Stochastic Resonance in Neuromorphic Semiconductor Devices having a Double-Well Potential

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Noise and fluctuations may play a significant role in neural information processing. One of the key phenomena for this implication is so-called "stochastic resonance" (SR) [1] in neural systems; e.g., a visual pathway in a cat primary visual cortex optimally utilized SR-like process to improve signal detection while preventing spurious noise-induced activity and keeping the SNR high [2]. Our motivation here is to exploit noise and fluctuations in micro- and nano-electronic systems to construct a robust brain-inspired computing system, based on the neuromorphic approach.

Several electronic SR systems, especially for weak-signal detection, have already been proposed in the literature (see e.g., [3]). SR could be utilized for not only weak-signal detection but also logical memory operations, if the SR system has bistable properties (having a double-well potential). We here propose a device-oriented double-well potential system that can easily be implemented by standard CMOS technologies. The system is described by the same dynamics as the traditional analog neuron model. Firstly, we introduce a potential function obtained from the proposed dynamics, and show the bistable conditions. Then we examine the SR behavior in the system by extensive computer simulations. As in traditional SR systems, we applied sinusoidal inputs to the system where the potential barrier is dynamically fluctuated (but the barrier is not flatten with this input). The stable points can be fluctuated by adding Gaussian noises when the barrier is vanished by the noise addition. As a result of calculations of signal-to-noise ratios (SNR) of the temporal outputs for variant noise strength, we found that the system exhibited qualitatively the same SR characteristics as in traditional double-well SR systems. Finally, we show experimental results of an electronic SR system that was implemented by a simple CMOS circuit (a single operational amplifier), and demonstrate that the circuit exhibits the same SR behaviors as demonstrated in the proposed double-well potential system.

References

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