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Analysis of Heat Transfer in Electronic Control Unit of Automobile

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ABSTRACT

In recent years, electrical equipment are drastically developing and miniaturizing. Higher integration of semiconductor devices leads to these developments. On the other hand, higher integration of semiconductor devices on one chip and higher integration of electrical devices in one package means increase of heat generation density. Only copper is present in the ECU which has thermal conductivity is high. . The percentage of copper increases thermal conductivity of the board increases. Thermal conductivity increases temperature decreases. Component placement is also an important factor for the board temperatures. Multiple trials for components location can be performed in order achieve an optimal thermal design effect. Selecting high conductivity substrate material is more advantageous to reduce board temperature.

Keywords:Computational Fluid Dynamics(CFD), Electronic Control Unit, Integrated Circuits, Metal Oxide Semiconductor Field Effect Transistor(MOSFET)

I. INTRODUCTION

Electronic equipment has made its way into practically every aspect of modern life, from toys and appliances to high-power computers. The reliability of the electronics of a system is a major factor in the overall reliability of the system. Electronic components depend on the passage of electric current to perform their duties, and they become potential sites for excessive heating, since the current flow through a resistance is accompanied by heat generation. Continued miniaturization of electronic systems has resulted in a dramatic increase in the amount of heat generated per unit volume, comparable in magnitude to those encountered at nuclear reactors and the surface of the sun. Unless properly designed and controlled, high rates of heat generation result in high operating temperatures for electronic equipment, which jeopardizes its safety and reliability. 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. Most electronic devices operate for long periods of time, and thus their cooling mechanism is designed for steady operation.

1.1 GeneralizedIntroduction to Use of PCB

Nowadays, electronic circuit devices can be found everywhere around us. Printed Circuit Boards (PCB) are an essential part of computers, audio and video devices, automobiles or airplanes, and also in less common applications as diverse elements of spacecrafts and telecommunication satellites.The boards are made fromglass reinforced plastic with copper tracks in the place of wires. Components are fixed in position by drilling holes through the board, locating the components and then soldering them in place. The copper tracks link the components together forming a circuit.

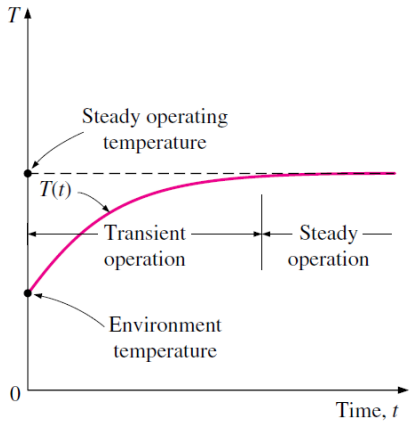

Fig. 1: temperature graph in electronic equipment

1.2 PCB in Application to Automobile ECU

In recent years, electrical equipment are drastically developing and miniaturizing. Higher integration of semiconductor devices leads to these developments. On the other hand, higher integration of semiconductor devices on one chip and higher integration of electrical devices in one package means increase of heat generation density. The operation of integrated circuits (IC) at elevated temperature is a major cause of failures in electronic devices and a critical problem in developing more advanced electronic packages. This is because the life expectancy of electronic components reduces exponentially as the operating temperature rises . One such example of an electronic device is the electronic control unit (ECU) in automotives whose function has increased and is expected to further rise in the foreseeable future The electronic content in today's automobiles is increasing staidly as numerous applications now use electronic control. Application from entertainment and comfort of power train and body electronics increasingly use electronic control circuits for better reliability and performance. Severe competition and stringer pollution and safety norms and fuel economy are some of the factors influencing auto industry to look for new technologies using electronic controls. For many electronic circuits printed circuit board forms the basic foundation for interconnecting and packaging. Microcontroller can be described in simple words as heart and brain of electronic circuits.

1.3 Problem Statement

The ECU is overheated when vehicle is under loaded condition. Due to the overheating of ECU vehicle control system not working properly and some packages are damaged due to overheating and the temperature range is -20 to 80˚ c. Without increasing its volume , cooling required for the following ECU.

II. OBJECTIVES

In electronic cooling temperature is very important parameter without increasing the cost of the product. Following objectives will require decreasing the temperature of the ECU.

1. To determine the temperature of Electronic circuit board by experimentally.
2. Validate the experimental result with numerical method.
3. To determine the high temperature problem in ECU.
4. Find out best suitable thermal design for electronic control unit with the help of computational fluid dynamics

2.1 Methodology

In the projects only conduction cooling is possible because structure of the ECU. Following two methods are used for conduction cooling in this work.

2.1.1 Component Placement (SOGA)

The component placement is very effective and chi pest technique in electronic cooling. Thermally well designed electronic circuit board increases the life of the board.

2.1.2 Thermal Conductivity

Increase the thermal conductivity of the board with replacing the board material and copper percentage of the board.

III. EXPERIMENTAL WORK

The experimental work is very important to analyze the different parameters. Today in market lot of software facilities are available but there is lot of considerations in the software analysis. It will be very important to the experimental testing for perfect temperature as well as other quantities for the validating the result with the software analysis.

3.1 Experimental Layout

New electronic control unit which are runs on the programmed control due to that DC power supply cannot be provided. The following figure shows the experimental layout. Fortunately ECU is present in the driver's cabin in the vehicle. The thermocouple wires are attached on the surface of the packages. AC power supply is provided to the temperature indicator to indicate the temperature at different location. Vehicle starts normally under unloaded condition and temperature measured up to steady state condition is occurred. Temperature indicator having only AC Current is available due to one reason all test is conducted at normal condition. A

thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots, where a temperature differential is experienced by the different conductors.

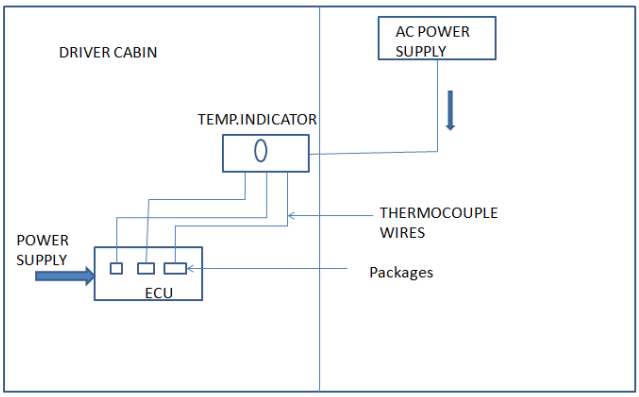

Fig. 2: temperature graph in electronic equipment

3.2 Procedure

In this projects following procedure are followed to measure the temperature at the different location.

1. First all the instrument set up check and noted down the initialise temperature of the environment as well as inside ECU.
2. Vehicle starts and noted down the temperature of the different points as well as outside temperature.
3. Vehicle running continuously up to readings comes at the steady state condition.
4. After confirmation of steady state stop to take the readings. And check the engine ideal condition with the help of software.
5. This procedure repeats all the packages which are present on the ECU.

IV.COMPUTATIONAL FLUID DYNAMICS OF ECU

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 (PCBs) 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. High temperatures detrimentally affect electrical performance of printed circuit boards.

4.1 Computational Model

ANSYS Icepak, you 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. Our tools enable you to accurately simulate different cooling scenarios for single and rack-mounted boards along with component power and copper resistive losses in trace layers.

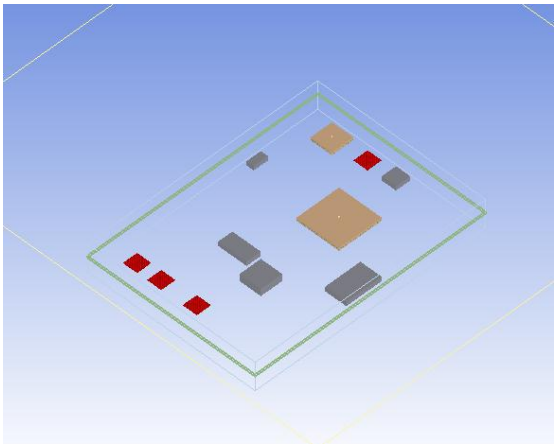

Fig. 3:CFD Model of ECU

4.1.2 Packages

The following table gives the dimensions of the different component which are placed on the board. These packages are the most heat generating sources on the board.

Packages	Simplification	Dimension
MOSFET	Heat source	0.01 x 0 x 0.01 m
MOSFET	Heat source	0.01 x 0 x 0.01 m
MOSFET	Heat source	0.01 x 0 x 0.01 m
MOSFET	Heat source	0.01 x 0 x 0.01 m
SMD	Block	0.01 x 0.003 x 0.01 m
SMD	Block	0.005 x 0.003 x 0.01 m
PLCC	Block	0.015 x 0.003 x 0.025 m
IC	Block	0.02 x 0.003 x 0.01 m
Voltage Regulator	Block	0.015 x 0.005 x 0.015 m
QFP	QFP	default
QFP	QFP	default

Table 1: Packages in ECU for CFD Analysis

4.1.2 Enclosure

The enclosure consists of aluminum with 4mm thickness. The shape of the enclosure shape is also simplified into rectangular shape. The ECB of ECU is closely fitted between upper and lower plate of the enclosure. The model case was constructed as being entirely sealed as a close approximation to the real case geometry. As four edges of the PCB (printed circuit board) are close in contact with the case, thermal contact resistance is also considered in the model.

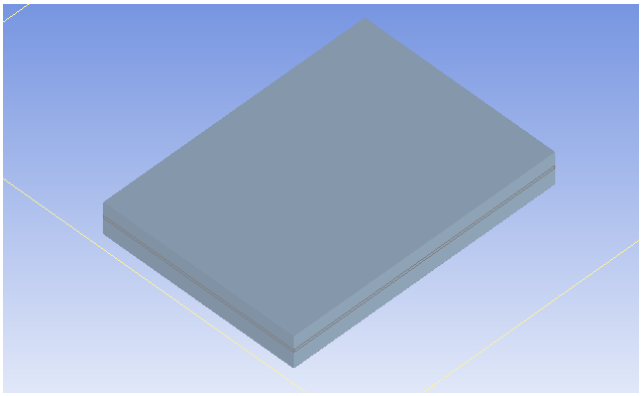

Fig. 4:Enclosure in CFD Model

V. DIFFERENT TECHNIQUES FOR HEAT TRANSFER IN ECU USING CFD MODEL

5.1 Effect of Copper

Only copper is higher thermal conductivity present in the ECU. The percentage of copper increases thermal conductivity of the board increases. Thermal conductivity increases temperature decreases. As the copper is the primary heat transfer medium of PCB in plane directions, the additional copper thus provides greater ability to conduct heat. From a thermal design point of view, the designed PCB with the more layers, the thicker thickness, the bigger copper coverage area, the better thermal performance will be more easy to achieve, and also with increased costs. The percentage of copper varies from 20 to 80 percentages. The manufacturing consideration of last limit is maximum 65%. So the copper percentage increases from 50% to 65%, temperature decreases from 1.5 to 2˚c.

5.2 Component Placement

Component placement is old method but it is still used for thermal design in electronic cooling. The optimal placement of electronic components on a printed circuit board (PCB) requires satisfying multiple conflicting design objectives as most of the components have different power dissipation, operating temperature, types of material and dimension. In addition, most electronic companies are currently emphasizing on designing a smaller package electronic system in order to increase the system performance.

VI. CONCLUSION

Thermal management and thermal management design in automotive ECUs has long been a challenging issue as it's compact on the devices reliability and endurances. The automotive electronic control unit (ECU) package faces the same challenge of thermal management as the industry in general.

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