Thermal Analysis of Arduino Uno Microcontroller

Richa Tripathi, Akshaya Simha, Harshith C

***Abstract**: It so happens that microcontrollers tend to get heated by immense temperature effects due to environmental changes and disturbances. Many microcontrollers have thermal temperatures ranging from 10 °C to 50 °C. In this study, design and thermal analysis of microcontroller are presented where systems operate on ARDUINO microcontroller. Microcontrollers are used for automation and robotics applications. Various industrial applications can use this microcontroller in the future by using IoT principles. Hence, there is a need for thermal analysis of the microcontroller. Arduino UNO is taken for study. The effect of various factors such as thickness and length of PCB were studied. Throughout the study, it was observed that there is a 50-60% achievement in heat dissipation with the modified microcontroller.*

Keywords: Arduino, PCB, UNO, microcontroller, thermal

I. INTRODUCTION

Printed Circuit Board (PCB) is a collection of organic and inorganic compounds that consists electronic components that are to be connected. Arduino is an open-source electronics circuit board interfaced in various applications like robotics, automation, and industries. Arduino uses the concept of hardware interfacing with multiple components like sensors, actuators, LEDs, etc. and software programming using Arduino IDE. In certain conditions, Arduino microcontroller has been in use across multiple automation companies that can replace the popular Programmable Logic Controllers (PLC).In various manufacturing industries, Arduino is excellent in IoT that monitors multiple systems. Arduino collects the data of the methods that can manage temperature, humidity, and other physical variables.Great care is taken in studying and analyzing the system about how thermal propagations occurs that can lead to malfunctions in extreme conditions, like testing the microcontroller near blast furnaces in steel industries.

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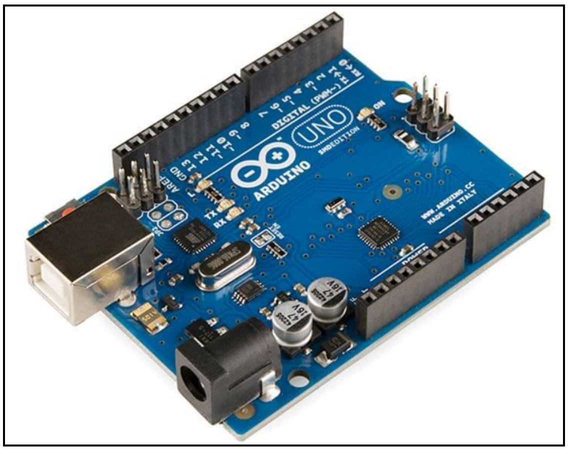

Fig. 1: Arduino UNO microcontroller

The main causes of failure of industrial equipment are due to dust and temperature uncertainties. 55% of failures occur due to an undesirable rise in temperature and bad thermal design. For every 10 °C rise in temperature, there is a drastic reduction in its life by half.

Thermal challenges also proliferate in traditional electronic design that is analyzed for temperature, heat dissipation, and thermal stresses are integrated circuits (ICs), capacitors, heat sinks, USB connectors, etc. that performs useful data transmission.

A study of "Thermal Analysis of Printed Circuit Board (PCB) [1] of Avionics Equipment" by Dr. N. V. Srinivasulu has reported that proper heat dissipation of microcontroller is linked with the performance of the electronics. Hence there is a study required for thermal analysis which includes temperature distribution, heat flux, and properties of circuit board over temperature distribution. Another unique study "Thermal Analysis of a PCB Assembly [2]" by Clinton Smith in PADT was done. This study was done to analyze the PCB in various thermal conditions. He concluded that there is a need for characterizing the maximum temperatures in the device and investigate conductivities, heat flux and lineplots.

In this regard the current study deals with the thermal analysis of microcontroller and improving heat dissipation for better performance of microcontroller.

1. Methodology:

1) 2.1 Model design:

The model is designed in SOLIDWORKS 2019 CAD software. The dimensions have been measured practically. Certain alterations have been done in the area of Arduino's

PCB to simplify the design of the CAD model which is shown in the Fig. 7.

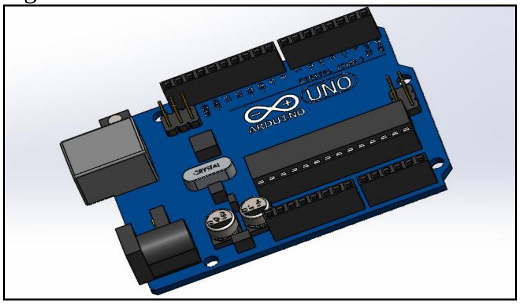

Fig. 3: Arduino UNO (Isometric view)

B. *2.2 Work procedure:*

The research methodology for the current study is represented in the following flowchart.

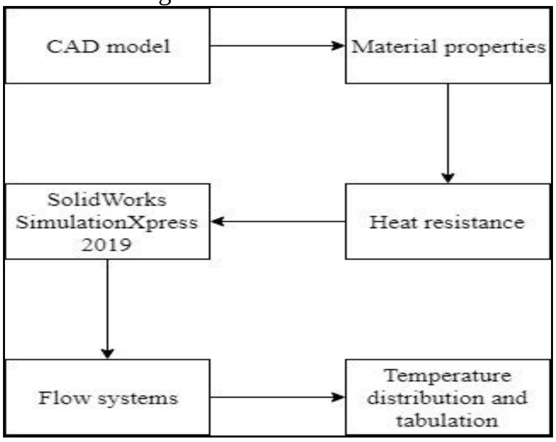

Fig. 4: Flowchart of simulation

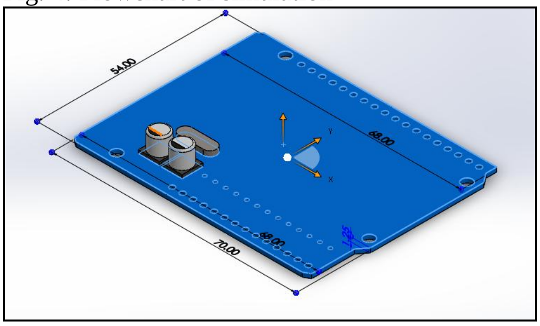

Fig. 5: CAD model having dimensions

The dimensions have been altered as shown;

	Actual dimension	New dimension
Length(L)	68mm	75mm
Width(W)	53mm	60mm
Thickness(h)	1.75mm	2.5mm

After removing the clutters in the CAD model, Arduino looks as shown below:

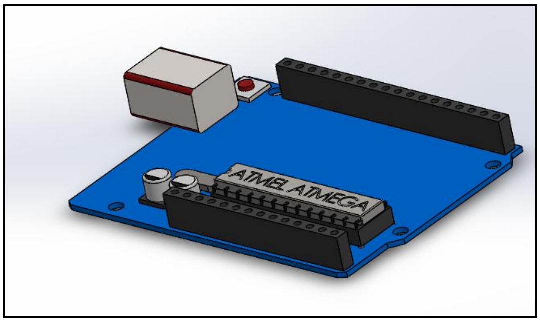

Fig. 6: Uncluttered Arduino board

Uncluttering process of the design reduces the simulation process by nearly 50% without hampering the accuracy of the results.Now, for the actual thermal process, materials used in the Arduino board are fed into the SolidWorks Materials section that has “glass epoxy laminate” material. It is selected for the study. Epoxy is a uniform material used in electronic components like capacitors, PCBs, LEDs, etc. that have been considered in the simulation.

A SolidWorks add-in called SimulationXpress is loaded. A new thermal study is used and following details were input:

i. Heat power = 25 W
ii. Units = SI
iii. Convection = 250 W/m^2
iv. Convection current = 100 W/m^2
v. Voltage = 5 V
vi. Current = 1 A

Thermal loads that can be added into the simulation are as shown below in the figure.

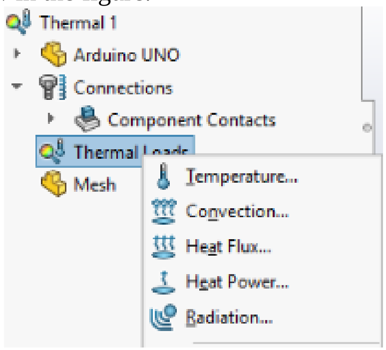

Fig. 7: Types of heat transfer thermal loads

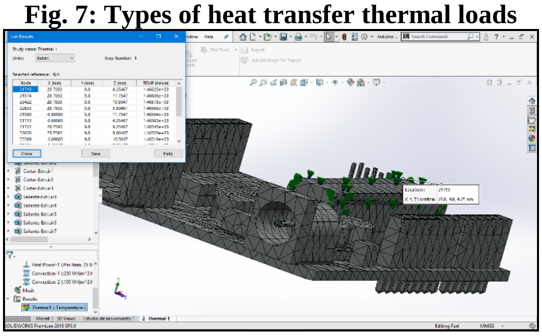

Fig. 8: Meshing process

As shown above, the meshing process is a fundamental process that is done in this simulation.

In coarse meshing process, the element that needs to be broken into smaller fragments will be bigger than 3.5 mm. This value can be optimized depending on the RAM size and CPU frequency of the PC. On an 8GB RAM, it took a minute to discretize and mesh the Arduino board with the removal of unwanted components like capacitors and LEDs. With obvious reasons, fine will increase the time for meshing but will account with more accuracy and precision.

The input parameters include:

i. Ambient temperature = 300 K
ii. Convection coefficient = 100 W/m^{2}K

The thermal plot of IC which shows the thermal distribution of heat convection is shown Fig. 9.

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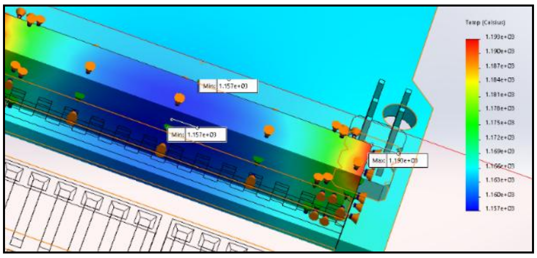
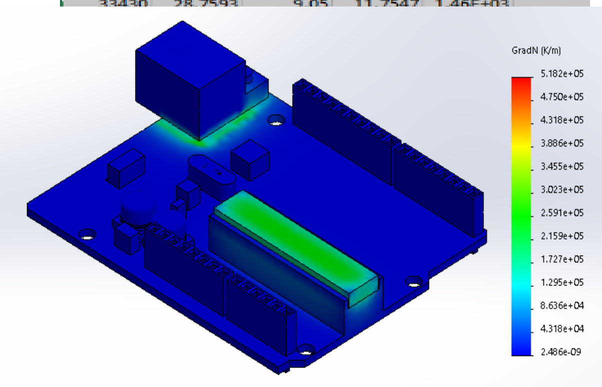


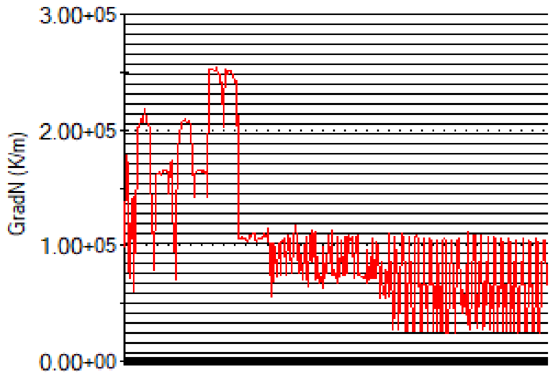
Fig. 9: Thermal plot of IC

C. *Results and discussion:*

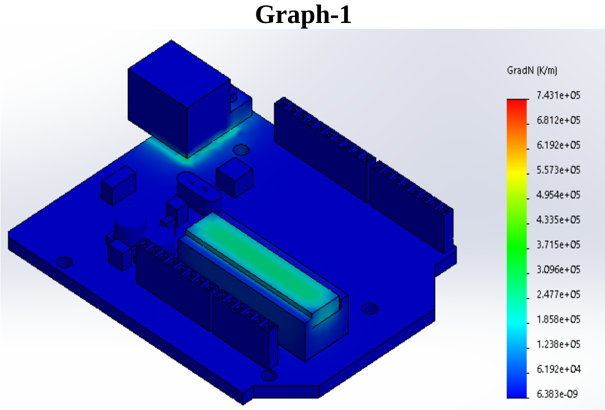
After the simulation, the following result is obtained:

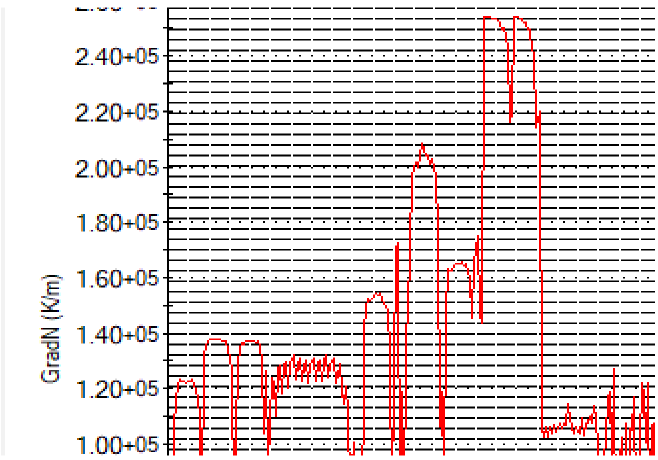
Units: Kelvin				
Selected reference : N/A				
Node	X (mm)	Y (mm)	Z (mm)	TEMP (Kelvin)
31719	28.7593	9.8	4.25467	1.47E+03
31574	28.7593	9.8	11.7547	1.47E+03
33422	28.7593	9.8	10.5047	1.47E+03
32633	28.7593	9.8	5.50467	1.47E+03
31589	-6.69065	9.8	11.7547	1.47E+03
31713	-6.69065	9.8	4.25467	1.47E+03
31721	28.7593	9.8	9.25467	1.47E+03
32630	28.7593	9.8	8.00467	1.47E+03
33309	-6.69065	9.8	10.5047	1.47E+03
32664	-6.69065	9.8	5.50467	1.47E+03
31720	28.7593	9.8	6.75467	1.47E+03
32636	28.7593	9.05	4.25467	1.46E+03
31711	-6.69065	9.8	9.25467	1.46E+03
32669	-6.69065	9.8	8.00467	1.46E+03
31712	-6.69065	9.8	6.75467	1.46E+03
33430	28.7593	9.05	11.7547	1.46E+03





Graph-1





Graph-2

Above graphs are showing the heat dissipation in old and new models of microcontroller .Old microcontroller is dissipating heat at $5.18*10^5$K/m. new modified microcontroller is dissipating the heat at $7.43*10^5$K/m. This implies that 40%-45% increase in heat dissipation. This results in improved circulation of thermal conductivity, when large controllers/peripherals are added to Arduino microcontroller.

II. CONCLUSION:

In Industries ,55% of failures occur due to an undesirable rise in temperature and bad thermal design. In this paper ,we can see Ardino-uno microcontroller is dissipating more heat with modified microcontroller .the following are the thermal analysis which results that with only 10% change in dimension can increase the heat dissipation by 40%-50%.By the use of modified microcontroller ,we can decrease the probability of failure of electronic equipment. With the increase in dimension although the heat dissipation is increased but weight of the device also increased as well. So it is recommended to use microcontrollers of 1.75mm thickness.

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