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CMOS IC Design of Current Output-Type Hardware Neural Networks for MEMS Microrobot

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Abstract: This paper presents the 3.75 mm square size CMOS integrated circuit (IC) chip design of the current output-type hardware neural networks (HNN) which is a locomotion generator of the micro electro mechanical systems (MEMS) microrobot. The actuator of the microrobot is artificial muscle wires which contracts by supplying the electrical current. Previously, we constructed the voltage output-type HNN CMOS IC chip. The constructed IC chip could control the locomotion of the microrobot. However, constructed IC chip needs peripheral circuit outside of the IC chip to drive the actuator because of conversion from voltage to current. In this paper, we propose the current output-type HNN CMOS IC chip which can output the driving waveform directly.

1. Introduction

In general, computer programming by micro controller is used for motion control of a robot. However, the robot control by computer programming is difficult to perform the advanced autonomous control. On the other hand, insects or animals perform autonomous control using brain. Therefore, artificial neural networks control is advantageous than computer program control because artificial neural networks can implement the excellent functions of brain. Especially, insects realize advanced autonomous control by compact systems. Thus, we are studying about the microrobot which can mimic insect. In addition, microrobots have been studied and developed in various fields such as medical field, precise manipulation, and so on. Using the microrobot system in those fields, microrobot is required further miniaturization and functionalization. For this reason, MEMS technology based on the IC production lines has been studied for making the simple components of the microrobot[1].

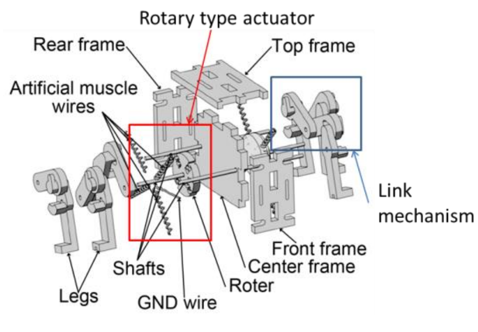

Figure 1. Components of the MEMS microrobot.

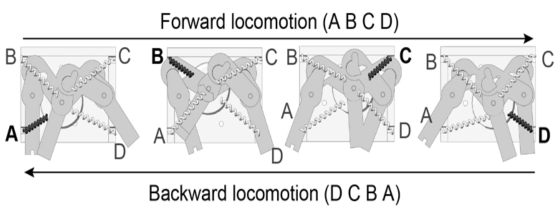

Figure 2. Schematic diagram of locomotion.

We are studying about HNN which can generate the locomotion of the MEMS microrobot. Previously, we constructed the voltage output-type HNN CMOS IC chip which could control the locomotion of the microrobot[2]. However, constructed IC chip needs peripheral circuit outside of the IC chip to drive the actuator because of conversion from voltage to current. Therefore we consider about reducing the circuit size by current output to contract the artificial muscle wire.

In this paper, we propose the current output-type HNN CMOS IC chip design which can output the driving waveform of the MEMS microrobot without using the peripheral circuit.

2. MEMS Microrobot

Figure 1 shows the components of the MEMS microrobot. The size of the microrobot is 4.0mm × 2.7mm × 2.5mm, width, length, height size. The frame components, the link mechanism and the rotary type actuator are made from silicon wafer which is micro processed by the MEMS technology. The rotary type actuator consisted of a rotor, GND wire, shaft and 4 pieces of helical artificial muscle wires.

Figure 2 shows the schematic diagram of locomotion of MEMS microrobot. Through contracting 4 pieces of helical artificial muscle wires by current, the MEMS microrobot can generate the locomotion. The wires shrink at high temperature by the current flowing, and extend at low temperature by stopping the current flowing.

3. Current Output-Type Hardware Neural Networks

Figure 3 shows the circuit diagrams of the basic components of HNN. The basic components of HNN consists of a cell body

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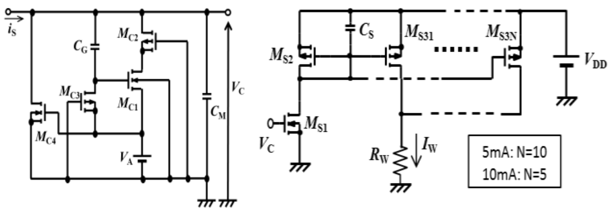
model and a synaptic model. The circuit diagram of cell body model is shown in figure 3 (a). Cell body model has the same basic features of biological neurons such as threshold, refractory period, and enables the generation of continuous action potentials. The circuit parameters of the cell body model were as follows: C_G=20pF, C_M=1pF, M_{C1}, M_{C2}: W/L=10, M_{C3}: W/L=0.1, M_{C4}: W/L=0.3. The voltage source V_A= 2.8V. The circuit diagram of synaptic model is shown in figure 3 (b). Synaptic model receives the output voltage from the cell body model, and output the current to the artificial muscle wires of microrobot. In this study, we designed MOSFETs of the synaptic model to flow the output current I_W=50mA (The resistance of the artificial muscle wire is R_W=10Ω.). In addition, the output current from single pad of CMOS IC were designed two types such as 5mA and 10mA, respectively. The circuit parameters of synaptic model were as follows: C_S=1pF, M_{S1}: W/L=20, M_{S2}: W/L=2, $M_{S31\text{-}S3N}$: W/L=45 (5mA), 83 (10mA). The voltage source V_{DD}=3.8V.

Figure 4 shows the example of output waveform of the IC chip. The blue line is a waveform of the output voltage from a cell body model, the red and green lines are waveforms of the output current of the synaptic model (red: 5mA, green: 10mA). Output current I_W is obtained about 50mA in both cases. The output waveform was calculated by using HSPICE (circuit simulator).

Figure 5 shows the example of layout pattern of the CMOS IC chip. This IC chip was made by Phenitec Semiconductor Corporation CMOS 0.6μm design rule. The layout size of each MOSFETs were as follows: M_{C1}, M_{C2}: W/L=50μm/5μm, M_{C3}:



(a) Cell body model.　　(b) Synaptic model.

Figure 3. The circuit diagrams of the basic components of HNN.

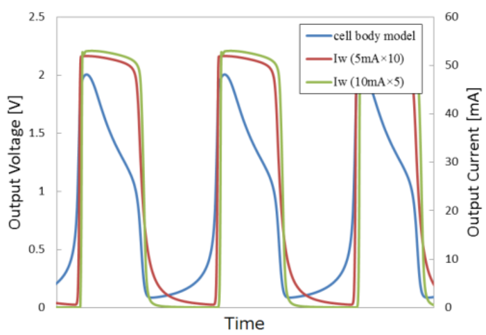


Figure 4. Example of output waveform of the IC chip.

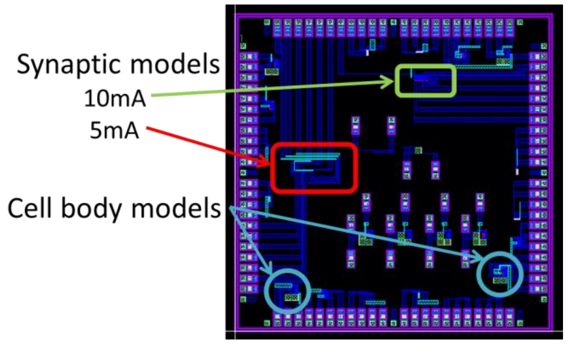


Figure 5. Example of layout pattern of the CMOS IC chip.

W/L=6μm/60μm, M_{C4}: W/L=3μm/10μm, M_{S1}: W/L=12μm/0.6μm, M_{S2}: W/L=1.2μm/0.6μm, $M_{S31\text{-}S3N}$: W/L=27μm/0.6μm (5mA), 50μm/0.6μm (10mA). The layout size of each capacitor is as follows: C_G=124μm width, 62μm length. C_M, C_S=20μm width, 20μm length. The layout size of each MOSFETs and capacitors satisfies the design rule.

4. Conclusions

In this paper, we proposed the current output-type HNN CMOS IC chip design which can output the driving waveform of the MEMS microrobot without using the peripheral circuit. As a result, we developed the CMOS IC chip design which could output a driving current to actuate the artificial muscle wire. The result was calculated by using circuit simulator HSPICE. In the future, we will mount the CMOS IC bare chip to MEMS microrobot directly.

5. Acknowledgments

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6. References

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