International Journal For Technological Research In Engineering
Volume 3, Issue 8, April-2016 *ISSN (Online): 2347 - 4718*

DESIGN OF TWO PHASE LOOP THERMOSYPHON FOR INTEL I7 MICROPROCESSOR

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Abstract: Power density of microprocessor is increasing which in turn increases the heat dissipation. The classical method of heat dissipation by fan does not suffice the purpose effectively. Thus an attempt is made to provide an effective and efficient way by liquid cooling of microprocessor by two phase loop thermosyphon. In the current paper a loop thermosyphon is designed for Intel® Core™ i7-990X Processor.

Keywords: Boiling heat transfer, Microprocessor Cooling, Two Phase loop Thermosyphon

I. INTRODUCTION

Thermal design power of microprocessor like Intel® Core™ i7-990X Processor Extreme Edition (12M Cache, 3.46 GHz, 6.40 GT/s Intel® QPI) is 130 Watt indicating future microprocessors with more demanding performance tend to have more TDP thus indicating modification in current cooling system to meet the future requirement. In the current paper liquid cooling is proposed as a solution to the problem which is achieved by two phase loop thermosyphon. It incorporates liquid cooling and hence high heat transfer per unit area can be achieved through vaporization of the fluid in an evaporator attached to the microprocessor. Thermosyphons are heat exchanging devices that circulate fluid through natural convection. The movement of the coolant occurs due to change in the density of the coolant, without an external source. The change in density of the coolant occurs in thermosyphon applications because of rise in the coolant temperature or phase transition. The portion of the coolant which is less dense rises and the denser portion falls. This phenomenon creates a force which drives the coolant to movement. As the circulation of the coolant occurs naturally, the thermosyphons do not use external surface forces, such as pumps. As the difference in the coolant densities is the driving force for the movement, the thermosyphon is dependent on the gravitational field and thus requires to be placed in such orientation as it is designed.

1.1 Theoretical Diagram of thermosyphon

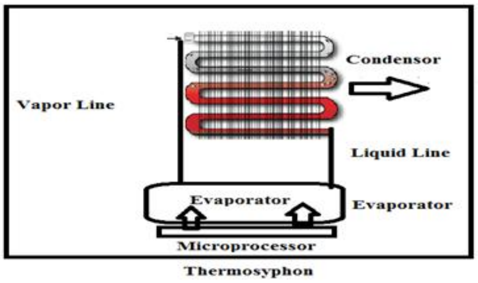


Figure 1

II. DESIGN PROCESS

2.1 Verifying Cooling requirement

The first step in designing the thermosyphon is to verify the cooling requirements and the available space for integrating the device with the CPU. The baseline specifications and parameters chosen:

Table 1

S.no	Process parameter	Value
1	Thermal Design Power [TDP (Q_1)	130 W
2	Maximum CPU Case Temperature (T_{case}) T_{Case}=[0.170*TDP]+43.3°C	78°C
3	Maximum Internal Ambient Temperature	25-45°C
4	Available Evaporator area	40.5 mm x 36.74 mm

2.2 Coolant Selection

The most important parameter is the selection of fluid there are many things to be considered as it should be nonflammable, non-toxic, low global warming potential, as there is no ideal fluid so choosing the right coolant is always a compromise. The main criteria for the selection here is the saturation temperature of the fluid and temperature of microproceor, the saturation temperature of the fluid must be well below the temperature of the microprocessor so that fluid can initiate boiling, the temperature of microprocessor is obtained by Core Therm indicating an average of 75°C.Which favors Methanol to be selected as a coolant as its saturation temperature is quite well below the temperature of microprocessor.

2.3 Design of Thermosyphon Evaporator, Condenser and Fins

The material for evaporator which is compatible with the fluid is copper. With the constraint of available area of microprocessor the dimension of the evaporator are found. By area density (β) empirical Correlation for compact heat exchangers, heat exchanger with β > 700 m2/m3 the volume of evaporator is found out to be 1500 mm3.

$Q_{Boiling}=00.9\rho_v\, h_{fg}[\sigma g(\rho_l-\rho_v)/(\rho_l-\rho_v)^2]^{1/4}$ [1]

Q=heatflux

ρv= density of vapor kg/m3

hfg = enthalpy of Vaporization, J/Kg
σ= surface tension of liquid vapor interface, N/m
g = acceleration due to gravity, m/s2
ρl = density of liquid, kg/m3
ρv = density of vapor , kg/m3

In the case of condensation in thermosyphon condensers, the influence of the vapour flowing along the condensate with same velocity has to be taken into account. Correlations have been found from empirical studies on how the heat transfer coefficient is related to the vapour quality, Reynolds number (Re) and Prandtl number (Pr). Condensation can be described with equation [2]. When following requirements are met: $100 \leq Re \leq 63\ 000$, $1 \leq Pr \leq 13$, the Nusselt no.(Nu) for the condensation is:-

$$Nu = 0.023\ Re^{0.8}Pr^{0.4}[\{(1-x)^{0.8}\} + \{3.8(1-x)^{0.04}\ x^{0.76}\}/\ p^{0.38}]$$ [2]

The heat transfer coefficient for condensation ($h_{Convection}$) can be calculated by:

$$h_{Convection} = [00.23\ Re^{0.8}\ Pr^{0.4}\ [(1-x)^{0.8} + \{3.8\ (1-x)^{0.04}\ x^{0.76}\}/\ p^{0.38}]]/D_h$$ [3]

where D_h is hydraulic diameter.

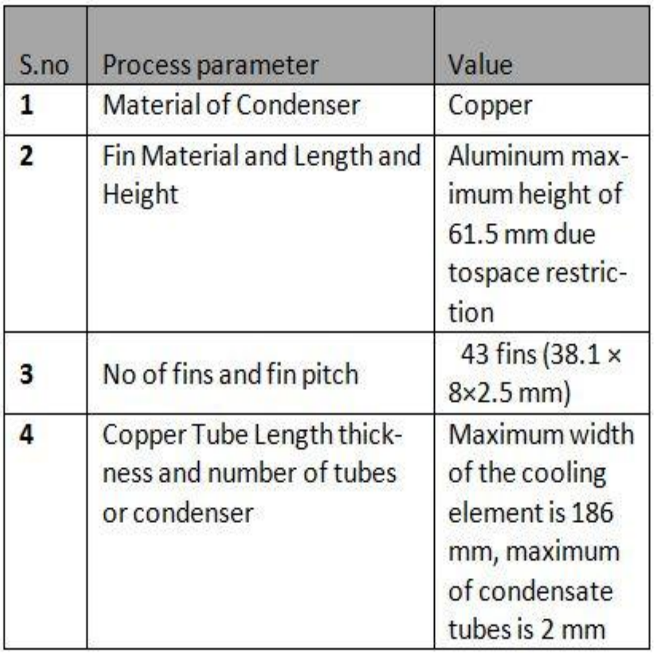
Heat transfer coefficient fund out to be of order 350 W/m^{2}K, however, it can be enhanced further with powerful fans that force the air flow to move even faster. Heat transfer coefficient can reach up to 3000 W/m^{2}K with the fans

Heat conducted from the base of the fin considering fin is attached from both ends, the heat load (Q_{fin}) equation can be stated to be according to:

$$Q_{fin} = [T_{Vapor} - T_{ambient}]\ mKA tanh(1/2mH)$$ [4]

Where T_{vapor} is the temperature of the fluid, H is height of fin, m is a variable defined by the features of the fin and its surroundings. The generic equation for the variable m is:

$$m = (\alpha P/\lambda A)^{1/3}$$ [5]



S.no	Process parameter	Value
1	Material of Condenser	Copper
2	Fin Material and Length and Height	Aluminum maximum height of 61.5 mm due tospace restriction
3	No of fins and fin pitch	43 fins (38.1 × 8×2.5 mm)
4	Copper Tube Length thickness and number of tubes or condenser	Maximum width of the cooling element is 186 mm, maximum of condensate tubes is 2 mm

Table 2- Data calculated from above relation [2]-[5]

III. RESULT AND DISCUSSION

The design of thermosyphon in the above paper is carried out considering theoretical parametric heat transfer relation although there is need to optimize the parameters to get more absolute results through simulation software's, The results indicate that when the thermosyphon condenser is used with fan it will remove heat more effectively and efficiently than using a fan alone however, a better design of condenser may prove sufficient to dissipate heat through natural convection.

IV. CONCLUSION

In this paper design of a two-phase thermosyphon for cooling Intel® Core™ i7-990X Processor is presented. The mathematical result represent that liquid cooling is the most effective heat transfer mode for future microprocessors.

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