Quantum capacitances and resistances of electron boxes and transistors

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The issue of coupling quantum systems to classical ones appeared from the very first days of quantum physics. One notable example is the Bohr-Einstein photon box thought experiment. While such thought experiments could not be realized a century ago, when quantum mechanics was still being formulated, experimentalists now routinely work with coupled classical and quantum systems. In contrast to natural quantum systems (like photons), artificial ones are often operated dynamically and are coupled to driving and readout electronics [1].

In our work [2], we are interested in dissipative semiclassical systems, where a classical electromagnetic field is used to probe a quantum electronic system. The effective reactance may include capacitive and inductive terms that incorporate geometric, quantum, and tunneling components; while the effective resistance may be composed of Sisyphus and Hermes terms linked to relaxation and decoherence, respectively.

Our approach demonstrates how to introduce quantum and tunneling capacitances as well as Hermes and Sisyphus resistances, and how these values are modified when the dynamics of the subsystems become mutually dependent. We present the cases of a Cooper-pair box, a single-Cooper-pair transistor, a double quantum dot, and a single-electron box. Our approach is quite general, and such quantum reflectometry provides a convenient part of the quantum toolbox.

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