A Guide to Quantum Computing & What Sets SEEQC Apart

What is quantum computing?

Quantum computers have the potential to complete specific algorithms at higher speeds and greater accuracy beyond the power of our most advanced supercomputers. To best understand quantum computing and its massive potential, we must first understand the purpose of computing itself.

Classical computing exists to process and manipulate data. These computers manipulate *bits* to store data in the binary language, a series of 1's and 0's. Because bits are binary, they can only exist in one state at a time — each bit can only be 1 or 0, never both.

Similarly, quantum computers use *quantum bits* or *qubits* to store and manipulate information. Not so similarly, qubits can exist in many states simultaneously, meaning they can exist as a 1 *and* a 0. This trait of qubits is fundamental to quantum mechanics and computing.

Making Qubits

Qubits take time and effort to make. Unlike bits, they're not easily and readily accessible. This plays a huge role in the production and implementation of quantum computers. There are two primary ways to make qubits.

One way is by cooling superconducting circuits to extremely low temperatures. Through deep cooling, qubits can be isolated in a controlled quantum state.

The second way is to create an extreme vacuum chamber. By trapping individual atoms in electromagnetic fields on silicon chips, qubits are isolated in a controlled quantum state.

Controlling Qubits in a Quantum State

In order to control the input and output of a quantum computer, we must control the state of qubits by putting them in a usable state. To best control the state of a qubit, quantum computing uses three primary mechanical traits.

- **Superposition** occurs when a qubit is in a combination of states. In classical computing terms, this would be if a bit were both 1 and 0 simultaneously.

- **Entanglement** occurs when a pair of qubits exist in the same quantum state, working together as a system.

- **Interference** occurs when qubits interact or respond to their surroundings, causing their behavior to slow and then stop. Interference allows us to manipulate the qubit to different states.

Fault Tolerance and Quantum Supremacy

Quantum computers can perform and complete several different functions and algorithms. The most common application for quantum computers is completing an algorithm to find the best solution among many. Currently, most quantum computers use huge amounts of energy to run only one algorithm at a time. The future of quantum computers is a fault-tolerant quantum computer capable of running several algorithms simultaneously for long periods of time using less energy than existing technology.

There are two main goals when trying to achieve a fault-tolerant quantum computer: a high qubit count and a low error-rate.

With a high qubit count, a quantum computer can manipulate and store more data. However, unlike bits, qubits must go through a physical process to be created and maintained, thus slowing the process of achieving a high qubit count.

Effective quantum computers must achieve a low error rate to accurately manipulate the necessary qubits. By manipulating the qubits with a low error rate, the machine can provide factually accurate information instead of meaningless noise.

Quantum supremacy is the highest achievable rank of quantum computing, reached only when a quantum computer can complete an algorithm conclusively beyond the power of a supercomputer. This was achieved by Google in 2019 when Dr. John Martinis led an experiment in which a quantum computer carried out a specific calculation that is beyond the practical capabilities of regular, 'classical' computers.

Commercialization

While many consider quantum supremacy to be the end-all-be-all goal for quantum computing, SEEQC believes the true test is commercialization. Quantum computers can reach commercialization when application-specific quantum computing systems can solve current, on-going problems. Without commercialization, there is little real-world incentive for quantum computing.

To reach commercialization, quantum computers must have the properties of fault tolerant systems scaled down to a reasonable size, structure and use-case.

Commercialization is where SEEQC differs from its counterparts.

What Makes Seeqc Different?

Lower-Scale Production Methods

The most common quantum computer production method is CMOS (complementary metal-oxide-semiconductor) fabrication in cryogenically-cooled systems. This method requires a large amount of energy to store and create the qubits needed to power the quantum machine.

SEEQC uses a different method. Through SFQ (single-flux quantum) electronics, SEEQC has developed a "system-on-a-chip" approach to quantum. SFQ technology allows SEEQC to drastically reduce the number of required input and output lines connecting room-temperature electronics and qubits, enabling greater scaling potential and lower energy consumption, thus reducing operating interference.

Reduced Operational Methods

Current quantum computing methods require each qubit to be individually connected. This wiring process, combined with the qubit count needed to make quantum viably useful, makes scaling quantum incredibly difficult. If engineers continue this method, quantum may never reach its full potential.

The entire quantum industry is working to eliminate the need for the wiring process by replacing the analog process entirely with integrated qubit control. The power consumption for this alternative practice is 0.0002 mW/qubit, a figure which is four to five orders of magnitude lower power than analog CMOS designs.

SEEQC's 3-Pronged Approach

- **SFQuClass Digital Quantum Management (DQM):** AKA, SEEQC's "system-on-a-chip." The DQM is a chip that controls and reads qubits using digital single-flux quantum pulses. It greatly reduces the complexity of connections, thus reducing the amount of energy needed to run a quantum machine.

  The chip controls qubits digitally, using digital pulses instead of microwaves, increasing the speed of the system. It is built using SFQuClass digital superconducting circuits (a more energy-efficient circuit technology).

- **Application-Specific Quantum Computers:** In place of giant all-purpose machines, SEEQC works with various industry leaders to co-develop quantum computers that solve industry-specific problems. By reducing the range of the computer, the resources needed to run it also decrease, thus improving the computer's overall performance. In short: SEEQC is making fewer qubits do more jobs. By co-developing hardware and algorithms for specific, optimal solutions, SEEQC is able to decrease the time it takes to get quantum computers to market.

Hybrid Classical Quantum Computing: SEEQC aims to combine quantum technology with existing superconducting classical computing technology to create industry-leading fast hybrid quantum-classical computers.

For quantum computers to accurately process data, they must perform quantum error correction, classical algorithms, qubit management while interfacing with classical computer systems.

SEEQC's cryogenic technology allows these functions to integrate in a cryostat, reducing the system's complexity, and in turn lowering latency, cost and error rates.

For more information please visit seeqc.com