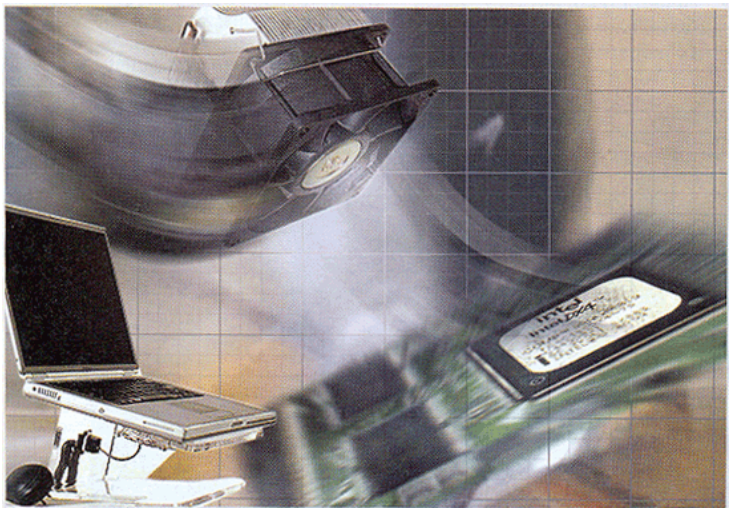
Cooling of Electronic Equipment

With the advent of VLSI (very large scale integration) technology the heat dissipation in the circuit has gone up many folds with every new design. So, nowadays, the semiconductor industry is facing the problem of fast removal of heat from the chip and the system. The problem of heat removal from the electronic chips is an old one. However, recently it has become very prominent due to increasing numbers of circuits being packed into a single chip and at the same time, the dimensions of the chip are also shrinking. This is resulting in the heating up of chips and consumption of more power. In light of the ongoing developments in the area of electronics the Moore's Law still holds well today, even after forty years, as the data density has doubled approximately every 18 months.

- Ravi Kumar



Starting from the era of mainframe computers of 80s to the present day laptops and other microprocessor – based applications, the computation speed has gone up many folds. It is for sure that in coming years the microprocessor based equipment will influence the human life in a significant manner. The users of laptop computers must be aware of the fact that the computer hardware generates heat; this is due to the fact that no device works on 100 percent efficiency. Hence, some losses are bound to take place in the electronic circuit and these losses are evident in the form of heat generation in the chips. Therefore, all, the electronic devices generates heat due to dissipation of energy in the circuit.

With the advent of VLSI (very large scale integration) technology the heat dissipation in the circuit has gone up many folds with every new design. So, nowadays, the semiconductor industry is facing the problem of fast removal of heat from the chip and the system. The problem of heat removal from the electronic chips is an old one. However, recently it has become very prominent due to the increasing numbers of circuits being packed into single chip and at the same time, the dimensions of the chip are also shrinking. This is resulting in the heating up of chips and consumption of more power. In light of the ongoing developments in the area of electronics the Moore's Law still holds well today, even after forty years, as the data density has doubled approximately every 18 months. Most experts agree that the Moore's Law will hold for at least another two decades.

Today the heat dissipation rate from electronic chips is touching 100 W / cm2, which is supposed to be very high heat dissipation rate. Further, these chips are confident in a tight place in the system and this creates serious problem of cooling these microelectronic chips. In fact, poor thermal management shortens the life of these chips. Since, high power-small size scenario is prevalent in the electronic industry for many years the microprocessor cooling system should be more and more compact, efficient and should be designed as an integrated part of the cooling system. There are a number of cooling options of electronic chips. Some of the options are discussed below in brief.

Air Cooling

The air – cooling is provided for the cooling of computer microprocessor chips. Every desktop computer consists of a fan at the backside of computer for the cooling of CPU. With the advent of high density chips this method of cooling has become almost ineffective due to limited space in the reduced size of equipment and resistance to air flow by compact packing of components in the system. Therefore, traditional air-cooling of new microelectronic chips is not possible as these chips dissipate high heat flux.

Falling Film Cooling

In a electronic systems the falling film cooling is relatively more effective than the air cooling and it can be achieved by the gravity driven flow. In such systems, the liquid starts boiling after coming in the contact with the hot surface of the chip, thus, resulting in enhanced heat transfer. As close loop for such type of cooling method consist of a pump, condenser, reservoir and cooling chamber. The high heat transfer coefficient can be obtained with this type of cooling method, however, the lack of adaptability in different orientations limits the application of this technique in the cooling of electronic chips.

Spray Cooling

Spray cooling is another technique of cooling electronic circuit. In this type of cooling a low velocity spray is continuously applied on the chip surface. This gives a more uniform surface area temperature. The spray, cooling may provide good cooling of the chip surface and it also keeps the chip away from surface erosion.

Heat Pipe

The heat pipes have very high effective thermal conductance. They are capable of transferring large quantities of heat over sizeable distances with insignificant temperature drop. The high thermal conductance of heat pipe facilitates to maintain the surface at an almost uniform temperature during heat transfer, making the heat pipe capable of being used as a heat spreader from the chip surface. Being a passive device, as the heat pipes do not consume any external energy, they are reliable and have longer life. In fact, heat pipes are a very good solution that increases the dissipation of heat from the circuit at almost uniform temperature.

Problems with Air Cooling

The simplest mode of cooling any component is the cooling by air. The electronic units are normally cooled down by circulating air with a fan. With the increase in density of transistors in a chip from a few thousand of two decades back to the present tens of million transistors, the order of heat dissipation from the chips has increased enormously. So, it is imperative to make the cooling of electronic chips much more effective. Since, the heat transfer coefficient for air is very low; in order to attain high heat flux the required air velocity may become comparable to sonic velocity. Further, at high fan speed the noise level in will also be high, which is not desirable in the electronic systems for most of the applications. In addition, the fans are also liable to mechanical failure. In fact, next generation computers will be requiring greater cooling that can be supplied by the force convection by the circulation of air and thermal management of chips will become one of the top design criteria.

In place of air cooling the liquid cooling can provide high heat dissipation rate from the chip as the liquids are definitely a better heat transfer media than air. This type of system will have minimum audible noise. Some of the manufacturers have discarded the air-cooling systems and have adopted the liquid cooling systems. Hence, for the heat flux of 100 W/cm2 or more the heat dissipation by the liquid vapor phase change in the microchannels attached / machined on the chip surface is the most viable solution.

Microchannel Heat Sink Cooling

Extensive research is being carried out, throughout the world, to study the heat transfer during flow of coolant like refrigerants, methanol, water etc. in the heated microchannels. In this process a number of parallel microchannels are cut on silicon wafer using photolithography or by the laser machining on the surface attached to the electronic chips. The hydraulic diameter, dh, of these microchannels ranges from 30-300 μm. the liquid flowing in these microchannels takes away the heat generated in the electronic chips. These types of systems are quite, and can be accommodated in the restricted space inside the equipment. The major advantage of microchannel heat sink is the very high heat transfer coefficient. Since, it is a close loop system, the liquid is either circulated by thermosyphon or by a micropump. The surface area to volume ratio of microchannel is 4/dh, where dh is the hydraulic diameter of microchannel. This assist in developing a compact and efficient design of heat exchanger. In fact, to design an efficient micro heat sink, it is imperative to have the relationship between different design parameters viz. pressure drop across the microchannels, heat transfer coefficient, heat flux, mass velocity and thermophysical properties of coolant.

The advantage of cooling the electronic chips by dissipating heat through the liquid flowing in the microchannels is that the heat transfer coefficient is high as it is inversely proportional to the hydraulic diameter, dh, of the channel. It is to be noted that the coolant temperature rise along the channel is very high in case of single phase flow because all the heat generated by the electronic device is carried away by relatively small amount of liquid. Therefore, it is preferred to have a two-phase flow cooling system. Companies like Apple Computer have already accepted the liquid cooling system to cool the IBM processors of their new G5 computers as the conventional air cooling system would have turned the computers into hot ovens.

Reference Book:

Cooling India
Vol. 2 No 1
February-April 2006

Author:

Ravi Kumar
Associate professor,
Department of Mechanical & Industrial Engineering,
Indian Institute of Technology, Roorkee