Piezoelectric energy harvesting from strongly colored supra Gaussian fluctuations: An electronic analogy

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Recently[1,2], we have proposed a wide-spectrum piezoelectric energy-harvesting model based on a monostable oscillator obeying a Woods–Saxon[3] potential

$$U(x) := -V_0/\{1+\exp[(|x|-r)/a]\},$$

capable of interpolating between square-well and harmonic-like behaviors. We found an increase of the output rms voltage V_{rms} for deep potential wells and low noise intensity σ, as the model external noise $\eta(t)$ became supra Gaussian (Fig. 1). We chose for $\eta(t)$ the process defined by

$$\tau\dot{\eta} = -V_q'(\eta) + \xi(t), \text{ with} \quad (1)$$
$$V_q(\eta) := \ln[1+\tau(q-1)\eta^2/2]/[\tau(q-1)]$$

and $\xi(t)$ white, Gaussian, unit variance because it is easy to generate dynamically and depends on only two parameters (q and τ) with clear interpretation: for $q = 1$, $\eta(t)$ is Ornstein–Uhlenbeck's with correlation time τ, for $q < 1$ it is bounded, for $1 < q < 5/3$ it is supra Gaussian (finite variance but constructively contributing higher cumulants), and for $q > 5/3$ it is fat-tailed (in particular for $q = 2$, it is Cauchy's)[4]. Those results led us to conclude that a deep square-well potential acts as a selector of the large highly correlated oscillator excursions provoked by the supra Gaussian noise.

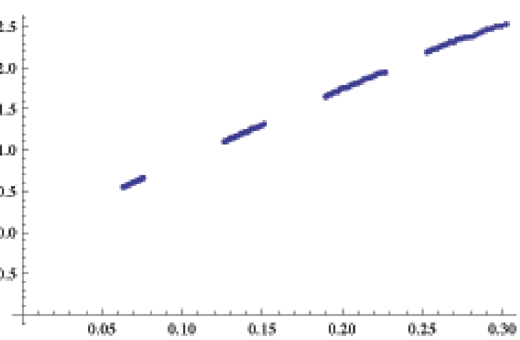

FIG. 1. V_{rms} *vs* σ_{eff} for $V_0 = 10$, $\sigma = 0.2$, and $a = 0.05$.

In order to further explore that mechanism, we performed a real experiment on an incomplete but illustrative electronic analog: $\eta(t)$ noise synthetized by means of Eq. (1) is fed to the circuit in Fig. 2 using a `MATLAB` function, through the computer's audio output. The Zener diode is a metaphor of the square-well potential and the OP AMP is required because the `MATLAB` output is limited between ± 2V. As q grows larger than 1 (and thus $\sigma_{eff} := \sigma\sqrt{2/[\tau(5-3q)]}$ increases, Fig. 3), so does the frequency of Zener current peaks (Fig. 4).

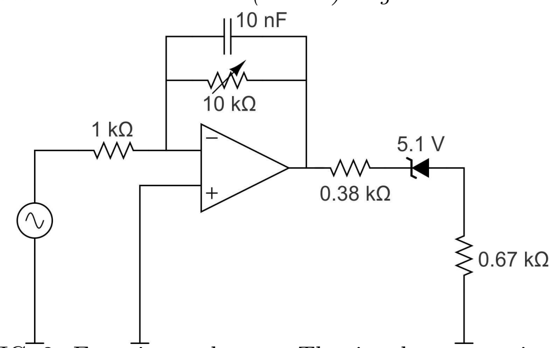

FIG. 2. Experimental setup. The signal generator is a computer.

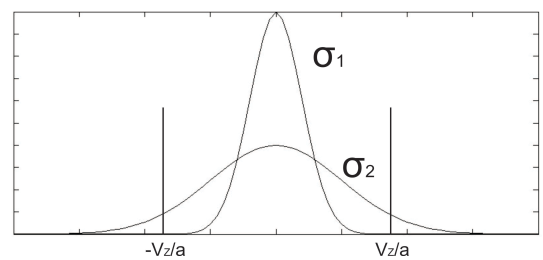

FIG. 3. V_z/a: Zener voltage over amplification factor.

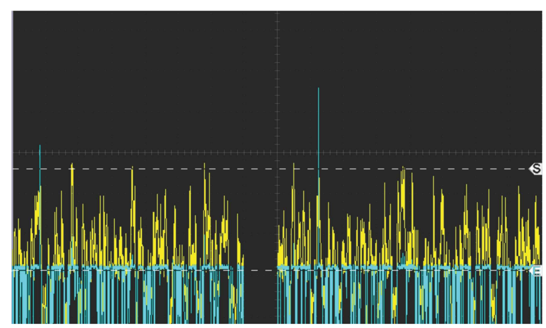

FIG. 4. $q = 1.6$, $\sigma = 0.4$.

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