Advanced Quantum Testbed at Lawrence Berkeley National Laboratory

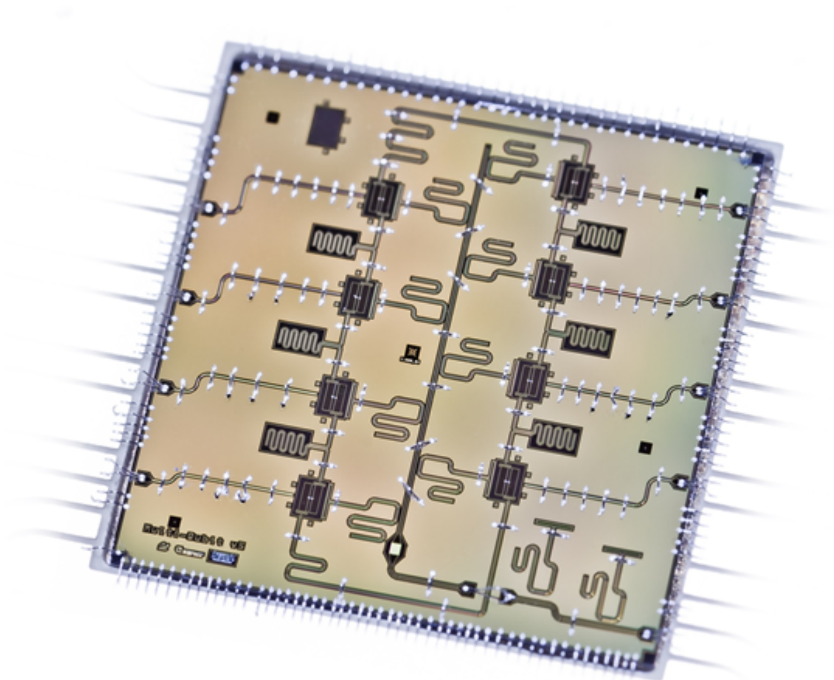
AQT at LBNL Capabilities

This information is current as of **August 17, 2020.** Please check our website for updates.

Baseline AQT QPUs:

The initial QPU available to AQT users will be the 8-qubit ring design chip.
The current specifications and typical parameters for this QPU are:

- Eight transmon qubits in ring, with nearest neighbor connectivity
- Resonance frequency range: 5.2-5.8 GHz
- Typical anharmonicity: 250 MHz
- Multiplexed readout with travelling-wave parametric amplification (TWPA)
- Readout fidelities: >97%
- Coherence times: T_1 ~ 100 us, T_2^{echo} ~ 100 us (with fluctuations)



For detailed information, see: Kreikebaum, J. M., et al. "Improving wafer-scale Josephson junction resistance variation in superconducting quantum coherent circuits." Superconductor Science and Technology 33.6 (2020): 06LT02

Advanced Quantum Testbed at Lawrence Berkeley National Laboratory

In the future, the AQT will provide access to Spidernet-8, a novel 8-qubit QPU with arbitrary dynamically reconfigurable (up to all-to-all) qubit-qubit connectivity. Additionally, this QPU will provide support for bosonic encoding with interfacing to transmon qubits. The QPU contains the following elements:

1. Eight Tunable Transmon Qubits
    a. Nominal Frequency Tunable Range: 5.5 GHz-6.5 GHz
    b. Nominal Anharmonicity: 230 MHz
    c. **Expected** Coherence Times: T1 = 40us, T2 = 20us
2. A Linear Microwave Resonator Coupled to All Transmons
    a. Nominal Frequency: 6 GHz
    b. Nominal Coupling to resonator drive: ~2 kHz
    c. **Expected** Quality Factor: 1 million

Expected parameters are listed as follows:

1. Qubit-Qubit Connectivity: Dynamically reconfigurable up to all-to-all (programmable with room-temperature controls)
2. Qubit Pair Photon-exchange and Pair-creation Rate: tunable up to 10 MHz
3. Qubit to the Common Resonator Mode Coupling [0,5] MHz, [0, 26] MHz, [0, 100] MHz (three design variants)

Available Gates:

Single-qubit gates:

- Isolated error rates ~5×10^{-4}, measured by randomized benchmarking (RB)
- Simultaneous error rates 2×10^{-2}, measured by cycle benchmarking (CB)

Cross-resonance gates:

- Nearest-neighbor microwave gates between fixed-frequency qubits
- Typical gate times between 100 to 200 ns
- Controlled-NOT (CNOT) gate error rates ranging from 1% to 4%, measured via interleaved randomized benchmarking (IRB) and cycle benchmarking (CB)

(Future) Parametric flux-modulation gates

- Flux-tunable coupler between nearest neighbor fixed-frequency qubits
- Fermionic simulation (fSim) gate: combination of controlled phase (CZ) and iSWAP
- Gates less than 50 ns

AQT

Advanced Quantum Testbed at Lawrence Berkeley National Laboratory

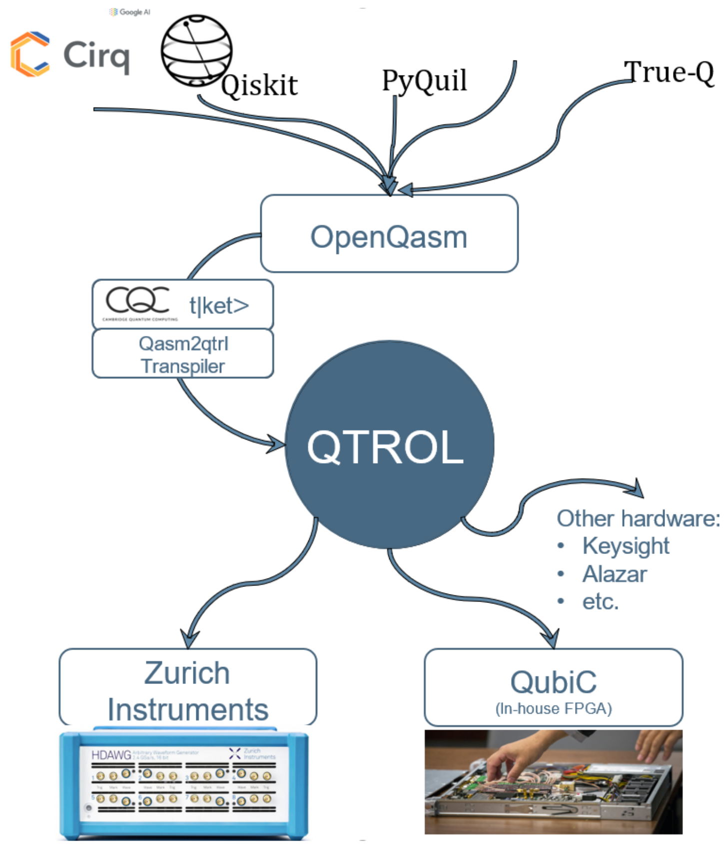
Control Hardware:

The standard control hardware available to AQT users consists of Zurich Instruments devices. HDAWG units (High Definition Arbitrary Wave Generator) are used for qubit control, operating at 2.4 GSPS with a bandwidth of 750MHz. For qubit readout, we use UHFQA units (Ultra High Frequency Quantum Analyzer), operating at 1.8 GSPS with a bandwidth of 600MHz. Triggering and synchronicity among multiple devices is orchestrated through a PQSC (Programmable Quantum System Controller). This setup enables state-detection on-the-fly, enabling fast reset and fast feedback to less than a microsecond point-to-point.

In addition, the AQT team is developing an in-house control solution, dubbed QubiC (for Qubit Control), to accommodate custom control needs and lower-level access control to the hardware than can be provided by proprietary commercial hardware. The current QubiC design consists of AQT-developed HDAWGs, with optical fiber synchronizations expected to be available soon, as well as customized hardware for control of the upcoming Spidernet-8 processor described above. If you have needs or interests in the categories of, but not exclusively: developing better synchronization solutions for superconducting (SC) qubit systems; specialized electronics designed for your project or more efficient control of SC processors; access to control hardware as close as possible to the qubit level (i.e. pulse level) which cannot be accommodated using the standard Zurich Instruments devices or other proprietary commercial solutions, please contact the AQT team to discuss QubiC access, development, and use. AQT is open to partnering on projects in co-developing, customizing, and optimizing control hardware solutions that might require too much specialization or flexibility for commercial vendors.

Advanced Quantum Testbed at Lawrence Berkeley National Laboratory

Programming Stack:



To support QubiC, AQT has developed an early-stage programming stack whose development is ongoing. AQT can accept circuits from widely-used software illustrated at the top of the graph on the right. AQT can work with users to provide access with non-standard software, if required for a project. AQT can also provide access initiated at any starting point in the programing stack, if the circuit is produced in the OpenQasm format, as well as alternate types of access since AQT is developing an in-house instruction set architecture (ISA). From OpenQasm, circuits will be optimized using t|ket> and transpiled into sequences compatible with QTROL, the AQT's control software, using AQT's Qasm2qtrol transpiler. QTROL then interfaces with the control hardware to run the experiment. AQT is open to developing specialized software at the QTROL level for nonstandard user software needs. Access to the programing stack can also be provided or developed for users interested into pursuing their own circuit optimization solutions. AQT is open to partnering on projects with users who are interested in co-developing and optimizing the programming stack.