Phase-charge duality in Josephson junction circuits:
Role of inertia and effect of microwave irradiation

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We investigate the physics of coherent quantum phase slips in two distinct circuits containing small Josephson junctions:

- a single junction embedded in an inductive environment and
- a long chain of junctions.

Starting from the standard Josephson Hamiltonian, the single junction circuit can be analyzed using quasi-classical methods; we formulate the conditions under which the resulting quasi-charge dynamics is exactly dual to the usual phase dynamics associated with Josephson tunneling.

For the chain we use the fact that its collective behavior can be characterized by one variable: the number m of quantum phase slips present on it. We conclude that the dynamics of the conjugate quasi-charge is again exactly dual to the standard phase dynamics of a single Josephson junction. In both cases we elucidate the role of the inductance, essential to obtain exact duality.

These conclusions have profound consequences for the behavior of single junctions and chains under microwave irradiation. Since both systems are governed by a model exactly dual to the standard resistively and capacitively shunted junction model, we expect the appearance of current-Shapiro steps. We numerically calculate the corresponding current-voltage characteristics in a wide range of parameters. Our results are of interest in view of a metrological current standard.