ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Analysis of Heat Sink


D Venkata Siva Prasad
Post Graduate Student
Department of Mechanical Engineering,
Global College of Engineering & Technology,
Kadapa, A.P.

Netha Jashuva, M.Tech (Ph.D), MISRD, AMIE
Associate Professor, HOD
Department of Mechanical Engineering
Global College of Engineering & Technology,
Kadapa, AP.

ABSTRACT

The present trend in the electronic packaging industry is to reduce the size and increase the performance of the equipment. As the power of these systems increases and the volume allowed diminishes, heat flux or density is spiraled. The cooling of modern electronic components is one of the prime areas for the application of thermal control techniques. Of the many thermal-cooling techniques, forced air-cooling being one such extensively used technique due to its simple design and easy availability of air. The present study is to design an air cooled high power electronic system to dissipate heat from selected electronic components.

A heat sink for removing heat from a heat source such as an integrated circuit, a power supply, or a microprocessor. The heat sink includes a base having an airflow passage. The base is also adapted contact at least a portion of the heat source. The heat sink further includes a pad placed in thermal contact with the base. The pad is configured with an array of individual conduits positioned over the air flow passage of the heat sink base. The array of individual conduits permits air to flow from the air flow passage, through the array of conduits.

1. INTRODUCTION TO THERMAL MANAGEMENT

The term thermal management encompasses the technology of the generation and control of heat in electronic circuits. Heat is an unavoidable by product of every electronic device and circuitry and is usually detrimental to performance and reliability. Heat may be generated by the devices themselves or may be present from other sources, internal or external. The trend in electronic packaging industry and subsystems has been to reduce size and increase performance both of which contribute to heat generation and concentration. Evidence of this trend can be seen in the higher levels of integration in semiconductors and the increased usage of hybrids and multi-chip modules. Placing more functions in a similar package has resulted in higher heat densities, mandating that thermal management be given a high priority in the design cycle in order to maintain system reliability. Clearly thermal management is one of the more important tasks of the packaging engineer. Developing a new systematic process leading to a thermal design meeting the requirements of the circuits without being excessive will result in a circuit meeting not only the performance requirements, but the cost and the reliability as well.

2. NEED FOR ELECTRONIC COOLING

Both the performance and reliability of electronic circuitry are strongly influenced by temperature. Exposure to temperatures beyond which the circuit is designed to withstand may result in failure of the circuit to perform to specification or in failure altogether. The maximum temperature to which the circuit will meet the electrical specification with power applied, and the maximum storage temperature is defined as the maximum temperature when the power is off, to which the circuit may be exposed for a given period of time without detrimental effects.

Soft failures: Circuit continues to operate, but does not meet specifications when the temperature is elevated beyond the maximum operating temperature Circuit returns to normal operation when the temperature is lowered Failure is due to change in component parameters with temperature.

Hard failures (short time): Circuit does not operate Circuit may or may not return to normal operation when temperature is lowered. Failure is likely due to component or inter connection break down, but may also be due to changes in component parameters with temperature.

Hard failures (long term): Circuit does not operate at any temperature. Failures are irreversible. Failures may be caused by corrosion or intermetallic formation or similar phenomenon. Failures may also be caused by mechanical stresses due to difference in temperature coefficient of expansion between a component and substrate.

Soft failures happen as a result of the tendency of the parameters of both active and passive components to exhibit a degree of sensitivity to temperature. As the temperature increases, the cumulative effects of component parameter drift may eventually cause the circuit output variables to deviate from the specification.

Hard failures in the short run may occur as a result of component overload as a result of excessive heat or as a result of the breakdown of component attach or packaging materials. Hard failures in the long term may occur for a variety of reasons such as corrosion, chemical reactions and intermetallic compound formation all of which are accelerated by elevated temperature. Hard failures may also occur as a result of mechanical stress due to differences in the temperature coefficient of expansion between two materials joined together such as a component mounted to a circuit board.

3. MODES OF HEAT TRANSFER

Electronic devices produce heat as a by-product. Besides the damage that excess heat can cause, it also increases the movement of free electrons in a semiconductor, which can cause an increase in signal noise. If semiconductor does not allow the heat to dissipate, the device junction temperature will exceed the maximum safe operating temperature specified by the manufacturer. When a device does so its performance, life and reliability are at stake.

Nature transfers heat in three ways: Convection, Conduction and Radiation. A brief introduction about the three is given below.

3.1. Conduction:

Conduction is the transfer of heat from an area of high energy (temperature) to an area of lower relative energy. Conduction occurs by the energy of motion between adjacent molecules and to varying degrees, by the movement of free electrons and the vibration of the atomic lattice structure. In the conductive node of heat transfer there is no appreciable displacement of the molecules. In many applications we use conduction to draw heat away from a device so that convection can cool the conductive surface, such as in air-cooled heat sink. For a one dimensional system, the following relation governs conductive heat transfer:

$$Q=-K*A*\blacktriangle T/L$$

Where
q = heat flow rate(J/s)
k = thermal conductivity of the material (W/m K)
A = cross-sectional area for heat transfer
$\blacktriangle$T = temperature differential (oC)
L = length of heat transfer (m)

Convection:

Convection is a combination of the bulk transportation and mixing of macroscopic parts of hot and cold fluid elements, heat conduction within the coolant media, and energy storage. Convection can occur as the result of expansion of the coolant media in contact with the device. We call this free or natural convection.

Convection can also be due to other forces such as a fan or a pump forcing the coolant media into motion. The basic relationship of convection from a hot object to a fluid coolant presumes a linear dependence on the temperature rise along the surface of the solid, known as Newtonian cooling. Therefore

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

qc = hc A(Ts- Tm)

where,
qc = convective heat flow rate from the surface (J/s)
A= surface area for heat transfer (m2)
T s= surface temperature (oC)
T m= cooling media temperature (0C)
hc= coefficient of convective heat transfer (W /m2 K)

3.3. Radiation:

Radiation is the only mode of heat transfer that can occur through a vacuum and is dependent on the temperature of the radiating surface. Although researchers do not yet understand all the physical mechanisms of radioactive heat transfer, it appears to be the result of electromagnetic waves and photonic motion. How much heat is transferred by radiation between two bodies having temperatures of TI and T2 is found by:

qr = εσF1,2A(T14- T24)
where,
qr = amount of heat transferred by radiation(J/s),
ε = emissivity of the radiating surface (highly reflective=0, highly absorptive= 1.0),
σ = Stefan-Boltzman constant (5.67X10-8 w/m2 K4),
F1, 2 = shape factor between surface area of body 1 and body 2,
A = cross-sectional area for heat transfer (m2),
TI= surface temperature of body 1,
T2 = surface temperature of body 2.
The basic concern of the present study being only the forced convection type of heat transfer more focus is made on it.

4. CONVECTION HEAT TRANSFER IN ELECTRONIC EQUIPMENT

The molecular motion at the heat transfer interface is the result of conduction through the stagnant thermal boundary layer. Heat transfer through this layer is based upon Fourier's Law, dt = qL/kAc. In convective heat transfer the engineer is faced with estimating the heat transfer coefficient, hc, for a surface. Usually this coefficient comes from texts of empherical formulae, which are based on actual experiments and observations. We cannot calculate the heat transfer coefficient exactly because we can analytically solve only the differential equations governing convection for the simplest flows and geometries.

4.1. Fluid Properties:

4.1.1. Specific heat (Cp):

Every material has a thermal capacity. In the SI system, we measure thermal capacity as the heat required to make 1.0 kg of material 1.0°C warmer. In the English system of units it is the temperature required to increase the temperature of 1.0 Ibm of a material by 1.0 of. Since this capacity is proportional to a material's mass, we call this the specific heat. We use the specific heat of water as the reference standard of one calorie per gram oC. Since a calorie is 4.184 KJ, the specific heat of water at 20°C can be expressed in SI units as 4.184 kJ/kg K. The lower the specific heat, the easier it is for the material to absorb heat energy. This property is significant in calculating how readily the fluid can absorb heat from an electronic component.

4.1.2. Thermal expansion (α):

The thermal expansion of a fluid is especially important in determining heat transfer under conditions of natural convection. The temperature differential between the electronic component and the ambient environment causes the fluid to expand and become less dense. Heat transfer has increased because of the temperature induced motion of the fluid. When we heat a material, although the internal cohesive forces remain the same, the materials gain energy and vibrate in larger paths. This is the cause of thermal expansion. Just as the structure of a liquid allows easier compression, it also allows greater thermal expansion than a solid material. The coefficient of thermal expansion is the increase in volume per degree change in temperature.

Volumetric expansion can become detrimental in applications that contain a fluid in a sealed enclosure. Such applications are found in the "black boxes" used to contain military electronic equipment. These boxes self-seal when disconnected from a system. The fluid inside the box may experience a temperature rise during handling or storage. Since the liquid inside is nearly incompressible, engineers must design the case to with stand the internal pressure generated by the expanded fluid.

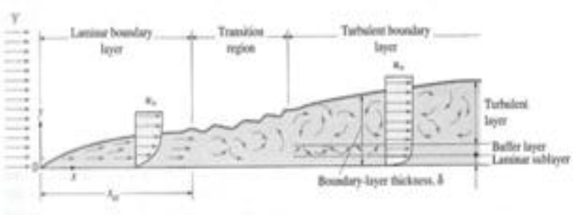
4.1.3. Density (ρ):

Weight is an interaction of two bodies, usually earth and an object. The weight of an object is proportional to the object's mass. Density is the object's mass per Unit volume.

A cubic centimeter of water, at 4°C has a mass of one gram.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

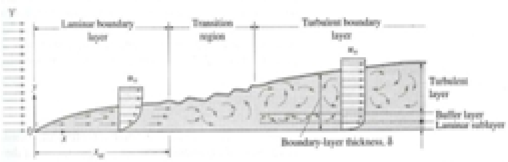
4.2 Boundary Layer Theory:



The development of the boundary layer for flow over a flat plate, and the different flow regimes.

The boundary layer phenomenon is found in both natural and forced convection modes of heat transfer. The fluid turbulence affects the thickness of the boundary layer and therefore that rate of heat transfer. The figure depicts a heated stationary surface at temperature Ts, surrounded by a cooler, moving fluid, at a bulk temperature of T, and free-stream velocity of U. Note that the fluid velocity decreases closer to the stationary surface. Since the fluid at the interface is also stationary, Fourier's conduction equation determines the heat transfer through this region.

4.3 Laminar and Turbulent Flow:



The development of the boundary layer for flow over a flat plate, and the different flow regimes.

An essential first step in the treatment of any convection problem is to determine whether the boundary layer is laminar or turbulent. Surface friction and the convection transfer rates depend strongly on which of these conditions exists. As shown in Figure, there are sharp differences between laminar and turbulent flow conditions. In the laminar boundary layer, fluid motion is highly ordered and it is possible to identify streamlines along which particles move. Fluid motion along a streamline is characterized by velocity components in both the x and y directions. Since the velocity component v is in the direction normal to the surface, it can contribute significantly to the transfer of momentum, energy, or species through the boundary layer. Fluid motion normal to the surface is necessitated by boundary layer growth in the x-direction.

In contrast, fluid motion in the turbulent boundary layer is highly irregular and is characterized by velocity fluctuations. These fluctuations enhance the transfer of momentum, energy, and species, and hence increase surface friction as well as convection transfer rates. Fluid mixing resulting from the fluctuations makes turbulent boundary layer thicknesses larger and boundary layer profiles (velocity, temperature, and concentration) flatter than in laminar flow. The foregoing conditions are shown schematically in Figure for velocity boundary layer development on a flat plate. The boundary layer is initially laminar, but at some distance from the leading edge, small disturbances are amplified and transition to turbulent flow begins to occur. Fluid fluctuations begin to develop in the transition region, and the boundary layer eventually becomes completely turbulent.

Where the characteristic length x is the distance from the leading edge. The critical Reynolds number is the value Rex for which the transition begins, and for flow over a plate, it is known to vary from 105 to 3x105, depending on surface roughness and the turbulence level of the free stream.

This location is determined by a dimensionless grouping of variables called the Reynolds number,

4.4 Natural or Free Convection:

When a surface is maintained in still fluid at a temperature higher or lower than that of the fluid, a layer of fluid adjacent to the surface gets heated or cooled. A density difference is created between this layer and the still fluid surrounding it. The density difference introduces a buoyant force causing flow of fluid near the surface. Heat transfer under such conditions is known as free or natural convection. Thus free or natural convection is the process of heat transfer which occurs due to "movement of the fluid particles high density changes associated with temperature differential in a fluid" This mode of heat transfer occurs very commonly, some examples given below:

1. The cooling of transmission lines, electric transformers and rectifiers.
2. The heating forums by use of radiators.
3. The heat transfer from hot pipes and ovens surrounded by cooler air.

4. Cooling the reactor core (in nuclear power plants) and carry out the heat generated by nuclear fission etc.

In free convection, the flow velocities encountered are lower compared to flow velocities in forced convection, consequently the value of convection coefficient is lower, generally by one order of magnitude. Hence, for a given rate of heat transfer larger area could be required. As there is no need for additional devices to force the liquid, this mode is used for heat transfer in simple devices which have to be left unattended for long periods.
The rate of heat transfer is calculated using the general convection equation given below:

$$Q=hA(t_s-t_{\square})$$

Where
Q = heat transfer, J/s
h = convection coefficient, W / m2 °C .,
A = area m2, and
t□ = temperature of fluid

In many systems involving multimode heat transfer and therefore play an important role in the design or performance of the system. Moreover, when it is desirable to minimize heat transfer rates or to minimize operating cost, free convection is often preferred to forced convection.

5. CHOICE OF HEAT TRANSFER METHOD

Once the heat has been conducted from the electronic component to the cooling fins, it must then be transferred to the surrounding environment by one of the following means:

- Radiation and natural Convection.
- Forced air cooling.
- Forced liquid cooling.
- Liquid evaporation.

The above list of heat transfer methods is arranged in order of increasing heat transfer effectiveness. For a given fin area, the least heat can be transferred by radiation and natural convection, more can be transferred by forced air cooling, even more can be transferred by forced liquid cooling, and the most can be transferred by liquid evaporation.

The list is also arranged in order of increasing cooling system complexity. Heat transfer by radiation and natural convection requires no auxiliary equipment just the cooling fins themselves and is the simplest design. Forced air cooling requires a fan and fan controls and is more complicated. Forced liquid cooling requires a pump. Coolant reservoir, cooling fluid, etc., and is even more complicated.

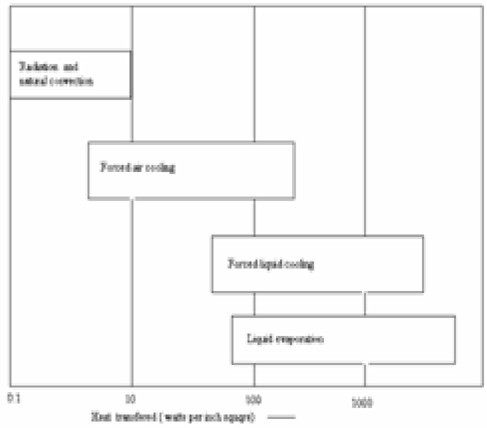


Fig 1 Relative effectiveness of heat transfer methods

5.1 Forced Air Cooling:

An order of magnitude increase in heat transfer can be achieved by blowing air over the electronic component, rather than relying on radiation and natural convection. The price that must be paid for this increased cooling is:

- Increased system complexity, because a fan and its associated equipment (such as ducting, dust filters, and interlocks) are required to force the air over the component.
- Reduced electrical efficiency for the system, because the fan requires electrical power.
- Increased vibration and acoustical noise.

Obviously heat transfer by radiation and natural convection should be used

5.2 Choice of the fan or blower.

These two problems must be solved jointly. The amount of air flow that a particular fan can provide is determined by the pressure into which the fan must work. Both the amount of heat transfer that can be obtained from forced air cooling and the pressure required to force air through the cooling fins depends on air flow and fin geometry. Consequently, the fin design must be made in conjunction with the choice of fan.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

5.3 Extended Surfaces

The trend in component design for airborne and a space application has been and will continue to be toward micro-miniaturization. Ordinarily, miniaturized electronic equipment is also quite small. Furthermore, air-which is inexpensive and often designer of electronic equipment cooling systems is often faced with the problem of cooling miniaturized, high heat-dissipating components to a rather low temperature with a fluid having definite heat transfer limitations. This dilemma can be summarized as being one of low (hS) product.

The coefficient of heat transfer can be improved in two ways:

- Use of a better fluid: This is often impossible because of weight and installation requirements. Use of a liquid coolant, for example, requires a pump, a heat exchanger, piping, valves, and possibly an expansion tank or other appurtenances required for handling the ultimate heat sink fluid.
- Use of the available coolant fluid at a higher velocity: This is often impractical because of the increased power required to force the fluid through the steam. Inspection of several correlations will show that a two fold increase in heat transfer coefficient requires a more than twofold increase in fluid velocity. At the same time, the twofold increase in fluid velocity results in almost a fourfold increase in pressure loss and possibly as much as an eightfold increase in power required. Power is weight, and because the fluid is circulated by a pump, fan, or blower, large penalties in weight must be expected under these circumstances.

6. ASSUMPTIONS

In the ensuing analysis the following simplifying assumptions are made.

- The heat flow is steady; that is, the temperature at any point in the fin does not vary with time.
- The fill material is homogeneous, and the thermal conductivity is constant and uniform.
- The coefficient of heat transfer is constant and uniform over the entire face surface of a fin.
- The temperature of a surrounding fluid is constant and uniform. Because one is dealing with cooling, this temperature is always assumed to be lower than that at any point on the fin.
- There is no temperature gradient within the fin other than along its height. This requires that the fin length and height be great when compared to width.
- There is no bond resistance to the flow of heat at the base of the fin.
- The temperature at the base of the fin is uniform and constant.
- There are no heat sources within the fin itself.
- Unless otherwise noted, there is a negligible amount of heat transferred by convection from the end and sides of the fin. Note that in this technology the faces of the fill are the surfaces that dissipate heat.

6.1 Determining Type of Flow:

Reynolds Number (ReL) = (ρ v L) /μ

Where ρ = density of air in Kg/ m3

V = Air flow velocity in m/s

L = Length of plate in metres

μ = Co- efficient of viscosity or Dynamic viscosity in N- s/m2

ReL = (1.1175 X 10 x 0.16) (19.9775 x10-6)

ReL = 89520.7 < 5 x 105

Therefore the flow is Laminar

In forced convection method for Reynolds number 5x 105 the flow is said to be Laminar, and for > 5x 105 the flow is said to be turbulent.

6.2 Super Components

Heat load = 18 Joules/sec .(Each)

Super component size = 50 x 40 x 16 mm

Quantity = 2 Nos

DESIGN CONSTRAINT:

The surface temperature of components should not exceed 70°C

(i.e.ts = 70°C)

6.3 Assumptions:

- Ambient temperature of air(ta)= 45°C
- Velocity of air (v) = 10 m/sec
- Thickness of fin (t) =1.5mm

Average temperature (or) Film temperature (tf) = (ts + ta)/2

tf = (70+45)/2

tf = 57.5°C

6.4 Thermal Analysis Of Heat sink

Fin height = 15mm
Fin thickness = 1.5mm
Fin width = 160mm
No of fins = 18
Material used = aluminium
Heat transfer coefficient (h) = 16W/m2-k
Thermal conductivity of the material (k) = 192W/m-k
Ambient temperature (Ta) = 450c
Surface temperature (Ts) = 700c

Steps Involved

Step1: Preferences

Click preferences and select the type of analysis is thermal analysis and then ok

Step2: Preprocessor

Element type

Click element type and add the element type as solid brick 8node70

Modelling

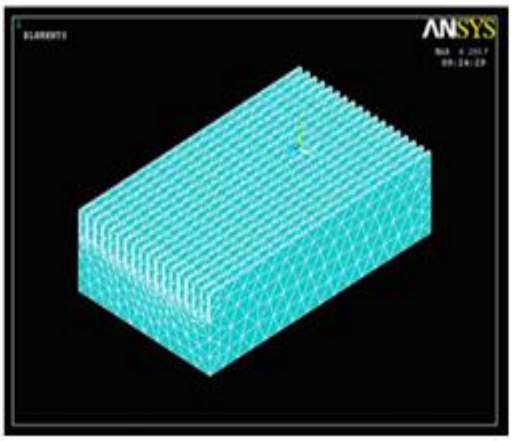
Model the geometric model with obtained dimensions

Meshing

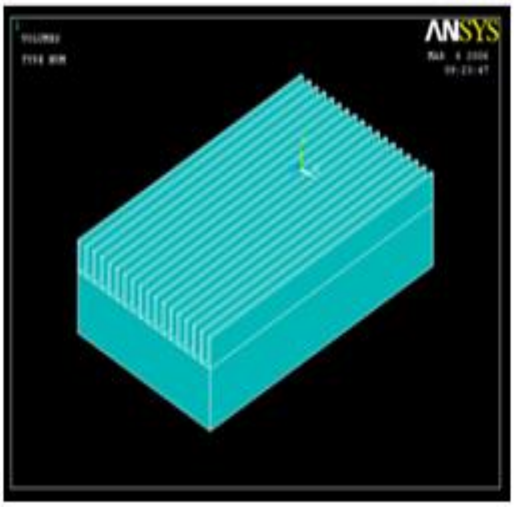
The model is meshed with free triangular mesh

Step3: Solution

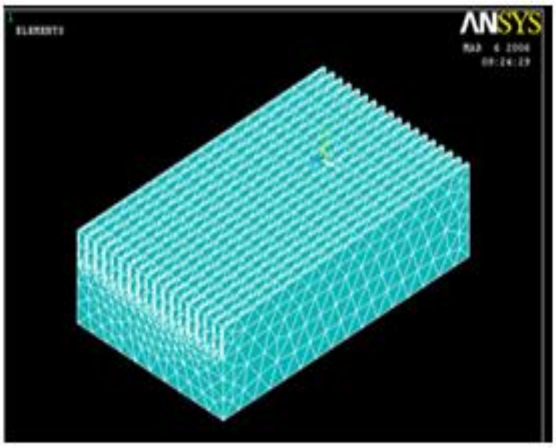
Apply loads: apply a convective load value of h=16W/m2-kand ambient temperature value of 450c to the fin surface area. Surface temperature value of 700c is applied to the base
of the heatsink
Solve: Solve the problem for obtain the linear solution



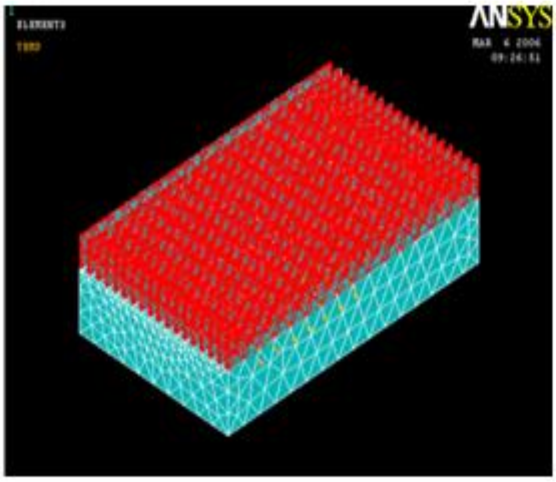
Geometric model of heat sink



Model after free triangular mesh



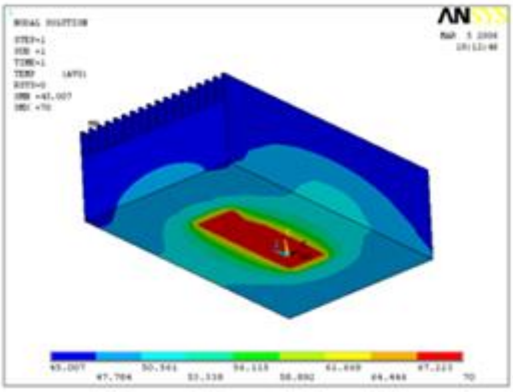
Model with applied thermal loads



Step4: General postprocessor

Plot results
Click plot results for to plot the nodal temperature values

Temperature profile



7. CONCLUSION

A heatsink device for cooling a chipset is provided. The heatsink device for cooling a chipset mounted on a printed circuit board to interface a central processing unit with a peripheral device, the printed circuit board including a plurality of installation holes near the chipset, the heatsink device including: a heatsink mounted to contact the top surface of the chipset to externally dissipate heat generated by the chipset, the heatsink having a pair of parallel guide grooves at the bottom edge regions which do not contact the chipset; and an installation unit which is fixed to be movable in each of the guide grooves and is connected to one installation hole of the printed circuit board, to bring the heatsink in contact with the top surface of the heatsink. The installation unit, which binds the heatsink to a chipset, is fixed to a bottom edge region to be movable along the bottom edge of the heatsink, so that the heatsink can be mounted on any printed circuit board having installation holes at a variety of different positions by adjusting the position of the installation unit to the position of the corre-sponding installation hole. The installation unit includes a spring to elastically push the heatsink toward the chipset and to absorb external vibrations or impacts, so that the chipset can be protected from external vibrations or impacts.

Fin height = 15mm
Fin length = 160mm
Fin thickness = 1.5mm
No of fins = 18
Fin gap = 1.5mm
Profile = rectangular
Material = Aluminum

Thermal analysis is also carried out on heatsink using ANSYS. Thev ANSYS results are compared with theoretical results and it has been concluded that the ANSYS results are in better agreement with the theoretical results.

8. BIBLIOGRAPHY

1. Rajput. R.K. “ A Text book of Heat transfer” , New Delhi: S.Chand ,2002.

2. Yunus A. Cengel “ Heat transfer- a practical approach” , New Delhi:Tata Mc-Graw-Hill,2002.

3. Kothanda Raman C.P. “Hand book of Heat transfer” , New Delhi: DhanapathRai,2002.

4. Gardener, K.A. “Efficiency of Extended surfaces” Trans. ASME, vol. 67, pp.621-635, 1945.

5. ANSYS Inc “Thermal Analysis Reference”,U.S.A,2002.

6. Tirupathi R. Chandrupatla Ashok , D. Belegundu “ Introduction to Finite Elements in Engineering” , Eastern Economy Edition,2002.

7. Todd M. Ritzer and Paul G. “Economic Optimization of Heatsink design & technology”, Inc Michigan, U.S.A , 2003.