

Problem statement and methodology engineering essay



Refrigeration or Cooling may be defined as the process of removing heat. This process may be accomplished by using one of the refrigeration systems; vapor compression, absorption or thermoelectric refrigeration systems. The first two systems need high and low pressure sides of a working fluid to complete the refrigeration cycle. The thermoelectric refrigeration system, however, uses electrons rather than refrigerant as a heat carrier. (Davis, 2005)

Thermoelectric coolers are greatly needed, particularly for the developing countries situation where long life and low maintenance are needed. In this aspect, thermoelectrics cannot be challenged, in spite of the fact that their coefficient performance is not as high as for a vapor compression cycle. Thermoelectric refrigerators have the advantages of being small, lightweight, rugged, reliable, and insensitive to orientation, noiseless, portable and low cost in mass production. (Davis, 2005) Thermoelectric cooler has been widely used in military, aerospace, instrument, and industrial or commercial products, as a cooling device for specific purposes. This technology has existed for about 40 years. (Riffat, 2000) Many researchers are concerned about the physical properties of the thermoelectric material and the manufacturing technique of thermoelectric modules. In addition to the improvement of the thermoelectric material and module, the system analysis of a thermoelectric refrigerator is equally important in designing a high-performance thermoelectric refrigerator. (Huang, 2000)

The heat flux generated in the processor chip is rising day by day at a very fast rate with development because of reduction in CPU sizes and large amount of heat load generated at the chip. Consequently, it is becoming a

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challenging task for researchers to handle such enormous amounts of heat fluxes.

Moore's had proved that number of transistors on a integrated circuit is increasing exponentially year after year . So heat load in the CPU also increases at the same rate with the increase in the speed moreover the size of the chip today which we normally talk about is of the order of mm which is in turn making problem more complicated. The high heat generation inside the CPU may result in slowing down the computation speed, failure of the processor chip, gate oxide breakdown, effect on screen resolution and many more electrical failures as well as mechanical failures (Davis, 2005)

Presently in CPU very complicated designs of air cooled heat sinks are used which dissipates heat to the surroundings by flowing large volumes of air. These heat sinks have two major shortcomings.

Due to space constrains air should be thrown at very high velocities and to maintain such velocities big size fan has to be used.

Also, the air flowing at high velocities creates a lot of noise.

Moreover, in air cooled units there is no active cooling device so we can't go below the ambient temperature. As a result working at high speeds in the hot ambient conditions had become extremely difficult.

Chip cooling is one of the bottlenecks in the high density electronics. There is need of some better cooling techniques for the same. So, now a day researchers are working a lot on liquid cooled systems, because they have nearly 10 times (Davis, 2005) the heat transfer coefficient than that of air <https://assignbuster.com/problem-statement-and-methodology-engineering-essay/>

cooled ones. In water based liquid cooling systems, the heat is pumped to water block by some cooling device from which water takes away the heat to finally throw it in the surroundings . The most commonly used device to pump heat to water block in such system is TEC (Thermoelectric coolers). TEC consumes their own power and cool down the chip by extracting the heat from it and transferring it to the water block. Water runs inside the channel in the water block and takes away the heat from it. The hot water is further cooled in the condenser. With the help of Thermoelectric water cooling system the chip temperature can be easily made to go below ambient temperature which is not possible by the existing systems, and thus the CPU can be made to operate at high speeds and higher loads in even hot ambient conditions. Thus TEC have potential opportunities for chip cooling and can prove very effective if a proper system is developed for the same.

1. 2 Problem statement

Chip cooling is one of the bottlenecks in high density electronics. An enormous amount of heat flux is generated by the modern processor chip. Nowadays many complicated designs of air cooled heat sinks are used, but off late the heat fluxes have attained such a level that to handle them very large volume flow rate of air is required. So due to space constraint, in order to achieve large flow rates, air should be blown at very high velocities which in turn result in increased levels of noise. Another major disadvantage of air cooling is that we can't go below ambient temperature and as a consequence, tendency of chip failure in the computers working in ambient condition of about 35°C - 45°C increases a lot.

For all these reasons it has become apparent that the heat fluxes have reached such a level that air cooling can't handle them efficiently. Thus the present scenario necessitates the use of active cooling devices.

Thermoelectric coolers having the ability to cool below ambient and having advantage of being compact, light weight, free of moving parts and precise temperature control have high potentials for chip cooling.

It is known that the temperature of the thermoelectric module is the main criterion for its reliability and performance. The temperature rise of the hot side above ambient is dependent on the thermal resistance of the path that the heat sink. Reducing the thermal resistance of the heat sink contributes to the reduction of the thermal resistance of the path and hence an increase in the performance. So a liquid heat exchanger with spiral flow passage having dimples is used. Dimples result in effective heat transfer by creating turbulence and thus enhancing the performance of the system.

1. 3 Research Objectives

Understanding the basics of Thermoelectric coolers, working of Thermoelectric Cooling Systems and parameters that governs the performance of such systems

Design, fabrication and development of an efficient thermoelectric cooling system for computer chips

Carrying out experimentation and analysis of the performance of the developed system

1. 4 Methodology

1. 5 Work Plan

These are some of the important tasks that would be performed during this research

Understanding the basic concepts of thermoelectric cooling

Study of the existing CPU cooling techniques

Literature review regarding the topic and study about the effect due dimples along the flow of water

Deciding the various parameters for which system has to be designed

Deciding about the thermoelectric module which will produce the desired cooling effect

Design of the experimental set up and identification of the various equipments to be required

Market survey for all the required equipments

Procurement of the equipments

Design and fabrication of the dimpled water block

Design and fabrication of the heat exchanger

Preparation of the experimental set up

Carrying out experiments and obtaining the results

Analysis of results

Checking out the performance of the thermoelectric module used

Comparison of the designed water block with some commercially existing water block

Discussions and conclusion

Report writing

1. 6 Expected Outcomes

An understanding of the application of thermoelectric cooling systems would be developed. Important advantages of the thermoelectric cooling systems in current scenario of high density electronics would be presented. The complete thermoelectric cooling unit for CPU chip would be designed, fabricated and tested for the desired loads

Chapter 2:

LITERATURE REVIEW

2. 1 The History of Thermoelectrics

In 1821, Thomas Seebeck discovered that a continuously flowing current is created when two wires of different materials are joined together and heated at one end. This idea is known as the Seebeck Effect (Figure 1. 1). The Seebeck effect has two main applications including temperature measurement and power generation. (Global Techno Scan, nd)

Figure 1. 1 Seebeck Effect

$$S = dV / dT;$$

S is the Seebeck Coefficient with units of Volts/K

S is positive when the direction of electric current is same as the direction of thermal current

In 1834, a French watchmaker and part time physicist, Jean Peltier found that an electrical current would produce a temperature gradient at the junction of two dissimilar metals. This effect is known as the Peltier Effect. This idea forms the basis for the thermoelectric refrigerator (Global Techno Scan, nd)

Figure 1. 2 Negative Peltier effect

a) For $\Delta T < 0$; Negative Peltier coefficient

When current is allowed to pass through n-type semiconductor shown in above circuit, high energy electrons move from right to left resulting in cooling of far end. Thermal current and electric current flow in opposite directions (Global Techno Scan, nd)

Figure 1. 3 Positive Peltier effect

b) For $\Delta T > 0$; Positive Peltier coefficient

When current is allowed to pass through p-type semiconductor shown in above circuit, high energy holes move from left to right resulting in heating of far end. Thermal current and electric current flow in same direction (Global Techno Scan, nd)

$q = \Delta T \cdot j$, where q is thermal current density (Heat flux) and j is electrical current density.

Also, $\Delta T = S \cdot T$ (Volts) Peltier coefficient

Where, T is the Absolute Temperature

Scottish scientist William Thomson (later Lord Kelvin) discovered in 1854 that if a temperature difference exists between any two points of a current carrying conductor, heat is either evolved or absorbed depending upon the material. If such a circuit absorbs heat, then heat may be evolved if the direction of the current or of the temperature gradient is reversed.

2. 2 Thermoelectric Refrigeration

A thermoelectric device is one that operates on a circuit that incorporates both thermal and electrical effects to convert heat energy into electrical energy or electrical energy to a temperature gradient. Thermoelectric elements perform the same cooling function as Freon -based vapor compression or absorption refrigerators. Energy is taken from a region thereby reducing its temperature. The energy is then rejected to a heat sink region with a higher temperature. Thermoelectric elements are in a totally solid state, while vapor cycle devices have moving mechanical parts that require a working fluid (Tellurex, nd)

Thermoelectric modules are small, sturdy, quiet heat pumps operated by a DC power source. They usually last about 200, 000 hours in heating mode or about 20 years if left on cooling mode. When power is supplied, the surface where heat energy is absorbed becomes cold; the opposite surface where

heat energy is released becomes hot. If the polarity of current flow through the module is reversed, the cold side will become the hot side and vice-versa. Thermoelectric modules can also be used as thermocouples for temperature measurement or as generators to supply power to spacecrafts and electrical equipment. (Tellurex, nd)

Thermoelectric devices can also be used as refrigerators on the bases of the Peltier effect. To create a thermoelectric refrigerator, heat is absorbed from a refrigerated space and then rejected to a warmer environment. The difference between these two quantities is the net electrical work that needs to be supplied. These refrigerators are not overly popular because they have a low coefficient of performance. The coefficient of performance for thermoelectric refrigerators can be calculated by dividing the cooling effect by the work input. (Tellurex, nd)

2. 3 Semiconductors

The semiconductor materials are N and P type, and are so named because either they have more electrons than necessary to complete a perfect molecular lattice structure (N-type) or not enough electrons to complete a lattice structure (P-type). The extra electrons in the N-type material and the holes left in the P-type material are called " carriers" and they are the agents that move the heat energy from the cold to the hot junction. Heat absorbed at the cold junction is pumped to the hot junction at a rate proportional to carrier current passing through the circuit and the number of couples. Good thermoelectric semiconductor materials such as bismuth telluride greatly impede conventional heat conduction from hot to cold areas, yet provide an easy flow for the carriers. In addition, these materials have carriers with a <https://assignbuster.com/problem-statement-and-methodology-engineering-essay/>

capacity for transferring more heat. Since semiconductors were found to have large Seebeck coefficients, good electrical conductivities, and poor thermal conductivities, one has made a breakthrough in the use of the Peltier-effect in thermoelectric devices to produce refrigeration. Currently, thermoelectric refrigerators, made of semiconductor, materials, have many interesting applications because of their small size, simplicity, quietness and reliability.

2. 4 Basic Working Principle of Thermoelectric Coolers

Thermoelectric coolers are semiconductor devices which works on the principle of Peltier effect (Haung, 2005) i. e. when a current is passed between the junctions of two dissimilar materials then a temperature difference is created between the two junctions. In thermoelectric coolers we have a P type and an N type semiconductor connected together when we pass the current, at the cold junction electrons travel from P side to N side as P type being at lower energy level and N type at higher energy level. So when electron travels it absorbs energy at the cold side. Similarly at the hot side electron travels from N side to P side thereby releasing the energy. And in this way a temperature gradient is established between hot side and cold side (Haung, 2005)

2. 5 Advantages of Thermoelectric Coolers

Thermoelectric coolers have some unique advantages over other cooling systems. The various advantages are (Chien, 2004)

Ideal for localized cooling due to small size

Highly controllable cooling power

Convenient power supply

Precise temperature control

Sub-ambient cooling capacity

Spot cooling

Compact, Quite, and free of moving parts

Low maintenance

2. 6 A typical thermoelectric cooling system:

Fig. 1 shows working of a thermoelectric system. The heating and cooling functions of the thermoelectric system can be interchanged by reversing the polarity of the direct current applied to it. Capacity control in a thermoelectric system can be achieved by varying the voltage applied to the couples either by a variable voltage control or by switching series and parallel circuits. As the voltage drops, the temperature difference between the hot and cold side is reduced. (Chien, 2004)

On the cold side of the module we have the heat source from which heat is to be removed and on the hot side we have a heat sink which finally throws the heat into the ambient. Design of the heat sink is an important parameter for improving the performance of the thermoelectric module. For many applications, the advantages of TEC outweigh its main disadvantage of low coefficient of performance. (Chien, 2004)

Figure 2. 1 Thermoelectric cooler (Chien, 2004)

2. 7 Thermal Parameters Governing Performance of TEC

The selection of a thermoelectric for a particular application is mainly dependent on the three important parameters. These are temperature of the hot surface (T_h), the temperature of the cold surface (T_c) and the amount of heat to be extracted at the cold side of the module (Q_c) (Haung, 2005).

The heat sink is attached at the hot side of the module where the heat gets released when the DC power is applied to the module. The hot side temperature of the module while using a air cooled heat sink whether natural or forced convection, can be found out using below equations (Haung, 2005)

$$T_h = T_{amb} + R_{th}(Q_h) \quad (1. 1)$$

$$Q_h = Q_c + Q_p \quad (1. 2)$$

The temperatures rise above ambient, of the hot side, takes place because of the thermal resistance of the heat. If we know the thermal resistance of the heat sink then the general estimates of the rise in temperature above ambient are as stated below: (Haung, 2005)

20°C to 40°C in case of Natural Convection

10°C to 15°C in case of Forced Convection

2°C to 5°C in case of Liquid Cooling (In this case is the rise above the liquid coolant temperature)

The performance coefficient for a thermoelectric cooling system can be calculated with the help of the following equation:

2. 8 Application of thermoelectric cooling

TEC (Thermoelectric Cooler) is different from conventional compression refrigeration; there are no moving parts. Since there are no moving parts, there is nothing to wear out and nothing is generating noise. There is no refrigerant to contain so the problem of handling a two-phase change over is simplified. Pressure tight tubing is replaced by electrical wiring. There is no ozone layer hazard (Melcor, nd). Thermoelectric coolers offer the potential to enhance the cooling of electronic module packages to reduce chip operating temperatures or to allow higher module powers. Thermoelectric coolers also offer the advantages of being compact, reliable, and their degree of cooling may be controlled by the current supplied. Unfortunately, compared to vapor-compression refrigeration, they are limited in the heat flux that they can accommodate and exhibit a lower coefficient of performance (COP). These two limitations have generally limited thermoelectrics to niche.

The thermoelectric coolers are used in the electronics of the cruise missile, critical equipment on aircraft, critical camera components in a pod aircraft navigation system and many military applications. Thermoelectric coolers provide compact heat exchangers that are not attitude-sensitive and do not contain excessive tubing and fittings that can be susceptible to vibration

2. 9 Previous Work done at International level

Till today air coolers are meeting the needs of CPU cooling, with the increased size of heat sinks and an increase in fan speed. The typical

resistance of air coolers with high fan speeds is $0.2^{\circ}\text{C}/\text{W}$ (Bar Cohen, 2000). But with further increase in the heat flux, air cooling techniques seem to be diminishing because of the limitations already mentioned. The next best solution to the problem is the use of liquid cooling techniques as the liquids have relatively very high convective heat transfer coefficients than air and thus minimizing the thermal resistance. The liquid cooling system involves “water block” for efficient heat transfer to the liquid.

Experiments have been carried out by mounting water blocks directly over the CPU chip and they have shown to be very efficient than the air cooled techniques. With the use of direct water-cooling techniques the chip temperature can be kept at 30°C for an ambient condition of 25°C with a CPU load of 60W whereas with air cooling it goes to 45°C (Bar Cohen, 2000).

But with the development of thermoelectric coolers it has made possible to take the chip temperature even below ambient. Thermoelectric Coolers have unique advantages over other cooling devices

Chein and Huang (2004) studied usage of thermoelectric cooler for electronic cooling. The cooling capacity, junction temperature, coefficient of performance (COP) of TEC and the required heat sink resistance at the hot side were computed. They found that the cooling capacity could be increased as T_c is increased and T_j is reduced. The maximum cooling capacity and chip junction temperature obtained were 207 W and 88°C , respectively. The required heat sink resistance on TEC hot side was found to be $0.054^{\circ}\text{C}/\text{W}$. A micro channel heat sink (with size of 55mm x 55mm with channel width of 0.3 mm) using water or air as coolant was also

demonstrated to meet the low thermal heat sink resistance requirement for TEC operated at maximum cooling capacity conditions.

Huang et al in 2005 studied the distribution of temperature for a thermoelectric cooler under the effects of Joule heating, Fourier Heat conduction, Thomson effect and convection and radiation heat transfer. They tried to analyze and explore some of the important things like Thomson effect's influence on the distribution of temperature, on the amount of heat that flows back to the cold side, the maximum temperature difference attained and the maximum amount of heat extracted etc. They finally concluded that other than improving the thermoelectric materials for increasing the cooling efficiency of the module the other possible way is to take the advantage of Thomson effect this also helps in improving the cooling efficiency.

Researches are already going on for incorporating thermoelectric water cooling systems for the CPU. The key factor in using such kind of systems is to have highly efficient water blocks with low thermal resistances and to have thermoelectric modules with proper Q_{max} . Many complicated water block design exist in the present market. The typical thermal resistances of the water blocks used presently for such systems are $0.08^{\circ}\text{C}/\text{W}$ (Bar Cohen, 2000).