Memory effects in a non-equilibrium Langevin equation describing effective cooling via feedback currents

P. De Gregorio[a], M. Bonaldi[b,c], L. Conti[d] and L. Rondoni[a]

[a] *Dip. di Matematica, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy, E–mail: paolo.degregorio@polito.it*
[b] *Istituto di Fotonica e Nanotecnologie, CNR-Fondazione Bruno Kessler, 38100 Povo, Trento, Italy*
[c] *INFN, Gruppo Collegato di Trento, Sezione di Padova, 38100 Povo, Trento, Italy*
[d] *INFN, Sezione di Padova, Via Marzolo 8, I-35131 Padova, Italy*

The possibility of measuring low-temperature signals by subjecting the analyzed source to an active feedback scheme has attracted a lot of interest in recent times. This is achieved driving the interaction between the measuring apparatus and the observed system out of equilibrium, through constantly recycling the currents induced by the latter on the former. The delay line produces an effective dissipation within the source-apparatus universe, beyond the constraints dictated by the Fluctuation and Dissipation Theorem. It is *as if* the source now operates at temperatures lower than the actual bath temperature. This technique has been applied successfully to – among others – diverse systems such as nano-mechanical oscillators and gravitational wave detectors. We have analyzed a Langevin model of the feedback effect. The feedback current adds a memory term to the equilibrium equation of a dumped oscillator, driving the circuital currents and charges of the measuring apparatus out of their equilibrium with the source. If the source is purely thermal, we can calculate explicitly the power spectrum of the current. One can show that for high quality factors the power spectrum of the current generated by the Langevin equation is (unsurprisingly) *almost* a Lorentzian curve, with effective dissipation, as if the system equilibrates at a modified temperature. Less obvious, the resonance frequency also depends on the feedback gain, due to the memory effect. We also show substantial deviations from such behavior, illustrating that equilibrium-like descriptions would be entirely erroneous in certain conditions. The system in fact behaves in a qualitatively different way in those circumstances, leaving no room for 'effective' adjustments. This apparently depends on the peculiar nature of oscillators with low quality factors.

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