Pulses and $1/f$ Noise

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1 Problem

Discuss the relation between pulsed phenomena and $1/f$ noise.

2 Solution

Low-frequency fluctuations with a $1/f$ frequency spectrum were first noticed by Johnson [1] in thermionic-emission currents in vacuum tubes, and exist in a very wide range on phenomena.[1] A feature common to most of these phenomena is that they involve a quasirandom sequence of pulses on the microscopic scale.

The spectrum of energies associated with a short pulse of characteristic width Δt is roughly flat up to $E_{\rm max} = \hbar/\Delta t$. In general, the pulse process can be associated with quanta (such as phonons or photons) of energy $\hbar\omega$, so the number spectrum of these quanta varies as $1/\omega$ up to $\omega_{\rm max} = 1/\Delta t$.

When a phenomenon consists of a sequence of closely spaced pulses, such that the macroscopic behavior is quasistatic, the microscopic behavior involve fluctuations with the frequency spectrum of the associated quanta, namely $1/\omega$, *i.e.*, $1/f$.

While the author considers the above to be fairly "obvious", the literature on $1/f$ noise mainly involves much more arcane, and less satisfactory, explanations. The above view was advocated by Handel in 1975 [11, 12] (in the context of Bremsstrahlung emitted by conduction electrons in collisions with lattice ions), although it seems to be regarded with surprising (to this author) skepticism.[2]

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[1] See, for example, [2]-[10].

[2] See, for example, sec. IIIC of [6]. Exceptions are [13, 14]. For a "fractal" view of $1/f$ noise, see [7].

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