Coupling-Enhanced Stochastic Resonance in Noisy Neuromorphic Devices

Gessyca Tovar, Tetsuya Asai, and Yoshihito Amemiya

Graduate School of Information Science and Technology, Hokkaido University
Kita 14, Nishi 9, Kita-ku, Sapporo, 060-0814 Japan.
Phone: +81-11-706-7147, Fax: +81-11-706-7890
E-mail: gessyca@lalsie.ist.hokudai.ac.jp

Noise and fluctuations are usually considered as "obstacles" in the operation of both analog and digital information-processing systems, and most strategies to deal with them are focused on the suppression. On the other hand, neural systems may employ different strategies that can "exploit" the properties of noise to improve the efficiency of neural operations. For example, Stacey *et al.* demonstrated that an array of simulated hippocampal CA1 neurons exhibited stochastic resonance (SR)-like behaviors where an optimal correlation value between the sub-threshold input and the output was obtained by tuning both the noise intensity and the connection strength between the CA1 neurons, and the correlation value was further increased as the number of the neurons increased [1]. Based on this model, we proposed a simple neural network model for neuromorphic semiconductor devices. Using a CMOS neuron device [2], we then designed an electrical neuromorphic network for the simple model. 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 output of this network is defined by a sum of the outputs of all the neurons. We carried out circuit simulations using a simulation program with integrated circuit emphasis (SPICE), with standard (typical) device parameters, and confirmed that i) without the electrical coupling, the circuit network exhibited a standard SR behavior (the input-output correlation value had an optimal value for the noise strength) and ii) the correlation value was further increased as the coupling strength increased. These results indicate that if we postulate signal transmission via the array of the neuron devices under a noisy environment where the noise strength is fixed, the transmission error rate could be tuned by the coupling strength, which results in possible communication between 3D integrated devices under power supply noises.

References

[1] W.C. Stacey and D.M. Durand, "Noise and coupling affect signal detection and bursting in a simulated physiological neural network", *J. Neurophysiol*, 88, 2598–2611, 2002.

[2] T. Asai, Y. Kanazawa, T Hirose, and Y. Amemiya, "Analog reaction-diffusion chip imitating the Belousov-Zhabotinsky reaction with Hardware Oregonator Model", *Int. J. Unconventional Computing*, 1, 2, 123-147, 2005.