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THERMAL- ELECTRICAL SIMULATION AND ANALYSIS OF LM7805 IC FOR ELECTRONICS POWER SUPPLY ADAPTER

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ABSTRACT

LM7805 IC is a fixed linear voltage regulator. The difference in the value of input voltage and output voltage comes as a heat. Now a days, the failure rate of an LM7805 IC increases exponentially with respect to their temperature variations. In the existing system, Aluminium is used as a heat sink to transfer the heat and aluminium heat sink reaches its limitations to transfer heat in a LM7805 IC chip. In this work, Aluminium heat sink is replaced by Aluminium Nitride. The electrical properties, heat dissipation, reliability and power consumption of Aluminium Nitride heat sink are analysed by using simulation software's (ANSYS and Multisim) .It is found that the Aluminium Nitride heat sink has lower current density, higher heat dissipation, highly reliable and less power consumption than that of Aluminium heat sink.

KEYWORDS: Multisim, ANSYS (v12), IC 7805

Voltage regulators assume a vital role in all electronic circuits, adapter and central processing units (CPUs) etc., and which provide a stable power supply to the circuits. It's basic for conveying power from the particular power supply to the integrated circuits at their respective and desired voltage levels (fixed or time-varying).The temperature-related effects are very important in determining both the performance and reliability of the circuit. In Voltage regulator 7805 IC, excessive heat produced due to variation in input source and output. In order to extend the lifetime of an electronics component such as voltage regulator, thermal analysis is most needed one.

Taigon Song et al.[1], suggested a thermal analysis methodology for silicon interposer-based mixed-signal 2.5D integrated voltage regulator designs. Thermal and electrical conductivity values are correctly taken into account considering nonlinear material properties for every material layer of the device structure [2].

Bian Heying et al [3], observed that Multisim is appropriate for a wide range of circuits. Here, the schematic voltage regulator circuit is intended in Multisim and varied output values are measured for corresponding changes within the input sources. Multisim [4] is that the schematic capture and simulation program designed for schematic entry, simulation, and feeding to downstage steps, like PCB Layout. In an experimental part, LM35 sensor is used to measure the thermal changes in the voltage regulator with the help of PIC controller (PIC 16F876A). Stefano de Filippis et.al [5] verified an electro-thermal simulation approach implemented in ANSYS(v12) to simulate power MOSFETs operating in forward conduction. The geometries for the Electric simulations are imported from CATIA to generate mesh. Ghorbanpour et al. [6] investigated the stress and electric potential fields in piezoelectric hollow spheres. Dai and Wang [7] presented the thermo-electro-elastic transient responses in piezoelectric hollow structures. The thermal conductivity of aluminium is 205 W/(m.k) and Aluminium nitride is 285 W/(m.k). Yingbin Bian et al [8] studied that Aluminium nitride (AlN) thin film, due to its electrical and thermal properties, can be used as thermal interface material for flexible electronics. It is studied from the literature survey that, very little work has been done on IC LM 7805 in the sense of thermos-electric properties and analysis. Therefore, in this research work thermo-electrical behaviour of IC 7805 is carried out by using ANSYS Software and replacing the existing Aluminium heat sink with Aluminium Nitride heat sink to meet out the objectives: a) To study the current density. b) To study the heat dissipation capacity. c) To analyse the reliability and d) To evaluate the power consumption of Aluminium and Aluminium Nitride heat sink.

Nomenclature

P_I = Power distributed in the input side.

P_D = Power / heat dissipated by the linear regulator in watt-W.

θ_{JA} = theta $_{JA}$ (junction to ambient) - °C/W

T_J= junction temperature rating - °C

T_A = ambient temperature - °C

P_D = power dissipated in watts – W

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DESIGN AND ANALYSIS

The schematic diagram of the proposed work comprise of voltage regulator LM7805 IC, Multisim, temperature measurement setup, and ANSYS as shown fig 1. The Voltage regulator IC maintains the output voltage at a constant value. Initially the VR Circuit was initially design with a support of resistors and capacitor after that the thermal and electrical properties which was carry out by ANSYS software and Multisim. Due to the continuous flow of charges and the usage, the regulator IC LM7805 gets heated. Schematic diagram to analysis the thermal –electric performance of voltage regulator LM7805 IC as shown in fig1.Multisim provided by National Instruments is associate electronic schematic capture and simulation program. It's utilized here to design the circuit and to find the simulation output such as transient response and temperature characteristics. The Experimental part consists of PIC Microcontroller (PIC16F876) and thermistor.

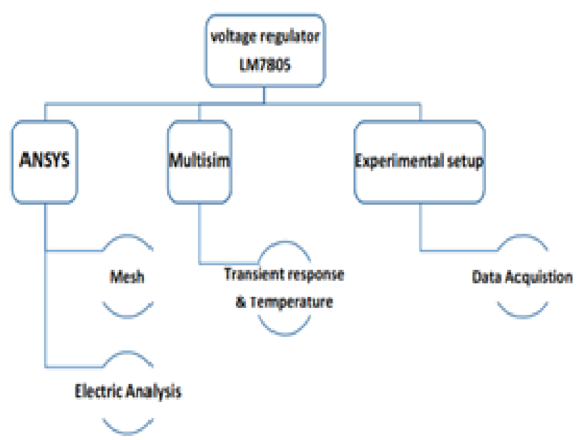

Figure 1: Schematic diagram to analysis the thermal –electric performance of voltage regulator LM7805 IC.

The 3D model of the MOSFET has been bring out using ANSYS Software based on the given technical specifications and geometric values [9]. The Electric field, current density and Joule heat are solved in the 3-D Electric (ANSYS).The numerical simulations results are derived by conducting iterative calculations until are the variables reach the steady state values. The simulation was also performed by NI Multisim software to obtain the temperature value of voltage regulator IC 7805 and Transient response. The experiments were carried out to investigate the performance of Voltage regulator at different input voltage and load. Measurements were taken and performance characteristics were calculated.

RESULTS AND DISCUSSION

Experiment on Voltage Regulator (VR)LM7805 IC

Many of the voltage sources cannot able to give fixed output due to fluctuations in the circuit. The voltage regulator IC 7805 is actually a member of 78xx series of voltage regulator ICs. This regulator IC also have provision of Aluminium heat sink. The input voltage to this voltage regulator can be up to 35V and this IC can give a constant 4.8-5.2 V for any value of input less than or equal to 35V which is the threshold limit. The operating temperature range, T_{OPR} is 0 to +125 °C and thermal resistance junction air $R_{\theta JA}$ is 65 °C. In IC 7805 voltage regulator**,** lots of energy is exhausted in the form of heat. The difference in the value of input voltage and output voltage comes as heat. Without a heat sink, this too much heat will cause malfunction.

The ideal calculation for heat generation is given by equation (1)- (4).

$$Heat\ generated =$$

$$(input\ voltage\quad 5) * output\ current$$

Power distributed in the input side,

$$PI = II \times VI. \ldots..(1)$$

Similarly, the power delivered to the load is

$$PO = IO \times VO \ldots..(2)$$

The difference between P_I and P_O is the power that is burned or dissipated by the regulator. The quantity of dissipated power (P_D) can be extracted by the following equation:

$$PD = PI - PO \ldots..(3)$$

P_D to the thermal specifications for a linear regulator:

$$PD = (TJ - TA)/\theta JA \ldots..(4)$$

By using these known values, equation will shows that the value of θ_{JA} is necessary in order to have enough thermal conductance or thermal dissipation capability for our linear regulator in a power supply circuit. Fig 2 shows that the regulated power supply PCB using voltage regulator IC 7805.

Thermal resistance is a heat spreader and equation (5) is given. This can be defined as the ratio of temperature difference between surface of microprocessor (T_b) and environmental air (T_0) to the total heat flow (Q) which can be removed to the environment under thermal conditions [10].

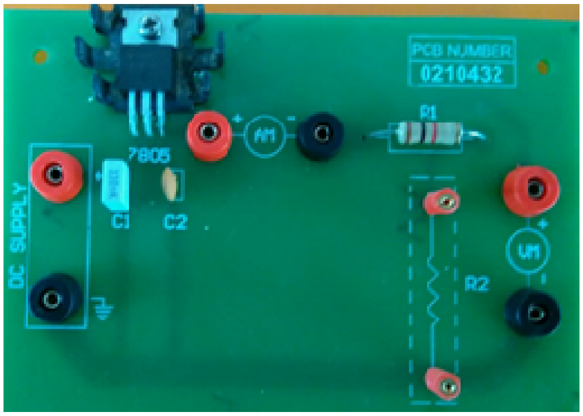

Figure 2: Regulated power supply PCB using voltage regulator IC 7805

$$R = \frac{Tb - Tc}{Q} \quad .....(5)$$

The Experimental setup to measure the change of temperature in IC7805 using PIC controller and sensor LM35 as shown in fig 3. Here, Aluminium is used as a heat exchanger because it has a good thermal conductivity properties. The result obtained shows that the variation of temperature from 22 °C to 36°C occur

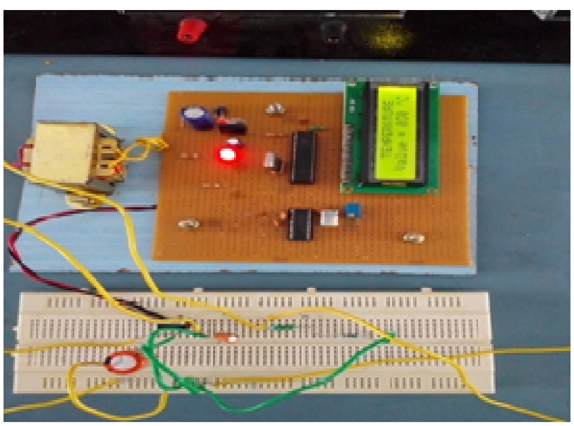

Figure 3: Experimental setup to measure the change of temperature in IC7805 using PIC controller and sensor LM35.

when the voltage level reaches 35V for a time 2s as shown in fig 4. The graph of temperature against voltage shows that, the temperature linearly increase when the input voltage was increased from 0 to 35V. This is because of difference in the value of input voltage and output voltage comes as temperature.

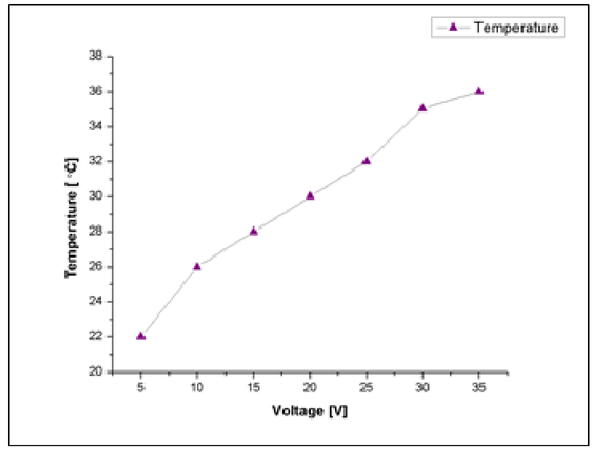

Figure 4: Temperature VS Voltages for Aluminium Heat sink

Multisim for Simulation

Multisim 11.0 is a design tools used for electronic circuit schematic and simulation. Multisim is also applicable to the board level analog / digital circuit design, which includes rich functions, such as circuit principle graph input, circuit hardware description language input, simulation and analysis [11].Here, Multisim software is been used to carry on simulation on the VR circuit with series connected resistance and capacitors. This design is appropriate for producing a linear and a constant output.

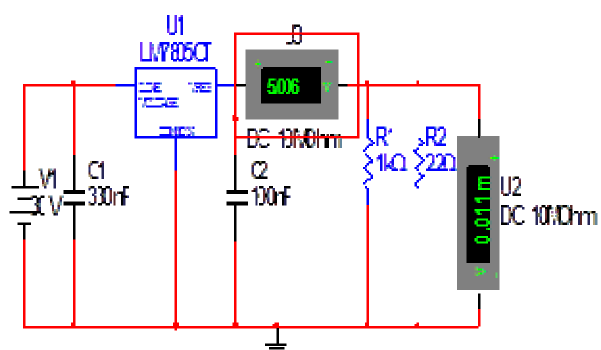

Figure 5: Schematic diagram for voltage regulator LM7805 with power supply 30 V using Multisim.

The values of capacitances and resistances are taken as R_1=1KΩ, R_2=22Ω, and C_1= 330nF, C_2= 100nF as shown in fig 5.The voltmeter and Ammeter are used in the circuit to obtain the volt-amp characteristics for the corresponding input voltage (0-35V).The maximum dropout voltage is 1.5V.The output of 7805 regulator is in range of 4.9 – 5.007 V, because of change in temperature and an input voltages.

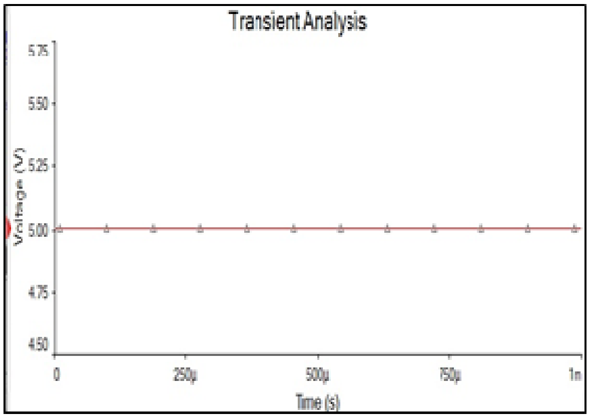

Figure 6: Transient analysis of voltage regulator IC 7805.

Fig 6, shows that the transient analysis of voltage regulator IC 7805 for time period up to 1m under different operating voltages (0-35V). However, the transient analysis shows that there is a 0.01% of output voltage changes and temperature of IC7805 increases to 36 V during a period of time 1 m with an input voltage

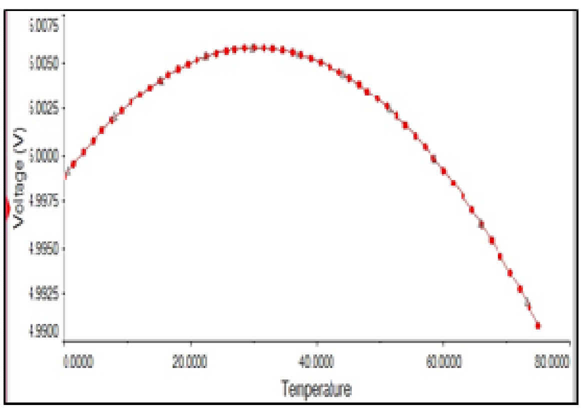

Figure 7: Change in temperature occur with respect to temperature at 30V

35V. Fig 7, shows that the change of temperature occur when an input voltage increase to 30V and their output is decrease to 4.9915 V. The maximum output voltage is 5.0052 V under operating voltage of 29V and their output decrease after increase of temperature. Similarly, the maximum output voltage is 5.00505 under operating voltage of 30 V and output decrease after increase of temperature as shown in fig 8. Fig 8, shows that the change of temperature occur when an input voltage increase to 35V and their output is decrease to 4.9905 V. The voltage –Temperature characteristic curve was obtained through the experimental work is similar to the simulation value get through the Multisim Software. So, the continuous usage of voltage regulator with the aluminium as heat sink will reduce the performance and lifetime of the regulator and increase the power consumptions.

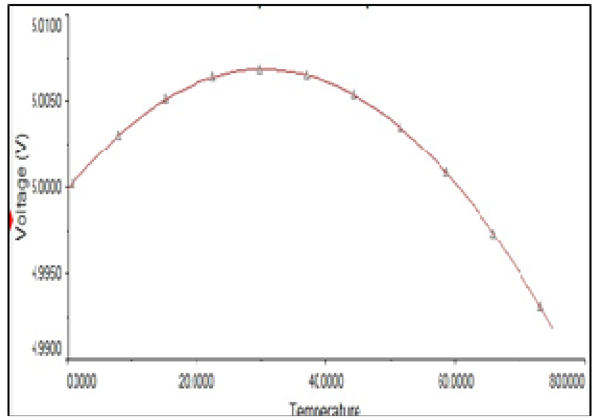

Figure 8: Change in temperature occur with respect to temperature at 35V

Steady-state Analysis Electric Conduction (ANSYS)-Optimization.

The Heat transfer performance and reliability of the voltage regulator IC 7805 was examined through steady–state analysis electric conduction (ANSYS). Thermal and electrical conductivity values are correctly taken into account considering nonlinear material properties for every material layer of the device structure [2].ANSYS simulation and modelling tools provide the sign-off accuracy and performance required to make sure the power noise integrity and reliability of even the most complex ICs, taking into account electro migration, thermal effects and electrostatic discharge phenomena [12].The first address the effects of the various input voltages and properties of the material on the thermal behaviour of the IC 7805 [13]. The geometries and meshing of Voltage regulator 7805 IC are shown in Figs. 6 and. Fig. 8. This geometry of voltage regulator of IC is (21.03mm x 4.50mm) with heat sink aluminium (Al) and three pins (fig 9).The boundary and initial conditions are defined before the simulation. A second task is the design of voltage regulator IC 7805 with aluminium nitride as a heat exchanger. In this model, the VR structure has been divided into five bodies so that each part could be meshed independently. To achieve the simulation efficiently, mesh were design in denser up to 2.5e^{-004}m. A test VR was employed to validate the electrical (ANSYS) simulation results. The tested device features with length X= 1.05e^{-002}m, length Y= 2.9253e^{-002}m and length Z= 3e^{-003}m active area and it is based on a Trench semiconductor technology. In Fig 11, simulated electric field intensity was obtained for IC 7805 with given input voltages as 25V. By the analysing of the electric field intensity for various voltages from 5-35 V shows that, it increases linearly with respect to an increase of input voltages (fig 12).

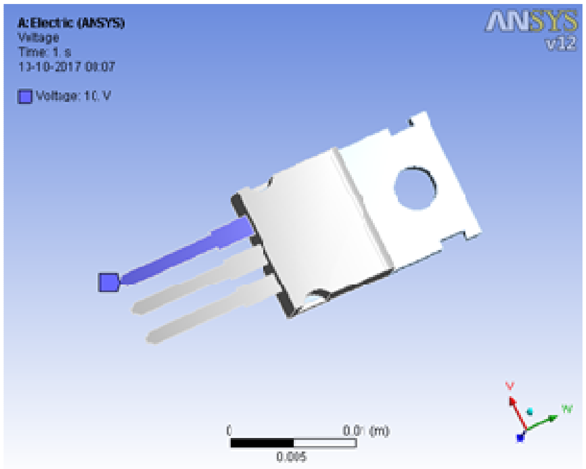

Figure 9: Geometry structure of voltage regulator IC 7805

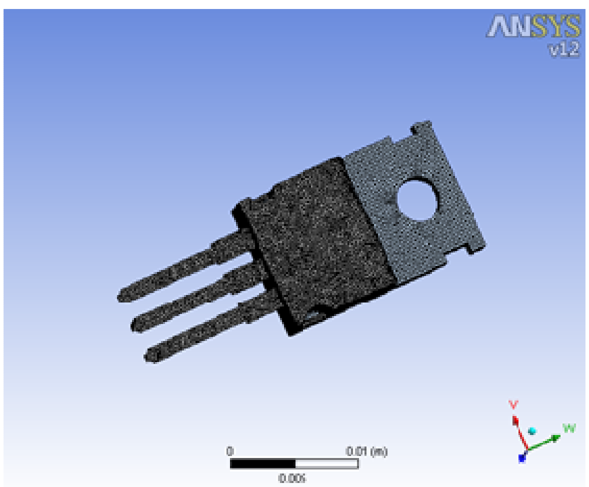

Figure 10: Mesh structure of voltage regulator IC 7805

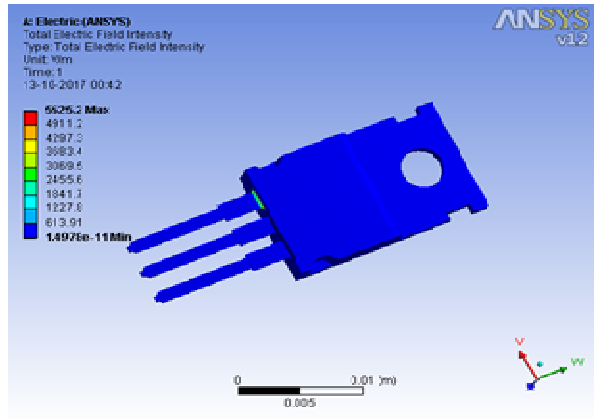

Figure 11: Simulated electric field intensity observed in IC 7805 for an input voltage 25V

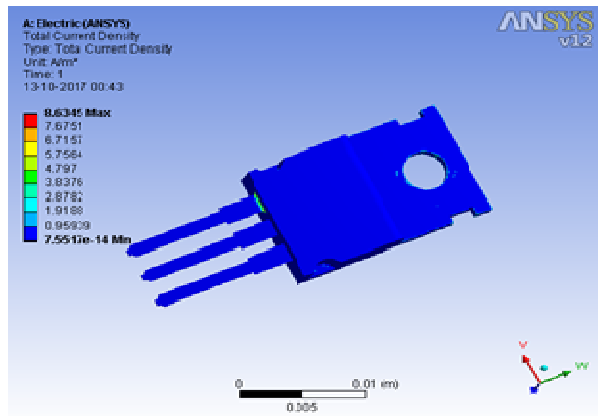

Figure 12: Simulation output of an electric field intensity for a input voltage from 5 -35 V

In Fig 13, simulated current density was obtained for IC 7805 with given input voltages as 25V.It was observed from the graph (fig 14),that the electric field was linear with respect to current density that because of ohmic contact mechanism.

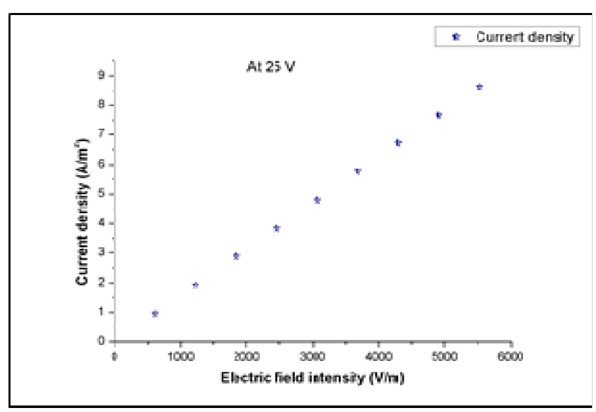

Figure 13: Simulated current density observed in IC 7805 for a input voltage 25V

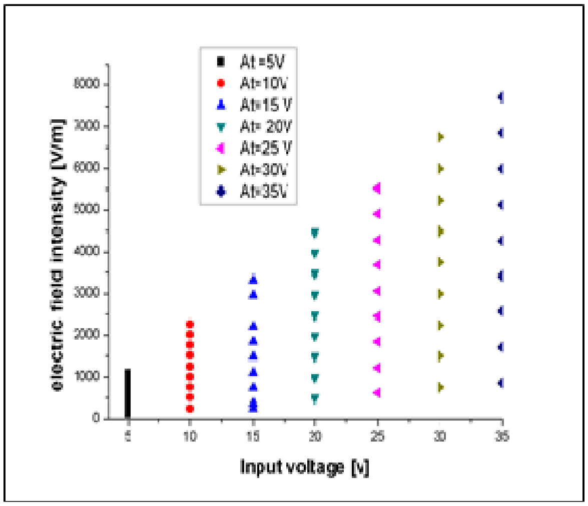

Figure 14: Simulation output of an electric field intensity and current density for a input voltage 25V

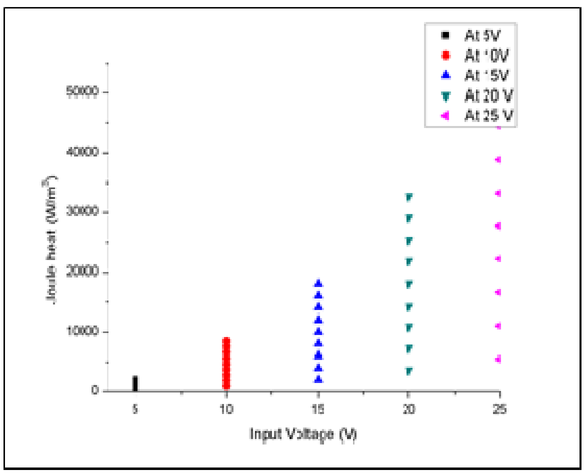

Figure 15: Simulation output of Joule Heat for IC 7805 at input voltage 25V

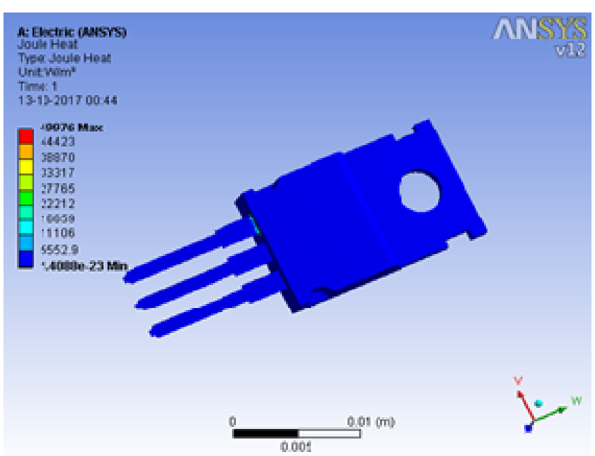

Figure 16: Simulation output of Joule heat with various input voltage form 5-25 V

The amount of heat produced in a current conducting chip, is proportional to the square of the amount of current that is flowing through the chip, when the electrical resistance of the chip and the time of current flowing are constant. Generally, Joule heating increases with applied voltage but in the modified heat exchanger, Aluminium nitride acts as heat sink and reduce the generated heat. The joule heat response of the Voltage regulator IC 7805 with aluminium as heat sink for an input voltage of 25V is presented in fig 15. Fig 16. Shows that there is a significant increase of joule heat is seen after increase of voltage from 0-25V.It's clearly observed that the dissipation of more heat affect the performance of voltage regulator. The powers consumption and reliability are joined together in the performance of IC. Here, the aluminium heat sink are replaced by aluminium nitride with help of ANSYS. Moreover, the thermal conductivity of the Aluminium nitride is high when compare to the Aluminium. This leads to reduction of joule heating at high voltage as shown in graph (fig 17). In fig 18, the joule heat distribution in active area of the voltage regulator are shown. It can be seen that simulated operating conditions leads to reduce the joule heat up to 7.6%.

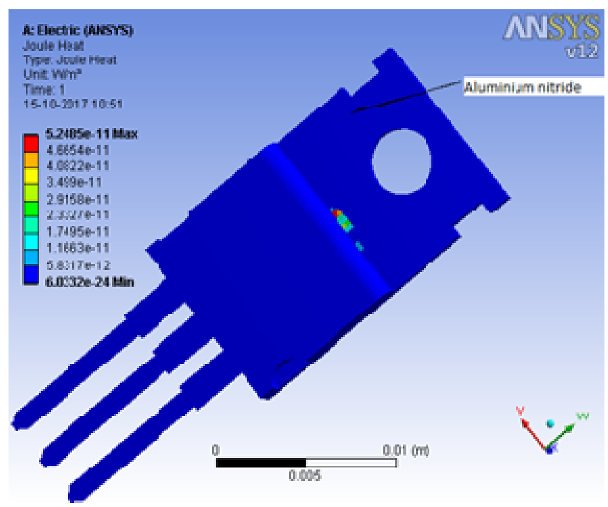

Figure 17: Simulated Joule Heat was observed in IC 7805 for a input voltage 25V –Heat sink as an Aluminium nitride

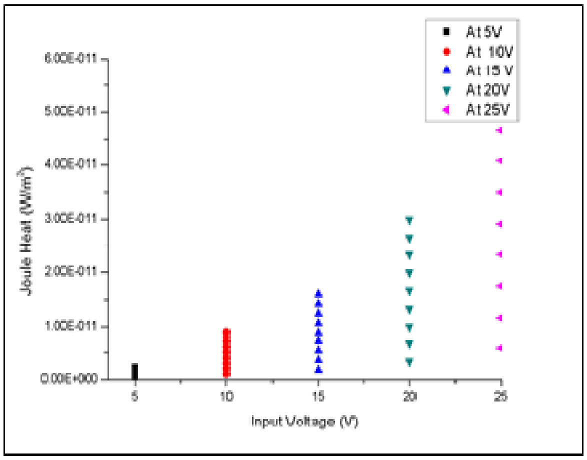

Figure 18: Simulation output of a Joule heat with various input voltage form 5-25 V- Heat sink as an Aluminium nitride.

CONCLUSIONS

In this experimental research work, thermos electrical behaviour of IC 7805 is carried out by using ANSYS Software (v12) and replacing the existing Aluminium heat sink with Aluminium Nitride heat sink. It is found that the aluminium Nitride heat sink has 3.4% lower current density, 9.9% higher heat dissipation, highly reliable and 7.02% less power consumption than that of Aluminium heat sink.

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