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Low-frequency two level systems and $1/f$ noise in Al/AlO$_x$/Al Josephson junctions for superconducting qubits: achieving a noiseless junction[1] CHRISTOPHER NUGROHO, VLADIMIR ORLYANCHIK, DALE VAN HARLINGEN, University of Illinois at Urbana-Champaign — The characterization of low-frequency two level systems (TLS) provides a connection between the generic $1/f$ noise in Josephson junctions to the TLSs observed in qubit energy spectroscopy. We present measurements of the tunneling-resistance noise in nanoscale Al/AlO$_x$/Al shadow evaporated junctions with areas $< (100\ \text{nm})^2$. As the junction area or the temperature is decreased we observed a crossover from ensemble-averaged $1/f$ noise to a random telegraph noise from isolated TLSs. From the area threshold for the onset of non-gaussianity, we estimate a density of TLSs in the amorphous AlO$_x$ barrier consistent with the magnitude of $1/f$ noise in larger junctions and the density of high frequency TLSs from qubit spectroscopy. Furthermore we may deduce the potential landscape of the TLSs by characterizing the switching times and signal variance as a function of voltage bias and temperature. In some junctions no fluctuators are active, giving rise to immeasurably small noise signal. We discuss the implication of our findings to qubit coherence times.

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