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(54) THERMOSIPHON WITH THERMOELECTRICALLY ENHANCED SPREADER PLATE

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(57) ABSTRACT

A cooling assembly includes a plate having a center portion for engaging and transferring heat from the electronic device and a peripheral portion surrounding the center portion. A heat sink overlies the plate and receives heat from the plate. A thermoelectric module is disposed between the peripheral portion of the plate and the heat sink for pumping heat laterally from the center portion of the plate to the peripheral portion of the plate and then to the heat sink.

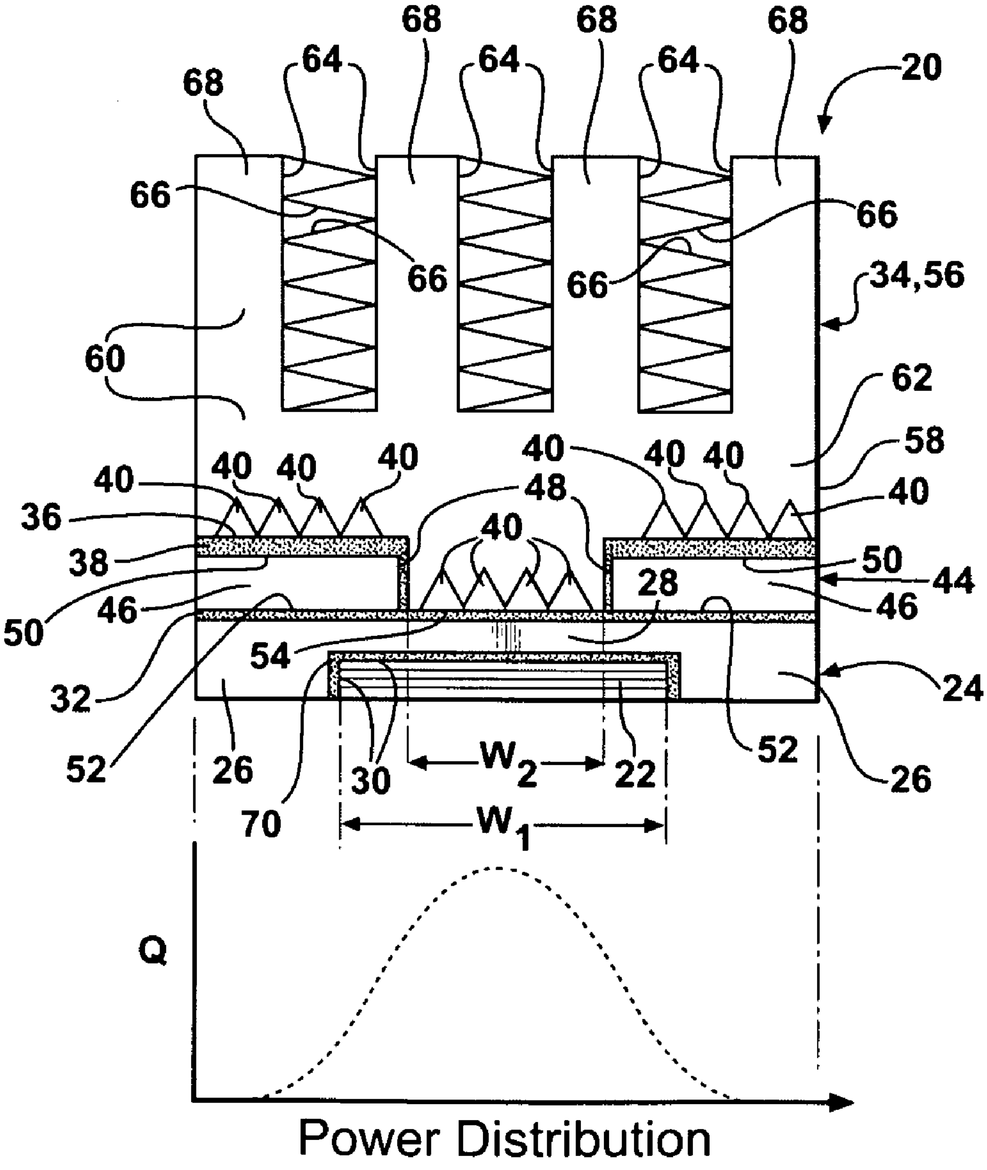


FIG - 1

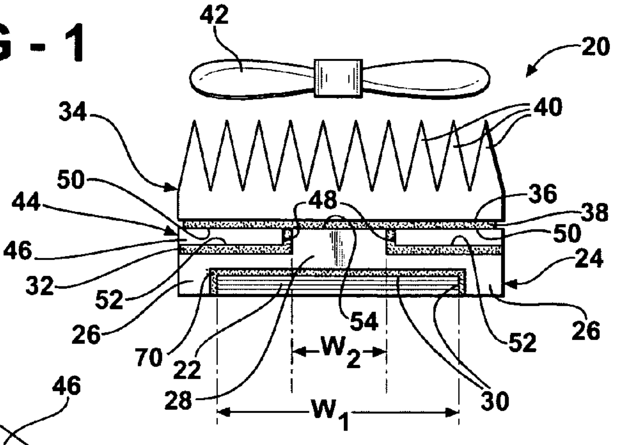
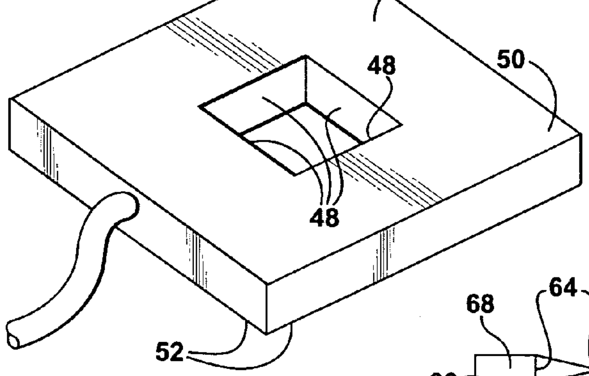


FIG - 2



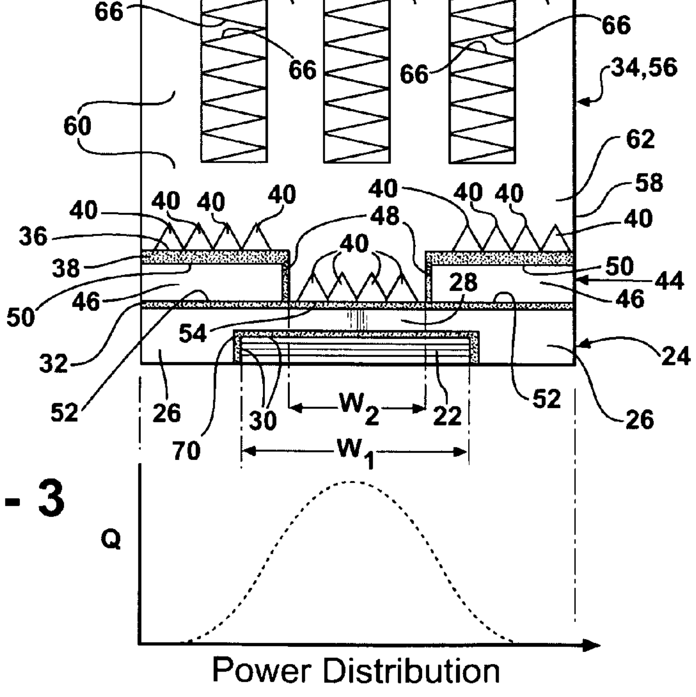


FIG - 3

FIG – 4

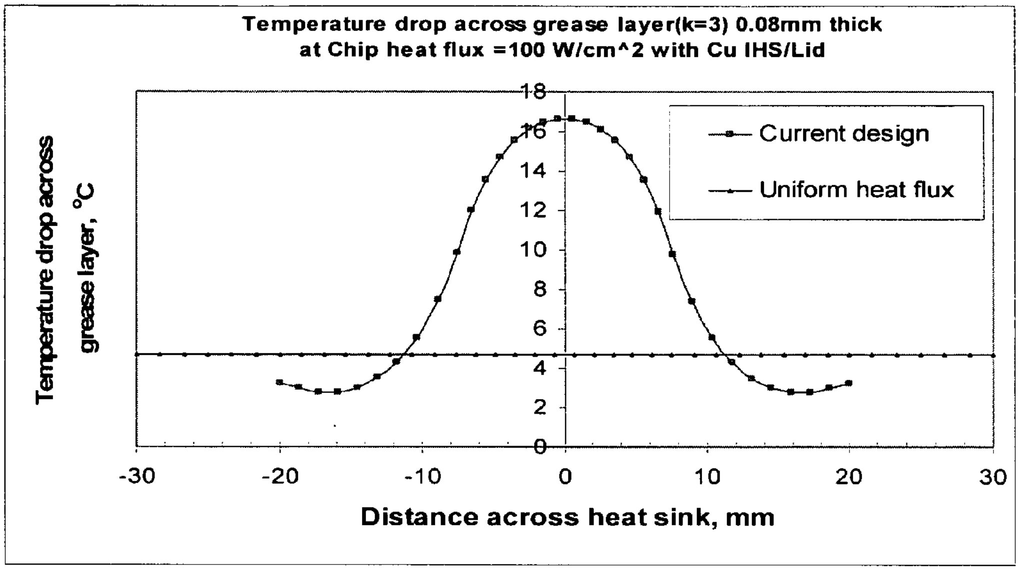
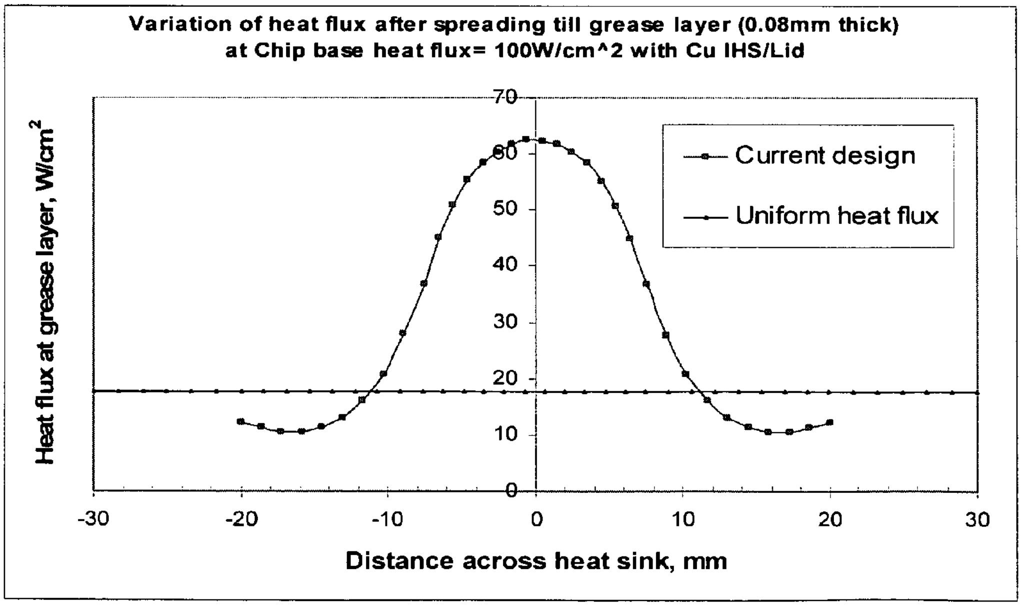

Temperature drop across grease layer(k=3) 0.08mm thick
at Chip heat flux =100 W/cm^2 with Cu IHS/Lid
Temperature drop across grease layer, °C
0
2
4
6
8
10
12
14
16
18
-30
-20
-10
0
10
20
30
Distance across heat sink, mm
Current design
Uniform heat flux

FIG – 5


Variation of heat flux after spreading till grease layer (0.08mm thick)
at Chip base heat flux= 100W/cm^2 with Cu IHS/Lid
Heat flux at grease layer, W/cm²
0
10
20
30
40
50
60
70
-30
-20
-10
0
10
20
30
Distance across heat sink, mm
Current design
Uniform heat flux

THERMOSIPHON WITH THERMOELECTRICALLY ENHANCED SPREADER PLATE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The subject invention relates to a cooling assembly for cooling an electronic device.

[0003] 2. Description of the Prior Art

[0004] The operating speed of computers is constantly being improved to create faster computers. With this, comes increased heat generation and a need to effectively dissipate that heat.

[0005] Heat exchangers and heat sink assemblies have been used that apply natural or forced convection cooling methods to dissipate heat from electronic devices that are highly concentrated heat sources such as microprocessors and computer chips. These heat exchangers typically use air to directly remove heat from the electronic devices; however air has a relatively low heat capacity. Thus, liquid-cooled units called LCUs employing a cold plate in conjunction with high heat capacity fluids have been used to remove heat from these types of heat sources. Although LCUs are satisfactory for moderate heat flux, increasing computing speeds have required more effective heat sink assemblies.

[0006] Accordingly, thermosiphon cooling units (TCUs) have been used for cooling electronic devices having a high heat flux. A typical TCU absorbs heat generated by the electronic device by vaporizing the working fluid housed on the boiler plate of the unit. The boiling of the working fluid constitutes a phase change from liquid-to-vapor state and as such the working fluid of the TCU is considered to be a two-phase fluid. The vapor generated during boiling of the working fluid is then transferred to a condenser, where it is liquefied by the process of film condensation over the condensing surface of the TCU. The heat is rejected into a stream of air flowing through a tube running through the condenser or flowing over fins extending from the condenser. Alternatively, a second refrigerant can flow through the tube increasing the cooling efficiency. The condensed liquid is returned back to the boiler plate by gravity to continue the boiling-condensing cycle.

[0007] An example of a cooling system for electronic devices is disclosed in U.S. Pat. No. 6,474,074 to Ghoshal.

[0008] The Ghoshal patent discloses a cooling assembly having a thermoelectric module disposed on a surface adjacent to a condensing portion of the assembly. The thermoelectric module dissipates heat from the condensing portion and turns vapor into liquid.

[0009] Although the prior art dissipates heat from electronic devices, as computing speeds increase, there is a continuing need for cooling devices having more efficient or alternative heat transfer capabilities as compared to the conventional electronic cooling assemblies.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0010] The invention provides a cooling assembly for cooling an electronic device. The assembly includes a plate having a center portion for engaging and transferring heat from the electronic device and a peripheral portion surrounding the center portion. A heat sink overlies the plate and receives heat from the plate. The assembly further includes a thermoelectric module for pumping heat from the plate to the heat sink. The assembly is distinguished by disposing the thermoelectric module between the peripheral portion of the plate and the heat sink for spreading heat laterally from the center portion of the plate to the peripheral portion of the plate and then through the thermoelectric module to the heat sink.

[0011] Accordingly, by introducing the thermoelectric module to the peripheral portion of the plate, the temperature gradient near the peripheral portion of the plate is increased. An increased temperature gradient near the peripheral portion of the plate results in an increased heat transfer rate through the peripheral portion. The subject invention utilizes the thermoelectric module to introduce resistance heating along the periphery of the heat sink to render heat sink more effective without significantly increasing the thermal load on the heat sink. The subject invention provides for an even or uniform temperature distribution across the entire heat sink, thus enhancing the overall performance and efficiency of the assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0013] FIG. **1** is cross-sectional view of a first embodiment of the subject invention;

[0014] FIG. **2** is a perspective view of a thermoelectric module used in the subject invention;

[0015] FIG. **3** is a cross-sectional view of a second embodiment of the subject invention and a plot showing the power distribution of the electronic device;

[0016] FIG. **4** is a graph showing a computer simulation of the temperature drop across the grease layer interfacing with the heat sink in current practice; and

[0017] FIG. **5** is a graph showing a computer simulation of the heat flux across the grease layer interfacing with the heat sink in current practice.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a cooling assembly **20** is generally shown for cooling an electronic device **22** in FIGS. **1** and **3**.

[0019] In a first embodiment of the subject invention, as shown in FIG. **1**, the assembly **20** includes a plate **24** generally indicated having a generally rectangular peripheral portion **26** surrounding a center portion **28**, i.e., a top hat shaped lid. The plate **24** engages and transfers heat from the electronic device **22**. A cavity **30** is defined in the bottom of the center portion **28** of the plate **24** for receiving the electronic device **22**. The cavity **30** is generally rectangular to conform with the shape of the electronic device **22**, but may be any shape known in the art of electronic devices. A first grease layer **32** is disposed over the top of the plate **24** and establishes a predetermined thermal interface between the plate **24** and all the components that come into contact with the top of the plate **24**.

[0020] A rectangular heat sink **34** generally indicated overlies the plate **24** for receiving heat from the plate **24**. The heat sink **34** includes a base **36** and a second grease layer **38** disposed over the base **36** of the heat sink **34**. The second grease layer **38** establishes a predetermined thermal interface between the base **36** of the heat sink **34** and all the components that come into contact with the base **36** of the heat sink **34**. A plurality of heat transfer fins **40** extend upwardly from the base **36** and absorb heat from the plate **24**. The heat transfer fins **40** are generally triangular in cross-section but may be any cross-sectional shape known in the art, such as, rectangular, conical or cylindrical. The assembly **20** may include an air moving device **42**, such as a fan, disposed adjacent to the heat sink **34** for moving air over the heat sink **34**.

[0021] The assembly **20** is distinguished by having a generally rectangular thermoelectric module **44** generally indicated disposed between the peripheral portion **26** of the plate **24** and the heat sink **34** for transferring, conveying or pumping heat laterally from the center portion **28** of the plate **24** to the peripheral portion **26** of the plate **24** and then through the thermoelectric module **44** to the heat sink **34**.

[0022] In FIG. **2**, the thermoelectric module **44** includes a rectangular working portion **46** that defines a rectangular through hole **48**. The working portion **46** includes a hot side **50** that engages the base **36** of the heat sink **34** and a cold side **52** that engages the peripheral portion **26** of the plate **24**. The thermoelectric module **44** transfers heat absorbed by the cold side **52** to the hot side **50**. The thermoelectric module **44** establishes a thermal deferential between the cold side **52** and the hot side **50** to electrically pump heat from the cold side **52** to the hot side **50** by the use of electrical energy.

[0023] One of the plate **24** and the heat sink **34** includes an extension **54** that extends into the through hole **48** and into engagement with the other of the plate **24** and the heat sink **34**. In FIG. **1**, the extension **54** extends from the top of the center portion **28** of the plate **24** into the through hole **48** and into engagement with the base **36** of the heat sink **34**. In FIG. **3**, the extension **54** extends from the base **36** of the heat sink **34** into the through hole **48** and into engagement with the plate **24**. The cavity **30** has a first width (w_1) and the extension **54** has a second width (w_2). The first width (w_1) of the cavity **30** is greater than the second width (w_2) of the extension **54**.

[0024] In a second embodiment of the subject invention, as shown in FIG. **3**, the heat sink **34** generally indicated comprises a thermosiphon cooling system. The thermosiphon cooling system includes a housing **56** generally indicated which is generally cubical and hermetically sealed. The housing **56** includes a generally rectangular lower portion **58** which defines the base **36** and an upper portion **60**. A refrigerant **62** is disposed in the lower portion **58** of the housing **56** for liquid-to-vapor transformation. The heat transfer fins **40** are disposed in the lower portion **58** of the housing **56** for transferring heat from the electronic device **22** to the refrigerant **62** for liquid-to-vapor transformation.

[0025] The upper portion **60** includes a plurality of spaced cooling chambers **64** that extend through the housing **56** and a plurality of cooling fins **66** disposed within cooling chambers **64**. The cooling chambers **64** are separated in the upper portion **60** of the housing **56** by generally rectangular condenser fingers **68** that extend upwardly in the upper portion **60** from an open space above the refrigerant **62** for receiving the vapor from the refrigerant **62**.

[0026] The heat in the assembly **20** is rejected into a stream of air flowing through the cooling chambers **64** and over the cooling fins **66**. The assembly **20** may include a fan that is disposed adjacent to the housing **56** for moving air through the cooling chambers **64** and over the cooling fins **66**. Alternatively, the assembly **20** may include a second refrigerant **62** that flows through the cooling chambers **64** to dissipate heat from the assembly **20**. The assembly **20** may also be liquid cooled.

[0027] FIG. **3** further shows a plot detailing the power distribution of the electronic device **22**. The heat flux distribution on the surface of the electronic device **22** is highly non uniform with a high heat flux in the center of the electronic device **22** and a progressively lower heat flux toward the periphery of the electronic device **22**. By introducing the thermoelectric module **44** to the peripheral portion **26** of the plate **24** heat is pulled away from the center of the electronic device **22** towards the peripheral portion **26** of the plate **24**. The heat that is pulled to the peripheral portion **26** of the plate **24** is then absorbed by the cold side **52** of the thermoelectric module **44** and transferred to the heat sink **34** through the hot side **50** of the thermoelectric module **44**. The introduction of the thermoelectric module **44** thus creates a more uniform heat distribution across the base **36** of the heat sink **34**.

[0028] The electronic device **22** may be a computer chip **22**. The plate **24** is called a lid or integrated heat sink (IHS) in the chip **22** industry. The plate **24** is typically 1.5-2 mm thick and made out of a copper based alloy. The plate **24** is permanently bonded to the silicon substrate of the electronic device **22** by means of an epoxy layer **70** of low thermal conductivity. In a typical symmetrically designed computer chip **22** most of the heat is dissipated in the central core of the computer chip **22**. This leads to heat transfer at a high heat flux (watts/cm^2) through the central core of the electronic device **22**. Heat transfer at a high heat flux through the central core of the electronic device **22** results in a large temperature drop across the epoxy layer **70**.

[0029] The second grease layer **38** is used to flexibly attach the external heat sink **34**, such as, an air-cooled heat sink, LCU, or thermosiphon, to the plate **24**. In the stack up of thermal resistances originating from the silicon substrate of the electronic device **22**, the resistance of the second grease layer **38** is the highest. This is primarily due to the low thermal conductivity of the second grease layer **38**. Typically, the thermal conductivity of the second grease layer **38** is of the order of 3-6 W/m° C. In comparison the thermal conductivity of pure copper is 380 W/m° C. The transfer of heat at high heat flux through the second grease layer **38** due to minimal lateral heat spreading results in a large temperature drop at the center and a lower temperature drop in the periphery. The ultimate consequence of concentrated heat transfer though the core of the electronic device **22** is the electronic device **22** having a higher surface temperature at the center. The higher the maximum surface temperature of the electronic device **22** the lower the computing speed and reliability of the electronic device **22**.

[0030] The above fact is shown in FIGS. **4** and **5** and further illustrated through the following example. Heat transfer by conduction as it occurs in an electronic device **22** is governed by Fourier's law of heat conduction; Heat Flux q"=k*dT/dx, thermal conductivity times temperature gradient.

[0031] Typically, for a square electronic device **22** of size 35 mm×35 mm, 80% of the total heat is dissipated through the central core having a size of 10 mm×10 mm. Of the total 125 Watts dissipated by the electronic device **22**, 100 Watts is dissipated in the central 1 cm^2 area leading to a heat flux of 100 W/cm^2. The remaining 25 Watts is dissipated in the peripheral region of area 11.25 cm^2, resulting in a heat flux of 2.22 W/cm^2. Thus the heat flux is non uniformly distributed over the silicon substrate of the electronic device **22**.

Heat flowing at 100 W/cm^2 through the second grease layer **38** of thickness 0.08 mm and conductivity 4 W/m° C., results in a temperature drop of 20° C. just across the second grease layer **38**, while heat flowing at the peripheral regions at a heat flux of 2.22 W/cm^2 results in a temperature drop of less than 0.5° C. A temperature drop of 20° C. at the central region of the electronic device **22** results in an undesirable significant increase in the maximum temperature of the electronic device **22** at the core.

[0032] The thermoelectrically enhanced spreader plate **24**, addresses the primary problem of insufficient lateral heat spreading by pumping heat through the peripheral regions. By forcing heat to flow to the peripheral regions through the thermoelectric module **44**, the heat flux through the central region is significantly reduced, even though the heat flux distribution at the origin of the electronic device **22** is concentrated at the center. The lateral heat spreading forced by the thermoelectric module **44** thus results in a lower temperature drop across the epoxy layer **70**, and much lower temperature drop across the second grease layer **38**, leading to a lower maximum surface temperature at the center of the electronic device **22**.

[0033] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A cooling assembly for cooling an electronic device comprising;

a plate having a center portion for engaging and transferring heat from the electronic device and a peripheral portion surrounding said center portion,

a heat sink overlying said plate for receiving heat from said plate, and

a thermoelectric module for transferring heat from said plate,

said thermoelectric module being disposed between said peripheral portion of said plate and said heat sink for pumping heat laterally from said center portion of said plate to said peripheral portion of said plate and then to said heat sink.

2. An assembly as set forth in claim **1** wherein said thermoelectric module includes a working portion defining a through hole overlying said center portion of said plate, said working portion having a hot side engaging said heat sink and a cold side engaging said peripheral portion of said plate for transferring heat absorbed by said cold side to said hot side.

3. An assembly as set forth in claim **2** wherein one of said plate and said heat sink includes an extension extending into said through hole and into engagement with the other of said plate and said heat sink.

4. An assembly as set forth in claim **3** wherein said plate defines a cavity disposed in the bottom of said center portion of said plate for receiving the electronic device.

5. An assembly as set forth in claim **4** wherein said cavity has a first width and said extension has a second width, said first width being greater than said second width.

6. An assembly as set forth in claim **3** wherein said heat sink includes a base and a plurality of heat transfer fins extending upwardly from said base for absorbing heat from said plate.

7. An assembly as set forth in claim **6** wherein said heat sink comprises a thermosiphon cooling system having a housing with a lower portion defining said base and an upper portion having a plurality of spaced cooling chambers extending through said housing.

8. An assembly as set forth in claim **7** including a refrigerant disposed in said lower portion of said housing for liquid-to-vapor transformation and wherein said heat transfer fins are disposed within said lower portion of said housing for transferring heat from the electronic device to said refrigerant for liquid-to-vapor transformation.

9. An assembly as set forth in claim **8** including a plurality of cooling fins disposed within said cooling chambers.

10. An assembly as set forth in claim **9** wherein said heat sink is generally rectangular, said plate is generally rectangular, and said thermoelectric module is generally rectangular.

11. An assembly as set forth in claim **10** including a first grease layer disposed over the top of said plate for establishing a predetermined thermal interface between said plate and said cold side of said thermoelectric module and said extension.

12. An assembly as set forth in claim **11** including a second grease layer disposed over said base of said heat sink for establishing a predetermined thermal interface between said base of said heat sink and said hot side of said thermoelectric module and said extension.

13. An assembly as set forth in claim **6** including an air moving device disposed adjacent to said heat sink for moving air over said heat sink.

14. A cooling assembly for cooling an electronic device comprising;

a plate having a generally rectangular peripheral portion surrounding a center portion for engaging and transferring heat from the electronic device,

a cavity being generally rectangular and disposed in the bottom of said center portion of said plate for receiving the electronic device,

a first grease layer disposed over the top of said plate,

a heat sink being generally rectangular and including a base overlying said plate for receiving heat from said plate,

a second grease layer disposed over said base of said heat sink,

a plurality of heat transfer fins being generally triangular in cross-section and extending upwardly from said base for absorbing heat from said plate, and

a thermoelectric module having a generally rectangular working portion defining a rectangular through hole for transferring heat from said plate,

said thermoelectric module being disposed between said peripheral portion of said plate and said heat sink for pumping heat laterally from said center portion of said plate to said peripheral portion of said plate and then to said heat sink,

said working portion including a hot side engaging said base of said heat sink and a cold side engaging said peripheral portion of said plate for transferring heat absorbed by said cold side to said hot side,

one of said plate and said heat sink including an extension extending into said through hole and into engagement with the other of said plate and said heat sink,

said cavity having a first width and said extension having a second width and said first width being greater than said second width.

15. An assembly as set forth in claim **14** including an air moving device disposed adjacent to said heat sink for moving air over said heat sink.

16. An assembly as set forth in claim **14** wherein said heat sink comprises a thermosiphon cooling system having a housing with a lower portion defining said base and an upper portion having a plurality of spaced cooling chambers extending through said housing and including;

a refrigerant disposed in said lower portion of said housing for liquid-to-vapor transformation,

said heat transfer fins disposed in said lower portion of said housing for transferring heat from the electronic device to said refrigerant for liquid-to-vapor transformation, and

a plurality of cooling fins disposed within said cooling chambers.

* * * * *