Truly scalable quantum control for logical qubits

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Advancing superconducting quantum computing towards fault-tolerance requires simultaneously mastering quantum error correction, achieving high qubit fidelities, and scaling the technology as a whole. The quantum control system connecting users with quantum processing units (QPUs) is central to all of these challenges, demanding full-stack scalability, high signal fidelity and timing precision, and low-latency communication and processing capabilities.

We present the Zurich Quantum Control System (ZQCS), engineered for the challenge of building long-lived logical qubits. Its key features include an analog front end optimized for "five nines" gate fidelities on physical qubits, a system architecture designed for best match with logical qubit implementations, and high-bandwidth interfaces that tightly integrate its processing capabilities with classical compute resources.

Complementing the hardware, we present LabOne Q, our open-source software framework, demonstrated through the automated and parallelized tune-up of a 17-qubit QPU. The framework provides Python interfaces at the workflow-, gate-, and pulse-level for transparent multi-level access across all abstraction layers needed in QPU development. A high-performance Rust-based core reduces compilation times by more than an order of magnitude. Together, ZQCS and LabOne Q provide a scalable platform for the next major milestones towards fault-tolerant quantum computing.

Figures

Figure 1: The ZQCS Quant Control System to operate 1000-qubit-scale quantum computers.