Memcapacitor-Enabled On-Chip Cryogenic Tuning for Scalable Semiconductor Qubit Architectures

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INVESTIGATOR

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DETAILS

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Cryogenic Electronics
Neuromorphic Computing
Nanofabrication

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Quantum dots, semiconductor qubits, memcapacitor, germanium spin qubits, machine learning, cryogenic control, HfZrO2

Abstract

Quantum computers have the potential to solve problems that are impossible for today's machines, with applications in areas such as new materials, secure communications, and advanced artificial intelligence. A key challenge is that quantum devices, especially those based on structures called quantum dots**,** are very difficult to control. At present, researchers must manually adjust many electrical signals at extremely low temperatures, which makes scaling up to large quantum processors slow, complex, and costly.

This research program will develop a new way to control quantum dots using memcapacitors—a type of electronic component that can "remember" its past state and adjust its electrical properties without consuming power. By integrating these devices directly with quantum dots, we aim to create circuits that can automatically tune and stabilize qubits inside the cryostat (the ultra cold environment where quantum computers operate). This approach will reduce wiring, energy use, and human intervention, paving the way for larger and more reliable quantum processors.

This research combines nanofabrication, cryogenic testing, and machine learning to demonstrate that memcapacitors can enable adaptive, low-power control of quantum devices. In the short term, the project will establish fabrication protocols, validate cryogenic performance, and demonstrate automatic quantum dot tuning using integrated neuromorphic circuits. These outcomes will inform new design rules for cryogenic electronics. In the long term, the work aims to define a scalable, CMOS-compatible control framework, providing a clear path toward industry-ready quantum hardware.

This work is important for Canada's leadership in quantum technologies. It will strengthen collaborations with

Canadian research consortia and industry, while training the next generation of highly qualified personnel in advanced microelectronics, quantum device engineering, and artificial intelligence. The anticipated benefits include new intellectual property, contributions to Canada's growing quantum ecosystem, and progress toward practical quantum computers that can support innovation across science, technology, and industry.