the pattern here.

This is typically you know what comes here, long ago I think when they were second lecture I had mentioned to you; everything very rarely anything runs continuously including your own power supplies, you have a duty cycle. So, this is typically you know represents the duty cycle of the cycle; I mean of any of the items.

So, steady state temperature rise after infinite time is approximately 12 degree centigrade for the above excitation compared with 33 for the worst case with the constant transmitter, you have seen that you know this fact is seems to be so much, 3 times to give some indication of the expense of running the again some figures I want understand what this nice sitting thing, it is probably a pound sterling it is 0.75 transient analysis ah, it is 30 pounds and something else is about 33 pounds I do not know the duration or anything it is; obviously, it is expensive at that time probably salaries were much less.

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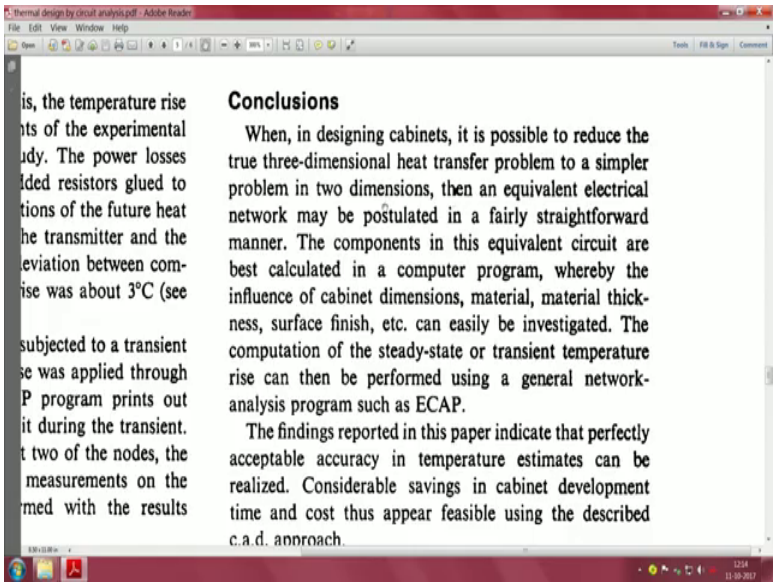

When in designing cabinets, it is possible to reduce the true 3 dimensional heat transfer to a simpler problem in 2 dimensions. In equivalent electrical network may be positive attend in a fairly straightforward manner, the components in this equivalent circuit are best calculated by in a computer program whereby the influence of cabinet dimensions material thickness, it is all can be investigated competition of the a transient temperature rise can then be performed, findings reported in this paper indicate that acceptable ardency.

Then the next page is probably you know full of all the acknowledgements. I am very happy; I also acknowledge all these this thing.

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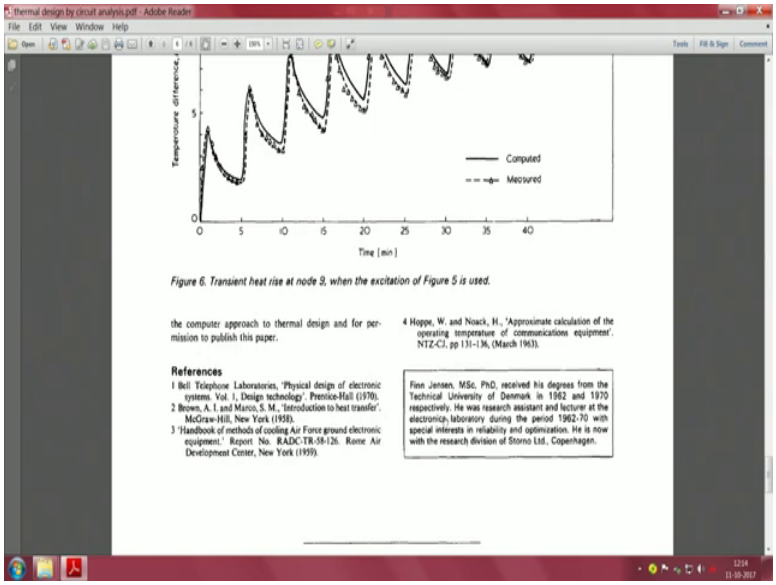

And probably, physical design of electronic systems is the same book which we also referred when we were doing these things, allow me to close this point and try to go to a nice, what do you call?

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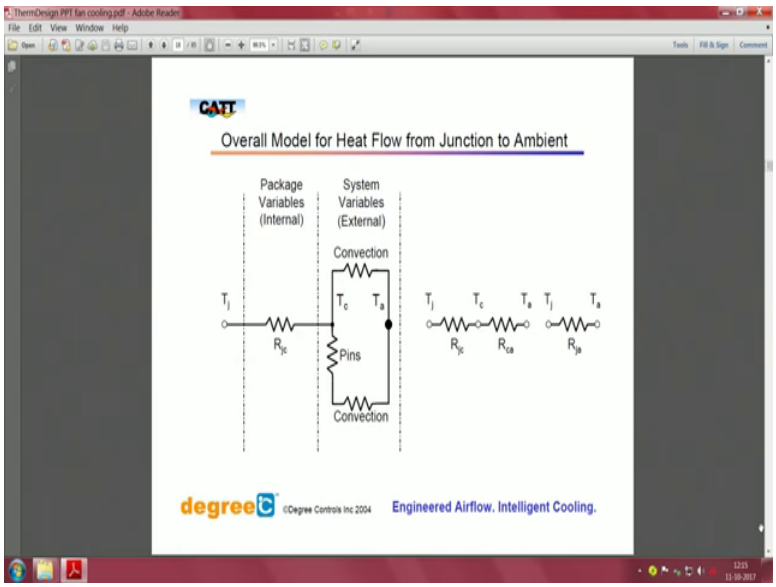

These days, this thing can be easily be evaluated by the modern programs we have seen this no, all these resistances while that was more a Ph.D. thing.

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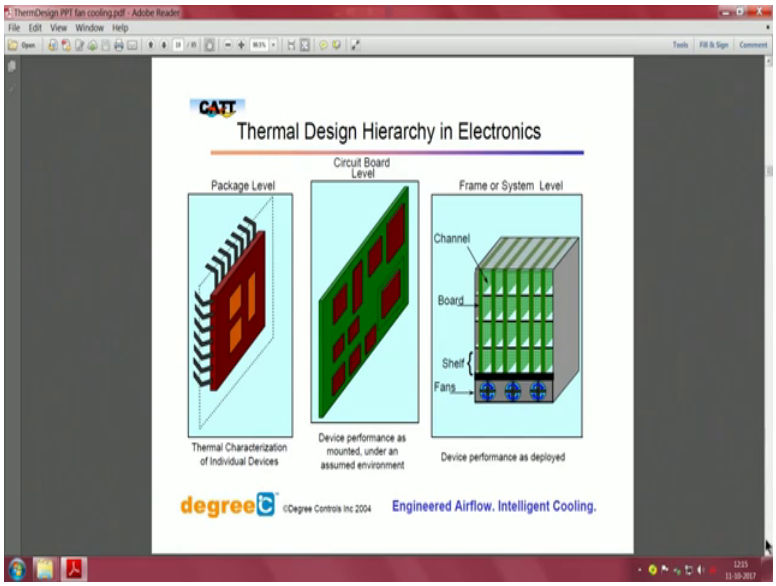

Coming back to we have a Package l Level analysis, then we have Circuit Board level, then we have Frame or System Level design ok.

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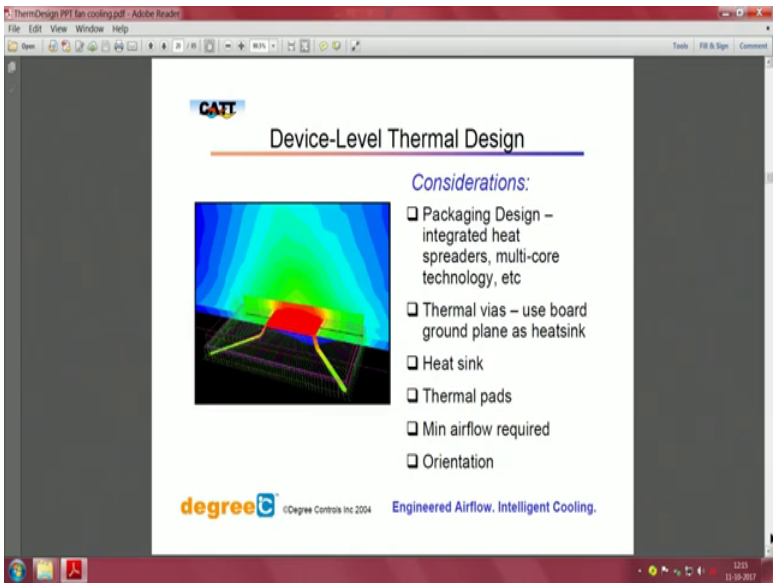

And this comes to we have all this beautiful colored pictures only with due respect for the people you have made it. I have left all these things saying you know degree controls cooling saying it is nice to think that you know. Things are so obvious except when you are using a IR camera, these are still what do you call visualizations that is created by very intelligent what do you call people.

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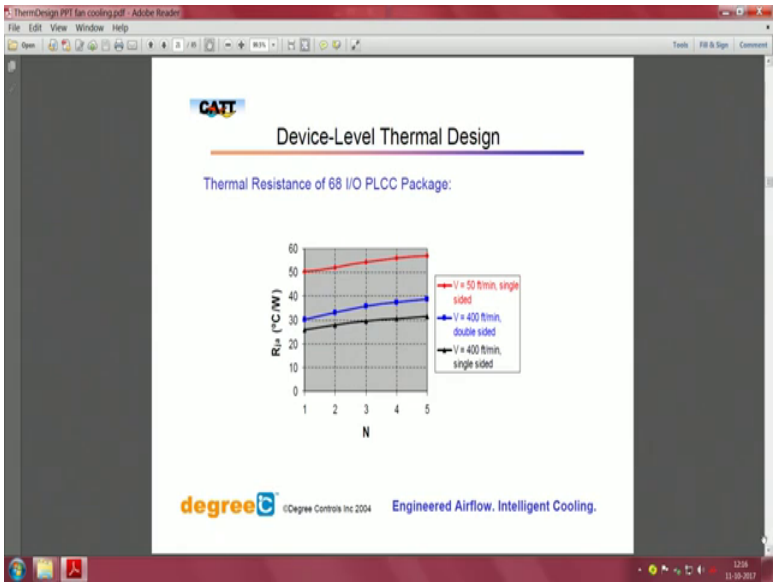

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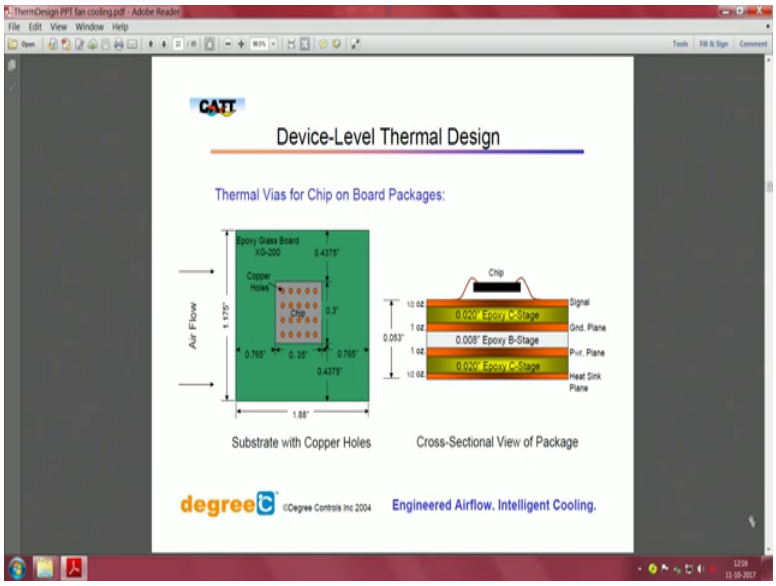

So, for even you know, all these type of you know what do you call multiple lead packages and all that and consideration of a board.

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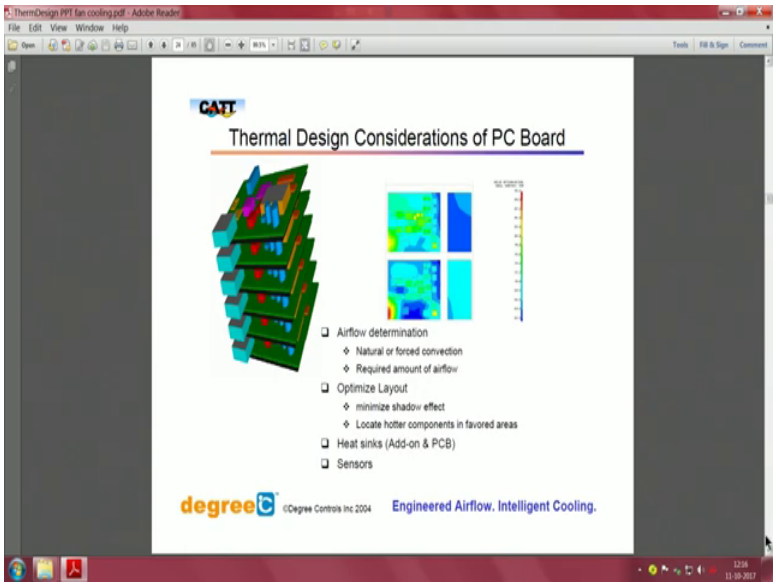

This is what I have talking to you. It is nice to think saying this is how it is this is a intuitive. At the bottom you know they have got, what do you call 90 degrees, I am sorry at the top they have 90 degrees and the bottom about 60 degrees.

And you know how the this whole a I what do you call a temperature profile can be created.

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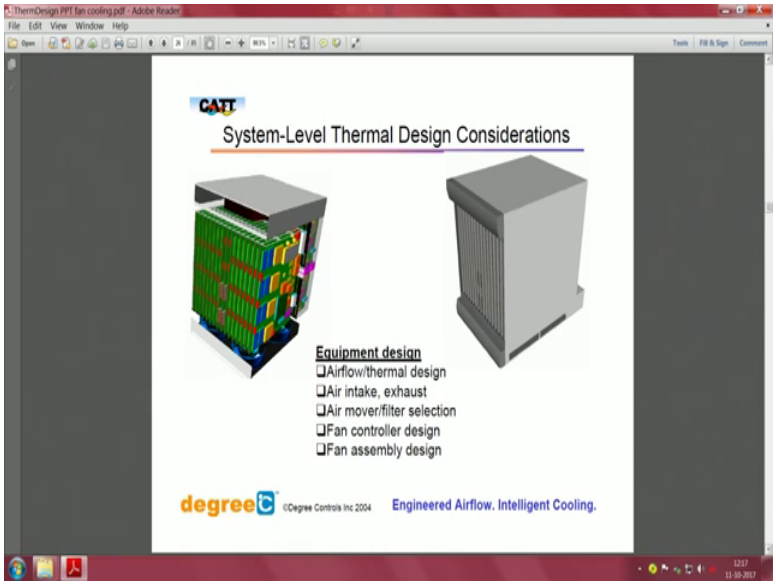

So, I will leave it at that because may being from the academic field; I take all these what do you call presentations a little with this thing saying I do not agree that they are buy,

but conditions apply and a little bit of creative visualization. I am sure your TV is bombarded with how to make your life better with left side bottom corner the small flash saying creative visualization. I will take leave at this point and then try to continue in the next lecture.

So, thank you for patiently going through this; one more time, allow me to acknowledge saying this is being meant as a educational exercise. I fully acknowledge the original authors from whose work I have taken and to make it authentic, I have presented the original work instead of trying to add my own what do you call coloration to that because things will get lost in translation and what is it is, transliteration. So, my stock example is the what do you call color of the heat sink and coming all the way to contact resistance and all the way to the thermal imagining which they show there. So, believe in what you do, you verify yourself. So, thank you go back to each of my lectures, go through it and be patient until we come to the end of the course so.

Thank you.