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NUMERICAL ANALYSIS AND SIMULATION OF CONJUGATE HEAT TRANSFER STUDY OF ELECTRONIC CIRCUIT BOARD

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ABSTRACT

Present-day interest in the thermal analysis of electronic circuit boards arises mainly because of the failure of such components as a result of thermal fatigue. A thermal/structural ANSYS model was integrated in this study to enable the predictions of the temperature and stress distribution of vertically clamped parallel circuit boards that include series of symmetrically mounted heated electronic modules (chips). The board was modelled as a thin plate containing heated flush rectangular areas representing the heat generating modules. The ANSYS model was required to incorporate the effects of mixed convection on surfaces, heat generation in the modules, and conduction inside the board. Appropriate convection heat transfer coefficients and boundary conditions resulted in a temperature distribution in the board and chips. Then structural analyses were performed on the same finite element mesh with structural elements capable of handling

orthotropic material properties. The stress fields were obtained and compared for the two models possessing different fibers orientations.

INTRODUCTION

Need of analysis of electronic pcb's:

'Electronic systems' cooling has been extensively examined recently because of the interest from both scientific and technological points of view. On the technological part with the improvements of the electronics systems, higher processing speeds, more power, smaller systems become more of a necessity than ever before. One of the most important results of these necessities is the need to handle more complex geometries. Therefore one of the biggest issues in the electronics systems is the cooling of these complex geometries. Especially in military, healthcare and aerospace applications, effective cooling is crucial. With an efficient cooling, electronics systems become more reliable and durable.
The failure rate of electronic equipment increases exponentially with temperature. Also, the high thermal stresses in the solder joints of electronic components mounted on circuit boards resulting from temperature variations are major causes of failure. Therefore, thermal control has become increasingly important in the design and operation of electronic equipment.
Developing effective cooling techniques of electronic systems is a major challenge. Therefore different cooling techniques have been developed to remove the heat from electronic components.
Two main types of cooling are air and liquid cooling
Air cooling is an inexpensive but reliable way of cooling. It is easy to find air; design and maintenance are also easy with air. Therefore, air cooling is used widely in electronic systems cooling.
Convection is a widely used cooling technique. Forced convection is a better choice when it is compared with natural convection as it provides higher heat transfer rates and higher Prandtl numbers. In forced convection, adding a fan to the system is one of the methods. Air is forced to move with the help of a fan. To decrease system temperature, fan speed,which is one of the important parameters in efficient cooling, should satisfy turbulent flow conditions.

KEYWORDS: Printed circuit board (PCB)

THERMAL MANAGEMENT:

Thermal management becomes critical when the power dissipation level increases in certain high performance use cases. Under these use cases integrated thermal management from package to the system level is needed to ensure the performance and reliability of the system. Several parameters are given below which influenced on the performance of printed circuit board (PCB).

Operating Environment:

Thermal management becomes a challenge especially when operating in a high ambient temperature environment. One way to constrain the environment ambient operating temperature for the device is to ensure it must be at or lower than a given temperature.

Consume Less Power - Generate less heat:

Heat in an embedded system is a by-product of power and the best way to generate less heat is to consume less power. Once heat is generated, the job then becomes to transfer it effectively by providing an efficient path from the device to the environment via thermal pads, epoxy or any method that makes use of conduction, convection, or facilitates radiation.

Heat transfer in printed circuit boards:

Heat transfer along a PCB is complicated in nature because of the multidimensional effects and no uniform heat generation on the surfaces. We can still obtain sufficiently accurate results by using the thermal resistance network in one or more dimensions.

Air Cooling: Natural Convection and Radiation:

Low-power electronic systems are conveniently cooled by natural convection and radiation. Natural convection cooling is very desirable, since it does not involve any fans that may break down. Natural convection is based on the fluid motion caused by the density differences in a fluid due to a temperature difference. A fluid expands when heated and becomes less dense.

Natural convection cooling is most effective when the path of the fluid is relatively free of obstacles, which tend to slow down the fluid and is least effective when the fluid has to pass through narrow flow passages and over many obstacles.

The magnitude of the natural convection heat transfer between a surface and a fluid is directly related to the flow rate of the fluid. The higher the flow rate, the higher the heat transfer rate. In natural convection, no blowers are used and therefore the flow rate cannot be controlled externally. The flow rate in this case is established by the dynamic balance of buoyancy and friction. The larger the temperature difference between the fluid adjacent to a hot surface and the fluid away from it, the larger the buoyancy force, and the stronger the natural convection currents, and thus the higher the heat transfer rate. Also, whenever two bodies in contact move relative to each other, a friction force develops at the contact surface in the direction opposite to that of the motion. This opposing force slows down the fluid, and thus reduces the flow rate of the fluid. Under steady conditions, the airflow rate driven by buoyancy is established at the point where these two effects balance each other. The friction force increases as more and more solid surfaces are introduced, seriously disrupting the fluid flow and heat transfer.

Liquid cooling:

Liquids normally have much higher thermal conductivities than gases, and thus much higher heat transfer coefficients associated with them. Therefore, liquid cooling is far more effective than gas cooling. However, liquid cooling comes with its own risks and potential problems, such as leakage, corrosion, extra weight, and condensation.

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Liquid cooling systems can be classified as direct cooling and indirect cooling systems. In direct cooling systems, the electronic components are in direct contact with the liquid, and thus the heat generated in the components is transferred directly to the liquid. In indirect cooling systems, however, there is no direct contact with the components. The heat generated in this case is first transferred to a medium such as a cold plate before it is carried away by the liquid.
Liquid cooling systems are also classified as closed-loop and open-loop systems, depending on whether the liquid is discarded or recalculated after it is heated. In open-loop systems, tap water flows through the cooling system and is discarded into a drain after it is heated. The heated liquid in closed-loop systems is cooled in a heat exchanger and recalculated through the system. Closed loop systems facilitate better temperature control while conserving water.
The electronic components in direct cooling systems are usually completely immersed in the liquid. The heat transfer from the components to the liquid can be by natural or forced convection or boiling, depending on the temperature levels involved and the properties of the fluids. Note that only dielectric fluids can be used in immersion or direct liquid cooling. This limitation immediately excludes water from consideration as a prospective fluid in immersion cooling. Fluorocarbon fluids such as FC75 are well suited for direct cooling and are commonly used in such applications.
Indirect liquid cooling systems of electronic devices operate just like the cooling system of a car engine.

THERMAL MANAGEMENT STRATEGIES:

The general strategy for thermal management focuses on:

- Increasing the heat-dissipation capability of the thermal solutions.
- Expanding the thermal envelopes of systems.
- Minimizing impact of local hot spots by improving heat spreading.
- Developing thermal solutions that meet cost constraints.
- Solutions that fit within form factor considerations of the product chassis.

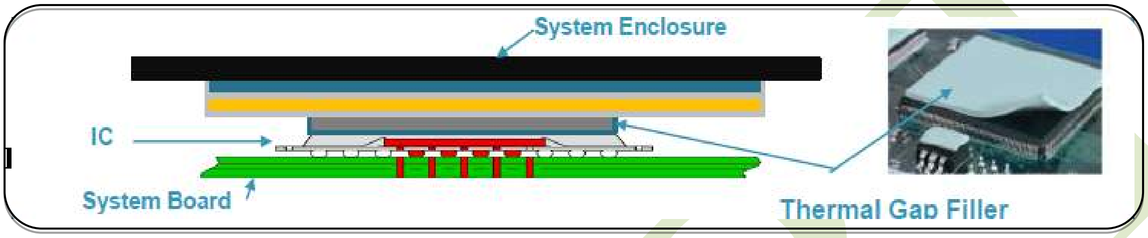
There are basically two types of thermal management strategies:

- **Active** thermal management techniques available for embedded systems provide lower thermal resistances and better heat dissipation, however are expensive and have large form factors.
- **Passive** thermal management techniques by enhancing conduction and natural convection provide more cost effective solutions, up to certain power levels without introducing any reliability concerns.

THERMAL MANAGEMENT TECHNIQUES:

(a) Thermal Gap Filler:

Gap filler is typically placed between the top/bottom of the high power component and case, removing air gap around the package, which is a thermal barrier due to very minimal air circulation.
The thermo-elastic gap filler material is often found in the handheld device for thermal management purpose as well as for better shock resistance.



- The use of gap filler with a higher thermal conductivity will result in better thermal dissipation capability. It helps in reducing the junction temperature (Tj), however, if used in isolation the direct heat path from the package to the system enclosure results in the skin temperature rise, generating hot spots.
- Proper attachment of the gap filler is important as well as using the correct thermal contact adhesives. Improper application can severely reduce the thermal conductivity of the filler. Data will be presented in subsequent thermal simulation section for comparisons.

(b) Heat Spreaders:

- A thermally conductive heat spreader can be placed on the high power components and this heat spreader can enable spreading and evening out of the hot spots and could be designed to make direct contact with the system enclosure as shown below.

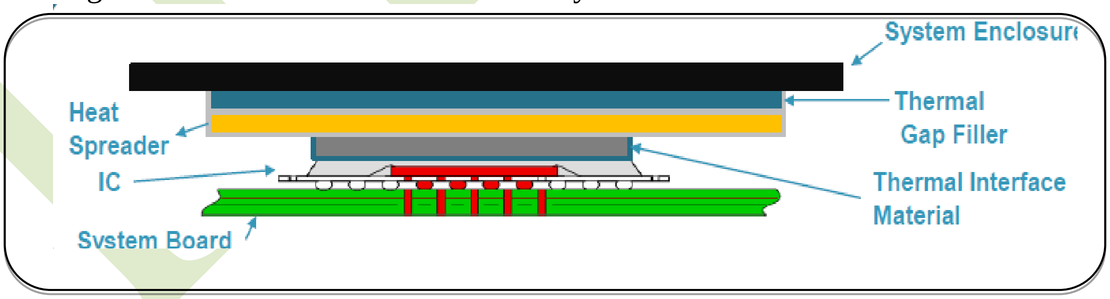


Fig. Heat Spreaders

- This design concept significantly increased the power dissipation capability, by reducing overall system thermal resistance.
- The type of heat spreader to be used is dependent on the customers' application available enclosure space and budget considerations.

(c) Component Placement:

- Designers also need to consider the impact of other components on the system board due to their heat generating capacity.
- Board population density influences thermal performance of the package and should be modeled accordingly. If the devices are very close the power consumed should be part of the thermal design power budget that needs to be modeled
- PCB's with a high density of high power component population experiences a significantly higher rise in temperature relative to the board being populated with a single high power component.
- Some heat generating devices have to be in close proximity to each other for signal integrity and layout concerns such as the DDR memories hence there is no easy solution around this problem.
- Designers consider all components and evaluate their placements on the PCB and location with respect to the final form factor housing. Ideally high power devices should not be placed in close proximity to ensure effective thermal dissipation.

(d) Board Design:

Typically more than 80% of the heat generated by a high power component is dissipated through the system board, when no thermal solution is implemented on the top of the package.This indicates that the primary heat path is from junction to the board.

(e) Increased PCB Metallization:

- Increase the heat dissipation (reducing thermal resistance) can also be achieved by increasing the metallization in the system board. Copper ground layers should be added as part of the board thermal solution.
- Details are provided on the PCB stack up of the freescale SDP Board used in thermal simulations in the next section of this document.

(f) More Thermal Attach Points:

- Special care should also be taken in design PCB thermal attach points which allow heat from the high power component or attached heat spreader to be effectively dissipated.

CONJUGATE HEAT TRANSFER:

Conjugate heat transfer corresponds with the combination of heat transfer in solids and heat transfer in fluids. In solids, conduction often dominates whereas in fluids, convection usually dominates. Conjugate heat transfer is observed in many situations. For example, heat sinks are optimized to combine heat transfer by conduction in the heat sink with the convection in the surrounding fluid.

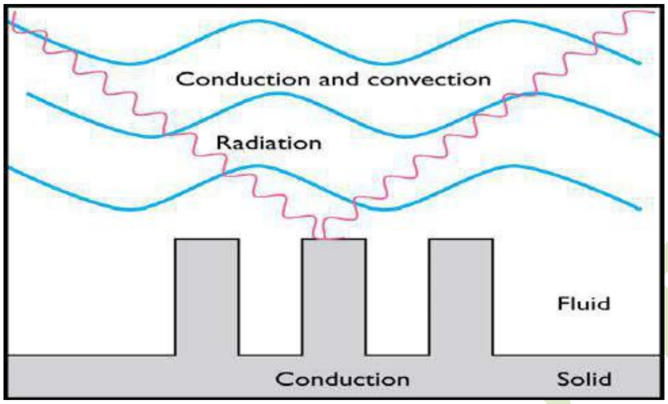


Fig. Heat Transfer In A System Containing Solid And Fluid (Conjugate Heat Transfer)

The Conjugate Heat Transfer interfaces describe heat transfer in solids and fluids and non-isothermal flow in the fluid. The heat transfer process is tightly coupled with the fluid flow problem and the physics interfaces include features for describing heat transfer in free and forced convection, including pressure work and viscous heating. These physics interfaces are available for laminar and turbulent non-isothermal flow. For highly accurate simulations of heat transfer between a solid and a fluid in the turbulent flow regime, low-Reynolds turbulence models resolve the temperature field in the fluid all the way to the solid wall in the Turbulent Flow, Low interface. The standard turbulence model in the Turbulent Flow.

The contemporary conjugate heat transfer model was developed after computers came into wide use in order to substitute the empirical relation of proportionality of heat flux to temperature difference with heat transfer coefficient which was the only tool in theoretical heat convection since the times of Newton. This model based on strictly mathematical stated problem describes the heat transfer between body and flowing over or inside it as a result of interaction of two objects. The physical processes and solutions of governing equations are considered separately for each object in two sub domains.

Joule heating:

Joule heating, also known as Ohmic heating and resistive heating, is the generation of heat by passing an electric current through a metal. The amount of heat released is proportional to the square of the current such that

$$H \propto i^2.R.t$$

When i, R ant t all are changing.

$$H = \frac{1}{J} i^2.R.t$$

Fig.5.2 Joule Heating

This relationship is known as Joule's first law or Joule–Lenz law. Joule heating is independent of the direction of current, unlike heating due to the pettier effect. Here 'H' is the heat generated in Joules, 'i' is the current flowing through the circuit in ampere and't' is in seconds. When any three of these are known the other one can be equated out. Obviously the value of J will depend on the choice of units for work and heat.

Now according to Joule's law I2Rt = work done in joules electrically when I ampere of current are maintained through a resistor of R ohms for t second.

$$Therefore,\ H = \frac{I^2Rt\ \ Joules}{4.2\ Joules/cal} = \frac{I^2Rt}{4.2}\ cal = 0.24I^2Rt\ \ cal$$

By eliminating I and R in turn in the above expression with the help of Ohm's law, we get alternative forms as:

$$H = 0.24VIt\ cal = 0.24\frac{V^2}{R}\ cal\ (as\ V = IR$$

In electric power transmission, high voltage is used to reduce Joule heating of the overhead power lines. The valuable electric energy is intended to be used by consumers, not for heating the power lines. Therefore this Joule heating is referred to as a type of transmission loss.

INTRODUCTION TO ANSYS ICEPAK:

Electronic devices today have smaller footprints and unique power requirements that call for superior thermal designs. Overheated components degrade product reliability, resulting in costly redesigns. To ensure adequate cooling of IC packages, printed circuit boards (PCB) and complete electronic systems, engineers rely on ANSYS ICEPAK to validate thermal designs before building any hardware. ICEPAK combines advanced solver technology with robust, automatic meshing to enable you to rapidly perform heat transfer and fluid flow simulation for a wide variety of electronic applications — including computers, telecommunications equipment and semiconductor devices, as well as aerospace, automotive and consumer electronics.

Rapid Thermal Simulation for Electronic Systems:

Developing better products in a shorter amount of time demands rapid thermal simulation capabilities. Icepack's streamlined user interface allows you to quickly create and simulate electronics cooling models using smart objects combined with extensive libraries of standard electronic components. You can create electronics cooling models by simply dragging and dropping smart objects (such as cabinets, fans, packages, printed circuit boards and heat sinks) to rapidly create and simulate models of complete electronic systems for a variety of different cooling scenarios.

Accurate Analysis for PCB:

High temperatures detrimentally affect electrical performance of printed circuit boards. As a result, engineers increasingly want to incorporate thermal effects into their PCB designs. With ANSYS ICEPACKS, we can import board layout from a variety of EDA tools for efficient thermal simulation. Board dimensions, component layout information, and electronic trace and via information can all be incorporated into a thermal simulation. The software tools enable us to accurately simulate different cooling scenarios for single and rack-mounted boards along with component power and copper resistive losses in trace layers. The end result is a high-fidelity prediction of PCB internal and component junction temperatures. ICEPACK provides features that are not available in other analysis packages, including accurate modeling of non-rectangular devices, contact resistance modeling, anisotropic conductivity, non-linear fan curves, lumped-parameter heat sink devices, external heat exchangers, and automatic radiation heat transfer view factor calculations

WHY PHYSICAL MODELS:

Physical models allow visualization, from examining the model, of information about the thing the model represents. A model can be a physical object such as an architectural model of a building. Uses of an architectural model include visualization of internal relationships within the structure or external relationships of the structure to the environment. Instrumented physical models are the most effective way of investigating fluid flows such as around hydraulic structures.

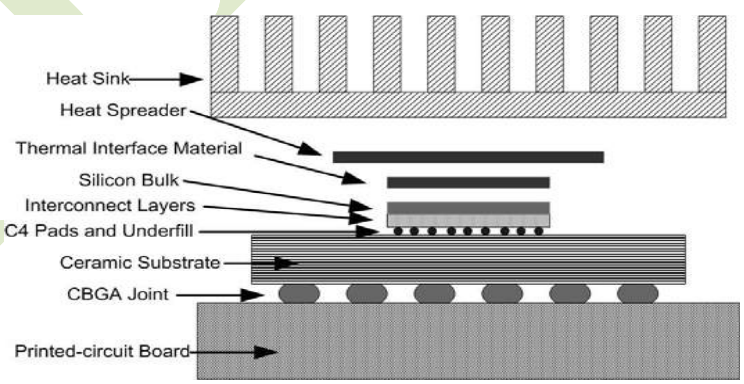


Fig. Thermal/Structural Boundary Conditions

These models are scaled in terms of both geometry and important forces, for example using Froude number or Reynolds number scaling with the demand for high-performance integrated circuits, there has been an escalation of power dissipation and heat flux at the silicon level. This has resulted in a greater impact of substrate and metal line temperatures on the reliability and performance of devices and interconnections. The temperature difference between the heat source and surrounding ambient causes heat to flow out of the system.

PROBLEM DESCRIPTION:

OBJECTIVE:

Numerical Analysis And Simulation Of Conjugate Heat Transfer Study Of Electronic Circuit Board

PROBLEM DESCRIPTION:

1. Model contains a PCB board and trace layers. Model is solved without the components with components. Conduction model is used for without components problem and forced convection method is used for model with components.
2. Determination of Joule/trace heating capacity of traces.

EXPECTED OUTPUT:

- **Conduction Only:**

1. Temperature distribution on PCB. Mid plane.
2. K_X distribution on PCB.

- **Joule Heating:**

1. Trace Temperature Contours with Forced Convection.
2. Trace Electric Potential Contours with Forced Convection.
3. Compare the maximum temperature for the cases with and without trace modeling.

MODEL ANALYSIS AND SIMULATION:

1 BASIC MODEL :

The model is provided by company as per requirement is shown below. The model contains no. of components, packages, assemblies, fans, blowers, networks electrical circuits, traces, heat sinks.

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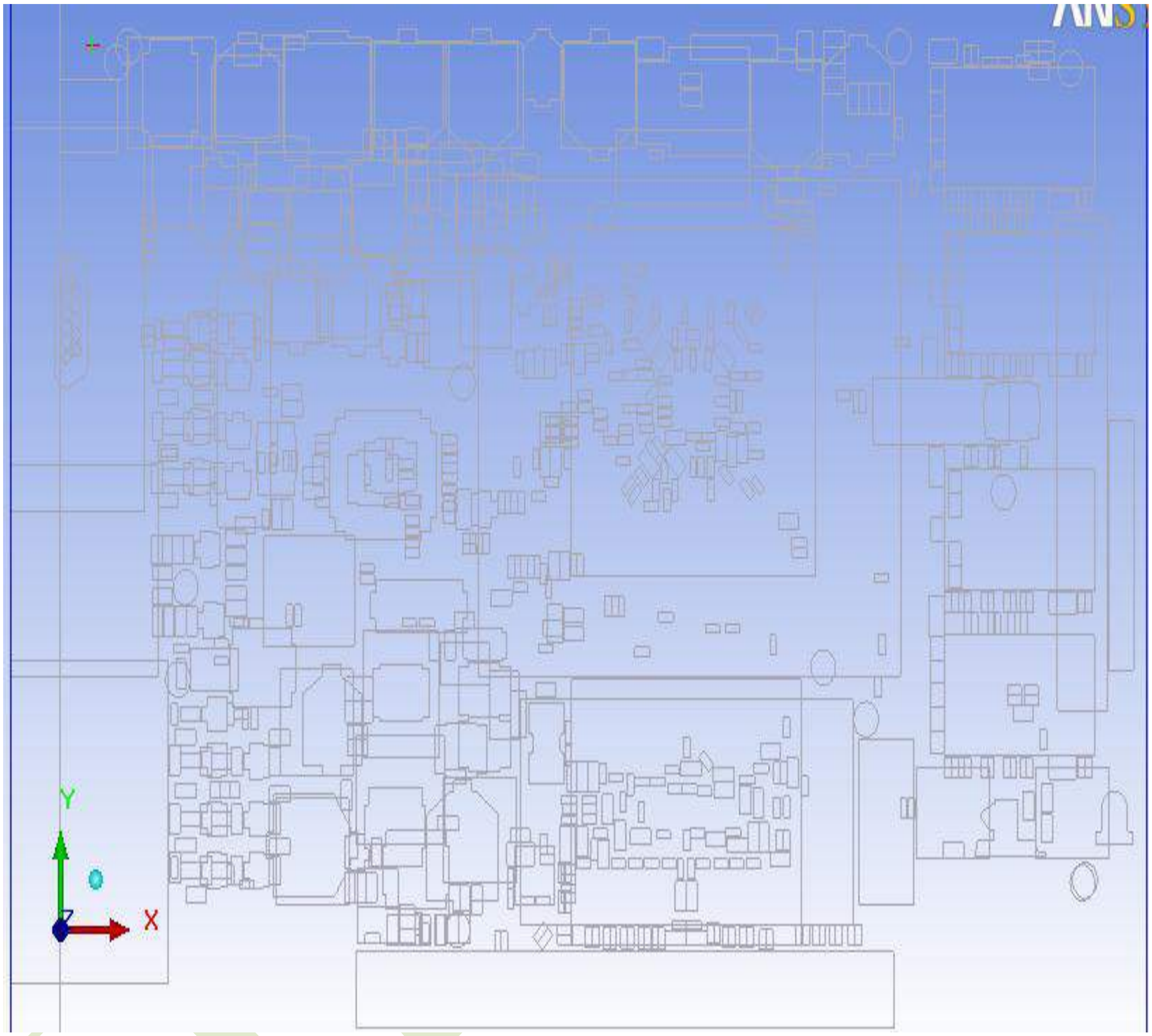

Fig. Basic Model Geometry

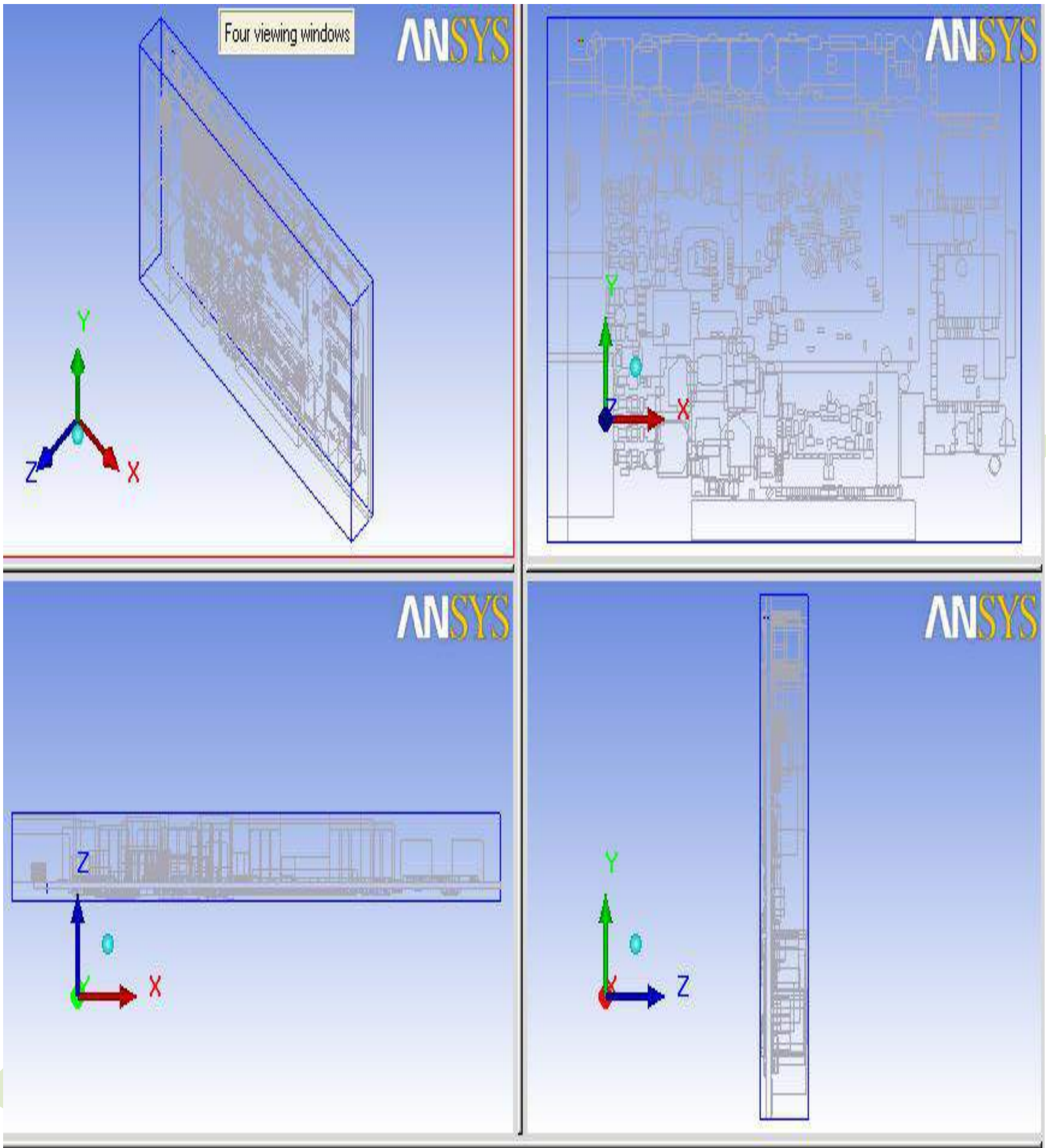

Fig. Basic Initial Model(All Views)

1. CONDUCTION MODEL :

Model :

Model is given bellow which have to solved with board outline.cabinate have two wall objects at the Min z and Max z sides of the cabinet. Boundary conditions for this model are Wall at the max z side-Heat flux:50000w/m^2 min z side-Temp:ambient.

a) Traces :

Following fig. shows trace layer imported into given model geometry. Generally traces of PCBs are heated when current passes from it. Trace layer thickness of board layers are given bellow.

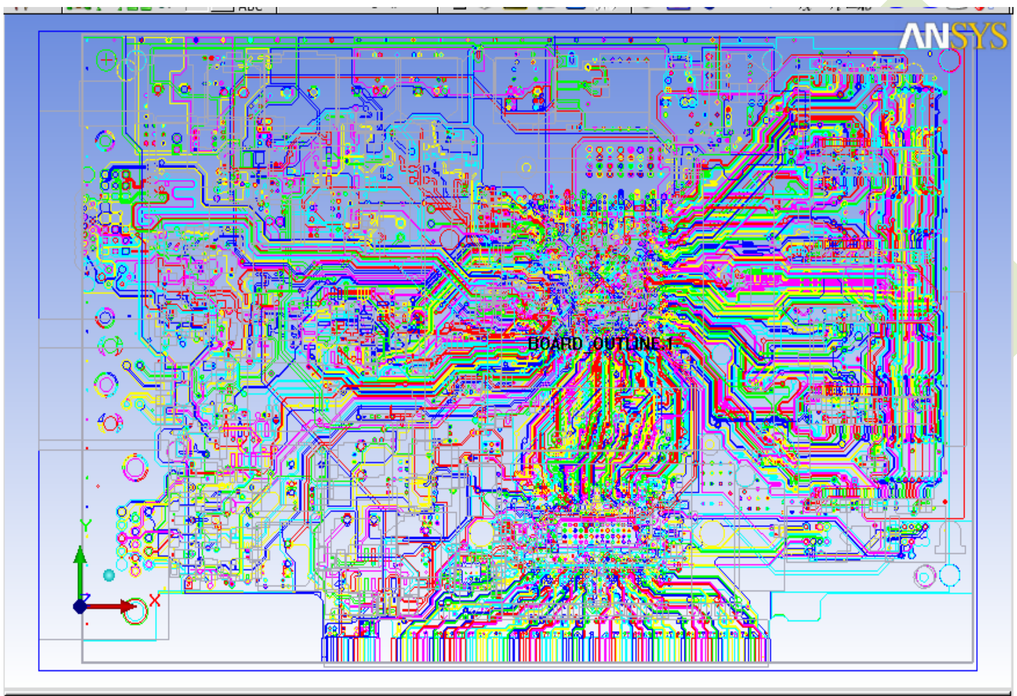

Fig. Colour By Traces Visualization.

b) Meshing:

The model is meshed with only PCB board outline and trace layers. All the parameters and boundary conditions as per requirement of company had been applied to model. Meshing parameters are given bellow.
Meshing: MAX X-5mm, MAX Y-3mm and MAXZ-0.05mm minimum gap is 1mm for all. Generate

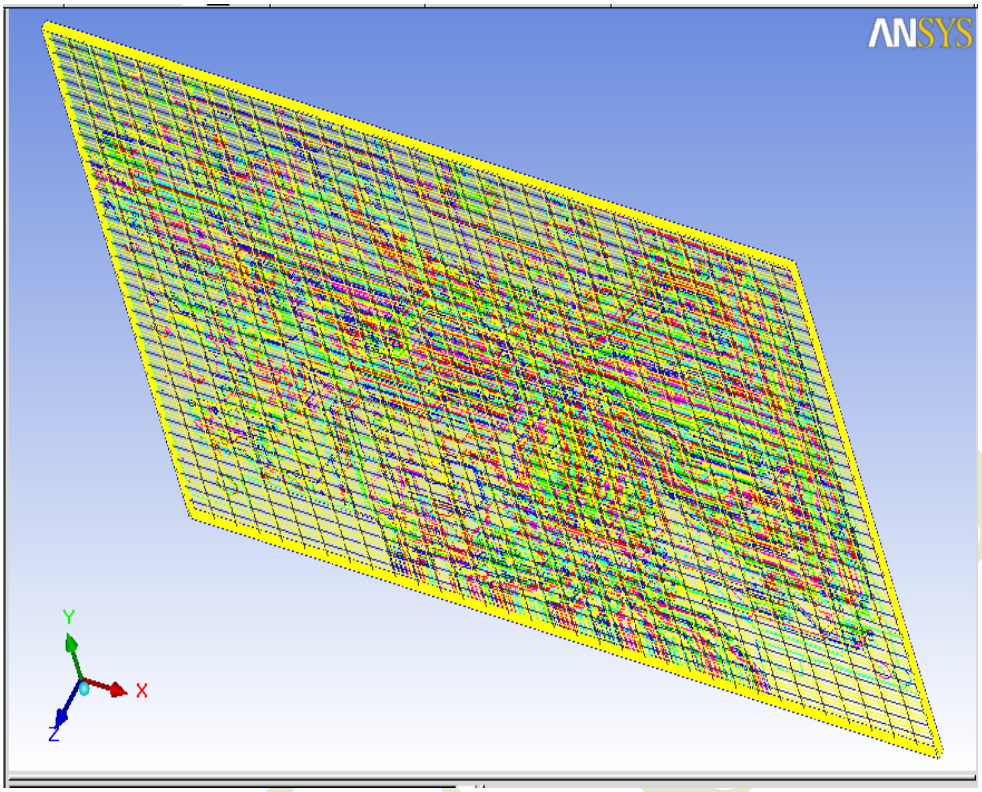

Fig. Meshing(Surface Wire Mesh)

c) Solution:

Model is solved after meshing with Physical and numerical settings:
1) No radiation.
2) Energy convergence criteria–1*e^-12.
3) Temperature in advanced settings –W.
4) Termination criterion and Residual reduction tolerance 1e-6.

d) Results:

1) The graph shows Solution Residuals for conduction model for 100 iteration.

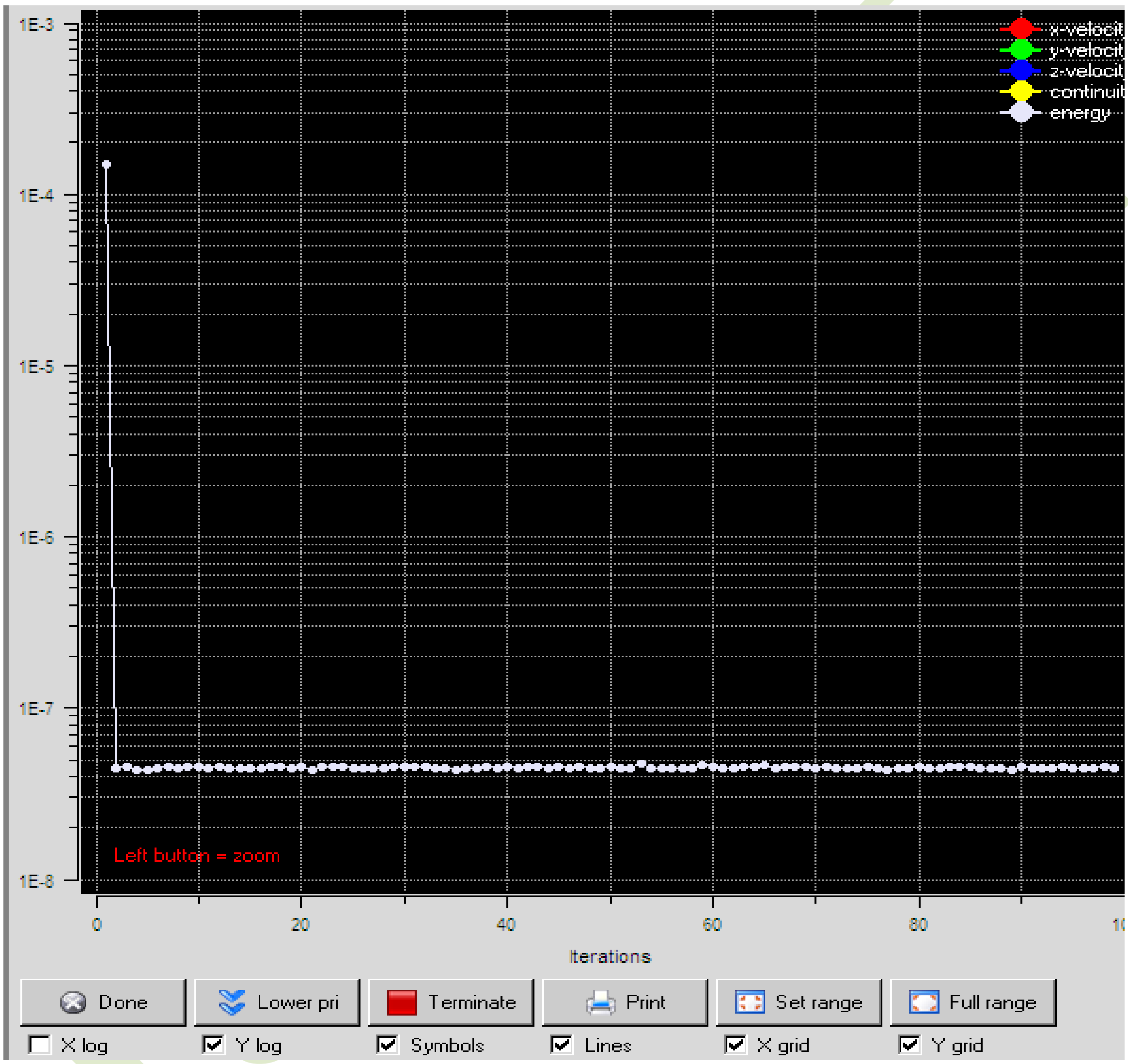

Fig. Solution Residuals For Conduction Model

2) Fig. Shows temperature distribution on PCB's mid plane. The temperature range and distribution of heat transfer is represented from blue to red

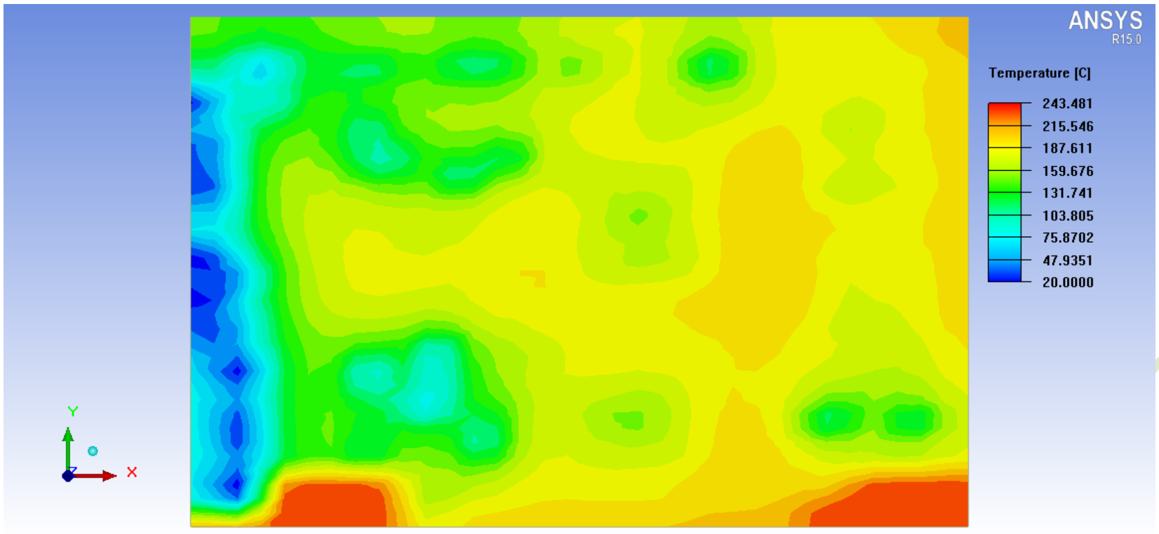

Fig. Temperature Distribution On PCBMid Plane.

3) fig. shows K_X distribution on PCB :

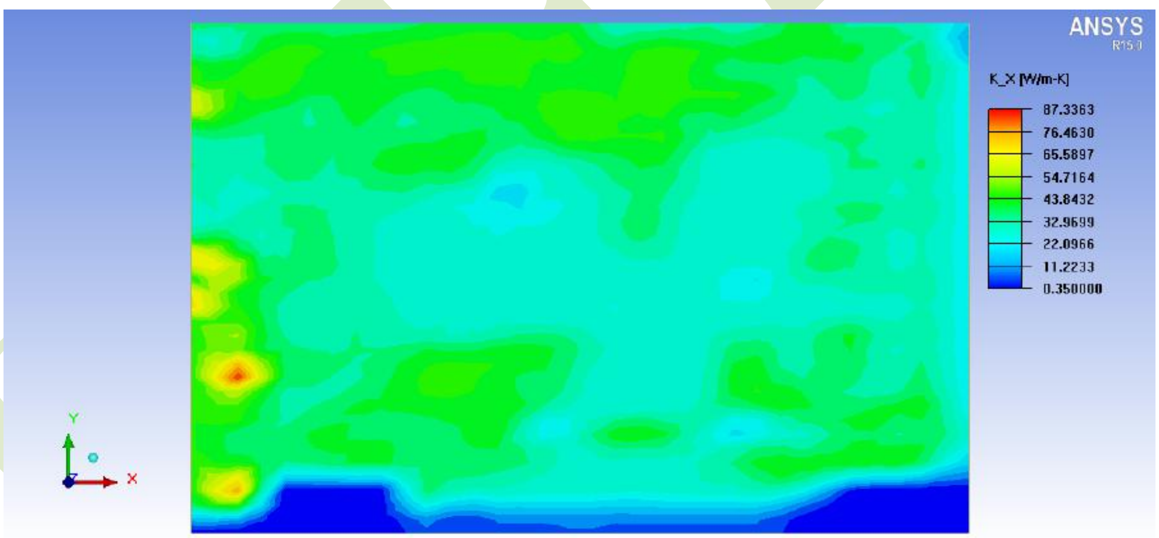

Fig. K_X Distribution

4) Fig. Shows temperature distribution on PCB's cut plane.

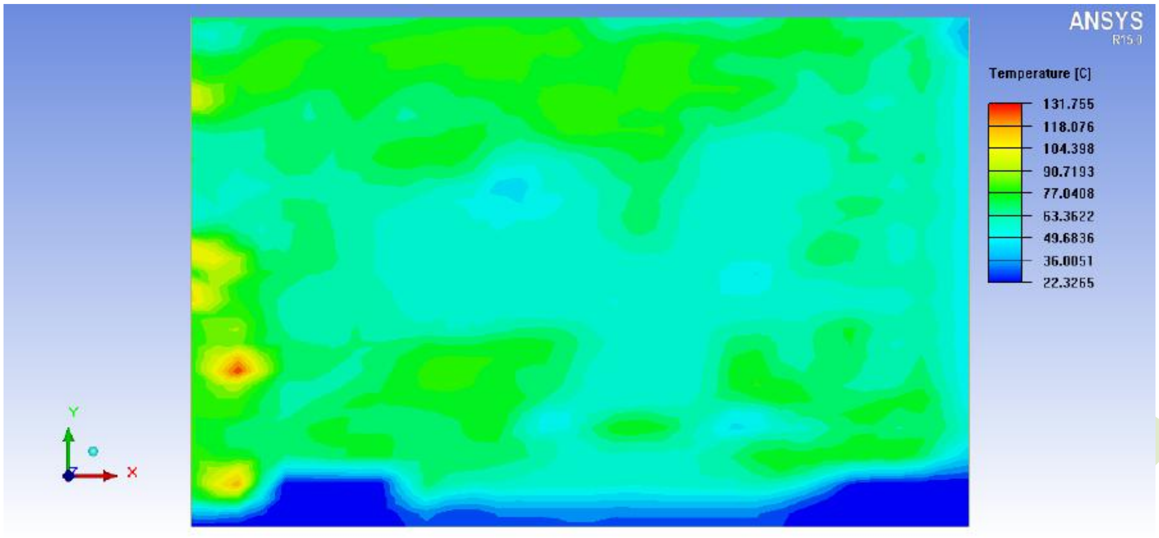

Fig. Temperature Distribution On PCB Cut Plane

2) TRACE/JOULE HEATING MODEL:

a) Model :

The model is given as per project requirement **:**

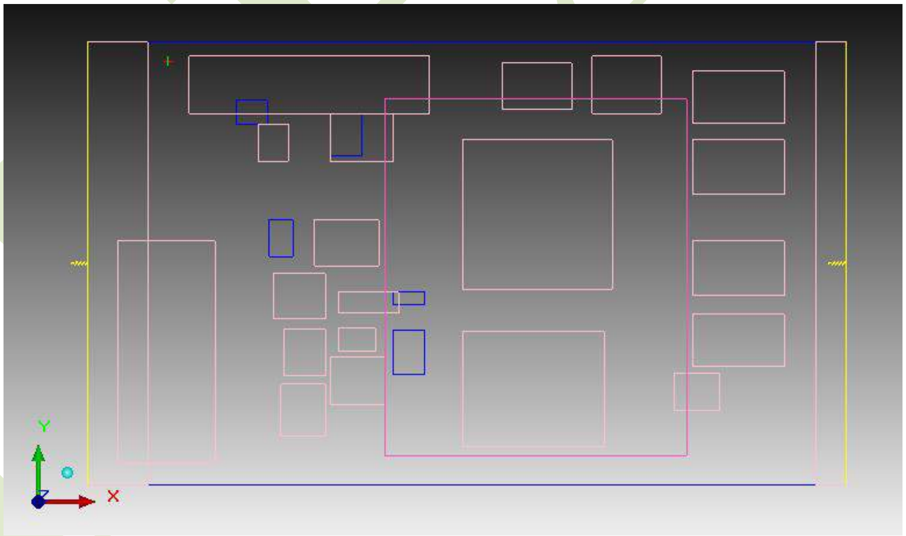

Fig. Model

- **Trace layer specification:**

1) Trace name: INT1 _3.Trace1_1724.
2) Max trace angle -135.
3) Min traces length -1.0 mm.

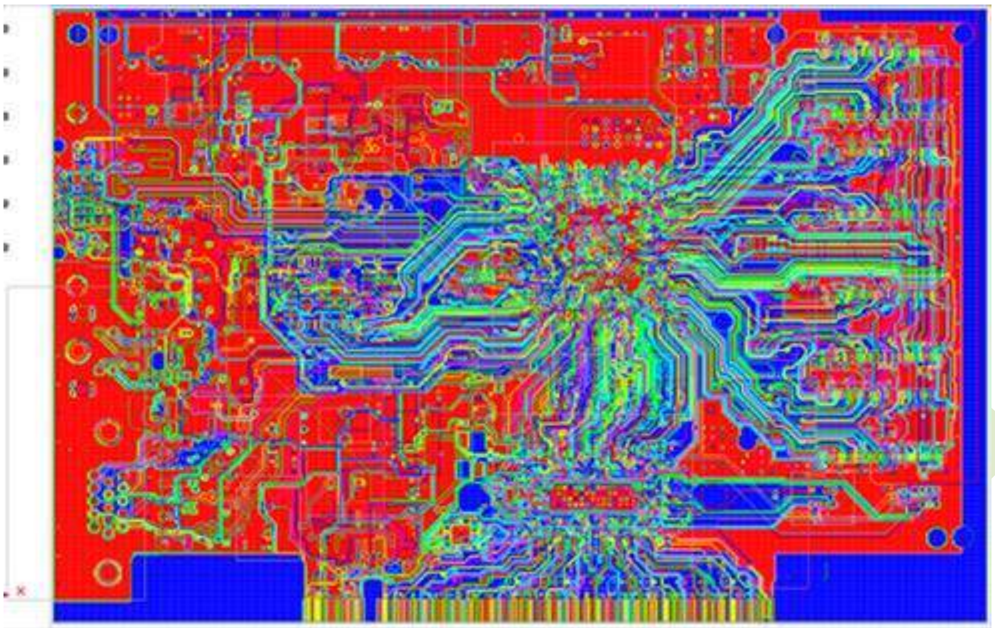

Fig. Model After Importing Trace Layers

b) Meshing:

The model is meshed with all components activated. Meshing parameters are given bellow
Meshing parameters for the assemblies:
MinX-1.524mm, minY-2mm,minZ-0.2mm,maxX-1mm,maxY-0.6482mm,maxZ-0.2mm.
Meshing parameters for model
Minimum gap:X-0.75..,Y-0.45mm,Z-0.035mm. MesherHD MAX X9mm,MAX Y-5mm.MAX Z-0.75mm.

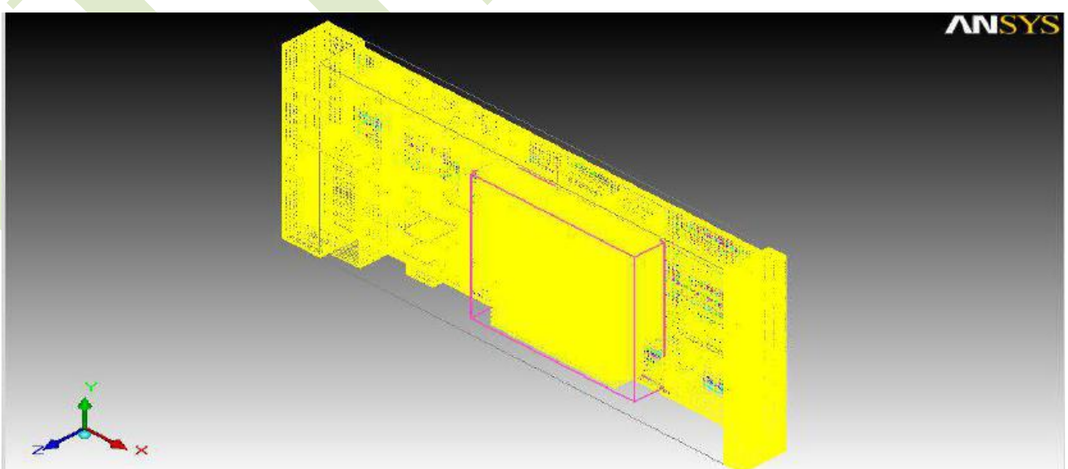

Fig. Meshing(Surface Wire Mesh)

c) Solution:

1) Velocity on opening on the MaxX side of the cabinets -1.5m/s.10.
2) Convergence criteria,
Flow-0.001, Energy-1e^-8.Iterations-120.

d) Results:

1) The graph shows Solution Residuals for conduction model for 120 iteration.

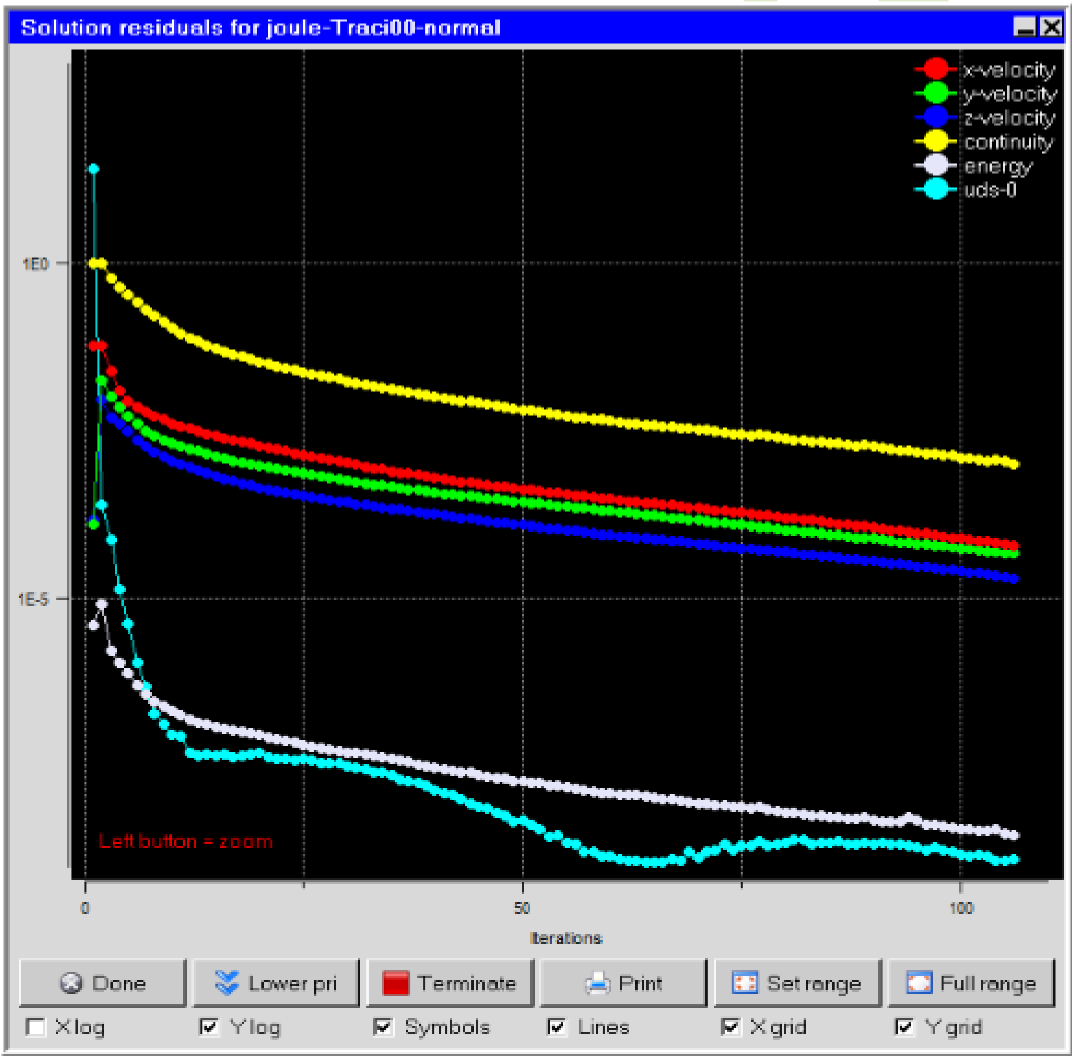

Fig. Solution Residuals For Conduction Model For 120 Iteration

2) Fig.shows Trace Temperature Contours with Forced Convection

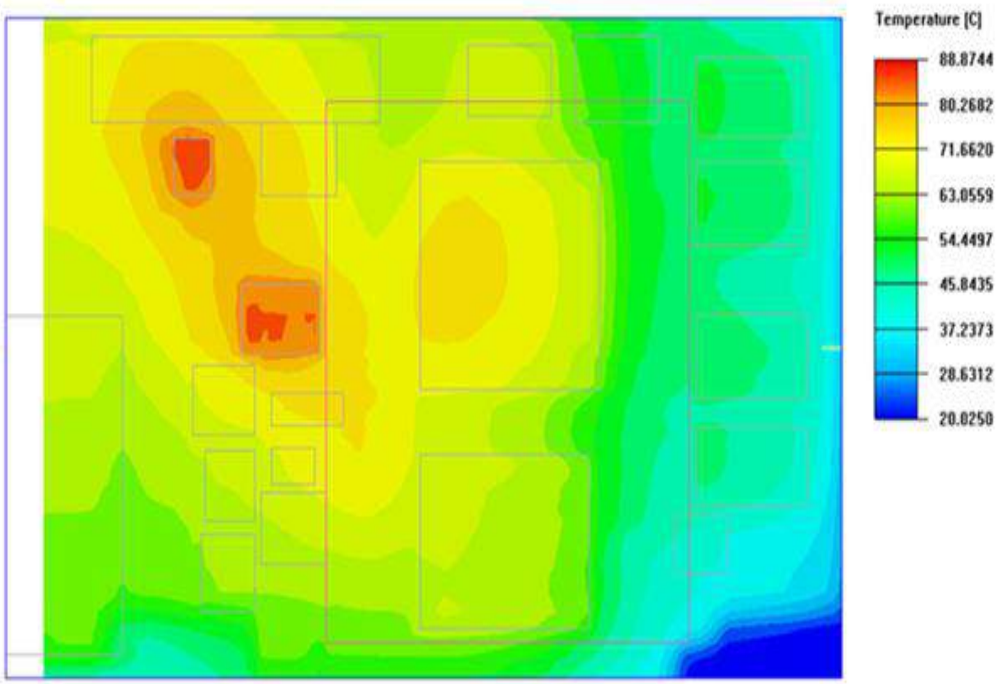

Fig. Trace Temperature Contours With Forced Convection

3) Trace Electric Potential Contours with Forced Convection.

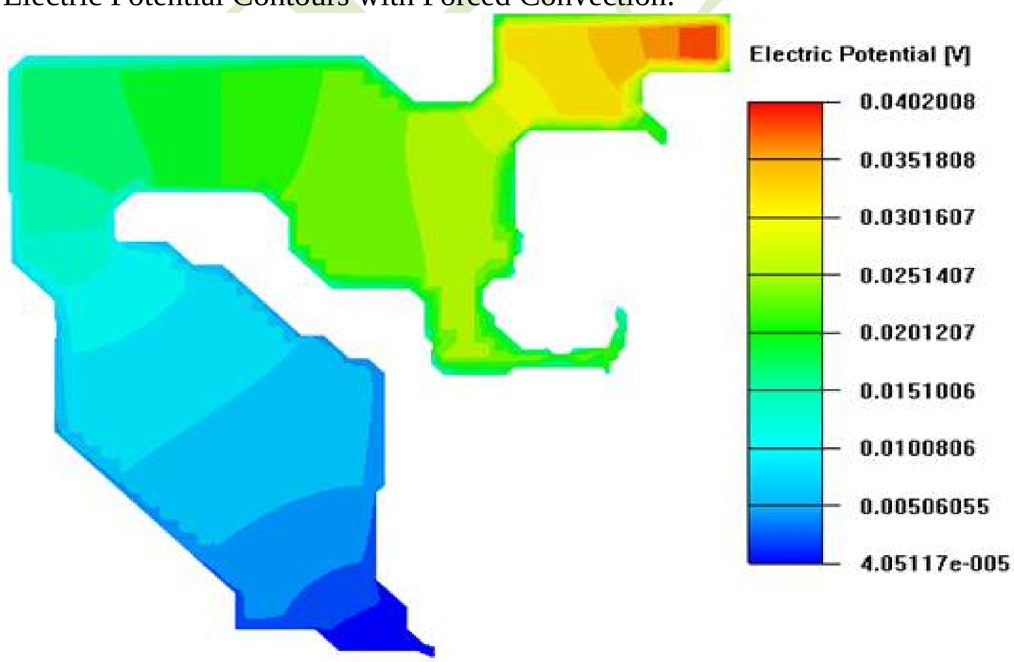

Fig. Trace Electric Potential Contours With Forced Convection

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4) Compare the maximum temperature for the cases with and without trace Modeling.

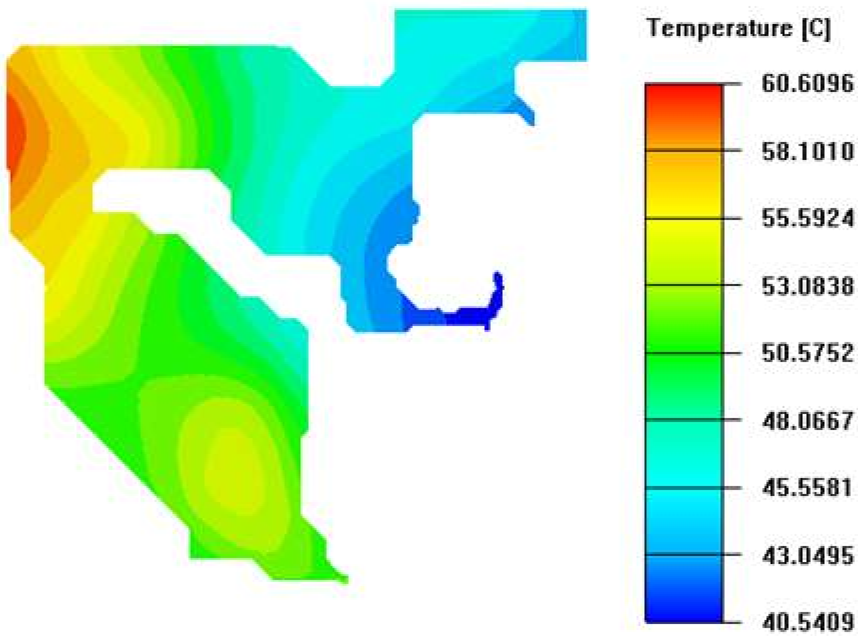

Fig. Max.Temperature For The Cases With And Without Trace Modeling

APPLICATIONS:

(a) Medical Applications:

Healthcare professionals depend on the accuracy and reliability of these instruments in order to provide reliable care to their patients. Bio-medical equipment have similar electronics cooling requirements, but with the unique sensitivity that their reliability may directly impact someone's well-being. Further, like with any other electronics, they are expected to perform at a higher response rate without failure. As the result, their thermal management is of paramount importance.

Medical applications present unique thermal challenges that are not necessary in other industries. These challenges are directly related to their use (ambient conditions) and fail-proof operation. In addition to these, a major challenge is associated with such devices interacting with humans in a compromised condition. Issues such as acoustic noise, EMI emissions, surface temperature constraints, dissemination of bacterial agents, etc. Add additional complexity to the thermal design, while attempting to keep the electronics cool for the highest response rate.

(b) LED Applications:

As the use of LED becomes more and more popular for illumination where incandescent lights are used commonly, their power consumption continues to increase, since more demand is placed on the LED for higher light output. High-power LEDs, often employed in arrays, require thermal management similar to other semiconductor devices and boards that are commonly seen in different electronics market sectors. Typically on the backside of the LED array, where as in a typical PCB, both sides of the board are often available for thermal management solutions. High temperatures not only degrade an LED'sexpected life, but also result in lower or non-uniform light output. The short-term effects are color shift and reduced light output, while the long-term effects are accelerated lumen depreciation and thus diminished lifespan. Many of the street traffic lights are daily reminders of how a poorly thermally managed LED light array can be adversely impactedby heat. As seen in many LED traffic lights, the central LED are burnt out which corresponds to the hottest points on the LED's PCB.

(c)Telecom Applications:

ATS is uniquely experienced in telecomm and datacommunication mechanical packaging and thermal design. ATS is considered the premier resource in this market sector based on its experience and diverse products offering that are specifically designed for telecomm and datacommunication equipment. As leaders in this market, ATS has resolved many thermal issues in the telecommunications industry. ATS's thermal analysis and design services' team is capable of analyzing the full packaging domain, including components, circuit boards (PCBs), shelves, chassis and system packaging to ensure optimal thermal performance.

(d) Aerospace Applications:

Avionics and other aerospace electronics embrace some of the world's most advanced technologies. Sophisticated electronics are often associated with more power consumption and as a result, higher heat generation requires acute attention to the thermal management challenges that they create.
As in other industries and applications, more power within smaller spaces result in excess heat problems. Because of this spatial constraint, unlike other industries, with aerospace components, the use of common heat dissipation devices is often not a viable option.

(e) Military And Defense Applications:

Many military electronics are often amongst the most sophisticated systems ever deployed. The unusual and rigid boundary conditions that range from a desert's surface to outer space create unique challenges in the design and thermal management of these systems. Such military electronics are deployed in communications, weapons, reconnaissance, targeting and evasion, payload delivery and discharge. Because of mission criticality and the rapid system response required, high power dissipation makes thermal management a critical issue for such systems.

(f) Automotive Applications:

As automobiles continue to deploy advanced electronics, heat dissipation is increasing at a rapid rate and thermal management is becoming more of a driving force than ever before. The computing sophistication that currently exists in most cars and trucks, rivals some of the complex telecomm and datacomm equipment on the market, with a major challenge of having uncontrolled ambient conditions that uniquely face automotive electronics. With the proliferation of electronics in smart-vehicles, vehicle-to-vehicle communications, vehicle-to-central office data exchanges, engines, cabins, lighting and environmental controls, effective thermal analyses must be undertaken to avert potential heat related issues that may put the operation of a vehicle in jeopardy.

(g) Embedded Computing Applications:

Excess heat can cause problems for many embedded computing applications. Thermal management directions provided by component makers may be inadequate or unavailable. As a result, engineering must take the time and trouble to set up thermal tests in order to find the most effective cooling solution.

Cooling embedded computing can be more complicated than other electronics. When resolving embedded heat issues, engineers are often faced with very little space available for heat sinks or fans, minimal air flow, densely crowded PCB's and custom designed PCB.

FUTURE SCOPES:

(a) Cooling With Lasers:

Laser cooling occurs when the amount of energy emitted by a solid, when exposed to an energy source, is more than the energy it absorbs. In other words, a laser aimed at certain materials will excite the materials' atoms to a higher energy state. These excited atoms absorb a little extra energy from the heat of the surrounding material. When they produce photons, the photons are of a higher energy than the initial laser energy and this radiation of energy cools the material.

While the electronics inside laser systems may require thermal management, lasers may one day have a major role in cooling electronic components. A research team at Singapore's Nanyang Technological University (NTU) successfully used a laser to cool down the semiconductor material cadmium sulfide, CDs. The results of their study could lead to the development of self-cooling computer chips and smaller, more energy efficient air conditioners and refrigerators that don't produce greenhouse gases. Having a laser to annihilate something isn't usually associated with chilling anything down. But a new experiment reduced the temperature of a semiconductor by about 40°C using a laser. Cadmium sulfide is an inorganic compound commonly used as a thin-film layer in solar cells, sensors and electronics.

The NTU researchers fabricated narrow strips of CDs, deposited on a substrate of silicon and silicon dioxide at room temperature. They used an optical-wavelength laser, tuned to the precise wavelength to interact with multiple modes of phonons in the semiconductor. When the laser photons interacted with this excitation, they canceled it out, damping the thermal fluctuations in the material. Because of this, the NTU research team successfully optically-refrigerated CDs from 20°C (68°F) down to -20°C (-4°F), a 40°C drop in temperature. Advances in cooling by laser, also described as optical refrigeration technology, could lead to compact, cost effective, vibration-free and cryogen-less cooling systems in many different applications.

CONCLUSION:

With successful compilation of project work we conclude that:

1. As the electronic circuits are being compact& the components have to place within control volume rate of heat generation , highly increased that's way thermal management of electric circuits are important.

2. The highly increased rate of heat conduction gives us the option of thermal management of electronic circuits. This thermal management is very important to control the fatigue & thermal failure of every component.

3. For the present electronic board we concludes that the heat convection rate is increased from bottom to top sides & right to left sides as per simulated model.

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