Who Needs Transistors? HP Scientists Create New Computing Breakthrough at Molecular Scale

February 1 2005

Research could send transistors the way of the vacuum tube

HP today announced its researchers have proven that a technology they invented could replace the transistor - the fundamental building block of computers for the last half century - leading to a new way to construct computers in the future.
In a paper published in today's Journal of Applied Physics, three members of HP Labs' Quantum Science Research (QSR) group propose and demonstrate a "crossbar latch," which provides the signal restoration and inversion required for general computing without the need for transistors. The technology could result in computers that are thousands of times more powerful than those that exist today.

"We are re-inventing the computer at the molecular scale," said Stan Williams, HP Senior Fellow and QSR director, and one of the authors of the paper. "The crossbar latch provides a key element needed for building a computer using nanometer-sized devices that are relatively inexpensive and easy to build."

QSR works on nanoscale electronic devices that will first supplement, and someday perhaps replace, silicon technology, which is expected to reach its physical limits in about a decade. In addition to exploring the fundamental scientific principles of computing at the molecular level, QSR is also looking at architectural issues and determining how such

tiny devices - thousands of which could fit across the diameter of a human hair - could be fabricated economically and in mass quantities.

The experimentally demonstrated latch consists of a single wire acting as a signal line, crossed by two control lines with an electrically switchable molecular-scale junction where they intersect. By applying a sequence of voltage impulses to the control lines and using switches oriented in opposite polarities, the latch can perform the NOT operation, which, along with AND and OR, is one of three basic operations that make up the primary logic of a circuit and are essential for general computing. In addition, it can restore a logic level in a circuit to its ideal voltage value, which allows a designer to chain many simple gates together to perform computations.

Standard semiconductor circuits require three-terminal transistors to perform the NOT operation and restore signals. However, it is generally believed that transistors will not be able to shrink down to the size of a few nanometers and remain operable.

"Transistors will continue to be used for years to come with conventional silicon circuits," said Phil Kuekes, senior computer architect, QSR, another one of the paper's authors, "but this could someday replace transistors in computers, just as transistors replaced vacuum tubes and vacuum tubes replaced electromagnetic relays before them."

Kuekes was previously awarded a patent on the crossbar latch (U.S. 6,586,965) in July 2003, and the Journal of Applied Physics report, titled "The crossbar latch: Logic value storage, restoration and inversion in crossbar circuits," demonstrates the application of the technology. Duncan R. Stewart, a QSR scientist and the third author, performed most of the testing that demonstrated that the device actually works. The paper underwent rigorous peer review before being published.

"We have previously demonstrated that we could make a working memory with molecular-scale junctions and logic devices that could perform simple logic operations such as AND and OR," Stewart said. "With the crossbar latch, we now have the final component theoretically needed for performing the multiple processing steps required for useful computing at the nanoscale."

The research on the crossbar latch was partially supported by the Defense Advanced Research Projects Agency (DARPA).