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Carbon Nanotube Computer: Transforming Scientific Discoveries into Working Systems

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The miniaturization of electronic devices has been the principal driving force behind the semiconductor industry, and has brought about major improvements in computational power and energy efficiency. Although advances with silicon-based electronics continue to be made, alternative technologies are being explored. Digital circuits based on transistors fabricated from carbon nanotubes (CNTs) have the potential to outperform silicon by improving the energy– delay product, a metric of energy efficiency, by more than an order of magnitude. Hence, CNTs are an exciting complement to existing semiconductor technologies. However, carbon nanotubes (CNTs) are subject to substantial inherent imperfections that pose major obstacles to the design of robust and very large-scale CNFET digital systems:

- It is nearly impossible to guarantee perfect alignment and positioning of all CNTs. This limitation introduces stray conducting paths, resulting in incorrect circuit functionality.
- CNTs can be metallic or semiconducting depending on chirality. Metallic CNTs cause shorts resulting in excessive leakage and incorrect circuit functionality.

A combination of design and processing technique overcomes these challenges by creating robust CNFET digital circuits that are immune to these inherent imperfections. This imperfection-immune design paradigm enables the first experimental demonstration of the carbon nanotube computer, and, more generally, arbitrary digital systems that can be built using CNFETs. The CNT computer is capable of performing multitasking: as a demonstration, we perform counting and integer-sorting simultaneously. In addition, we emulate 20 different instructions from the commercial MIPS instruction set to demonstrate the generality of our CNT computer. This is the most complex carbon-based electronic system yet demonstrated. It is a considerable advance because CNTs are prominent among a variety of emerging technologies that are being considered for the next generation of highly energy-efficient electronic systems.