F-7-4
Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp856-857

Robust and High Sensitive Myoelectric Signal Detection utilizing Stochastic Resonance with Carbon Nanotube Composite Paper-based Surface Electrodes

Kento Shirata[1], Seiya Kasai[1], Takahide Oya[2], Yosuke Hagiwara[3], Shunichi Kaeriyama[3], and Hideyuki Nakamura[3]

[1] Research Center for Integrated Quantum Electronics (RCIQE) and Graduate School of Information Science & Technology, Hokkaido University, N13, W8, Sapporo 060-8628, Japan
[2]Graduate School of Engineering, Yokohama National University, Tokiwadai 79-5, Hodogaya, Yokohama 240-8501 Japan
[3]The Semiconductor Technology Academic Research Center (STARC), Yokohama 222-0033, Japan
E-mail: shirata@rciqe.hokudai.ac.jp

Abstract

We investigated robust and high sensitive electromyography (EMG) detection using a stochastic resonance (SR) which was evolved in a nonlinear devices network. The SR phenomenon optimizes a response to a weak signal by adding noises. For the EMG signal detection system utilizing SR, we designed a surface-mount 8-parallel Schmitt Trigger network together with multiple surface electrodes. We also introduced a carbon nanotube-composite paper (CNT-cp) as flexible multi surface electrodes. Our system could achieve high signal-to-noise ratio even in motion although the conventional detection system did not work correctly.

1. Introduction

Man-machine interfaces (MMI) using biological signals has attracted much attention recently. Myoelectric signal (EMG) from the activity of muscles includes information of the motion of the human body and is useful for intuitive machine control. However, surface EMG signal induced in the electrode on the skin surface is very weak and easily buried in noise. Conventional EMG detection technique is bipolar lead, in which the EMG signal is amplified by a differential amplifier using two surface electrodes whereas noise is successfully canceled out. However, this technique is quite sensitive to fluctuation of contact between electrodes and the skin surface, and large noise is induced when the subject is in motion. To overcome this problem, we have investigated to use stochastic resonance (SR) in which optimizes a response to a weak signal by adding noise [1, 2]. The purpose of this study is to demonstrate robust and high sensitive surface EMG detection utilizing SR in a Schmitt Trigger network together with multiple surface electrodes made of carbon nanotube composite paper.

2. Design and Experimental

Basic mechanism of SR is noise-assisted state transition in a threshold or bistable system as shown in Fig. 1. Thus SR can be electrically caused using such as comparator, Schmitt Trigger, and field-effect transistor [3]. Figure 2 shows a diagram of our SR-based EMG detecting system together with a measurement setup. The system consisted of pre-amplifier, HPF for offset canceling, and BEF for filtering 50 Hz power line noise, and a 8-Schmitt Trigger parallel network for causing SR together with a summation circuit. Each input of the circuit in Fig. 2 was connected with a surface electrode. In this study we used carbon nanotube composite paper (CNT-cp) [4, 5] as a surface electrode, since it is flexible and is easily processed. The system was implemented on a surface mount substrate. For experiment, the multiple CNT-cp electrodes were put on the forearm in parallel with the muscle fiber as shown in Fig. 2. Noise superimposed in each input was transferred to the Schmitt Trigger without filtering, excepting DC and 50 Hz noise. The output of the system was total sum of the output signal of the Schmitt Triggers and it was monitored

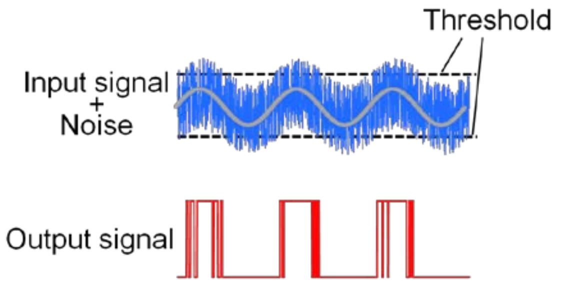


Fig. 1 Mechanism of stochastic resonance.

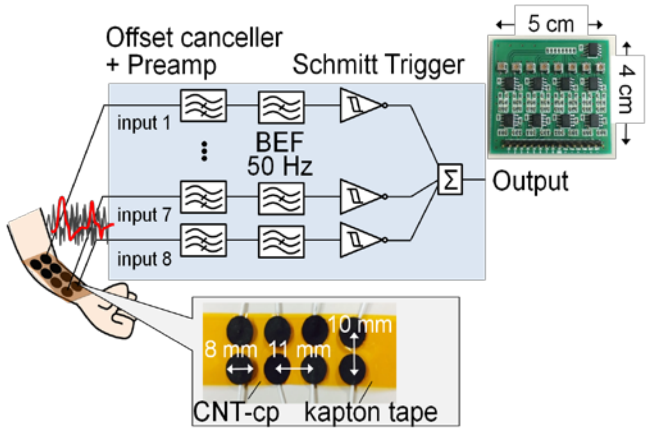


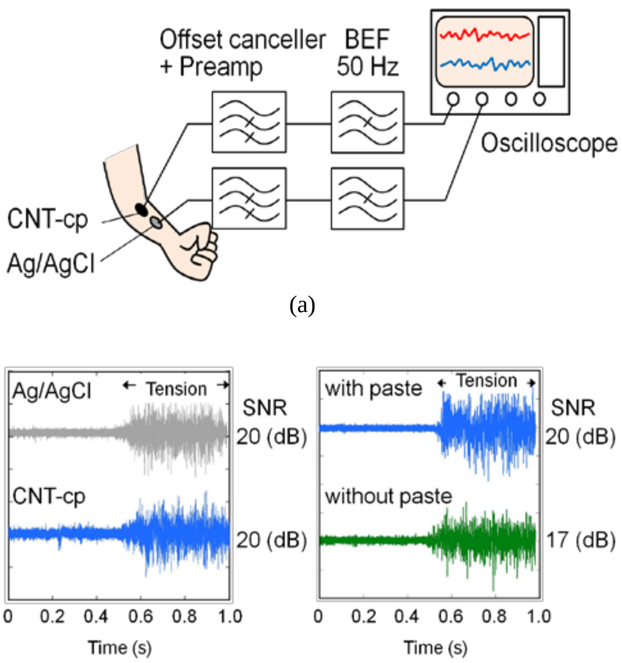
Fig. 2 SR-based EMG detection system with multiple surface CNT-cp electrodes.

by an oscilloscope. The size of the mounting SR circuit was 4 cm x 5 cm. The circuit was operated with dual supply voltage of V_{dd} = 5 V and V_{ss} = -5 V. Evaluated power consumption of this circuit was 70 mW. We set the hysteresis width of all Schmitt Triggers to be 0.1 V so as to adjusting the peak position of the SR to the superimposed noise intensity. We measured EMG signals in motion state swinging the arm backward and forward.

3. Results and Discussion

First we characterized the sensitivity of the CNT-cp to surface EMG. Figure 3(a) shows a set up for characterization of the CNT-cp electrode using unipolar lead technique where the EMG was induced by a surface electrode and was amplified. Conventional Ag/AgCl electrode was also characterized for comparison. Each electrode had a circular shape with 8 mm diameter. Figure 3(b) shows the EMG waveforms obtained using the CNT-cp electrode and the Ag/AgCl electrode, both with electrolyte paste. The signal detected using the CNT-cp electrode was similarly to that using the conventional one. Evaluated signal-to-noise ratio (SNR) was the same. Figure 3(c) compares the obtained EMG signals using the CNT-cps with and without electrolyte paste. The CNT-cp electrode could clearly induce the EMG even without paste. This result was attributed to the micro texture of the CNT-cp, which reduced the contact resistance between the electrode and the skin.

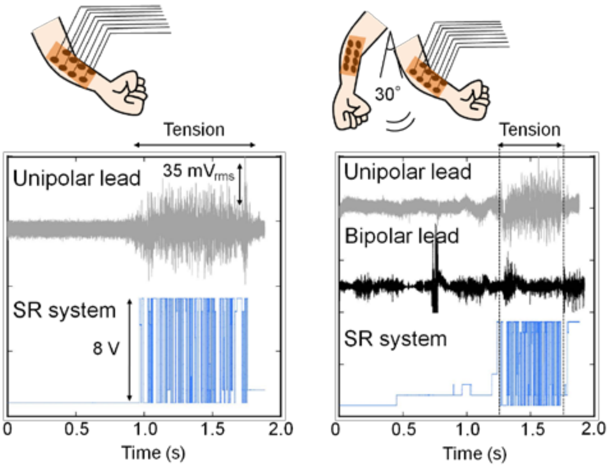
Figure 4(a) shows the EMG waveforms on the forearm in resting state obtained using the SR system and the unipolar lead. The SR system could detect the EMG with high SNR of 40 dB. Amplitude of the output pulses looked the same in the SR system, although those of the input pulse were not uniform. However the intensity of the EMG in the SR system was successfully converted to the width and density of the pulses owing to the nonlinear transfer curve of the Schmitt Trigger. Figure 4(b) compares the EMG waveforms in motion state from unipolar lead, bipolar lead, and the SR system. The bipolar lead showed fluctuated output regardless the tension of muscle and it could not detect the EMG signal at all. This is the problem of the conventional method. On the other hand, the output of the SR system could stably respond to the muscle tension with high SNR of 20 dB even in motion. The obtained result confirmed a good possibility of the SR system for practical application of surface EMG signal detection.



(a)

(b) (c)

Fig. 3 (a) Set up for surface electrode characterization, (b) obtained EMG from Ag/AgCl and CNT-cp electrodes, and (c) EMG from CNT-cps with and without electrolyte paste.



(a) (b)

Fig. 4 Detected EMG signal in SR system and conventional system; (a) resting state and (b) motion state.

4. Conclusions

We investigated robust and high sensitive myoelectric EMG signal detection system using stochastic resonance (SR) in Schmitt Trigger parallel network with CNT-cp multiple surface electrodes. The CNT-cp electrode showed good response comparable to the conventional metal electrodes. The SR system consisting of 8 Schmitt Trigger parallel network and multiple CNT-cp surface electrodes could detect the EMG signal in stable even in motion, showing a good possibility for man-machine interface application.

Acknowledgements

We thank KJ Specialty Paper Co. Ltd. for supplying CNT papers. This work was supported by STARC FS program.

References

[1] L. Gammaitoni et al., Rev. Mod. Phys. vol.70, p.223, 1998.
[2] Y. Imai et al., Jpn. J. Appl. Phys. vol. 53, p.06JE01, 2014.
[3] S. Kasai and T. Asai, APEX, vol.1, p.083001, 2008.
[4] Y. Fujitsuka and T. Oya, J. Nanotech., 2012, 819281, 2012.
[5] T. Oya and T. Ogino, Carbon, vol. 46, no. 1, p.169, 2008.