Effect of noise and quantum fluctuation on Josephson junction model with second harmonic

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Presence of noise, in general, brings up a disruption in a system, e.g., as errors in measurements and signals, or in destruction of order by thermal noise. However, in nonlinear systems, several other aspects of noise have been recognized, most notable of which are stabilization of unstable states, and amplifications of weak signals, broadly classified as noise induced phase transitions and stochastic resonance. Subsequently, noisy nonlinear dynamical systems have become an important class of problems with applications going beyond the realm of classical mechanics.

Our study shows a noise induced phase transition in a nonlinear system that has recently been seen in experiments, namely, a Josephson junction (JJ) with a current phase relation containing higher harmonics, such as $I = f_1 \sin\phi + f_2 \sin 2\phi$. Recently, a robust second harmonic current-phase relation has been established in a Josephson junction of two superconductors separated by a ferromagnetic layer [1]. For $f_2 = 0$ and $f_1 > 0$, it resembles a pendulum, and earlier studies have shown that in presence of high frequency vertical drive a pendulum achieves dynamic stabilization of a phase difference $\phi = \pi$. [2]. It now seems that the role of periodically modulated multiplicative noise in inducing or changing the transitions can now probably be explored experimentally [3]. For a JJ, if the second-harmonic term is neglected ($f_2 = 0$), then the 0 (π) state is stable for $f_1 > 0$ ($f_1 < 0$). At the $0 - \pi$ transition, the first harmonic becomes zero and the second-harmonic term dominates [4]. This is a first order transition. If the second harmonic is negative for $f_1 > 0$, the ground state phase changes continuously from zero to a nonzero value, resulting in a continuous symmetry breaking transition. For the two harmonic potential, i.e., $f_2 \neq 0$, we have studied the effect of a periodically modulated coloured noise. There are separate time scales due to high frequency stochastic drive in the system. Because of the separation of time scales, the system can be described by an effective potential, V_{eff}, for the slow component, obtained by integrating out the high frequency component of the dynamical variable. This elimination of rapid components produces higher harmonic terms in V_{eff} whose coefficients can be adjusted to generate a local minimum at π. We adopt the method of effective potential in this paper. In the process we obtain a general form for V_{eff} for any type of potential [5].

In our present work we study this two harmonic potential problem from two different angles. One is from a classical point of view where we would focus on the effect of multiplicative coloured noise for Josephson junction model. The other study is the effect of quantum fluctuations on the resistively shunted Josephson junction. Following Caldeira-Leggett model[6] we have studied the effect of damping in terms of interaction between the system and bath which are essentially an ensemble of harmonic oscillator. We have taken renormalization group(RG) approach to study the effect of quantum fluctuation. It has been shown that new fixed point appears in the RG flow diagram(as shown in Fig.1) for parameter value in a certain range.

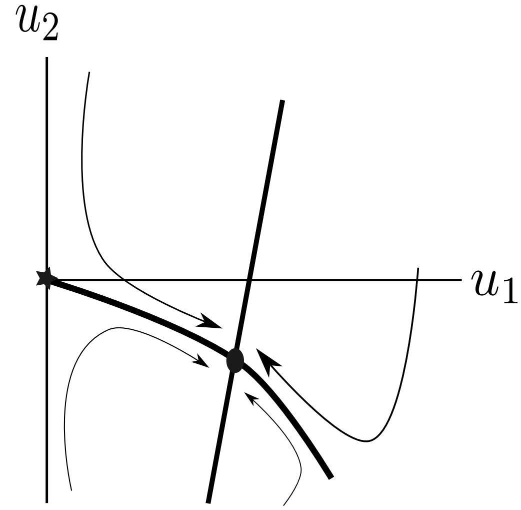

Figure 1: RG flow diagram for resistively shunted Josephson junction. u_1 and u_2 are the couplings for this system..

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