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Heat Transfer in Electronic Systems Printed Circuit Board: A Review

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HIGHLIGHTS

- Provide a detailed review of heat transfer methods in electronic devices.
- New environmentally friendly technologies are reviewed to improve heat transfer.
- Discussing the possibility of replacing RPCB with FPCB in electronic circuits.
- FPCB investment discussion to improve PCB thermal design.

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ABSTRACT

Thermal regulation has now become a staple in the design of electronic devices. As a result of technological advances in the electronic industry, component miniaturization and thermal system management are becoming more and more important. Due to the high demand for device performance and the need for better thermal management, this paper present a detailed theoretical review of heat transfer by conventional methods in electronic devices and equipment such as air cooling, water cooling, etc. to provide an ideal framework for a practical application in electronic cooling. With reference to the possibility of investing unconventional ways to reduce the energy consumed in the cooling process and preserving the environment through the possibility of replacing solid circuit boards with flexible circuits and studying their properties in improving heat transfer and deformation of P.C.B using the interaction of fluid structure under thermal and flow effects.

1. Introduction

Owing to the subsequent production of electronic tools such as P.C (C.P.U), L.E.D.s, and electric batteries, thermal management and heat transfer for electronic equipment is still one of the primary priorities. The most common method for keeping the surface temperature of electrical devices below the allowed operating temperature are cooled by air, cooled by liquid, cooled by a heat pipe, cooled by microchannel, and cooling by the phase difference. With the introduction of higher heat flux electronic devices, a classical cooling system is no longer capable of removing heat fluxes at a reasonable pace. Avalanche experiments have also shown the shortcomings of classical cooling methodologies and technologies used in the field of electronic cooling. As a result, an effective cooling system should be planned to meet the ever-increasing cooling demands. One of the most common uses of (H.T) technology has long been the design and maintenance of electrical equipment. Many advancements in electronic performance and improvements in thermal system design may have resulted in increased emitted energy and reduced component sizes over time. This improved thermal architecture is possibe due to advances in H.T technologies and analytical approaches and tools. Latest advancements in the field of (C.F.D.) have significantly increased system thermal architecture capabilities.[1]. Some studies and results showed the possibility of investing in non-traditional methods to increase and improve heat transfer, such as using the flexible printed circuit board in electronic devices and taking advantage of the feature of flexibile and lightweight in improving heat transfer and reducing the energy spent on the cooling process.

2. Reliability and Temperature

Heat has a variety of effects on parts of different methods. Including temperature circulation, heat treatment, and the temperature under steady operation. In the temperature spectrum of interest for electronic devices, it is a fact that the accuracy of electronics is an inverse function of component temperature in the temperature range that concerns electronic devices.

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Significant thermal improvements can be made by optimizing currents and cooling. However, in order to ensure the requisite quality, a significantly lower design limit is often desired, especially in military goods. Yeh and Zhang [1, 2]. Figure 1 shows how temperature affects the failure and performance of the devices.

3. Techniques of Heat Transfer

In the thermal design of electronic equipment, each of the three methods of H.T (conduction, convection, and radiation) has been used, Boiling and condensation, melting, and solidification is examples of phase shifts. As a result, no single design approach can be applied universally to all electronic devices [3].

3.1 Interfaces Thermal Resistances

Heat conduction is the main method of H.T within a component. This frequently necessitates H.T through different components and surfaces that are laminated, bolted, or glued to each other. Brackets, heat sinks, and P.C.B are also commonly used to mount components that are cooled by conduction. When heat is transferred through these contacts, a temperature difference will arise. This is because of any two supposedly flat surfaces, only a percentage of the point’s contact each other Figure 2 shows that when two items' surfaces come into contact, they may not indeed be in perfect contact, merely touching in a few discrete regions. As a result, the direct contact area makes up a relatively small percentage of the nominal contact area. Heat transmission across the interface happens via a mix of three modes, including point-to-point micro contacts, convection, and radiation, due to the presence of gaps and spots in the contact, resulting in an extra resistance and temperature reduction at the interface [5]. The thermal resistance at the interface is a multi-parameter feature. It is essential to consider contacting friction, fill compounds, and the thermomechanical properties of contact solids. A variety of factors, including thermal conductivity and hardness, affect thermal contact resistance. T.C.R can be reduced by using thermal grease, applying a soft foil, or painting one or both surfaces with a comparatively smooth mineral coating, in addition to raising the contact pressure. The most challenging element influencing thermal touch tolerance is the filler's hardness (the softer, the better) L. T. Yeh [1]. It is also worth remembering that, dependent on the thickness or thermal conductivity of the added material, using a softer filler than the materials would usually affect higher overall contact resistance. Depending on the price and ease of execution, each method of minimizing touch resistance has advantages and risks. The least expensive option is thermal grease, but it is not easy to spread evenly through a wide part, and it vaporizes in low-pressure conditions and or migrates to these other surfaces. To be reliable, metallic foils must be fluffy and delicate, making them challenging to work within practical applications. Furthermore, Soft metal coatings do not crease or curl and are exceptionally durable even in a vacuum. Nevertheless, this tactic could be costly. The ability of melt materials to retain molten alloy at the interface and separate sections after cooling limits their use to raise the resistance of the interface. Liquid-filled microscopic cavities may be too complicated to use. Surya Kumar and Andallib Tariq [4] investigated the steady-state thermal contact conductance of two solid brass bodies bearing flat and curvilinear contact varieties under various load conditions ranging from 0.27 to 4.0 KN. The steady-state thermal contact was calculated using a tailored and standard experimental set - up. The current study establishes a design method for T.C.C. estimation based on steady-state liquid crystal (L.C.) measurements, which provides vital insight into heat transfer across curvilinear contacts and can be used as the baseline measurements for any future scale resolved numerical models. Yaoqi Xian et al. [5] studied the role of) TCR. It is essential for ensuring the reliability and lifetime of any device that needs temperature control, particularly in the rapidly evolving fields of microelectronic packaging. Nevertheless, Due to the large number of factors that lead to TCR between two homogeneous or dissimilar materials, studying and predicting it is a difficult task. And [5], they explain in depth the concepts and advances of both the steady-state and transient approaches, as well as new applications for various material levels and characteristics from each TCR test methodology. Moreover, address the issues facing TCR characterization and suggest potential future study directions. Jeng Y. et al. [6] designed a TCC model that took into account elasticity, plasticity, and the anticipated results were compared to the experimental data using elastoplastic deformation of the asperities. Because the models and correlations produced are only applicable in certain situations, most theories tend to over predict or under predict the estimated TCC determined from experimental observations. Madhusudana .C. [7] proposed a method for predicting the thermal conductance of cylindrical joints in the case of radial heat flow. TCC's value is determined by the geometrical, Thermophysical, surface, and heat flux parameters of the cylinders, as well as maximum operating temperatures with minimum information on surface properties and the maximum temperature rise, the constructed theoretical model were compared to the experimental data of other researchers.

Due to its simplicity, ease of maintenance, and low cost, air-cooled is also a widely used and widespread process in electronic devices; it can be divided into natural & forced convection. Natural convection is an ideal cooling method for low-power electronic equipment. Natural convection cooling is ideal since it eliminates the need for fans, which can malfunction. To increase the temperature difference between the components and the air, forced convection is used by increasing the velocity and thus the flow rate of the fluid and the heat transfer. This means that heat is removed at much higher rates for a specified temperature difference between the components and the air. As a result, the surface temperature of the components is reduced significantly for a specified power dissipation [3].

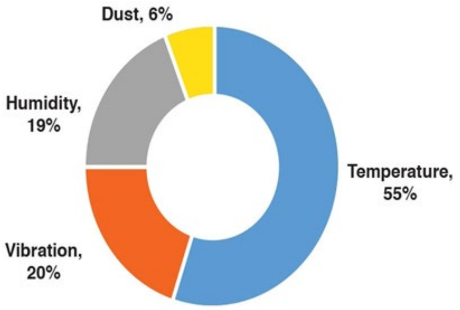


Figure 1: The most important cause for electronic failure [1]

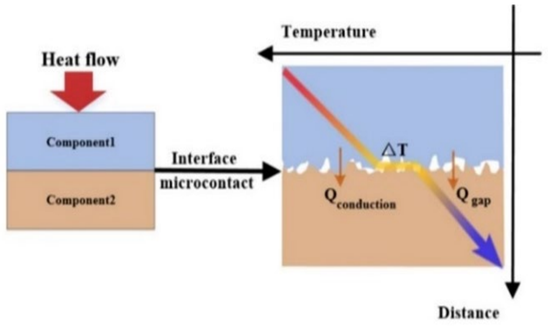


Figure 2: Field touch and temperature drop graphs [5]

3.2 Cooling by Air

Conduction along with the panels and possible radiation between the panels and the component increase the H.T problem. (CFD) software is typically used for a detailed review. Jalil &Habeeb. [8] Investigated the mixed convection cooling of a heat-dissipating electronic device in a rectangular enclosure cooled by an external airflow. The conjugate problem, which describes the flow and thermal fields in the air, is solved using the primitive variables method, which is explaining the airflow and its thermal fields. The interaction between the components is relevant here, and alternative configurations are evaluated based on their relative arrangement in the enclosure. The results are about values searching for appropriate placement of electronic components in an enclosed zone for effective heat removal. The source on the left vertical wall is the most advantageous in terms of cooling. Bugra Sarper et al. [9] examined buoyancy-induced flow and H.T. in a parallel plate channel with a heat Source array that mimicked an electronic package. They found that the blockage ratio of the heat source array is shown to have a substantial impact on buoyancy-induced flow and cooling performance. Dogan et al. [10] studied experimentally inside a horizontal channel, mixed convection H.T from arrays of discrete heat sources. They found that H.T may be enhanced due to buoyancy-induced flow by decreasing the request of ventilation power flow rate. Hanane Laouira et al. [11] H.T phenomena inside a horizontal Channel with an open trapezoidal enclosure exposed to a heat source of different lengths was numerically studied. A variable-length local heating system is embedded in the enclosure's bottom wall and maintained at a steady temperature as the heat source. The findings revealed that the heat source's length influences the distribution of isotherms. Furthermore, when the length of the local heat source rises, both the local and average Nusselt values rise. Furthermore, the highest temperature is found close to the heat source. Durgam, S et al. [12] examined natural and forced convection cooling of an aluminum heat source array mounted in a horizontal or vertical orientation on a substrate board and positioned in a horizontal channel to determine the best heat source array distribution in order to reduce the maximum excess temperature and to investigate the influence of substrate board conduction on heat transfer. Minbo Shim [13] used a numerical model to study the mixed-convective H.T of slanted-pin fins on an inclined hot surface in a laminar flow condition. Periodic boundary conditions in the lateral direction of fins were used to build the numerical model. The flow and heat transfer properties were described quantitatively and qualitatively concerning the channel-inclination angle. The difference in heat transfer characteristics between channel flow and open external flow was recorded, which is crucial in practice.

When struggling with natural convection problems, Radiation H.T cannot be neglected. Radiation could become a major concern, especially at high altitudes where there is little pressure. H.T from combined free convection and radiation for a pin-fin array. Anderson, A. M., and R. J. Moffat [14] focus on forced convection H.T in a channel using isolated components identical to those used in electronics cooling. For H.T, there are two kinds of cases that are restricted. First, since one uniform height element is located so close together, a smooth wall channel would approximate the new surface formed by their tops. Second, the dilemma can be modeled as flow over a single element since the elements are too far apart. There are readily available solutions to these limiting scenarios. The most significant concerns with few populated arrays exist in the middle ground. The elements are near enough to be considered individual elements, but not close sufficient to form a smooth surface. Flow isolation and recirculation are needed for direct cooling over components by forced convection, depending on the element spacing. Channel rise, component volume, and spacing between panels are also important factors to think about. The heat transfer coefficient typically decreases along the flow path after the third row until it approaches the fully shaped value. According to experimental results, the size of the entrance area is determined mainly by the approach velocity rather than a strong function of (Re) number (based on the approach velocity). Hussain, I. Y., & Abdulla [15] improved that Printed Circuit Board (P.C.B.) thermal layout modeling and optimization routine. Electronic components are modeled using thermal resistances, and the P.C.B. is modeled as a flat plate with different heat sources. For horizontal and vertical P.C.B. thermal transfer, so thermal and flux of natural convection H.T the consequences of optimization show that in free convection, the greater dimension of the P.C.B. should be oriented horizontally rather than vertically. Electronic components or sub-assemblies of high power should be situated close to the top of P.C.B. for the best total heat loss objective function. In natural convection, a horizontal up, sit-down is a problem. Large-power components must be located near the center of the P.C.B. modeling. Sarper et al. [16] examined the buoyancy-induced flow and heat transfer in a parallel plate channel with a heat source array, which resembles an electronic package. They observed that buoyancy induced flow the cooling performance is substantially impacted by the blockage ratio of the heat source array. Grimes et al. [17] the outlet flow of conventional axial cooling fans has been experimentally researched in order to meet the need for airflow prediction and comprehension in forced convection cooling electronic systems. This work provides significant and new design insight into forced cooling fluxes in electronic systems. Jalil et al. [18] studied the Fluid flow and heat transfer within a desktop computer numerically and experimentally.

According to the result, the temperature of the heat production elements starts decreasing with changes in inlet air velocity. The C.P.U temperature rises in a straight line with the (C.P.U) speed. The motherboard has the lowest temperature due to its position and volume (52 oC). The combined convection of air entering a two-dimensional horizontal conduit was numerically examined using the finite element method by Manca et al. [19]. The channel has an open cavity at the bottom that was subjected to a continuous heat flux at three separate points. They came to the conclusion that the opposing forced flow configuration had the highest Nusselt number. An inclined square water-filled channel with two symmetric open cubic chambers subjected to a constant wall heat flux was used to investigate unsteady laminar opposed mixed convection by Cardenas V. et al. [20]. The remaining channel and cavity walls were anticipated to be insulated. The overall heat transmission was discovered to be a nonlinear function of the channel inclination angle.

3.3 Cooling by Liquid

Liquids have substantially greater thermal conductivities than gases, which means they have far larger heat transfer coefficients. As a result, liquid cooling is significantly superior to gas cooling. However, liquid cooling has its own set of hazards and issues, including leakage, corrosion, added weight, and condensation. As a result, liquid cooling is reserved for applications with power densities that are too high for safe dissipation by air. There are two types of liquid cooling systems: direct cooling and indirect cooling. As shown in Figure 3.

Gangster Liang [22] conducted a comprehensive review that discussed the use of surface adjustment techniques to improve passive pool boiling. Surfaces at the macroscale and nanoscale, as well as multiscale (hybrid-scale) and hybrid-wettability approaches, are all concerned. However, in terms of fluid type, surface content, height, direction, development shape pattern and scale, and operational pressure, the study also highlights the lack of sufficiently large datasets for a given improvement scheme. As a result, the tools available for designing practical cooling systems are inadequate. Another essential phenomenon studied by T.Y. Tom Lee et al. [23] Shift from a highly efficient and frequently unstable H.T zone of nucleated boiling to a highly inefficient and unreliable heat transfer zone of film boiling, referred to as departure from nucleate boiling. (D.N.B.). The critical heat flux (CHF) has been the heat flux just before D.N.B. and the maximum heat flux that can be tolerated. The impact of dielectric fluid mixing on the critical heat flux in boiling pools has been studied by Qi Jim [24]. Figure 4 compares ranges of heat transfer coefficients attainable with different fluids and cooling schemes The CHF of perfluoropolyether fluids rose as the higher boiling liquid was introduced to the mixes, whereas the CHF of perfluorocarbon liquids remained fixed in all mix. This technique as well decreases temperature overshoot Improved surfaces have the ability to reduce temperature skip and raise the value of CHF because surface qualities are so important in pool boiling.

Fluids are contained in a conduit or duct to be cooled indirectly. The (Re), (Pr), boundary conditions, and fluid physical properties all play a role in the flow's H.T and friction. H.T in laminar flow or liquids is influenced by the configuration of the thermal boundary conditions and pipe cross-sections with a low temperature. In liquids having a high viscosity or turbulent flow, the configuration of the thermal boundary conditions and pipe cross-sections have no impact on H.T. (Pr). Because, in the former case, the entire thermal boundary layer has a uniform distribution of T.R. In contrast, in the latter instance, T.R is concentrated in the very thin laminar sublayer Consequently, the H.T correlation with one rounded cross-section tube cannot be extended to the others in laminar flow or liquids with a much lower (Pr). When it comes to the friction factor, it has the same behavior. The fluid movement and H.T of a laminar through a rectangular channel are of special advantage due to the extensive use of this type of construction in cooling electronics. Imran et al. [25] numerically and experimentally studied geometric optimization of a 3D serpentine mini-channel heat sink (S.M.C.H.S.). In a 3D mini-channel heat sink with different channel configurations, the finite volume system computational fluid dynamics technique is used to model single-phase forced convection for water-cooling laminar flow. The performance of the proposed design increases significantly when serpentine with two inlets and two outlets are used instead of conventional serpentine with one inlet and one outlet.

Figure 3: Direct Liquid cooling [21]

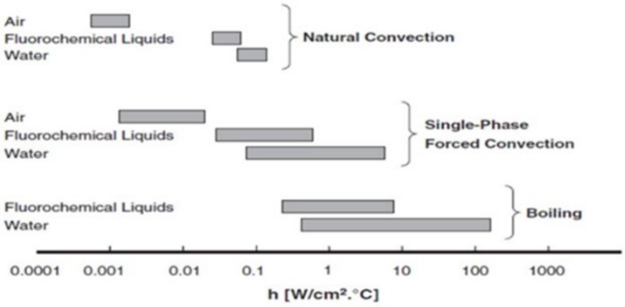


Figure 4: Ranges of H.T coefficients that can be achieved with various coolants [24]

Table 1: Differentiation of jet impingement and spray

	Jet impingement	**Spray**
rapidity	good	little
Erosion on the surface	(yes)	No
coefficient of heat transfer	Big at stagnation	At the wide-area, equitably
The temperature at the surface	Non-regular	Uniform
Size of nozzle	little	Big
Drop of pressure	Big	little
Overshoot of temperature	small	small

3.4 Spray and Jet Impingement

The usage of jet impingement cooling electrical equipment has grown in recent years. Directly connecting with hot regions and height H.T coefficients are two of the advantages of jet impingement. Gases or liquids can be used as working fluids. Furthermore, the jet impingement can be categorized as either a single-phase or two-phase jet. The H.T coefficient for jet impingement drops rapidly as it approaches the stagnation point, resulting in temperature differences over the heating surface. As a result, a multi-jet is frequently used. L. T. Yeh [1]**.** As a result, a multi-jet is widely used. W.W. Wits et al. [26] investigated the possibility of using directly injected cooling to cool the heat generated in a ball grid array. Conduction and convection were used in the H.T process. The coolant is put closer to the source of heat generation in order that improve heat transfer. The jet impingement cooling concept was used to move airflow through a hole in the board to touch conditioned air with a series of metal balls at the board's foundation, where the air flows from back to front. Paisarn Naphon and Somchai Wongwises [27] the heat transfer properties of jet liquid impingement in a small rectangular fins heat sink for a personal computer's central processing unit was studied experimentally. The temperatures of the central processing unit produced from the jet liquid impingement cooling system were found to be lower than those produced from the standard liquid cooling system; nevertheless, energy consumption increased. This study's findings are technologically relevant for efficient cooling systems for personal computers or electronic devices to increase cooling efficiency. The Jet impingement cooling is shown in Figure 5 [28]. A comparison was made between jet impingement and sprayed in terms of performance and thermal properties, and the preference was for jet impingement, as shown in Table [1].

3.5 Thermosiphon and Heat Tube

As seen in Figure 6, Heat tubes and thermosiphons are a three-sectioned closed-loop two-phase system. Evaporator, condenser, and capillary section. The only distinction between a heat tube and a thermosiphon is how the condensed fluid returns to the evaporator. Tubes rely on the capillary action of the internal wick and the working fluid to return condensate to the evaporator. In contrast, a thermosiphon relies on an outside compelled field, like gravity, the force of centrifugation, and so on. A thermosiphon is also known as a wickless heat pipe because it lacks a wick structure. It must be remembered that a heat tube or thermosiphon is simply a system that can move heat from one place to another. An additional cooling system is required to transfer heat from heat tubes or thermosiphons to the optimum heat sink. Rob Legtenberg et al. [29] based on mainstream P.C.B. fabrication procedures, a flat, micro heat pipe was investigated and integrated into the laminated structure of a printed circuit board (P.C.B.). The equivalent thermal conductivity is better than solid copper, according to the study's findings. A novel design will be investigated that includes the heat tube into the P.C.B from the design stage to output in order to get the best thermal efficiency at the lowest cost. Yun-Zhi Ling et al. [30] Three-dimensional oscillating heat pipes and phase change materials were used to study an efficient cooling system for electronic devices, with phase change materials retaining heat dissipated by the system and three-dimensional oscillating heat pipes essentially transferring the accumulated heat from phase change materials to the atmosphere The test results show that the surface temperature of electronic items can be maintained well below 100 oC, which is 35 ^{o}C colder than conventional air cooling.

3.6 Electronic Cooling Using Thermoelectric Technology

The Peltier effect has been used to invest T.E.C.T. with a thermoelectric cooler for high flux dissipation. M.S. Dresselhaus et al [31] studied thermoelectric coolers (TECs). The cooling method using thermoelectric modules (TEMs), often known as cooling technology, has the advantage of being noiseless and environmentally friendly. And having a faster reaction time. Unlike compression refrigeration, the Peltier effect allows the thermoelectric cooling process to operate without a mechanical move, resulting in noiseless cooling equipment. Thermoelectric technology has gotten a lot of attention because of all of these benefits. Yang Cai et al. [32] T.E.C.T. is analyzed in detail in order to demonstrate a detailed understanding of thermoelectric applications in electrical, cooling, and heating systems. The first thermoelectric cooler junctions will be cooled while the other stays heated, while a direct current flows through it. A thermoelectric cooler is a system that transfers current from one kind of part to another. (N to P-type). Several groups of P.N. kind semiconductor columns, metallic connectors, and two electrically insulating ceramic plates make up the thermoelectric assembly. As seen in Figure 7, the thermoelectric materials that make up the P.N. semiconductor columns are electrically and thermally connected in order. The two types of T.E.C.T. in electronic cooling are active thermoelectric cooling (T.A.C.) systems, which use T.E.C. as a cooler to absorb energy directly, and thermoelectric self-cooling (T.S.C.) systems, which use a thermoelectric generator (T.E.G.) to produce electricity from a temperature change.

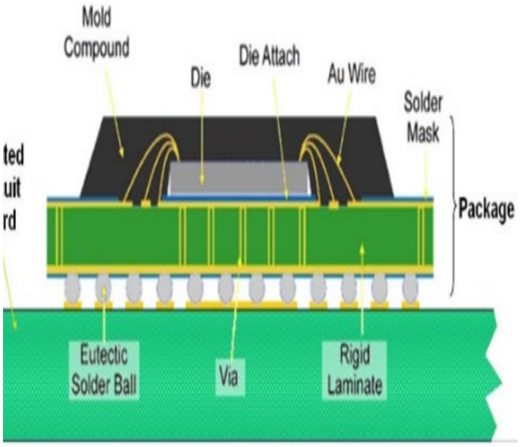
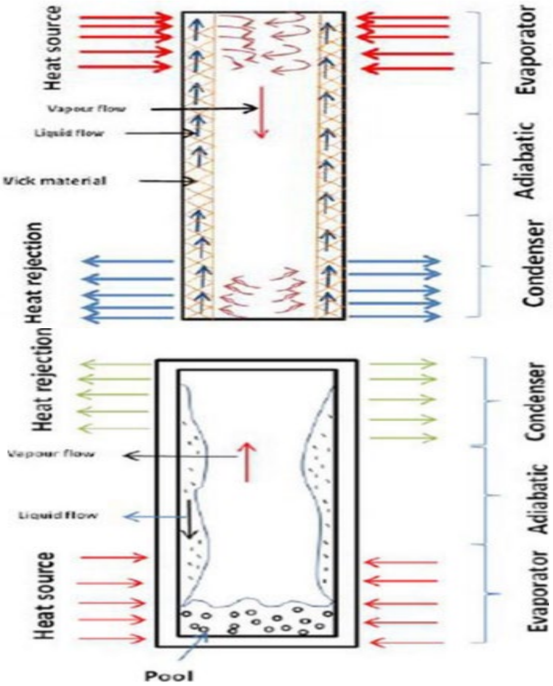


Figure 5: Jet impingement cooling [28]



A-Operation of wick heat pipe, B-Operation of thermosiphon

Figure 6: Heat pipe. [28]

To reduce thermal resistance between the hot side of the T.E.M. and the atmospheric climate, T.E.C.T. often works with other cooling methods such as cooling by air, cooling by water, cooling by heat tube, cooling by micro-channel, and Nano fluid cooled. This is because the average heat on the T.E.M.'s hot side significantly impacts the T.A.C. or T.S.C. system's Efficiency. Figure 8 shows the Thermoelectric technology publications from 2000 to 2018 [32] an air source thermoelectric heat pump system can deliver chilly air and hot water at the same time. Was created by Y. Cai. [33] They discovered that the thermal conductivity and specific heat allocations in hot and cold side heat exchangers can have a large impact on total cooling capacity and COP. Zhou et al. [34] introduced a thermoelectric-assisted indirect evaporative cooling system in which thermoelectric cooling (TEC) modules are sandwiched between channels of a flat plate cross-flow indirect evaporative cooler to improve heat transfer potential on the thermoelectric cooler's hot side to improve heat transfer potential.

3.7 Flexible Printed Circuit Boards Improve Heat Transfer

Because of the high demand for electronic products, the electronic and microelectronic industries have expanded rapidly over the last few decades, and flexible printed circuit boards (F.P.C.B.), as shown in Figure 9, have begun to replace rigid P.C.B. (R.P.C.B.) in some applications due to their versatility and sprightly weight. Mounting a temperature sensor array and a flow sensor on an F.P.C.B. for thermal and flow tests, mounting a flexible and lightweight L.E.D. on an F.P.C.B. for earthquake safety, and using F.P.C.B. in computer boards, wire-wound coils, winding motors, and electrodynamic bearings were among the applications used by research teams. Nonetheless, in inflow environments with heat impacts, the F.P.C.B.'s flexibility influences deformation and enhances the cooling impact. F.P.C.B. as a substrate for computer motherboard application was studied by A. M. Iqbal et al. [35] for temperature prediction. The comparisons were made on various P.C.B.s. It was discovered that F.P.C.B. could have an appropriate surface temperature. F.P.C.B. surface temperature remains nearly constant even at greater Re. Even though the current findings were limited to the board level, the findings can help advance F.P.C.B. Lim Chong Hooi et al. [36] examined the impact of airflow rate and heat on F.P.C.B. connected to a ball grid array (BGA) package and discovered that the Re number and heat have major effects on the deflection and stress of the F.P.C.B. As a result, when dealing with the F.P.C.B. underflow climate, it was critical to account for thermal effects. The findings could serve as a guideline for the F.P.C.B. industries. C.H. Lima et al. [37] Studied the comparison by replacing R.P.C.B. With F.P.C.B. Depending on the Nu number (Nu). When changing the values of Re numbers based on flow and temperature, as the research idea was to study the effect of deviation and the values of Nu number and Re numbers the numerical modeling was executed. Studied the simulation of the electronic cooling process. This project aims to analyze H.T and distortion of (F.P.C.B.) using fluid-structure activity under thermal & stream influences, where thermal and flow effects were previously studied on F.P.C.B. with attached (BGA) packages. Using fluid-structure interaction, Lima et al. [38] Investigated H.T & distortion (FPCB) under thermal & stream influences. This study simulates the electronic cooling mechanism when electronic devices generate heat while operating at F.P.C.B. under forced convection. C. H. Lim et al. [39] examined the impact of various Reynolds (Re) on F.P.C.B. connected with ball grid array (BGA) package in various arrangements, and the results indicate that the (Re) has a significant impact on the deflection and stress of the FPCB. The locations of the BGA package on the F.P.C.B., on the other hand, were found to be insignificant to the responses. [40] Flexible PCBs reduce the need for wires in the overall assembly design, making them lightweight and simple to install in any electrical device. The flexible PCB business is being shaped by several important trends, including the miniaturization of printed circuit boards and the development of green PCBs. Furthermore, the market is expected to be fueled by features such as packaging flexibility and quality performance. Figure 10 shows the Asia pacific FPCB market size, by end-use, 2015-2025 (USD billion).

4. Electronic Cooling Technology

Table 2 compares cooling and heat transfer methods in electronic devices; each technique has benefits, but it is not possible to limit the use of a particular method because each system has unique working conditions. For example, a flexible printed circuit board was added to increase heat transfer for its benefit, excellent flexibility., twist ability, lightweight, low cost, no energy requirement, strong demand for heat flux, fast H.T, and noise-free.

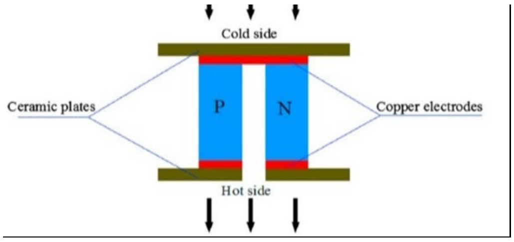


Figure 7: Thermoelectric element schematic diagram [32]

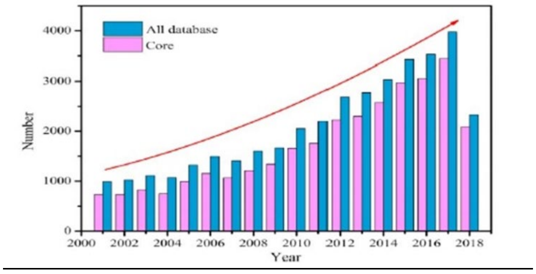


Figure 8: Depicts the advancement of thermoelectric technology [32]

Figure 9: Flexible printed circuit board [36]

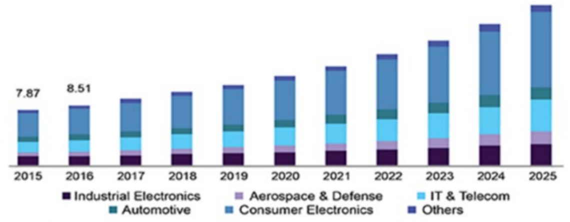


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Figure 10: The Asia Pacific FPCB market sizes [40]

Table 2: Advantages &limitation in Electronic Cooling

No.	Cooling techniques	Advantages	limitation
1	Cooling by Air	No loud sound, No electricity request	cooling load
2	Microchannel	Large heat flux request, product size, and weight requirements	Performance and constriction
3	Cooling by Liquid	Good heat flux, effective heat transfer	Leakage in Liquid
4	Others (e.g., Water jet, Nano fluid, micro-channel heat tube)	More efficient	similarity
5	Heat tube cooled	Good heat flux, effective heat transfer, no noise	seep, and high production maintains
6	Thermoelectric	elevation performance	Single T.E.C. modules have limited power, The hot side temperature should not exceed 60°C, or it may be harmed
7	F.P.C.B.	excellent flexibility, twist ability, lightweight, no energy need, fast heat transfer, and noise-free	Since F.P.C. has a high one-time initial cost for rigid P.C.B.s, careful caution must be taken during the assembly process since the circuit can be easily destroyed.

5. Conclusions

The present study conducted a comprehensive investigation of the methods of heat transfer in electronic equipment and electronic cooling. Various theories of heat transfer methods such as water or air cooling, heat pipes, and other methods have been highlighted, and a simple comparison is made between these types. The materials, physical parameters, basic modeling, and methods of analysis for these theories are also mentioned. In this study, the thermal design must deal with mechanical and electronic systems and operating environments, as there is no single design suitable for all applications where multiple methods of heat transfer are used concurrently within the device. In this paper, a previous survey of heat transfer technologies in electronic boards has been updated. Shedding light on the use of flexible panels and the possibility of having investment properties such as flexibility, lightness, reduced energy consumption to cool electronic devices, and environmentally friendly devices to improve heat transfer in electronic circuits by reviewing a set of research in this field.

Abbreviation

T.C.R → thermal contact resistance
RPCB→ rigid printed circuit board
P.B→ perforated- board
T.C→ thermal control
P.C.M→ phase- change- material
T.E.C→ thermal- electronic- cooling
H.T→ heat transfer
B.G.A→ ball grid array
T.C.C →thermal- contact- conductance
P.C.B →printed- circuit- board
F.P.C.B →flexible-printed-circuit- board
C.F.D→ computational-fluid -dynamics
E.C →electronic component
S.B →solid board
T.A.C→ thermal active cooling
T.R→ thermal resistance

Author contribution

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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