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Solid State Qubits with Current-Controlled Coupling

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The ability to switch the coupling between quantum bits (qubits) on and off is essential for implementing many quantum computing algorithms. We have demonstrated such control with two, three-junction flux qubits coupled together via their mutual inductances and via the dc SQUID (Superconducting Quantum Interference Device) that reads out their magnetic flux states. The flux in each qubit was controlled by an on-chip loop, and the chip was surrounded by a superconducting cavity that eliminates fluctuations in the ambient magnetic field. By applying microwave radiation to the device, we observed resonant absorption in each of the qubits when the level splitting in the qubit matched the energy of the microwave photons. With the qubits biased at the same frequency, the interaction produced an avoided crossing in their energy spectrum. At the avoided crossing transitions to the first excited state were suppressed and transitions to the second excited state enhanced, indicating formation of singlet and triplet states in the coupled-qubit system. The observed peak amplitudes were consistent with calculated matrix elements. When both qubits were biased at their degeneracy points, a level repulsion was observed in the energy spectrum. A bias current applied to the SQUID in the zero-voltage state prior to measurement induced a change in its dynamic inductance, reducing the coupling energy controllably to zero and even reversing its sign. The dependence of the splitting on the bias current was in good agreement with predictions. This work was performed in collaboration with P.A. Reichardt, B.L.T. Plourde, T.L. Robertson, C.-E. Wu, A.V. Ustinov, and John Clarke, and supported by NSF, AFOSR, ARO and ARDA.