December 22, 1998

Revision 1.0

Introduction to Thermal Solutions

1.0 INTRODUCTION

This paper discusses basic technology used to dissipate heat in computer system designs. A discussion of heatsinks, fans and heatpipe solutions is presented. The last section provides a list of third party vendors of thermal solution products.

2.0 HEATSINKS

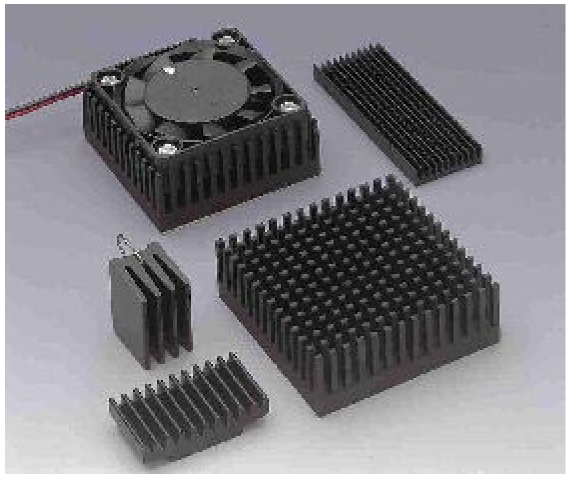
2.1 Introduction

A heatsink is simply a metal surface with pins or fins rising up off the surface. It is used to cool electronic devices. Each heatsink thermal solution can be categorized into five different types of solutions. The most simple is the passive heatsink solution which is used in applications that can either provide natural convection or that do not require much airflow. These types of solutions can normally handle a load of about 5-25 watts. The next level up is the semi-active heatsink solution which gets extra airflow from system fans. These can usually handle a load of about 15-50 watts. Active heatsink solutions actually incorporate a fan, which is attached to the solution. They can handle a load of about 10-160 watts. For larger (or unlimited) loads the designer can use liquid cooled cold plates, in which water, oil, or another liquid is pumped through tubes or passages in the cold plate to dissipate heat. The fifth type of solution is the phase-change recirculating system. This solution involves heatpipes that either contain a wick or are helped by gravity. This solution can handle a load of about 100-150 watts.

A main characteristic of heatsinks is thermal resistance (θ), which is measured in °C/W. For a heatsink with a thermal resistance of $\theta = 2$°C/W, every watt of heat it dissipates increases its temperature by 2°C. The larger the heatsink, the more surface area it has, and the better its thermal resistance. A simple (rough) formula for calculating the area needed for a heatsink is:

$$A = \left(\frac{50}{\Theta}\right)^2$$

Where the area is in cm^2 and θ is in °C/W.



Source: *www.fischerelektronik.de/fischer/produkte/kleinkk_e.html*

2.2 Types of Heatsinks

Plate Fin: These come in a wide variety of sizes, and the tooling costs depend on the distance between the fins. The smaller the distance the better the thermal performance.

Round Pin: These come either in a staggered or a straight line array. They are best suited for applications in which the direction of airflow is uncertain, or the airflow is less that 300 LFM. It is also suited for applications where air pressure drop is not a concern.

Elliptical Pin: The performance is less than round pin heatsinks but better than plate fin heatsinks. This comparison can only be made when all three have the same fin/pin thickness and separation. They are designed for specific airflow problems and have a great pressure drop capability. Their specific design lets air pass through the heatsink and cool other components.

Custom Cast Enclosures: This is an enclosure for an electronic device that also incorporates a heatsink. They are made specifically for devices that need to be enclosed as well as cooled.

Fan Heatsink: Almost all heatsinks can have a fan attached. The fan blows air across the fins/pins to cool them. This provides extra cooling and better thermal performance.

Once heatsinks are manufactured they may be surface treated. The coatings can be black anodize, solderable white bronze, or another material provided by thermal vendors.

3.0 FANS

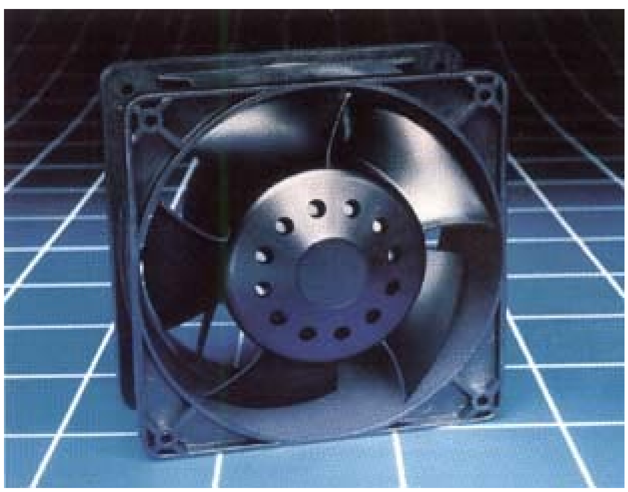
3.1 Introduction

Heatsinks are made to expand the surface area, which increases the amount of heat that can be cooled by the ambient air. To expedite the process, a fan can be added that blows across the heatsink and pushes the heat off the heatsink. Fans can be used in passive thermal solutions to blow hot air off of heatsinks, or they can be used alone to ventilate cool intake air across the integrated circuit component, pushing warm air out.

The typical fan involves a motor and a propeller. The motor can be either an AC induction motor or a brushless DC motor. The air that a fan produces blows parallel to the fan's blade axis. These fans can be made to blow a lot of air, but they work against low pressure.

Fans have two different types of bearings, sleeve or ball bearing. A lubricant is used on the bearings to reduce friction and to reduce wear on the bearings. The lubricant is chosen by its mechanical strength, hardness, wear, reliability and stability.

There are some side-effects that come from using fans. One issue is dust buildup, which affects the performance of the fan. Dust will slow down the fan's airflow, causing a higher chance of failure. Sleeve style fans are more susceptible to dust buildup failures than ball bearing fans. Other side effects include acoustic noise, vibration, and power consumption. Increased noise and high mechanical vibrations can also cause a fan failure.



Source*: www.electronics-cooling.com/Resources/EC_Articles/MAY96/may96_01.htm*

3.2 Types of Fans

Propeller fans: This is a very basic fan that consists of a motor and a propeller. Fan tip vortices can be a problem.

Tube Axial fans: These fans have a design similar to a propeller fan but have a venturi around the propeller that reduces vortices. This design is the one most used in electronic cooling systems.

Vane Axial fans: This fan comes with vanes attached to the propeller that straighten the airflow.

Notebook fans: These fans are designed to fit low-profile compact spaces. They have unidirectional flow and an on/off control function.

Waterproof fans: These fans are used to cool electronic equipment that is used outdoors. A silicone seal protects it from moisture.

Long-Life fans: These fans are designed to have a life expectancy of 100,000-200,000 hours.

Blowers: Blowers push air off of hot surfaces such as heatsinks and are used for spot cooling. They provide less airflow than fans and have higher air pressure than fans.

3.3 Fan Analysis

This table shows different fan laws depending on variables and constants when doing analysis.

Constants	Variable	Fan Laws
Diameter (D) Density (ρ)	Speed (N)	$G_2 = G_1(N_2/N_1)$ $P_2 = P_1(N_2/N_1)^2$ $HP_2 = HP_1(N_2/N_1)^3$
Speed (N) Density (ρ)	Diameter (D)	$G_2 = G_1(D_2/D_1)3$ $P_2 = P_1(D_2/D_1)^2$ $HP_2 = HP_1(D_2/D_1)^5$
Diameter(D) Speed (N) Volumetric Flow Rate (G)	Density (ρ)	$P_2 = P_1(\rho_2/\rho_1)^2$ $HP_2 = HP_1(\rho_2/\rho_1)^5$
Diameter (D) Mass Flow Rate (m.)	Density (ρ)	$G_2 = G_1(\rho_2/\rho_1)$ $P_2 = P_1(\rho_2/\rho_1)$ $N_2 = N_1(\rho_2/\rho_1)$ $HP_2 = HP_1(N_2/N_1)^2$

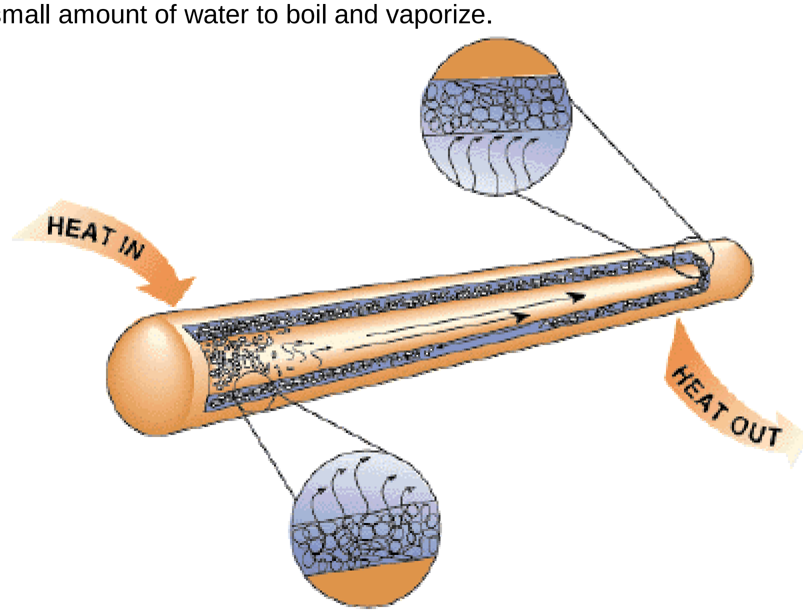
(source: Electronics Cooling: www.electronics-cooling.com/Resources/EC_Articles/MAY96/may96_01.html)

4.0 HEATPIPES

4.1 Introduction

A heatpipe is a product used as a thermal solution to cool electronic devices. It is mostly used in combination with other products made to cool these devices, but it may be used alone. A heatpipe is basically a sealed pipe with a wick structure inside. One end is called the evaporator and the other is called the condenser. The pipe is filled with liquid. When heat is applied to any part of the heatpipe this liquid will boil. This occurs in the evaporator end. With this increase in vapor pressure, the evaporated liquid will flow towards the condenser end where it is cooler. In this section the vapor is condensed back to its liquid form and flows back to the evaporator end. This job is carried out by the wick, which provides the capillary driving force that makes this liquid move back to the evaporator end. Many different liquids are used for working fluids in heatpipes. For heatpipes that will be used at cryogenic temperatures, helium and nitrogen fluids are used. For systems at higher temperatures, sodium and potassium fluids are used as the working fluid. In most thermal solutions for electronic applications, water, acetone, ammonia and methanol can be used as the working fluid.

Since a heatpipe doesn't have any moving parts, it is a highly reliable thermal solution. The only failures that it may encounter are due to gas being generated inside the heatpipe. But this problem can be avoided completely by carefully cleaning and assembling the solution. Some customers have concerns regarding the possibility of the fluid in the heatpipe leaking out. The amount of water in the heatpipe is usually less than 1cc for notebook applications. This water is inside the wick structure where the air pressure is less than 1 atm. At this pressure the water inside a heatpipe will boil at temperatures above the normal freezing point (32°F). In a worst-case scenario in which the heatpipe is punctured or split, air would fill the heatpipe. This would change the pressure to the point where the water would be at its atmospheric boiling point, causing the small amount of water to boil and vaporize.



Source: *www.thermacore.com*

4.3 Types of Heatpipes

Sintered powder: These are best suited for anti-gravity applications. They have high power handling, low temperature gradients and high capillary forces.

Grooved Type: These are low power heatpipes that perform the best when the are in a horizontal orientation or are working with gravity. The grooves provide a small capillary driving force. They are easily bendable and their performance can be improved when used with a screen mesh.

Screen Mesh: Their ability to transport power and their orientation are variable depending on the amount of layers of mesh used.

Flexible: Their flexibility comes from a “bellows” section in their structure. This characteristic allows an easier installation in devices which have confined or complex structures.

Sintered Structure: This type of heatpipe has a complex structure that can accommodate very tight bends. New technology on this heatpipe will allow it to function with over several meters inverted height, where the evaporator end (heated end) is several meters vertically above the condenser end (cooled end).

Bent Flexible: During manufacturing these heatpipes can be shaped into very tight bends. Similar to the Flexible heatpipes it has a “bellows” section between the evaporator and condenser ends that allows for this good flexibility. In addition, they also have a good anti-vibration characteristic.

Thermo Electric (Peltier): This type of design incorporates a heatblock, two heatpipes, and a lot of fins. The heat is absorbed by the copper heatblock and travels through the heatpipes to the fins.

Multi-Tube: These are mainly used in military applications in which the temperature range is very demanding. Half of the heatpipes are the copper/water type, which can handle temperatures above 5°C and the other half of the pipes are the ethanol type, which can handle really low temperatures.

Micro-heatpipe heatsinks: This device works in the same way a heatpipe would except they are smaller. They are ideal for cooling microprocessors and components in notebook computers. They were made to replace fans, which had problems with electricity consumption, noise level, electromagnetic interference, and reliability.

4.3 Heatpipe Performance

The following table was obtained from Isoterix Ltd. (www. eptx.com/isoterix/index.htm), which shows the standard heatpipe range.

	Length (mm)							Power (W)†
Diameter (mm)	**50**	**75**	**100**	**150**	**175**	**200**	**250**	
2	X	X	X					13.5
2.5	X	X	X					20.5
3	X	X	X	X	X			35
4	X	X	X	X	X	X		42
5	X	X	X	X	X	X		65
6		X	X	X	X	X	X	95
8			X	X	X	X	X	125
10			X	X	X	X	X	175
12			X	X	X	X	X	205

†Between +5° and +250°C (Horizontal)

The following table shows the advantages and disadvantages of using natural or forced convection airflows in heatpipe designs.

Thermal Alternatives	Advantage	Disadvantage
Heat Pipe/Natural Convection	No Fan Noise	Highest Fin Volume
	No Battery Drain (portable applications)	Highest Temp. Rise Above Ambient
	No Maintenance i.e., no Fan Replacement Required	Highest Weight Thermal Design
Heat Pipe/Forced Convection	Lowest Temp. Rise Above Ambient	Battery Drain (portable applications)
	Lowest Fin Volume	Fan Replacement Likely
	Lightest Weight Thermal Design	Fan Noise

Source: Thermacore, Inc.

5.0 VENDOR LIST

This list is provided for convenience. Intel does not endorse third party vendor products. The designer is responsible for verifying compatibility with Intel products.

5.1 Heatsink Vendors

Aavid Thermal Products, Inc.
200 Perimeter Rd.
Manchester, NH 03103-3326
603-528-3400
Fax: 603-669-2044

ABL (Aluminum Components) Ltd
Valepits Road, GArrets Green Industrial Estate
Garrets Green
Birmingham
B33 0TD
England
Tel: +44 121 789 8686
Fax: +44 121 789 8778

Advanced Thermal Solutions
36 Jaconnet Street
Newton, MA 02161 USA
Telephone: 617-965-8989
FAX: 617-326-1011
e-mail: cooling@aol.com
Web Address: http://www.qats.com

Chip Coolers Inc.
333 Strawberry Field Road
Warwick, RI 02886 USA
Telephone: 401-739-7600
FAX: 401-732-6119
Web Address: http://www.chipcoolers.com

Cooler Master
115 Fourier Ave.
Fremont, CA 94539 USA
Telephone: 510-770-0149
FAX: 510-770-0242
Web Address: http://www.coolermaster.com

Enertron USA, Inc.
2251 North 32nd Street, #19
Mesa, Arizona 85213 USA
Telephone: 602-854-7085
FAX: 602-854-7859
e-mail: enertron1@aol.com

ERM
1625 N. Clinton Ave
Rochester, New York 14621 USA
Telephone: 716-544-8080
FAX: 716-544-8482
Web Address: http://Info@heatsink.com

Fischer Elektronik
Nottebohmstr. 28
D-58511 Ludenscheid Germany
Telephone: 02351/4350
FAX: 02351/45754
e-mail: FischerElektronik@t-online.de
Web Address: http://www.fischerelektronik.de

Heat Technology Inc.
94 Main Street
Box 1184
South Lancaster, MA 01561 USA
Telephone: 508-365-5440
FAX: 508-365-5443
e-mail: heattech@ultranet.com

IMI Marston Limited
Wobaston Road
Fordhouses
Wolverhampton
WV10 6QJ
England
Telephone: +44 (0)1902 397777
Fax: +44 (0)1902 397792

Intricast
2160 Walsh Avenue
Santa Clara, CA 95050 USA
Telephone: 408-988-6200
FAX: 408-988-0683

Melcor Corp.
1040 Spruce Street
Trenton, NJ 08648 USA
Telephone: 609-393-4178
FAX: 609-393-9461
Web Address: http://www.melcor.com

Metals Group
9018 Soquel Drive
Aptos, CA 95003 USA
Telephone: 408-685-6056
FAX: 408-685-6058
Web Address: http://www.metalsgroup.com/index.shtml

National Northeast Corp.
33 Bridge St., P.O. Box 1000
Pelham, NH 03076
Toll Free: (888) 955-3556
Fax: (603) 635-1900

Robinson Fin Machines, Inc.
13670 Hwy. 68 South
Kenton, OH 43326
Tel 419-674-4152 Fax: 419-674-4154
Web http://www.robfin.thomasregister.com

R-Theta Inc.
6220 Kestrel Rd.
Mississauga, Ontario L5T 1Y9 Canada
Telephone: 800-388-5428
FAX: 800-567-7115
e-mail: sales@r-theta.com
Web Address: http://www.r-theta.com

TennMax
P.O. Box 9
Reading, Massachusetts 01867 USA
Telephone: 617-944-3293
FAX: 617-944-0903
e-mail: TennMax@aol.com
Web Address: http://www.TennMax.com

Thermacore Inc.
780 Eden Road
Lancaster, PA 17601 USA
Telephone: 717-569-6551
FAX: 717-569-4797
Web Address: http://www.thermacore.com

Wakefield Engineering Inc.
60 Audubon Road
Wakefield, MA 01880 USA
Telephone: 617-245-5900
FAX: 617-246-0874
Web Address: http://www.wakefield.com

Web Automation
11411 Plano Rd.
Dallas, TX 75243 USA
Telephone: 214-34808678
FAX: 214-348-8854
e-mail: webauto@flash.net

5.2 Fan Vendors

Degree Controls
4 Clinton Drive
Hollis, NH 03049 USA
Telephone: 603-883-5400
FAX: 603-883-6178
Web Address: http://www.degreec.com

Evox-Rifa, Inc.
300 Tri-State International #375
Lincolnshire, IL 60069 USA
Telephone: 847-948-9511
FAX: 847-948-9320
e-mail: service@evox-rifa.com
Web Address: http://www.evox-rifa.com

Fischer Elektronik
Nottebohmstr. 28
D-58511 Ludenscheid Germany
Telephone: 02351/4350
FAX: 02351/45754
e-mail: FischerElektronik@t-online.de
Web Address: http://www.fischerelektronik.de

Globe Motors
2275 Stanley Avenue
Dayton, Ohio 45404-1249
Phone: 937-228-3171
Fax: 937-229-8531

ITW Vortec
10125 Carver Road
Cincinnati, OH 45242 USA
Telephone: 513-891-7485 or 800-745-5355
FAX: 513-891-4092
e-mail: itwvortl@ix.netcom.com
Web Address: http://www.vortec.com

McLean Midwest, Subsidiary of Zero Corp.
11611 Business Park Blvd. North
Champlin, MN 55316 USA
Telephone: 612-323-8200
FAX: 612-576-3200
e-mail: sales@mcleanmidwest.zerocorp.com
Web Address: http://www.zerocorp.com

Melcor Corp.
1040 Spruce Street
Trenton, NJ 08648 USA
Telephone: 609-393-4178
FAX: 609-393-9461
e-mail: tecooler@melcor.com
Web Address: http://www.melcor.com

NMB Technologies Inc.
9730 Independence Avenue
Chatsworth, CA 91311
TEL: (818) 341-3355
FAX: (818) 341-8207

Qualtek Electronics Corp.
7675 Jenther Drive
Mentor, OH 44060 USA
Toll Free: 1-888-258-3468 (USA & Canada)
Phone: 1-440-951-3300
Fax: 1-440-951-7252
Email: qualtek@ix.netcom.com

Rittal Corp.
One Rittal Place
Springfield, OH 45504 USA
Telephone: 937-399-0500
FAX: 937-390-8392
Web Address: http://www.rittal-corp.com

Sanyo Denki America Inc.
468 Amapola Avenue
Torrance, CA 90501
Tel: 310-783-5400
Fax: 310-212-6545

Schroff, Inc.
170 Commerce Drive
Warwick, RI 02886 USA
Telephone: 401-732-3770
FAX: 401-738-7988
Web Address: http://www.schroffus.com

Sunonwealth Electric Machine Industry Co., LTD.
135 E Live Oak, # 208
Arcadia, CA 91006
Phone: 626-445-4122
Fax: 626-445-4152
Email: sunon@gus.net

TennMax
P.O. Box 9
Reading, Massachusetts 01867 USA
Telephone: 617-944-3293
FAX: 617-944-0903
e-mail: TennMax@aol.com
Web Address: http://www.TennMax.com

5.3 Heatpipe Vendors

Denso Sales California, Inc.
3900 Via Oro Ave
Long Beach, CA 90810
Telephone: 310-513-8544
FAX: 310-513-7319

Diamond Electric Mfg. Co., LTD.
5-13-12, Nishinakajima, Yodogawa-ku
Osaka 532, Japan
Telephone:
  Japan: 81-6-308-8420
  US: 313-529-5525
FAX:
  Japan: 81-6-303-0832
  US: 313-529-5359

Enertron
2251 North 32nd Street #19
Mesa, AZ 85213
Telephone: 602-854-7085
FAX: 602-854-7859

Fujikura America, Inc.
3001 Oakmead Village Drive
Santa Clara, CA 95051
Telephone: 408-988-7408
Fax: 408-727-3415

Furukawa Electric
200 Westpark Drive
Suite 190
Peachtree City, GA 30269 USA
Telephone: 770-487-1234
FAX: 770-487-9910
e-mail: joncox@mindspring.com
Web Address: http://www.furukawa-usa.com

Nissei Sangyo America, Ltd.
3070 Bristol St, Suite #570
Costa Mesa, CA 92626
Telephone: 714-513-9777
FAX: 714-513-9780

Noren Products:
1010 O'Brien Drive
Menlo Park, CA 94025-1409
Telephone: 415-322-9500
FAX: 415-324-1348

TennMax
P.O. Box 9
Reading, Massachusetts 01867 USA
Telephone: 617-944-3293
FAX: 617-944-0903
e-mail: TennMax@aol.com
Web Address: http://www.TennMax.com

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Web Address: http://www.thermacore.com