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THERMAL MANAGEMENT OF INERTIAL NAVIGATON SYSTEM IN AEROSPACE

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ABSTRACT

Inertial navigation system is the heart of every missile. In this project we did the thermal management on PCB (printed circuit board). These PCB`s are generally located inside a box of missile. These boxes are mounted on the chassis of INS in missile. So it is required to have huge number of PCB`s to run a control system, GPS, and navigation computers to calculate gravitational acceleration (not measured by accelerometers) and double integrate the net acceleration to maintain an estimate of the position of the host vehicle. So during missile working condition power is supplied to various chips/components (heat sources) like resistors, capacitors, processor, transformers, small batteries etc. While its running they generate the heat, so in this project we find how to reduce the dissipated heat from various heat sources by designing a general PCB having two or more layered materials and this model is imported into an ANSYS software (work bench v14.5) and did the steady state thermal analysis on PCB.

1 INTRODUCTION:

Inertial navigation system (INS) is a navigation aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate via dead reckoning the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external references. It is used on vehicles such as ships, aircraft, submarines, guided missiles, and spacecraft. Other terms used to refer to inertial navigation systems or closely related devices include inertial guidance system, inertial instrument, inertial measurement units (IMU) and many other variations. Older INS systems generally used an inertial platform as their mounting point to the vehicle, and the terms are sometimes considered synonymous. INSs contain Inertial Measurement Units (IMUs) which have angular and linear accelerometers (for changes in position); some IMUs include a gyroscopic element (for maintaining an absolute angular reference). Angular accelerometers measure how the vehicle is rotating in space. Generally, there is at least one sensor for each of the three axes: pitch (nose up and down), yaw (nose left and right) and roll (clockwise or counter-clockwise from the cockpit).Linear accelerometers measure non-gravitational accelerations of the vehicle. Since it can move in three axes (up & down, left & right, forward & back), there is a linear accelerometer for each axis.

Inertial Navigation Systems, unlike other **navigation systems**, **do** not depend on external (radio) measurements. Instead an INS keeps track of its position by accurately measuring acceleration (accelerometers) and rotation (gyroscopes). It therefore works in remote areas where there is no ground based navaids available.

2. VARIOUS FORMS OF NAVIGATION SYSTEMS:

Pilotage, which essentially relies on recognizing landmarks to know where you are. It is older than human kind.

- Dead reckoning, which relies on knowing where you started from plus, some form of heading information and some estimate of speed.
- Celestial navigation, using time and the angles between local vertical and known celestial objects (e.g., sun, moon, or stars).
- Radio navigation, which relies on radio- frequency sources with known locations (including GNSS satellites, LORAN- C, Omega, Tacan, US Army Position Location and Reporting System…)
- Inertial navigation, which relies on knowing your initial position, velocity, and attitude and thereafter measuring your attitude rates and accelerations. The operation of inertial navigation systems (INS) depends upon Newton’s laws of classical mechanics. It is the only form of navigation that does not rely on external references.
- These forms of navigation can be used in combination as well. The subject of our seminar is the fifth form of navigation – inertial navigation.

3.HEAT DISSIPATION:

Heat management for power devices is an even greater challenge. Higher-frequency signal processing and the need to shrink package size are pushing conventional cooling techniques to the brink.

PCBs play a critical role in thermal management, thus requiring a thermal design layout. Whenever possible, designers should keep power components as far away from each other as possible. Furthermore, they should be kept away from the PCB's corners, which will help maximize the amount of PCB area around the power components to facilitate thermal dissipation.

It's common for exposed power pads to be soldered to a PCB. Often, exposed-pad-type power pads conduct about 80% of the heat generated through the bottom of the IC package and into the PCB. The remaining heat dissipates through the package's sides and leads.

4.PCB:

Printed circuit board mechanically supports and electrically connects electronic

components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. Components (e.g. capacitors, resistors or active devices) are generally soldered on the PCB. Advanced PCBs may contain components embedded in the substrate.

PCBs can be *single sided* (one copper layer), *double sided* (two copper layers) or *multi-layer* (outer and inner layers). Conductors on different layers are connected with vias. Multi-layer PCBs allow for much higher component density.

FR-4 glass epoxy is the primary insulating substrate. A basic building block of the PCB is an FR-4 panel with a thin layer of copper foillaminated to one or both sides. In multi-layer boards multiple layers of material are laminated together.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part.

Modern PCBs are designed with dedicated layout software, generally in the following steps:

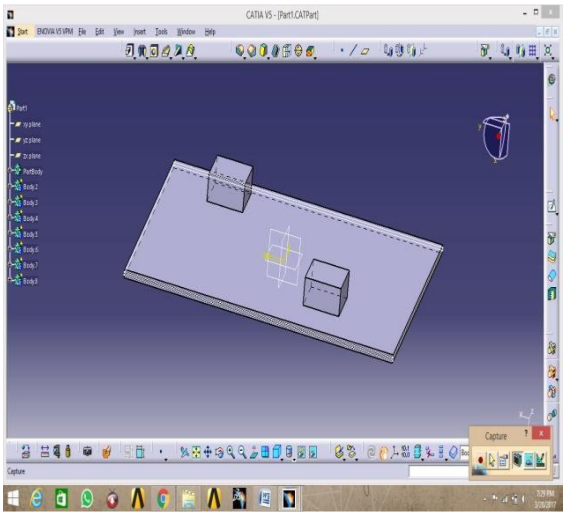
1. Schematic capture through an electronic design automation (*EDA*) tool.
2. Card dimensions and template are decided based on required circuitry and case of the PCB.
3. The positions of the components and heat sinks are determined.
4. Layer stack of the PCB is decided, with one to tens of layers depending on complexity. Ground and power planes are decided. A power plane is the counterpart to a ground plane and behaves as an AC signal ground while providing DC power to the circuits mounted on the PCB. Signal interconnections are traced on signal planes. Signal planes can be on the outer as well as inner layers. For optimal EMI performance high frequency signals are routed in internal layers between power or ground planes.[5]
5. Line impedance is determined using dielectric layer thickness, routing copper thickness and trace-width. Trace separation is also taken into account in case of differential signals. Micro strip, strip line or dual strip line can be used to route signals.
6. Components are placed. Thermal considerations and geometry are taken into account.
7. Signal traces are routed. Electronic design automation tools usually create clearances and connections in power and ground planes automatically.
8. Gerber files are generated for manufacturing.

5.PCB DESIGN IN CATIA:

We used the CATIA v5 R20 modeling software**.**

In this the PCB is designed by using three or more layers stacked one over other having very small thickness about 1 to 2 mm. And the overall thickness is about 3 to 6 mm.

And the heat sources having dimensions 20x20 mm^2 with a height of 10 mm are used.



Each layer having a dimension of 140x110 mm^2 with a thickness of 1 mm each are used.

6.MATERIAL APPICATION:

Bottom layer –aluminum

Middle layer-FR4 (flame retardant)

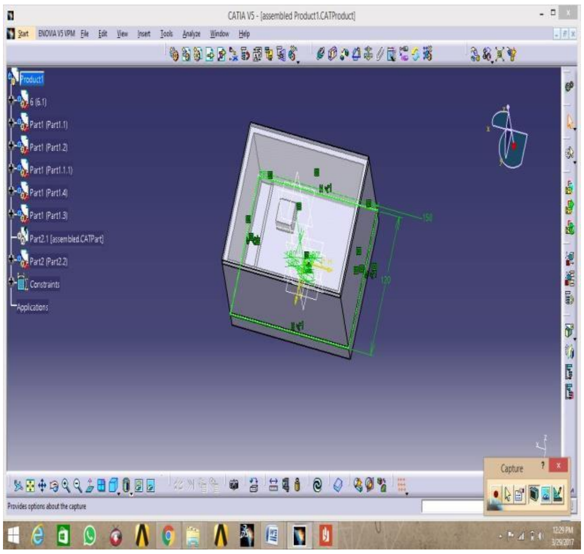
Upper layer- copper

Heat dissipating materials- copper (because of high thermal conductivity). Under steady state thermal analysis after applying all conditions like conduction, convection, power in watts the result is as follows.

Here we obtained a max temeperature of 85^{0}C and a minimum of 45^{0}C.

7. INSERTION OF PCB INTO A BOX:

Designed Catia model for inserting Pcb



It is a hollow enclosed rectangular box of 150x110 mm^2 having a wall thickness of 5mm.

And the applied material is aluminum.

After importing the complete assembly into ANSYS v14.5 and applying steady state thermal analysis the result will look like as below picture.

8.ADVANTAGES OF INS:

It is autonomous and does not rely on any external aids
or visibility conditions. It can operate in tunnels or
underwater as well as anywhere else.
• It is inherently well suited for integrated navigation,
guidance, and control of the host vehicle. Its IMU

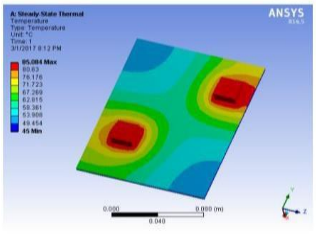
measures the derivatives of the variables to be controlled (e.g., position, velocity, and attitude).

• It is immune to jamming and inherently stealthy. It neither receivers nor emits detectable radiation and requires no external antenna that might be detectable by radar.

9.ANALYSIS RESULTS FOR HEAT DESSIPATION OF A PCB BOARD:

Temperature

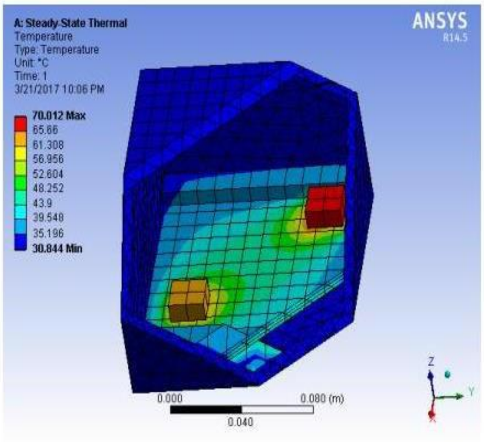
Subject:
Author:
Prepared For:
Date Wednesday, March 1, 2017
Comments:



10.ANALYSIS RESULTS FOR HEAT DECIPATION WHEN THE PCB IS CLOSED IN A BOX:

Temperature

Subject:
Author:
Prepared For:
Date Tuesday, March 21, 2017
Comments:



Maximum temperature - 70.012^0C.

Minimum temperature - 30.844^0C.

11.CONCLUSION:

If the temperature exceeds more than 80-90^0C in INS we use the latest heat flow methods for spontaneous heat transfer. There may be e.g.-

1. Heat pipe concept
2. Creating thermal conductive path on pcb`s.
3. Using phase change materials on Pcb mountings.

12.REFERENCES:

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