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EXPERIMENTAL DETERMINATION OF HEAT TRANSFER COEFFICIENT BY NATURAL CONVECTION FOR A COMMERCIALLY AVAILABLE HEAT SINK USED FOR COOLING OF ELECTRONIC CHIPS

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Abstract- Measurements have been conducted for experimentally determining the heat transfer co-efficient of a commercially available heat sink employed in electronic circuits. For determining the heat transfer coefficient the chip is replaced with a heating coil. The power input to the heating coil is obtained by measuring the input voltage and current. Temperature measurement for varying heat inputs is done using RTD thermocouples. Heat transfer co-efficient is computed from the measured data. This is done for different configurations of the heat sink.

***Keywords**: Electronic circuits, heat sink, heat transfer co-efficient, RTD thermocouples.*

I. INTRODUCTION

Electronic circuits are used in diverse fields such as aircraft, locomotives, space applications, ships, submarines, communication systems defence applications, etc. These electronic circuits generate heat that must be dissipated while keeping chip temperature inside cabinet within safe limits for optimum performance. The miniaturization of electronic devices has put a lot of constraints on the heat dissipation pattern of the circuit boards. Heat dissipation is achieved in many circuits by employing a suitable heat sink. So study of heat transfer co-efficient of heat sink becomes important.

Heat sinks are devices capable of removing heat from the system with which they are in direct contact by exchanging the extracted heat with another fluid or its surroundings. This is normally achieved by either increasing surface area of heat sink significantly or by increasing heat transfer coefficient. Today, heat sinks are usually applied to thermal management of electronic devices and systems. In the past decade, tight packing and rapid development of integrated circuit technology have increased thermal management requirements of electronic devices. Moore’s law predicts that the number of transistors in an integrated circuit will double every 18 months due to lowering of minimum manufacturing cost per component each year. These come with problem of effective heat removal for these systems to operate without failure, as the reliability of semi-conductor devices is inversely proportional to square of its change in temperature [1].

Extensive literature information exists relating to the study of natural convection flows with shrouded fins of varying fin tip clearance. For example, Patankar and his colleagues [Zhang and Patankar, 1984]; Karki and Patankar, [1985,1987] have carried numerical simulations of the enhancing effects of shrouded fins.[2]

II. EXPERIMENTATION

Fig. 1 shows the heat sink with the heating coil of about 34 ohms fixed to it for conducting measurements. The location and the size of the heating coil are selected so that it occupies the same place as that of the chip to which the heat sink is attached. The heating coil is fixed in such a way that one side of the heating coil heats the metallic surface of the heat sink while the other side is insulated using a strip of asbestos just covering the heating coil alone leaving the rest of the heat sink surface for heat transfer through natural convection. Later while calculating the effective area available for heat transfer the surface area covered by the heating coil and the asbestos strip is subtracted from the total surface area of the heat sink. In all, three RTD thermocouples have been fixed at three different locations as indicated in Fig. 1. Average of all the three temperatures measured by these thermocouples is used in calculating the heat transfer coefficient as discussed later.

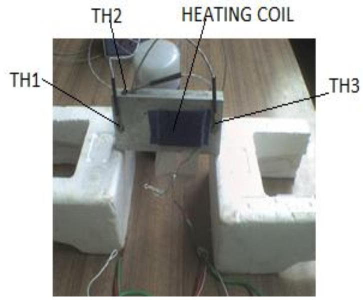

Fig. 1 Photograph of the heat sink with the heating coil and thermocouples denoted as TH1, TH2 & TH3.

A. Heat sink kept in the open air

Fig. 2 shows a photograph of the experimental set-up used for measurements. For the measurements described in this section the heat sink is kept at a height from the surface of the table to enable free flow of air from the bottom of the sink. Alternating current from mains is supplied to the heating coil attached to the heat sink through a dimmerstat as seen in the photograph (Fig.2). Voltage across the heating coil is measured using a voltmeter and current is measured using an ammeter. Heat dissipated and the associated heat transfer co-efficient are calculated using the following basic equations [2], [3].

$$Q = V\,I \qquad (1)$$

$$T = \frac{T1+T2+T3}{3} \qquad (2)$$

$$h = \frac{Q}{A(T-Ta)} \qquad (3)$$

where, Q = Heat generated by the heating coil, W
V = Voltmeter reading, V
I = Ammeter reading, A
T_1,T_2,T_3 = Temperature readings of thermocouples, ^oC
T = Average temperature of heat sink, ^oC
h = Heat transfer coefficient, W/m^2K
A = Effective area of the heat sink
= $21.705 \times 10^{-3}\ m^2$
Ta = Room Temperature,^oC
The results from measurement are tabulated in Table 1.

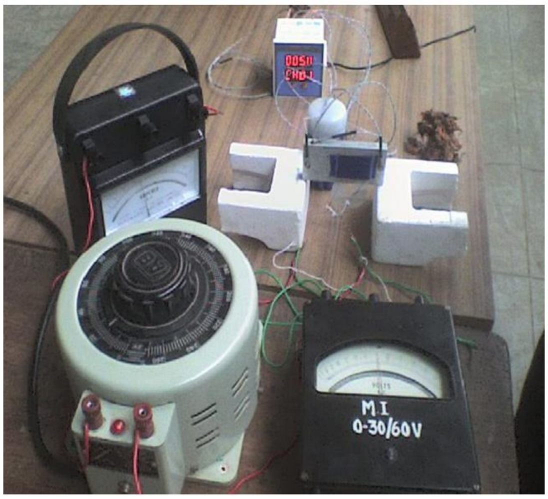

Fig. 2 Experimental setup with heat sink kept in the open air

Table-1. Experimental results for heat transfer coefficient for heat sink kept in open air

Sl. No	V((V)	I(A)	Q(W)	T(^{o}C))	Ta(^{o}C))	h(W/m^{2}K)
1	13.4	0.375	5.025	43.33	32	20.43
2	16.6	0.58	9.628	52.67	32	21.46
3	18.4	0.64	11.78	57.33	32	21.42

B. Heat sink kept in Amplifier box without top cover

As shown in Fig. 3, heat sink is kept in Amplifier box with top cover removed. Current is supplied from dimmerstat to the heating coil attached to the heat sink. The heating coil gets heated and transfers heat to the sink, increasing the heat sink temperature. Voltmeter and ammeter are used to measure voltage and current respectively. Heat dissipated and heat transfer co-efficient are calculated using Eq. (1),(2),(3). The results from measurement are tabulated in Table 2.

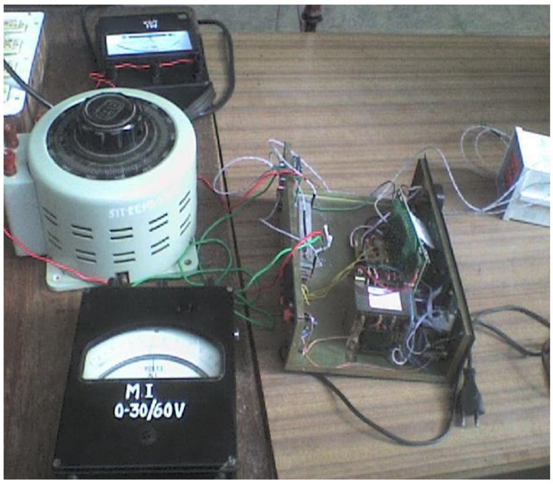

Fig. 3 Heat sink kept in the box with open top.

Table-2. Experimental results for heat transfer coefficient for heat sink kept in amplifier box without top cover

Sl. No	V((V)	I(A)	Q(W)	T(^{o}C))	Ta(^{o}C))	h(W/m^{2}K)
1	13.2	0.445	5.874	48.66	32	16.24
2	15.5	0.515	7.98	52.66	32	17.79
3	17.2	0.575	9.89	55.66	32	19.25

C. Heat Sink kept in Amplifier box with top cover

As shown in Fig.4, heat sink is kept in closed amplifier box. Current is supplied from dimmerstat to the heating coil attached to the heat sink. The heating coil gets heated and transfers heat to the sink, increasing the heat sink temperature. Voltmeter and ammeter are used to measure voltage and current respectively. Heat dissipated and heat transfer co-efficient are calculated using Eq. (1),(2),(3). The results from measurement are tabulated in Table 3. The results for all the three cases are plotted in Fig. 5.

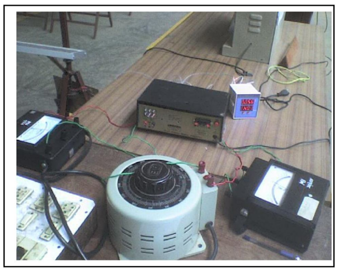

Fig. 4 Heat sink kept in the box with top closed

Table-3. Experimental results for heat transfer coefficient for heat sink kept in amplifier box with top cover

Sl. No	V((V)	I(A)	Q(W)	T(^{o}C))	Ta(^{o}C))	h(W/m^{2}K)
1	12.2	0.32	3.904	41.33	28	13.49
2	16.2	0.45	7.29	53	30	14.6
3	18.5	0.53	9.805	58.67	30	15.76

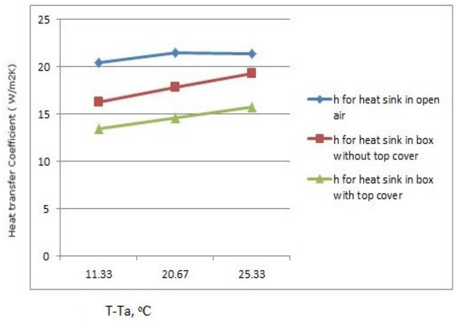

Fig. 5 Variation of heat transfer coefficient with temperature difference

III. CONCLUSION

The heat transfer coefficient is obtained experimentally for a commercially available heat sink at different configurations – in open air, in amplifier box without top cover, in amplifier box with top cover. It is found that heat transfer coefficient is lowest when heat sink is kept in Amplifier box. The measured values of the heat transfer coefficient can be used to test the various correlations used for theoretical prediction of the heat transfer coefficient within the range of measurement employed here.

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