



Cooling Technology For Electronic Equipment

Sung Jin Kim, Sang Woo Lee



Cooling Technology For Electronic Equipment:

Air Cooling Technology for Electronic Equipment Sung Jin Kim, Sang Woo Lee, 1996-04-26 Clear your bookcase of references containing bits and pieces of useful information and replace them with this thorough single volume guide to thermal analysis *Air Cooling Technology for Electronic Equipment* is a helpful practical resource that answers questions frequently asked by thermal and packaging engineers grappling with today's demand for increased thermal control in electronics Superbly organized for quick reference the book dedicates each chapter to answering fundamental questions such as What is the optimal spacing between the printed circuit boards What is a good estimate of the heat transfer coefficient and the associated pressure drop for forced convection over package arrays How are heat transfer and fluid flow characteristics in the entrance region different from those in the fully developed region What is the effect of substrate conduction on convection cooling The chapters written by engineers and engineering educators who are experts in electronic cooling are packed with details and present the latest developments in air cooling techniques and thermal design guidelines They provide problem solving analyses that are jargon free straightforward and easy to understand *Air Cooling Technology for Electronic Equipment* is a handy source of technical information for anyone who wants to get the most out of air cooling

Cooling Technology for Electronic Equipment Win Aung, 1988 From the preface The papers in this proceedings volume address both fundamental and applied issues related to cooling technology The author or authors of each paper clearly understand the need for general utility of results yet all are mindful of design and system considerations The materials included here have been selected from six preselected topics that deal respectively with natural convection air cooling forced convection air cooling liquid cooling conduction and contact resistances thermal modeling and systems problems This volume also includes a chapter at the end that is devoted to a discussion of recommended future research This book will serve as useful reference for system designers and researchers alike *Thermal Management and Cooling Technology for Electronic Equipment* Tom Calderaro, 2025-08-25 Thermal management and cooling technology are critical for the reliability and performance of electronic equipment ensuring devices operate within safe temperature ranges As electronic components become smaller and more powerful they generate significant heat which can impair functionality or cause failure Effective thermal management involves various techniques including heat sinks fans liquid cooling and thermoelectric coolers to dissipate heat efficiently Advanced methods like heat pipes and vapor chambers enhance heat transfer while innovative materials like phase change materials PCMs and graphene are explored for their superior thermal properties Moreover the integration of smart sensors and control systems enables real time monitoring and dynamic adjustment of cooling mechanisms optimizing energy consumption and prolonging device lifespan This book presents the complex subject of thermal management and cooling technology for electronic equipment in the most comprehensible and easy to understand language It is a valuable compilation of topics ranging from the basic to the most complex advancements

in this field The topics covered in this book offer the readers new insights in the field of electronics **Air Cooling Technology for Electronic Equipment** Sung Jin Kim,Sang Woo Lee,2020-07-24 Clear your bookcase of references containing bits and pieces of useful information and replace them with this thorough single volume guide to thermal analysis Air Cooling Technology for Electronic Equipment is a helpful practical resource that answers questions frequently asked by thermal and packaging engineers grappling with today s demand for increased thermal control in electronics Superbly organized for quick reference the book dedicates each chapter to answering fundamental questions such as What is the optimal spacing between the printed circuit boards What is a good estimate of the heat transfer coefficient and the associate pressure drop for forced convection over package arrays How are heat transfer and fluid flow characteristics in the entrance region different from those in the fully developed region What is the effect of substrate conduction on convection cooling The chapters written by engineers and engineering educators who are experts in electronic cooling are packed with details and present the latest developments in air cooling techniques and thermal design guidelines They provide problem solving analyses that are jargon free straightforward and easy to understand Air Cooling Technology for Electronic Equipment is a handy source of technical information for anyone who wants to get the most out of air cooling

Cooling of Electronic Systems Sadik Kakaç,Hafit Yüncü,K. Hijiata,1994-02-28 Electronic technology is developing rapidly and with it the problems associated with the cooling of microelectronic equipment are becoming increasingly complex So much so that it is necessary for experts in the fluid and thermal sciences to become involved with the cooling problem Such thoughts as these led to an approach to leading specialists with a request to contribute to the present book Cooling of Electronic Systems presents the technical progress achieved in the fundamentals of the thermal management of electronic systems and thermal strategies for the design of microelectronic equipment The book starts with an introduction to the cooling of electronic systems involving such topics as trends in computer system cooling the cooling of high performance computers thermal design of microelectronic components natural and forced convection cooling cooling by impinging air and liquid jets thermal control systems for high speed computers together with a detailed review of advances in manufacturing and assembly technology Following this practical methods for the determination of the parameters required for the thermal analysis of electronic systems and the accurate prediction of temperature in consumer electronics Cooling of Electronic Systems is currently the most up to date book on the thermal management of electronic and microelectronic equipment and the subject is presented by eminent scientists and experts in the field Vital reading for all designers of modern high speed computers

Cooling Techniques for Electronic Equipment Dave S. Steinberg,1991-10-22 Details infallible techniques for designing electronic hardware to withstand severe thermal environments Using both SI and English units throughout it presents methods for the development of various reliable electronic systems without the need of high speed computers It also offers mathematical modeling applications using analog resistor networks to provide the breakup of complex systems into

numerous individual thermal resistors and nodes for those who prefer high speed digital computer solutions to thermal problems

Cooling of Electronic Equipment Allan W. Scott, 1974 *Electronic Materials Handbook*, 1989-11-01

Volume 1 Packaging is an authoritative reference source of practical information for the design or process engineer who must make informed day to day decisions about the materials and processes of microelectronic packaging Its 117 articles offer the collective knowledge wisdom and judgement of 407 microelectronics packaging experts authors co authors and reviewers representing 192 companies universities laboratories and other organizations This is the inaugural volume of ASMAs all new Electronic Materials Handbook series designed to be the Metals Handbook of electronics technology In over 65 years of publishing the Metals Handbook ASM has developed a unique editorial method of compiling large technical reference books ASMAs access to leading materials technology experts enables to organize these books on an industry consensus basis Behind every article Is an author who is a top expert in its specific subject area This multi author approach ensures the best most timely information throughout Individually selected panels of 5 and 6 peers review each article for technical accuracy generic point of view and completeness Volumes in the Electronic Materials Handbook series are multidisciplinary to reflect industry practice applied in integrating multiple technology disciplines necessary to any program in advanced electronics Volume 1 Packaging focusing on the middle level of the electronics technology size spectrum offers the greatest practical value to the largest and broadest group of users Future volumes in the series will address topics on larger integrated electronic assemblies and smaller semiconductor materials and devices size levels

Direct Liquid Cooling for Electronic Equipment, 2014 This report documents a demonstration of an electronic equipment cooling system in the engineering prototype development stage that can be applied in data centers The technology provides cooling by bringing a water based cooling fluid into direct contact with high heat generating electronic components This direct cooling system improves overall data center energy efficiency in three ways High heat generating electronic components are more efficiently cooled directly using water capturing a large portion of the total electronic equipment heat generated This captured heat reduces the load on the less efficient air based data center room cooling systems The combination contributes to the overall savings The power consumption of the electronic equipment internal fans is significantly reduced when equipped with this cooling system The temperature of the cooling water supplied to the direct cooling system can be much higher than that commonly provided by facility chilled water loops and therefore can be produced with lower cooling infrastructure energy consumption and possibly compressor free cooling Providing opportunities for heat reuse is an additional benefit of this technology The cooling system can be controlled to produce high return water temperatures while providing adequate component cooling The demonstration was conducted in a data center located at Lawrence Berkeley National Laboratory in Berkeley California Thirty eight servers equipped with the liquid cooling system and instrumented for energy measurements were placed in a single rack Two unmodified servers of the same configuration located in an adjacent

rack were used to provide a baseline The demonstration characterized the fraction of heat removed by the direct cooling technology quantified the energy savings for a number of cooling infrastructure scenarios and provided information that could be used to investigate heat reuse opportunities Thermal measurement data were used with data center energy use modeling software to estimate overall site energy use These estimates show that an overall data center energy savings of approximately 20 percent can be expected if a center is retrofitted as specified in the models used Increasing the portion of heat captured by this technology is an area suggested for further development *Transport Phenomena In Thermal Control* Guang-Jyh Hwang,1989-08-01 A collection of research papers into transport phenomena in thermal control closely related to several important aspects of cooling technology Articles provide overviews of current advances and details of individual technologies including electronic and turbine cooling and Marangoni convection [Guide Manual of Cooling Methods for Electronic Equipment](#) Cornell Aeronautical Laboratory,United States. Navy Department. Bureau of Ships,1956

Embedded Cooling Of Electronic Devices: Conduction, Evaporation, And Single- And Two-phase Convection

Madhusudan Iyengar,Justin A Weibel,Mehdi Asheghi,2024-01-10 This book is a comprehensive guide on emerging cooling technologies for processors in microelectronics It covers various topics such as chip embedded two phase cooling monolithic microfluidic cooling numerical modeling and advances in materials engineering for conduction limited direct contact cooling with a goal to remedy high heat flux issues The book also discusses the co design of thermal and electromagnetic properties for the development of light and ultra high efficiency electric motors It provides an in depth analysis of the scaling limits challenges and opportunities in embedded cooling including high power RF amplifiers and self emissive and liquid crystal displays Its analysis of emerging cooling technologies provides a roadmap for the future of cooling technology in microelectronics This book is a good starting point for the electrical and thermal engineers as well as MS and PhD students interested in understanding and collaboratively tackling the complex and multidisciplinary field of microelectronics device embedded cooling A basic knowledge of heat conduction and convection is required *Thermal Management of Microscale Electronic Equipment Using Pulsating Heat Pipes* Pawan Singh Kathait,2020 Last two decades witnessed a massive growth in the electronics industry Electronic equipment such as mobile phones and computers are now an integral part of our daily life The ease of use has driven the electronic industry to develop more powerful yet smaller electronic products There is an ongoing quest for developing powerful yet miniaturise electronic equipment While in use a piece of electronic equipment generates excess heat and the amount of heat generation increases with the increase in products performance and miniaturisation The excess heat if not checked can render the device useless untimely system crash or can decrease its reliability Therefore the thermal management of an electronic device is necessary to keep the device in its optimal use state without any failure There are many thermal management techniques in use this thesis focuses on one such technology called pulsating heat pipes PHP PHP is a relatively new technology in electronic cooling space however due to its straightforward

design the ability to handle high heat fluxes and simple manufacturing has made it a very promising electronic cooling technology. This research project aims to analyse the performance of PHP as an electronic cooling device. For achieving the aims and objectives of the study, two test rigs were designed and fabricated. The first test rig was a single loop pulsating heat pipe (SLPHP) and the other one was a multi loop pulsating heat pipe (four loops). A PHP takes some time to reach its operation state, often referred to as quasi steady state. Before reaching a quasi steady state, a PHP goes through a start up process. An efficient thermal management technique must initiate its operation as soon as the electronic device reaches a certain peak heat flux level. Also, the cooling device must keep the operating temperature of the electronic equipment below its maximum permissible temperature. Though there are studies regarding the startup of a PHP, however, none of them are for PHP as an electronic cooling device. For understanding the start up process of a PHP, a single looped pulsating heat pipe was fabricated from a 670 mm long copper tube with an internal and external diameter 3.25 mm and 4.75 mm respectively. Water was used as the working fluid. Experiments were conducted for different filling ratios (50 %, 60%, 70% and 80%) and heat loads (20 W, 33 W, 55 W and 76W). Two types of start up behaviour were observed: a gradual soft start up and a sudden hard start up as reported previously. Contrary to previous claims, the two types of start ups were found to be independent of the heat load. Experiments revealed that the probability of the PHP undergoing a sudden start up was higher at a higher filling ratio, which was attributed to the higher level of flooding of the evaporator section at higher filling ratios. Experimental results also show that for similar heat load and filling ratio, during sudden start up, time is more as compared to smooth start up. Besides, after a sudden start up, the PHP works at a higher operating temperature as compared to a gradual start up. Therefore, the sudden start up is not desirable for a PHP based device employed for electronic cooling. It was also shown that to suitably design a thermal solution based on PHP for electronic cooling, the calculation of thermal performance must include start up temperature and start up time. The multi loop PHP experimental setup was designed to evaluate the performance of the PHP under non uniform heating conditions. In electronic cooling, there are situations where non uniform heating could occur. For example, a data centre houses a large number of processing units, each running at different operating load, generating a different level of heat fluxes. Another example is a high performing laptop or desktop in which, along with CPU, graphic card and RAM, might require cooling. Furthermore, the surface of the microprocessor itself can have different levels of heat fluxes at different locations. Though each equipment or unit has its cooling device, however, a single device working under different heat load could save much space, which could allow further miniaturisation and can reduce the operation cost of the cooling device. The studies about non uniform heating of a PHP are scarce. Two critical parameters in a PHP operation are heat input and filling ratio (FR). However, the studies on the effect of non uniform heating on the performance of the PHP at different filling ratios are limited to a narrow range (50% - 70%). Furthermore, the mechanism of how non uniform heating affects PHP performance at different filling ratios is not yet clear. For studying the effect of non uniform heating, a four loop water based

CLPHP closed loop pulsating heat pipe was fabricated from a copper tube that had an internal diameter ID 3 25mm The thermal performance of the CLPHP was measured over a range of filling ratios FR 20% to 80% total power input 80 W to 360 W and two stage non uniformity with a power difference $Q_1 - Q_2$ 40 W to 140 W Results show that the thermal resistance of the PHP under non uniform heating increase on increasing Q The study also revealed that the impact of non uniform heating is significant at low FR 20% however at high FR 50% the influence of non uniform heating diminishes Non uniform heating was also found to affect the operational ceiling of the PHP For example in this study the optimal filling ratio during uniform heating was 20% and no dry outs were observed However during non uniform heating dry outs were recorded for FR 20% at various heating levels which resulted in very high thermal resistance Investigation of flow patterns during non uniform heating revealed the reason for the unusual trend of thermal resistances at different filling ratios The flow pattern evolution during a non uniform heating condition was found to be different from the flow transitions during uniform heating Independent localised flow patterns were observed for low filling ratio whereas at high filling ratio high heating side was found to govern the flow pattern across the PHP The optimal filling ratio during uniform heating was to be 20% which was changed to FR 60% for non uniform heating A dimensionless non uniform heating coefficient is also proposed to quantify the effect of non uniform heating

Electronics Cooling S. M. Sohel Murshed, 2016-06-15 Featuring contributions from the renowned researchers and academicians in the field this book covers key conventional and emerging cooling techniques and coolants for electronics cooling It includes following thematic topics Cooling approaches and coolants Boiling and phase change based technologies Heat pipes based cooling Microchannels cooling systems Heat loop cooling technology Nanofluids as coolants Theoretical development for the junction temperature of package chips This book is intended to be a reference source and guide to researchers engineers postgraduate students and academicians in the fields of thermal management and cooling technologies as well as for people in the electronics and semiconductors industries

Proceedings of the International Symposium on Cooling Technology for Electronic Equipment, March 17-21, 1987, Hilton Hawaiian Village Hotel, Honolulu, Hawaii Pacific Institute for Thermal Engineering, 1987

Handbook of Thermal Management Systems Fethi Aloui, Edwin Geo Varuvel, Ankit Sonthalia, 2023-08-24 Handbook of Thermal Management Systems e Mobility and Other Energy Applications is a comprehensive reference on the thermal management of key renewable energy sources and other electronic components With an emphasis on practical applications the book addresses thermal management systems of batteries fuel cells solar panels electric motors as well as a range of other electronic devices that are crucial for the development of sustainable transport systems Chapters provide a basic understanding of the thermodynamics behind the development of a thermal management system update on Batteries Fuel Cells Solar Panels and Other Electronics provide a detailed description of components and discuss fundamentals Dedicated chapters then systematically examine the heating cooling and phase changes of each system supported by numerical analyses simulations

and experimental data These chapters include discussion of the latest technologies and methods and practical guidance on their application in real world system level projects as well as case studies from engineering systems that are currently in operation Finally next generation technologies and methods are discussed and considered Presents a comprehensive overview of thermal management systems for modern electronic technologies related to energy production storage and sustainable transportation Addresses the main bottlenecks in the technology development for future green and sustainable transportation systems Focuses on the practical aspects and implementation of thermal management systems through industrial case studies real world examples and solutions to key problems *Heat Transfer in Electronic Equipment, 1991*

A. Ortega,D. Agonafer,B. W. Webb,1991 **Design Manual of Natural Methods of Cooling Electronic Equipment**
United States. Ships Bureau,1962 *Guide Manual of Cooling Methods for Electronic Equipment* United States. Navy
Department. Bureau of Ships,1956 **Cooling Electronic Equipment** ALLAN D. KRAUS,1965

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