Promoting Superconductive Temperatures via A Vacuum Cooling System In Electronics

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Abstract

Superconductors are materials which conduct electricity with zero resistance. These materials can be utilized in computers in order to create more efficient circuitry. However, in order for superconductors to work, they must reach extremely low temperatures, nearing absolute zero. This becomes a problem, as the means of cooling materials to the proper temperature can be expensive and complicated. Instead of developing a more efficient cooling system, this project deals with creating a more efficient cooling environment. Instead of cooling a computer in the normal atmosphere, it was cooled inside a vacuum. The vacuum was hypothesized to be a better environment due to the fact that there would be less particles in the system, meaning there would be less residual heat from gaseous particles vibrating. To test this hypothesis, a computer was cooled using a liquid cooling system, and the processor temperature was measured in the hardware management screen of the Basic Input/Output System. This temperature was taken at five minute intervals for fifteen minutes while the computer was in normal state, wrapped in the sealing material, and inside a vacuum. The data showed that in the control, or normal setting, the temperature increased twice as much as it did in a vacuum setting. Thus, it can be concluded that cooling in a vacuum is more efficient than cooling in standard atmospheric conditions.

Introduction

Superconductors

Superconductors are materials experiencing a superconducting state; that is, they allow electric currents to flow through them with negligible resistance. Such materials have been the topic of a great deal of interest within the scientific community over the past few decades. With no resistance in an electric circuit, they may unlock the key to a great deal of innovations in public power, transportation, and even another area of science that has recently blossomed: computing.

These materials, when cooled to the proper temperature; which may lie anywhere between zero and two hundred fifty six degrees Kelvin (Eck), allow for the passing of electrons in pairs called "Cooper pairs" (Dull, & Kerchner, 1994). Essentially, the Cooper Pairs are formed as one electron moves through the electron cloud in a lattice material (Figure 1). The negative charge of the particle attracts the nuclei of the surrounding lattice, causing them to bend slightly inward. This bending causes a momentary positive charge in that area, which attracts one more electron towards it. The new electron then begins to travel in the wake of the first one quite quickly. It is similar to the effect of a car driving on the freeway, creating a vacuum behind itself as it displaces air, and allowing the following cars to move more quickly.

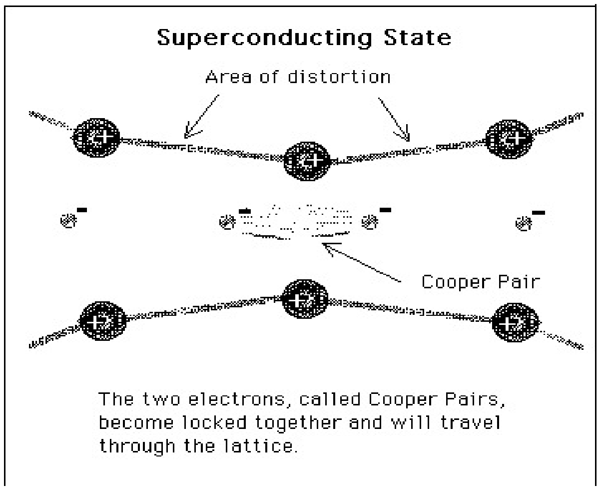


Figure 1

A diagram depicting cooper pairs moving through the material's lattice

http://www.cartage.org.lb/en/themes/sciences/Physics/SolidStatePhysics/Superconductivity/Fundamentals/fig5.gif

This cooper pair relationship exists in all conductors. However, a basic law of physics is that the warmer a material is, the more it will vibrate (Dull & Kerchner, 1994). Thus, when materials are at room temperature, the vibration of the molecules is much higher than when they are cooled to the superconductive temperatures. Those vibrations at higher temperatures cause the cooper pairs to be broken up, before they ever have a chance. Those vibrations do not only break up the cooper pairs, but will often knock the electrons out of place, causing them to fly off in the form of heat energy. This loss is known as resistance in a circuit, and can be attributed to data loss in the field of computing. Figure 2 shows the resistance in a superconductor ($YBa_2Cu_3O_7$) vs. the temperature of the material. Once the material has been cooled down, there is significantly less vibration, and the cooper pairs are free to move about without fear of being split up and lost in the vibration, hence there being no resistance.

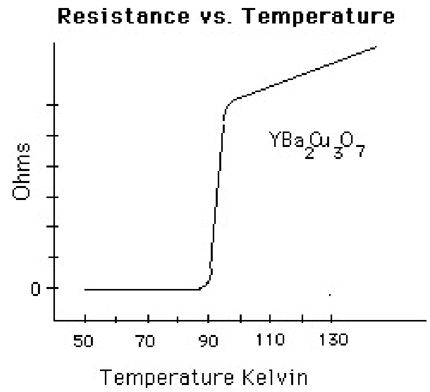


Figure 2

A graph of the resistance present in a superconductor at certain temperatures.

http://www.ornl.gov/info/reports/m/ornlm3063r1/fig6.gif

Application in Computers

Superconductors can be utilized in computer circuits due to the utilization of one of their many properties called the Josephson effect, in which two superconductors, only connected by some insulating material, will move the cooper pairs through that material, effectively creating an electric switch called a Josephson junction (Savage), as seen in Figure 3.

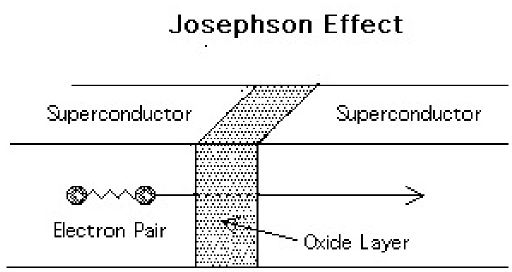


Figure 3

A Josephson Junction

http://reimer-hamburg.net/htc/fig13.gif

Benefits

When computers and computer processors are built with superconductors, they experience an enormous increase in the speed of computations and data flow. In theory, these processors could run up to 120Ghz; which is one hundred twenty billion computations per second (Superconductor report, 2007).

Not only do these particular processors reach incredible speeds, but they also use considerably less power, due to the fact that there is no resistance in the circuit, and thus no loss of electricity. Without that added heat of electron loss, there are also no risks of the processor being damaged by heat (as can be seen in many modern computers). If a primarily superconducting computer were to be put on the market, it would completely revolutionize home computers for the rest of history, providing society with the answer to all lag, speed issues, and connection problems.

Not only would home computing be revolutionized, but the field of computing in general could be completely changed through the use of Superconducting Quantum Interface Devices, or SQUIDs. These devices use superconductors to detect even the most minute magnetic variations. Such devices can be utilized in quantum computers as qubits, which are essentially quantum sized bits (like that of a regular computer, just smaller). The SQUIDS would simply use the direction of current flow as byte information (Altman). There is no doubt that superconductors may be the greatest innovation in computers since silicon microchips.

Drawbacks

While superconductors in computers may have some truly groundbreaking implications and benefits, there are still some drawbacks, as with any new technology. The most prevalent and obvious one is that of cooling the materials to make them superconduct.

As mentioned early, superconductors range in operating temperatures from zero Kelvin to approximately two hundred fifty six Kelvin. For the uninformed, zero kelvin is considered to be absolute zero, and two hundred seventy three kelvin is translated into zero degrees Celsius, or thirty two degrees fahrenheit. It is easy to imagine then the incredible lengths it might take to cool even the least cold-intensive superconductors. Superconductors can be organized into two categories according to their relative operating temperatures.

Type I

Type I superconductors are those that are slightly conductive at room temperature, and require the lowest operating temperature. These are typically “soft” metals, and are the most common, and first discovered superconducting materials. These metals (such as Lead, Mercury, Tin, and Cadmium) all need to be cooled to a temperature between 0.000325 Kelvin to 7.196 Kelvin (Eck). Such materials are not practical for consumer purposes, or even most government or research purposes (besides very specialized work focusing primarily on superconductivity, and not application as much). It is unlikely that any of these materials might be used in superconducting computers. Luckily for the field of computer engineering, there is a second group of superconductive materials.

Type II

The type II superconductors are all more recent discoveries. Most of them are metals or metal alloys and have significantly higher operating temperatures which can get to the temperature of two hundred and fifty four degrees Kelvin (Eck). These compounds are more frequently used in application in the real-world, because cooling methods can be scaled down slightly. A very common coolant used on type II superconductors is liquid nitrogen, because its temperature is 77 Kelvin, and can effect a very wide variety of materials.

Cooling System Drawbacks

One of the major hurdles in superconductive computers is the fact that the equipment used to cool these materials are large, expensive, and energy intensive. After a prolonged amount of time, the amount of money and energy spent on the cooling system of a superconductive computer would outweigh the money and energy saved by using superconductors in said computer, making the entire thing useless in conventional practice A standard cooling system for these superconductors can be seen in Figure 4. Thus, there is a call for solutions in either: more efficient cooling processes, or more efficient superconductors. It will be the focus of this project to improve the overall cooling process of a computer, in hopes of applying that to the superconducting computer problems.

Figure 4

Superconductor computer cooling system (in background)

http://www.iqcd.ucsb.edu/gwinngroup/Francisco%20Computer.jpg

Potential Solution

In an effort to find a more suitable environment for computer cooling in hopes of application in the superconducting field of computer engineering, this project will be trying out a rather undocumented and novel approach in cooling systems: cooling in a vacuum. If heat energy is defined as the vibration of particles, it follows logic that in a vacuum, where there is a significantly reduced amount of particles, there will be less heat in the system as a whole. That would mean that the entire system will stay cooler easier.

Materials

Supplies	Equipment
Movers Wrap Scotch Tape Tap Water	Custom-Built mBTX computer Thermaltake CL-W0075 BigWater 735 12cm Liquid Cooling System Vacuum Pump

Procedure

In order to test the effect of cooling in a vacuum, three tests were run: one in normal atmospheric conditions as a control, one with the computer in its vacuum wrap, without the vacuum turned on, to see how the wrap affects cooling, and a third with the computer in an actual vacuum.

The testing was done on a computer with an Intel MicroBTX form factor motherboard, with an LGA775 processor socket, running a Pentium D processor at 2.80 gigahertz. Installed on the computer was a ThermalTake BigWater liquid cooling system.

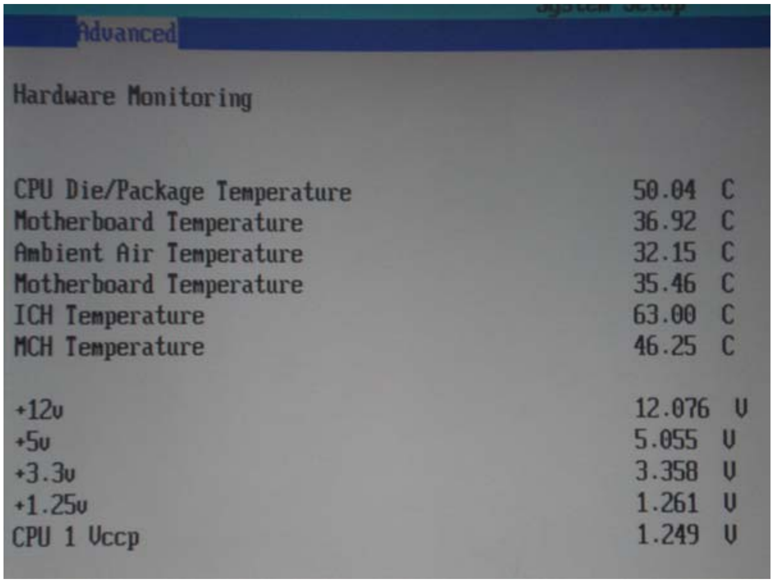
Before initial testing, the computer was given fifteen minutes of rest, to get the initial temperature of the processor as controlled as possible. Once the computer was turned on, the basic input/output system, or BIOS screen was immediately brought up, which had a page for hardware monitoring. The core temperature was taken from this BIOS screen at start up, and then once every five minutes for fifteen minutes, a time chosen in case cooling did not work effectively, so that the computer would be spared any heat damage over a prolonged amount of time.

Once the control test was run, the computer was completely wrapped in movers wrap, a very strong and impermeable plastic wrap. Holes were cut for the wires leading to the monitor, keyboard, mouse, and radiator. These holes were further sealed with duct-tape, to make the case air-tight. Once it was air-tight, it was given another fifteen minutes of rest time, to keep the processor at a controlled temperature, or as close as possible. The same testing as described above was done with the computer wrapped.

After the second test, a third was conducted, this time with the vacuum pump engaged, and a vacuum being created in the computer case. Again, an initial temperature was taken, along with being taken once every five minutes for fifteen minutes. Figure 5 shows the temperature monitoring page from the BIOS settings.

Figure 5

Hardware Monitoring BIOS Screen, Taken by Researcher



The results of the entire project are represented fully in Table 1.

Results

Trial Type	Initial Temp. (Degrees Celsius)	Temp of 5 Minutes (Degrees Celsius)	Temp of 10 Minutes (Degrees Celsius)	Temp of 15 Minutes (Degrees Celsius)	Net Change (Degrees Celsius)
Control	50.04	54.96	57.23	58.80	+8.76
Wrapped, No Vacuum	48.62	53.46	55.97	58.92	+10.30
Vacuum	54.76	57.43	58.79	59.64	+4.88

Conclusion

In studying the effects of a vacuum environment upon the cooling efficiency of a computer system, it seems that in this context, the computer only shows a 4.88 degree increase in temperature over the course of fifteen minutes, in contrast to running the same computer in normal atmospheric conditions, which saw an increase of 8.76 degrees Celsius. This specific example shows that a vacuum environment can increase cooling efficiency of approximately 50%.

This conclusion was reached through a controlled experiment in which computers were cooled in both the vacuum environment and normal atmospheric conditions, and the cooling was observed in both cases.

Such an increase in cooling efficiency can be beneficial to society as our computing technology advances and we build processors and hardware that run even hotter than ever before. They will require intensive cooling processes that can be enhanced in a vacuum environment.

Building off that principle, the industry could begin developing superconductive hardware for even more speed and efficiency for use in smaller systems, because the vacuum environment would reduce the need for bulky, unseemly cooling mechanisms, such as the ones that exist today.

Limitations

The project is limited in several ways. The hardest limit to account for is the fact that Processors have a built-in “health management” portion of their hardware. This health management will sense the core temperature, and will adjust the speed settings accordingly (slowing down slightly to reduce the temperature). This management portion is full of complex and proprietary algorithms and logic switches. Thus, it was not accounted for in the data or the experimentation, and could have seriously skewed the results by altering core temperatures automatically.

Another drawback in the hardware was the lack of appropriate sensors for the operating system, Ubuntu. The goal was to test the computer running under load (i.e. running programs and applications). However, the monitoring software that needed to be used was not compatible with the type of sensors in the motherboard, and thus the project’s scope was limited to testing only the basic input/output system’s heat generation.

Finally, a more mundane limitation was the lack of a consistent starting temperature, which was difficult to achieve in a room without climate-control. The starting temperature varied, and as such, the afore-mentioned health-management may have started working earlier during different trials.

Future Studies

To more accurately gauge the effect that vacuums have on cooling, it would be worthwhile to test a plain piece of conductive material inside a vacuum, and also cool it in normal atmospheric conditions. This could act as a more controlled trial, and show the difference in cooling on a simpler scale.

Moving forward from that would be the design of a different processor with compatible sensors in order to observe the cooling effects of a vacuum in an actual computer, without having to take into account the tampering from the health management and the limitations from a lack of proper sensors.

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