

The Sandia Cooler

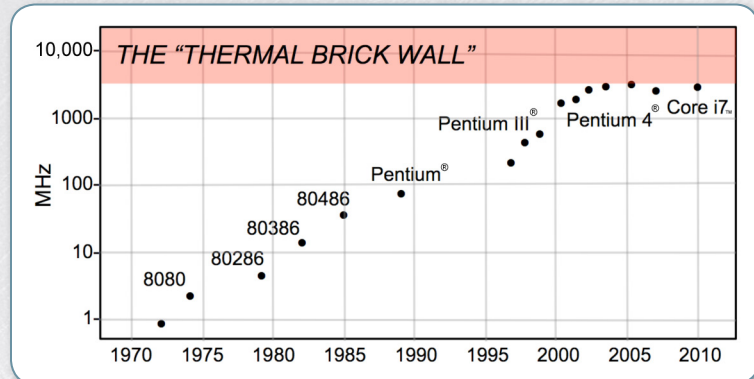
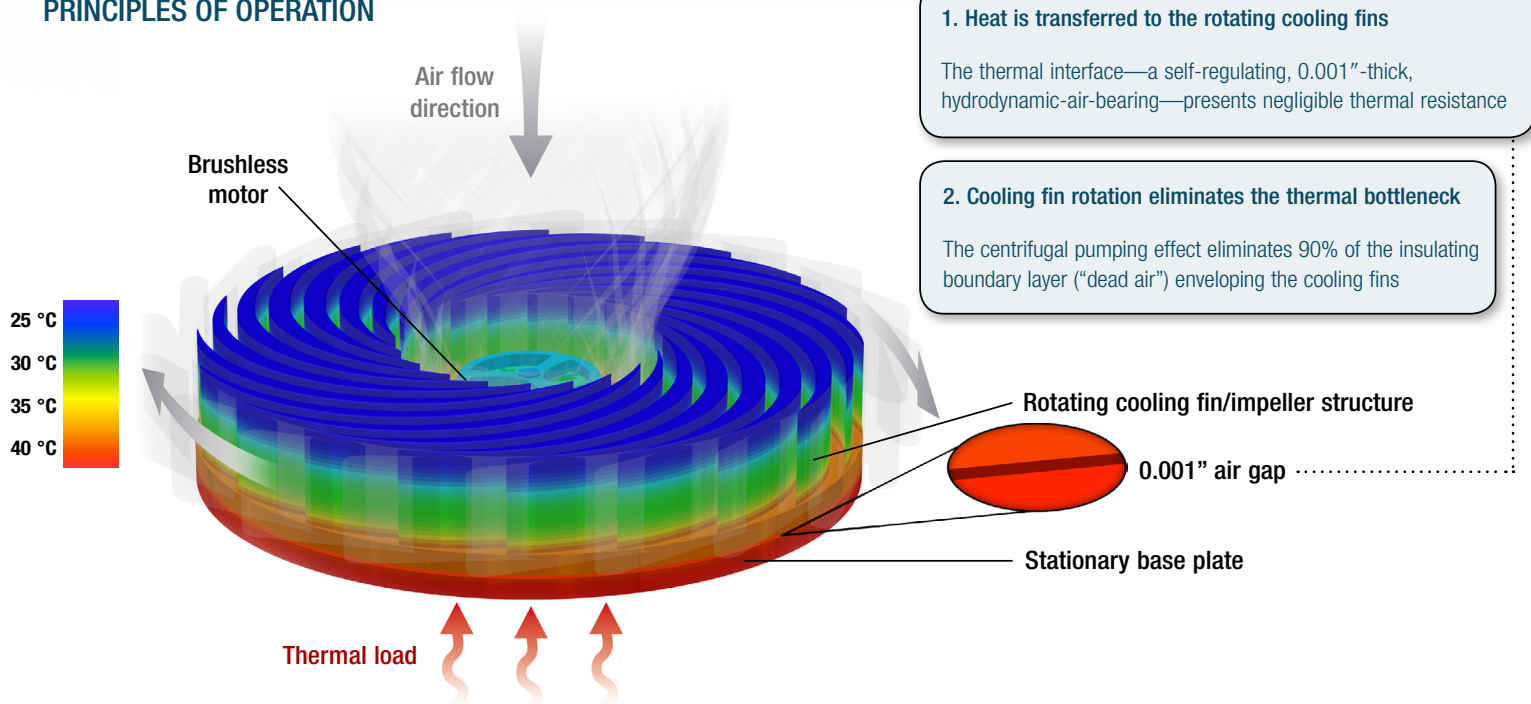
A fundamental breakthrough in heat transfer technology for microelectronics

EXECUTIVE SUMMARY

In a conventional CPU cooler, the heat transfer bottleneck is the boundary layer of “dead air” that clings to the cooling fins. This insulating layer is largely unaffected by the impinging airflow generated by the fan. The radically different approach described below overcomes this thermal bottleneck, generating a several-fold improvement in cooling performance in a device that is smaller, quieter, and immune to clogging by dust.

In this new device architecture, heat is efficiently transferred from a stationary base plate to a rotating (ccw) structure that combines the functionality of cooling fins with a centrifugal impeller. Dead air enveloping the cooling fins is subjected to a powerful centrifugal pumping effect, providing a 10x reduction in boundary layer thickness at a speed of a few thousand rpm. Additionally, high-speed rotation completely eliminates the problem of heat exchanger fouling. The “direct drive advantage,” in which relative motion between the cooling fins and ambient air is created by rotating the heat exchanger, provides a drastic improvement in aerodynamic efficiency. This translates to extremely quiet operation. The above benefits have been quantified on a proof-of-concept prototype.

PRINCIPLES OF OPERATION



Timeline of CPU clock speeds

BENEFITS

- Dramatic increase in cooling performance without resorting to exotic methods
- 10x smaller than current state-of-the-art CPU coolers
- Exceptionally quiet operation
- Immune to dust fouling
- Simple, rugged, and cost-competitive design

FREQUENTLY ASKED QUESTIONS

Principles of Operation

Q: Is the thermal resistance of the air gap region large enough to be a problem?

A: No. For example, in our current prototype device the thermal resistance of the air gap region is 0.02 C/W.

Q: How does a hydrodynamic air bearing work?

A: A video of a very rudimentary hydrodynamic air bearing is available at <http://www.youtube.com/watch?v=ed3uWxV2tXg>

Q: Does the stationary base plate simply consist of a solid piece of thermally conductive material?

A: As in a conventional forced convection heat sink, the base plate acts as a heat spreader, and may comprise solid piece of thermally conductive material or be implemented in the form of a heat pipe.

Q: Is the radial-air-flow architecture depicted here the only possible device geometry?

A: No—a wide variety of device geometries are possible, including axial-flow configurations, and devices in which more than one rotating cooling fin/impeller operate in parallel to further lower thermal resistance.

Real-World Practicality

Q: Can the device be mounted in any orientation?

A: Yes—the air bearing assembly is held together by magnetic attraction (between the stator and permanent-magnet rotor).

Q: Is an air bearing suspension mechanically stiff and rugged?

A: Yes—because the rate of change of the pressure lifting force with respect to gap distance is extremely large.

Q: What other types of equipment use air bearings?

A: Devices range from hard disk read-write heads to large CNC milling machine spindles.

Q: What if small (less than 0.001") particulates are somehow introduced into the air gap region?

A: They are swept outward and ejected by centrifugal force.

Q: How do you prevent contact between the air bearing surfaces at low rpm?

A: Depending on the application, one of several simple, passive mechanisms may be implemented.

Manufacturability

Q: Does the 0.001" air gap require tight manufacturing tolerances?

A: No—the hydrodynamic air bearing gap distance is passively self-regulating.

Q: Is the surface quality/flatness spec of a conventional heat sink mating surface adequate?

A: Yes. For example, conventional fabrication processes such as cold forging can be used.

Performance

Q: Based on laboratory testing of early prototype devices, what kind of performance is expected for a CPU cooler based on Sandia's air bearing heat exchanger principle?

A: We expect to achieve 0.05 C/W in package that is considerably smaller and quieter than conventional high-performance CPU coolers. Because low-thermal-resistance CPU coolers are particularly susceptible to performance degradation due to cooling-fin fouling (a thin layer of dust can easily increase thermal resistance by a factor of 2), the added benefit of immunity to fouling is also a crucial performance specification. Further reductions in thermal resistance would likely involve engineering trade-offs against device size and dBa rating.

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