Hexapod-Type Microrobot System with Artificial Neural Networks Integrated Circuit

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World Smallest!!

Hexapod-Type Microrobot System
(MEMS Microrobot)

4.0mm x 2.7mm x 2.5 mm in size

I. My Research History

The B.S. degree, the M.S. degree and the Ph.D. Electronic Engineering. (Analog Electric Circuits)

Discrete circuit. CMOS IC design.

Keywords:
Pulse-type hardware neuron model
Pulse-type hardware neural networks

I. My Research History

Research Assistant
Integrated Sciences in Physics and Biology (Biology)

Electrode.

I. My Research History

Research Assistant
Precision Machinery Engineering
Assistant Professor
Precision Machinery Engineering

Flying type Walking type Swimming type

MEMS microrobots.

I. My Research History

MEMS microrobot system.

I. My Research Facilities

Key technology of my research.
Micro fabrication technology (Micro Mechanical Systems) —fabricate the small size body of the robot
Analog CMOS IC technology (Micro Electro Systems) —construct the small size brain of the robot

MEMS: Micro Electro Mechanical Systems
Both technology are made by silicon wafer.
I. My Research Facilities

**Micro fabrication technology**

Research Center for Micro Functional Devices, Nihon University.

II. Introduction

**Microrobots for several applications**

- Medical field: M. NOKATA, Ritsumeikan Univ.
- Precise manipulations: O. Fujikawa, Yokohama National Univ.
- Blood clot: Inside the blood vessel
- Blood vessel of human: 18–30 mm; Capillaries: 8–20 μm

**Definition of the robot**

1. Sensor
2. Control (Intelligence)
3. Actuator

Insects is amazing! → Biomimetics

II. Introduction

**Analog CMOS IC technology**

We don’t have a foundry. Collaborating with foundry.

1. VLSI Design and Education Center(VDEC), the University of Tokyo
   - On-Semiconductor-SANYO Semiconductor Corporation (0.8μm)
     - USD:1,000
   - Phenitec Semiconductor Corporation (0.6μm)
     - USD:6,100

2. Digen Technology Inc.
   - X-FAB (0.35μm)
     - USD:4,300

**I. My Research Facilities**

**Micro fabrication technology**

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**II. Introduction**

- **Further miniaturizations**
  - Mechanical machining and assemblies
  - Micro fabrication technology based on the IC production lines

- **Higher functionalizations**
  - Programmed control by a microcontroller
  - Dominant system among the robot control
  - Insects realizes the excellent functions by simple system.
  - Active neural networks control

**II. Introduction**

We are studying about millimeter size micro robot system which can control the locomotion by active artificial neural networks.

- MEMS micro robot using PZT actuator (Piezoelectric Zirconate Titanate)
- MEMS micro robot using SMA actuator (shape memory alloy)
I will show the 4.0 × 2.7 × 2.5 mm size micro robot system with a small size SMA actuator and analog hardware neural networks locomotion control.

In this presentation

III. MEMS Micro Robot

A. Basic Components

B. Locomotion Mechanisms

2 s to finish the 1 cycle locomotion.

III. MEMS Micro Robot

A. Basic Components

Artificial muscle wire

Heat

Cool

Shape Memory Alloy

Heat

Cool

Buck to original crystal orientation

Cool

Could not buck to original crystal orientation

Crystal orientation are random

Backward locomotion (D C B A)

III. MEMS Micro Robot

B. Locomotion Mechanisms

2 s to finish the 1 cycle locomotion.

IV. Analog Hardware Neural Networks

A. Pulse-Type Hardware Neuron Model

Circuit parameters

Class II neuron

- HH model
- BVP model

The voltage source \( V_{in} = 3.3 \, \text{V} \)
IV. Analog Hardware Neural Networks

A. Pulse-Type Hardware Neuron Model

Fig. 5. Circuit diagram of synaptic model.

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<th>Circuit parameters</th>
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<td>$C_{23}=C_{34}=C_{41}=1,\text{pF}$,</td>
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<tr>
<td>$M_{11}=15$, $M_{12}=16$, $M_{21}=15$, $M_{22}=16$, $V=1$, $I=1$.</td>
</tr>
<tr>
<td>The voltage source $V_{	ext{syn}}=5,\text{V}$.</td>
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B. Synchronization phenomenon

Cell body model

(a) Excitatory mutual coupling.

(b) Inhibitory mutual coupling.

Fig. 6. Synchronization phenomena of P-HNN.

C. Circuit Architecture of AHNN

Fig. 7. Connection diagram of AHNN.

D. Measurement results of the IC Chip

(a) $V_{	ext{G}=0}\,\text{V}$

(b) $V_{	ext{G}=3}\,\text{V}$

Fig. 9. Output waveform of the IC chip.

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<th>Circuit parameters</th>
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<tr>
<td>$C_{1}=10,\text{pF}$, $C_{2}=2,\text{pF}$, $M_{1}=15$, $M_{2}=16$, $V=10$, $I=0.1$.</td>
</tr>
</tbody>
</table>
| The voltage source $V_{	ext{G}=2}\,\text{V}$.
| $C_{3}=C_{4}=1\,\text{pF}$, $M_{11}=15$, $M_{21}=16$, $M_{22}=15$, $M_{12}=16$, $V=1$, $I=0.3$. |
| The voltage source $V_{	ext{G}=3}\,\text{V}$. |

E. Locomotion of MEMS Micro Robot

Fig. 10. Locomotion of the MEMS micro robot.

Size: $4.0 \times 2.7 \times 2.5\,\text{mm}$

Locomotion speed: 26.4 (mm/min)

Step width: 0.88 (mm)
We construct the TEG of current output-type artificial neural networks IC bare chip for the purpose of further miniaturizations.

V. Measurements and results

Electrical system: 0.31 g
Microrobot: 0.02 g

We showed the 4.0 × 2.7 × 2.5 mm size micro robot system with a small size SMA actuator and analog hardware neural networks locomotion control.

As a result, we developed the following conclusions.

(a) 4.0 × 2.7 × 2.5 mm size micro robot could fabricated by MEMS technology.
(b) The IC chip of P-HNN could output the driving waveform which is necessary to actuate the MEMS micro robot.
The parts of piezoelectric element impact-type MEMS microrobot were made from Si wafer by microfabrication technology.

Walking mechanism
- 6 legs are arranged on the either side, and these connected by the link mechanism.
- The rotor is connected to the link mechanism through the shaft.

Walking motion
- Impact head hits rotor and generates rotary motion.
- Low power consumption is achieved by using the multilayer ceramic piezoelectric element.

Thanks for your attention!