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Development of Hexapod-Type MEMS Micro-robot with Mounted Bare Chip IC

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Abstract: This paper reports mechanisms and a control system of millimeter size micro-robot. The micro-robot is fabricated by a micro electro mechanical systems (MEMS) technology. The micro-robot has hexapod and link mechanism that mimics an insect. The motion is generated by the actuator that uses artificial muscle wires. Control system is composed if an artificial neural networks integrated circuit (ANNIC) and driving circuit. This system is miniaturized by using a chip-on-board process. The sideways, endways, and height dimensions of the hexapod-type MEMS micro-robot are 4.0 mm, 2.7 mm and 2.5 mm, respectively. The sizes of the control system are 9.4mm, 7.5mm and 2.5mm, respectively.

１． Introduction

Researches of the micro-robot are actively done with the development of micro-fabrication technology. Most researched micro-robots are manufactured by micro electro mechanical systems (MEMS) technology[1]. Also, the control systems that can respond to various conditions like insect are required. Therefore, an artificial neural networks (ANNs) that mimics the living organisms has been focused as a means of realizing the active control and flexible control. The ANNs are implemented by software approaches and hardware approaches. For the micro-robot, the hardware approach is advantageous because it can realize continuous process and nonlinear at high speed[2]. Moreover, the micro-robot is required a non-wire system for move freely.

In this paper, we produced the micro-robot with mounted control systems. The structure is constructed by miniature components and actuator is use an artificial muscle wire based on shape memory alloy. The control system using pulse-type hardware neural networks (P-HNN) and this circuit is built on integrated circuit (IC). Then, micro-robot mounted control system is realized.

２． System of Micro-Robot

Figure 1 shows a diagram of the micro-robot. The micro-robot dimensions are 4.0 mm, 2.7 mm, 2.5mm in the sideways, endways and height directions. The components of the micro-robot are fabricated by MEMS technology, and artificial muscle wire is used for the actuator. Artificial muscle wire shrinks at high temperature and extends at low temperature. Four artificial muscle wires are stretched on four directions between the rotor and the frames. An electric current supply in rotational order to the artificial muscle wire of four line. and Joule heat is generated in the wire. Therefore, the wire shrinks and extends in rotational order, actuator is rotated in a clockwise direction. Front and hind legs are moved in the counter direction relative to the center leg which is connected to the rotary actuator by a link mechanism. Walking pattern and structure of the micro-robot is emulating the insect.

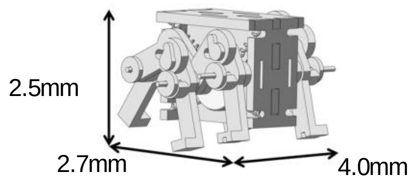

Figure 1. Mechanism of the designed micro-robot

３． Artificial Neural Networks Integrated Circuit

Figure 2 shows the circuit diagram of the ANNIC. The motion control of the micro-robot is realized by using the cell body model and the inhibitory synaptic model.

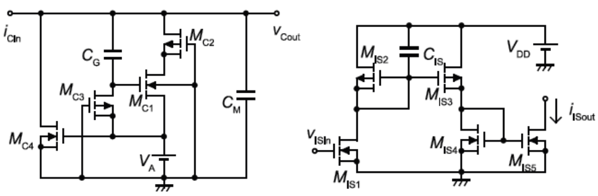

Figure 2.Circuit diagram of the ANNIC.

The cell body model and the inhibitory synaptic model have the same basic features of biological neurons such as threshold, refractory period, spatio-temporal summation characteristics, and enables the generation of continuous action potentials. Artificial neural networks (ANNs) are prepared based on Central Pattern Generator (CPG). CPG is performing rhythmic movements like walking organism. Figure 3 shows the schematic diagram of the CPG. ANNIC is constructed to combine the inhibitory 12 synaptic model

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and 4 neuron model. Output is four ports.

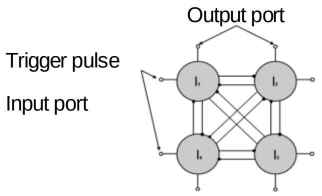

Figure 3.Connection diagram of CPG

４． Control system

Figure 4 shows the ANNIC bare chip and peripheral circuits. Barechip IC of the ANNs is used for the miniaturization of the control system. ANNIC bare chip was wire bonded to pad pattern of the peripheral circuits using ultrasonic wire bonding technology. The peripheral circuit has a two-layer structure. The sideways, and endways dimensions of the top layer were 7.5 mm, 9.4 mm. And bottom layer were 7.5 mm, 6.9 mm.

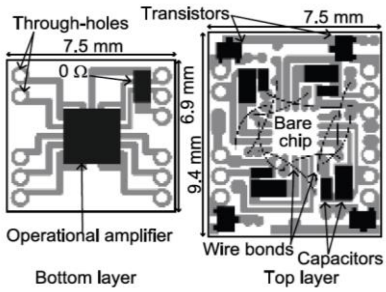

Figure 4: ANNIC with peripheral circuit.

５． Result

Figure 5 shows the mechanical system of the micro-robot. The mechanical system weight is 0.02g. The dimensional error of the parts of micro-robot was measured by an optical con-focal microscope. The dimensional error was found to be always within ±5μm. Dimensional errors were extent that does not affect the fabrication of micro-robot. Figure 6 shows the driving waveform that generated by ANNIC bare chip and peripheral circuits. Weight of the control system was 0.31g. ANNIC bare chip was able to output a drive waveform required for operation of the micro-robot using artificial muscle wire. Then, hexapod-type MEMS micro-robot was able to foot step motion. Step width of the micro-robot was 0.88 mm.

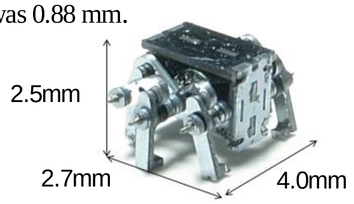

Figure 5 Mechanical system of the micro-robot.

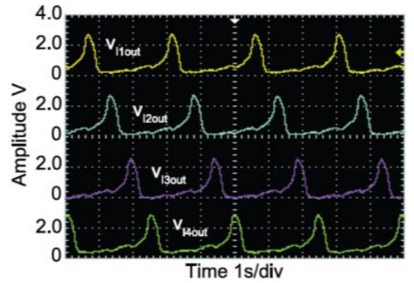

Figure 6.Driving waveform generated by ANNIC and peripheral circuits

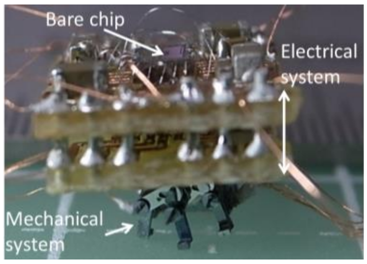

Figure 7. Complete system of the hexapod-type MEMS micro-robot system.

Figure 7 shows the micro-robot system was completed. Weight of all systems was 0.33g. The future, miniaturization of the peripheral circuits is required in order to walk the micro robot.

５． Conclusions.

This paper proposed for the hexapod-type MEMS micro-robot mount on ANNIC bare chip was achieved. Then, hexapod-type MEMS micro-robot was able to foot step motion. Step width of the micro-robot was 0.88 mm.

Acknowledgments

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