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Superconducting Phase Qubits: Two-Qubit Tomography and Adjustable Coupling

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Proof of principle quantum gates and algorithms have now been implemented using superconducting qubits. Some of the next goals for superconducting qubits include the development of scalable coupling schemes between qubits and the implementation of benchmarking methods that will allow for the direct comparison of superconducting qubit gate and algorithm performance to that of other quantum computing architectures. We first present work on benchmarking a universal quantum gate implemented using fixed, capacitive coupling. We use standard quantum process tomography as the benchmarking tool to obtain the fidelity of the universal gate. Additionally, we show how the chi matrix obtained from quantum process tomography can be analyzed to extract useful information about correlations of the noise acting on our system. The drawbacks of using fixed coupling and its effects on gate performance will also be discussed. Motivated by these drawbacks, we describe the need for tunable coupling and show how it can be implemented using a modular, drop-in coupler that is built from simple circuit components. We show how this element can be used to vary the two-qubit interaction strength between 0 and $\sim$100 MHz, allowing us to potentially remove problems inherent with fixed coupling. Finally, we present experimental data demonstrating dynamic control of the coupling strength using vacuum Rabi oscillation experiments.