

Optimizing attenuators for energy-efficient cryogenics with low-error qubit operation

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Microwave-controlled qubits operate at millikelvin temperatures in cryogenic systems, where thermal noise propagating through control lines can induce unwanted qubit transitions and degrade performance. Attenuators suppress this noise and help stabilize the qubits, but they also dissipate microwave power as heat at cryogenic stages, increasing the cooling demand and the associated energy consumption. Here we determine the attenuation configuration that minimizes the cryogenic power cost under the constraint that the qubit error probability per control step remains below a target value. Using a Lagrange-multiplier approach, we derive analytic expressions for the optimal attenuations for an arbitrary set of cooling-stage temperatures and cooling efficiencies, and obtain a corresponding analytic expression for the minimum consumption power. We then illustrate the consequences of these results for realistic cryogenic architectures, including a typical system with six cooling stages.