Neuromorphic CMOS analog circuit exhibiting array-enhanced stochastic resonance behavior with population heterogeneity

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Stochastic resonance (SR) is a phenomenon in which the response of a system can be enhanced in the presence of an optimal level of noise. It is well known that there are several noise sources in the nervous system and neurons are subject to these noises. Moreover, it has been observed that SR gets further enhanced by local couplings between neurons (array-enhanced SR). For example, Stacey et al. demonstrated that an array of simulated hippocampal CA1 neurons exhibited SR-like behaviors where the correlation between the output and a sub-threshold input signal in the network increased as the coupling strength between the neurons was increased, and the correlation value was further increased as the number of the neurons increased. Motivated by these findings, we proposed a neural network model composed of Wilson-Cowan neuron model that is suitable for neuromorphic semiconductor devices. In the network each neuron device is electrically coupled to its four neighbors to form a 2D grid network. All the neurons accept a common sub-threshold input. The firing of each neuron is recorded and is converted into a series of pulses of amplitude 1 and 0 corresponding to the firing and non-firing states respectively. The output of the network is then defined by the sum of all the pulses. We carried out circuit simulations using a simulation program with integrated circuit emphasis (SPICE), with typical CMOS device parameters, and confirmed that without the electrical coupling, the circuit network exhibited a standard SR behavior and that the correlation value was further increased as the coupling strength increased. These results indicate that, as suggested by biological and simulated evidence, unreliable (possible semiconductor nano) devices could be use to develop reliable information processing systems.