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Ultra-low-power, Microwave-multiplexed Qubit Controller Using Adiabatic Quantum-flux-parametron Logic

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***Abstract*–To build large-scale superconducting quantum processors, it is crucial to develop cryogenic qubit controllers (QCs) that can manipulate many qubits inside a dilution refrigerator. However, it is challenging to achieve scalable QCs because the cooling power of a dilution refrigerator is too small (~10 μW at ~10 mK) to operate conventional logic families such as complementary metal–oxide–semiconductor (CMOS) logic and rapid single-flux-quantum (RSFQ) logic. In the present study, we propose a scalable QC using an ultra-low-power superconductor logic family, namely adiabatic quantum-flux-parametron (AQFP) logic. The AQFP-based QC, which we refer to as the AQFP-multiplexed (AQFP-mux) QC, produces multi-tone microwave signals for qubit control with an extremely small power dissipation of ~80 pW/qubit. Furthermore, the AQFP-mux QC adopts microwave multiplexing to reduce the number of coaxial cables for operating the entire system. These features ensure very high scalability and indicate the possibility of implementation with qubits at ~10 mK. As a proof of concept, we demonstrate an AQFP-mux QC chip that produces microwave signals at two output ports through microwave multiplexing and demultiplexing. The chip was fabricated by a 10-kA/cm^2 four-Nb-layer process provided by the AIST, namely the high-speed standard process (HSTP), and basic microwave control was performed at 4.2 K. Experimental results show an output power of ~80 dBm, on/off ratio of ~40 dB, and mixing operation at each output port. These results indicate the feasibility of energy-efficient, scalable qubit control using AQFP logic.**

***Keywords (Index Terms)*–AQFP, energy-efficient, microwave switch, mixer, multiplexing**

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