QUANTUM INFORMATION

Inefficient qubits are not fit for the desktop

Quantum computers might one day be able to factor huge numbers or search vast databases, but when it comes to word-processing or accessing the internet, forget it. That is the conclusion of two US physicists, who have calculated the energy efficiency of a quantum computer and compared it with that of a traditional, classical machine. Julio Gea-Banacloche of the University of Arkansas and Laszlo Kish of Texas A&M University say that classical computers are far better at carrying out general-purpose tasks (*Fluctuation and Noise Letters* **3** C3).

Still at the very early stages of development, quantum computers rely on the properties of quantum mechanics to perform large numbers of calculations in parallel. They exploit the ability of a quantum particle to be in two states at the same time, such as the spin of a nucleus pointing simultaneously up and down relative to an applied electric or magnetic field. With the two states representing a one and a zero, N such particles – referred to as qubits – can then be combined or "entangled" so that they represent 2^N values simultaneously. A quantum computer would, in principle, be able to process each of these values at the same time, making it exponentially faster than a classical computer.

However, Gea-Banacloche and Kish argue that this speed would come at a price for many applications. They compared the minimum energy needed to perform an error-free logical operation on both a quantum computer and a classical machine. They calculated that the error – caused by quantum fluctuations – involved in switching a qubit is inversely proportional to the energy used in the switching. But they found that the error in the classical case – arising from thermal noise – decreases exponentially with increasing switching energy. They therefore concluded that to operate below a certain error rate, a classical computer requires less energy than a quantum device.

"It is sometimes suggested, especially in the popular press, that quantum computers might be the natural successors to today's conventional digital computers, as the current trends in miniaturization reach the atomic level," say Gea-Banacloche and Kish. "While it is true that there are a few special tasks that a quantum computer could perform much faster than a classical computer, such as factoring integers, it may not make sense to push conventional computers into the quantum domain for anything other than these very special purpose tasks."

What is the future for quantum computing?

David DiVincenzo of the IBM TJ Watson Research Center in New York believes Gea-Banacloche and Kish are "entering an area of fruitful discussion". But he does not think their work is conclusive. "Quantum computers could conceivably be used for more general-purpose computing if it were possible to recover some fraction of the energy expended when switching a qubit," he says. "For example, if the energy for the quantum computation comes from a laser beam this could perhaps be partially recycled using a photovoltaic cell."

Andrew Steane of Oxford University points out that factoring is not the only significant problem that could be tackled by quantum computers. "The use of quantum computers to work out properties of systems described by quantum mechanics will probably prove to be of wide interest to many parts of science," he says. "In physics this is obvious, and in chemistry it is also fairly clear. But I would argue its usefulness will extend to biochemistry."

A full-scale operating quantum computer is still probably decades away. Up to now, physicists have managed to build devices with up to seven qubits, but a workable device is likely to require at least 10 to 20. However, a step in this direction was made a few weeks ago when David Wineland of the National Institute of Standards and Technology in Boulder, Colorado, and colleagues showed in principle how data could be moved around a quantum computer. Wineland and co-workers entangled two qubits made from beryllium ions in a single trap and then separated them into two distinct traps. They then carried out different operations on the individual ions and found that they were still entangled. "We want to extend this now so that we can entangle these qubits with others in different traps," says Wineland.

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