Superconducting qubit readout and control system based on FPGA and development of a pulse sequencer

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Abstract

This thesis presents the development of a superconducting qubit control and readout system based on FPGA technology, with a focus on the design of a pulse sequencer and the integration of frequency-multiplexed control. The system leverages the Quantum Instrumentation Control Kit (QICK), an open-source Xilinx RFSoC-based platform capable of direct digital synthesis and acquisition of microwave signals up to 9 GHz. The QICK firmware was extended to support the simultaneous generation and readout of multiple frequency-multiplexed tones, enabling the control and measurement of several qubits coupled to a shared feedline. This approach optimizes the number of controllable qubits relative to the available ADC and DAC resources on the RFSoC 4x2 board. Furthermore, this work includes the development of Qubase, a Python-based pulse sequencer that allows users to easily define and execute complex sequences of control and measurement pulses through the QICK Python interface. The resulting architecture is both flexible and scalable, providing a foundation for efficient multi-qubit experiments and enabling advanced techniques such as quantum error correction and real-time feedback.