M-13

Study on a Cell Body Model and Its Relation with Stochastic Resonance

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Abstract: In this paper, we study the presence of Stochastic Resonance (SR) in a cell body model by adding noise to the circuit's input. First, we design a random noise source and add it to the model. Then, we analyze its response to frequency and the benefits in the output oscillation and amplitude. These results, allow us to evaluate the improvement in the output's signal to noise ratio (SNR). Finally, we propose a different type of noise source, where frequency can also be changed. We have concluded that noise make a significant impact in the cell body model's behavior.

1. Introduction

Noise is known as an undesirable signal. However, it has been demonstrated that random noise has a good effect in weak signals[1]. Noise can enhance weak signals in order to make them detectable for sensors. In electronics, this is applicable to nonlinear threshold systems. Since a cell body is a non-linear system and it is modeled in an electronic circuit, it is possible that random noise affects its dynamics.

In this paper, we analyze the effect of Stochastic Resonance (SR) in a cell body model [2] by adding noise.

2. Proposed Cell Body Model with a Noise Source

In order to add noise to the cell body model circuit, a random sequence is externally generated and added to the circuit. The sequence was simulated in HPSICE as a Piecewise Linear Source (PWL) and added to the circuit as V_{noise}, shown in Fig.1. The proposed cell body model is shown in Fig. 2.

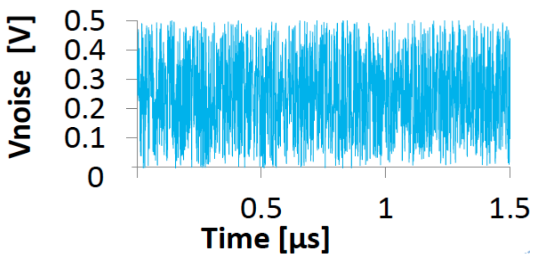

Fig.1 Noise source V_{noise}= 0.5[V]

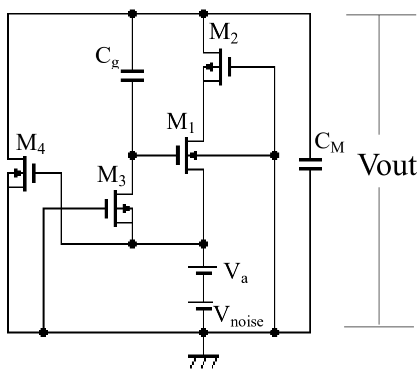

Fig.2 Cell body model with a noise source

3. Stochastic Resonance Characteristics

Figure 3 shows a range of needed input value, named as V_a, which actives the cell body model circuit making possible to obtain its characteristic oscillation. Here, we also compare the change in the range of V_a, when noise is applied to the circuit.

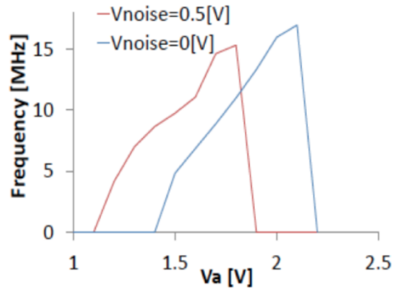

Fig.3　V_a vs. frequency characteristic

To analyze the cell body model behavior and verify the results shown in Fig.3, we consider V_a=1.2[V] and V_{noise}=0.5[V]. The results show that firing was improved by the noise's presence.

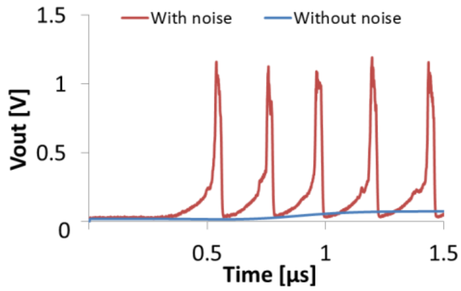

Fig.4 Firing improved by noise

To study how the circuit's firing is affected by noise, V_a is settled at 1.5[V] and V_{noise} at 0.2[V]. The results show that when noise is added, the circuit begins to oscillate faster. Likewise, the refractory time is minimized and the delay time is shorter like in Fig.5

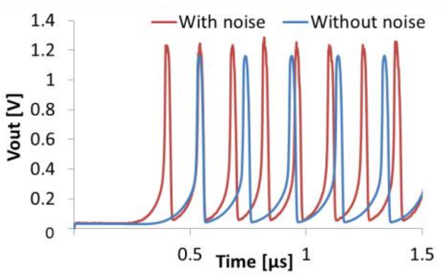

Fig.5 Circuit response to noise

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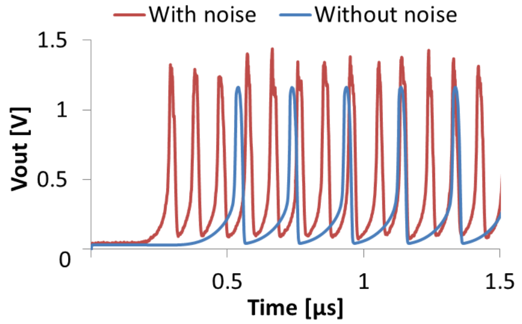
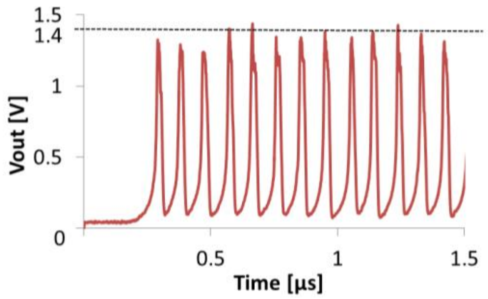
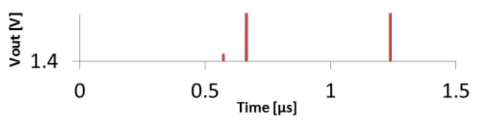
Additionally, when the noise level is increased, the output signal increases as shown in Fig.6 (a). Thus, the signal can cross a wanted limit like in Fig.6 (b). For this study, the threshold value is 1.4[V]. The crossing values are shown in Fig.6 (c).



(a) Firing when V_a=1.5[V] and V_{noise}= 0.5[V]



(b) Output crossing a 1.4[V] threshold



(c) Threshold crossing values

Fig.6 Cell body model output

Figure 7 shows the Signal to Noise Ratio (SNR) of the threshold crossing points for V_a=1.5[V] and V_a=1.6[V]. The circuit signal to noise (SNR) value was obtained by using noise standard derivation and the output average.

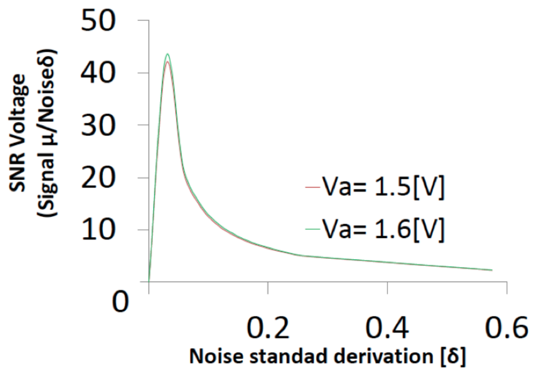


Fig.7 SR behavior in the cell body model output

In order to simulate the cell body model response to different types of noise, we propose the model shown in Fig.8. Using a sine wave source (V_s), we modify the noise frequency. Similar to section 2, V_n is implemented as a PWL source.

A Fast Fourier Transform (FFT) Spectrum Analysis was performed to evaluate the SNR. The FFT output is shown in Fig.9, where the vertical axis is measured in voltage gain and the horizontal axis is measured in frequency. The SNR values were taken at 1.6[MHz] and plotted in Fig.10.

The cell body cell was analyzed when V_a is 1.2[V]. Even though, there is no firing output for this value, when noise is added the output oscillates. Same performance can be observed when Vs is connected. However, Vs makes the circuit reach its highest SNR faster. This could be influenced by the frequency and amplitude of the sine wave source. Although, the FFT results show the presence of SR, the model requires more study.

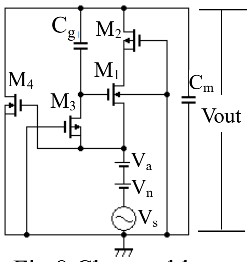


Fig.8 Changeable frequency noise

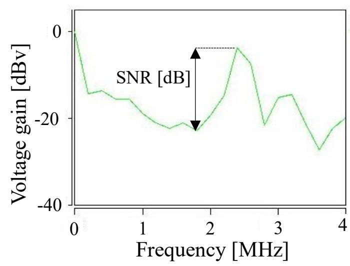


Fig.9 FFT output

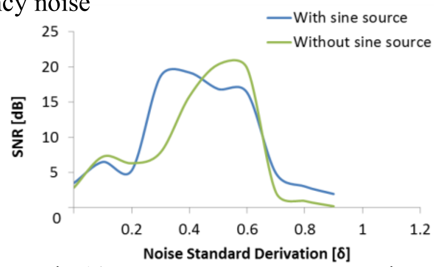


Fig.10 Frequency response to noise

4. Summary

We have studied how the cell body model behaves in presence of noise, when noise is added as an external source to the input. We have found an improvement in the circuit's response, since noise made possible a faster oscillation in the circuit. It also helped reducing the needed voltage range for V_a and increasing the output amplitude level. This increment enables the circuit to reach a threshold value. The improvement is based on the level of the noise, which shows the importance of an appropriated amount of noise. From this, we have a possible relation between the cell body model and Stochastic Resonance (SR).

In the future, we plan to use these characteristics for faster data transmission in an Artificial Neural Network (ANN). Thus, SR can be use advantageously in pattern recognition systems, machine learning, and other fields related with Artificial Intelligence.

5. References

[1] Hänggi Peter : "Stochastic resonance in biology. How noise can enhance detection of weak signals and help improve biological information processing" ChemPhysChem , Vol.3, No.3 pp. 285-290 (2002).

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