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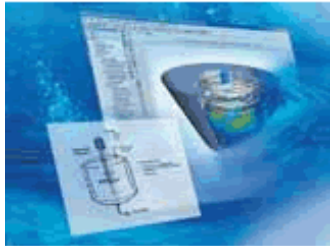
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News

Aug 29, 2008

Heat has long been regarded as useless or even harmful in electronic circuits. But some researchers think that it might be possible to build computers that process phonons – pulses of vibration that carry heat – rather than conventional electrons.

Physicists in Singapore and China have now taken a step towards such thermal computation or “phononics” by devising a model for storing thermal information. Although their scheme has yet to be tested experimentally, the researchers claim that bits of information could be read out without destroying the stored data ([arXiv:0808.3311v1](#)).

In a conventional electronic circuit, the states “0” and “1” are usually defined by standard voltages. In thermal circuits, however, the states are defined by two arbitrary temperatures. In-line with the second law of thermodynamics, a temperature drop leads to a heat current flowing from a hot to a cold area. Generally, the larger the temperature drop the larger the heat current, which is known as positive differential thermal resistance.

These currents are carried by phonons, which are difficult to control because as they are bundles of energy that have no electrical charge and therefore cannot be manipulated using electromagnetic fields.

Missing memories

Researchers have already managed to build a thermal diode and have even shown that it could be possible to build thermal transistors and logic gates – all standard components for functional thermal devices. But memory is required to store the output after performing logical operations.

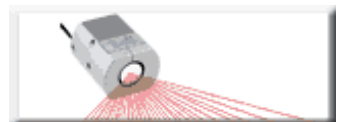
Now, [Baowen Li](#) from the National University of Singapore and Lei Wang from Renmin University of China in Beijing have devised a theoretical model for such thermal memory. Their model takes into account a key element in thermal logic gates – yet to be demonstrated experimentally – by generating a “negative differential thermal resistance” (NDTR). An NDTR means that a large temperature drop leads to a small heat

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current and a small temperature drop leads to a large heat current.

In their model of thermal memory, Li and Wang considered two heat baths, held at a constant temperature, each sitting at the end of a rod. The other, free ends of the rod do not touch each other, but are nevertheless weakly coupled so that there is an NDTR between them. The final component of their model is a "particle" that sits at the end of one the rods, near the gap between the pair.

Reading and writing

Li and Wang then consider what happens when an object – connected to its own heat bath – cools this particle down to an arbitrary temperature, dubbed "0". This is what they call the "writing" process.

To "read" out the temperature of the particle they use another object – dubbed the "reader" – which is set at a temperature halfway between "0" and another temperature, defined as "1". The particle then warms up when this reader is brought into contact with it, which causes a large heat current to flow from the particle, down the rod to the heat bath.

However, there is only a small heat flow in the other rod as it is connected via NDTR. In other words, the current in the second rod minus the current in the first rod is negative. This draws heat away from the particle, which cools back down to "0". As the reader is in contact with the particle, the reader also moves into the "0" state. In other words, it has read out the original "0" state of the particle.

In a similar manner, Li and Weng also showed that if the particle is prepared in the "1" state which is hotter than the reader, then it can also be read out without the state being destroyed.

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Data cannot be stored for a long time before the heat leaks away. Li calculates that thermal memory will have to be refreshed every 100 μ s if the rods were made of carbon nanotubes. This is much more frequent than electronic DRAM currently used in computers today that require refreshing every 64 ms.

Not so instant recall

Another difficulty with thermal memory is the slow access times. “The big difference is between the speed of electromagnetic waves and phonons,” Li told physicsworld.com. Phonons travel at speeds around 1000

ms^{-1} , hundreds of thousands of times slower than electromagnetic waves. “The speed of thermal memory is a key issue that needs further investigation,” he says. Once and if, NTDR is experimentally realized, Li and colleagues are confident that thermal memory will be the next step towards thermal computers.






The speed of thermal memory is a key issue that needs further investigation

About the author

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1

The heat is on!

I like memory that does not require "refreshing". With MRAM you can turn your computer off and start it up very quickly. Not so in the process described above. In fact, phonon based data seems to be FAR more volatile than even current systems, not to mention the design issues.

Readers: What applications benefit from this approach?

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