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High-fidelity gates in Josephson phase qubits

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Complex algorithms for a quantum computer require error correction and robust calibration protocols for extended pulse sequences. We present significant progress towards both of these goals with our detailed measurements of gate fidelity and coupled qubit experiments with multi-pulse sequences. We measure single qubit gate fidelities of 0.98, limited by energy relaxation; and by carefully separating out gate and measurement error we construct a complete error budget. Using the new metrological technique of "Ramsey filtering" we show how one important error process can be measured and reduced to a level of 10^{-4}, a magnitude believed to be near the fault tolerant threshold. This measurement demonstrates that our quantum system remains in the two-state qubit manifold during our single qubit operations. This precision and accuracy is made possible by custom control electronics that can create arbitrarily shaped microwave pulses.