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Pulse-type hardware neural networks circuit for PWM servo motor control

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Abstract: This paper presents the pulse-type hardware neural networks circuit (P-HNNC) which could control pulse width modulation (PWM) servo motor of robots. Basic components of P-HNNC were pulse-type hardware neuron model (P-HNM). P-HNM generated oscillatory patterns of electrical activity such as living organisms. Basic components of the P-HNM corresponding to the cell body circuit, the axon circuit and the synaptic circuit. P-HNM had the same basic features of biological neurons such as threshold, refractory period, spatio-temporal summation characteristics and enabled the generation of continuous action potentials. P-HNM was constructed by MOSFETs without any inductors could be integrated by CMOS technology. As a result, we showed that P-HNNC could control the PWM servo motor from 0 to 180 degrees. Same as the living organisms, P-HNNC realized the control of PWM servo motor without using any software programs, or A/D converters.

Keywords: Pulse-type Hardware Neuron Model, Neural Networks, Servo Motor, Humanoid Robot.

1 INTRODUCTION

Programmed control by a microcomputer has been the dominant system among the robot control. However, some advanced studies of artificial neural networks have been paid attention for applying to the robot control. A lot of studies have reported both on software models and hardware models [1-3]. For example, oscillatory patterns of artificial neural networks have been used to operate movement of the robot. Oscillatory patterns of electrical activity are ubiquitous feature in nervous systems. Living organisms use several oscillatory patterns to operate movement, such as swallowing, heart rhythms, and so on [4]. To clarify oscillatory patterns, coupled neural oscillators are paid attention. Synchronization phenomena or bifurcation phenomena of coupled neural oscillators have been studied using the Hodgkin-Huxley model or the Bonhoeffer-van der Pol model. Therefore, the synchronization phenomenon of the coupled neural oscillators using mathematical neuron models has proposed for generating the oscillatory patterns of living organisms [5-7]. However, using the mathematical neuron models in large scale neural networks is difficult to process in continuous time because the computer simulation has been limited by the computer performance, such as the processing speed and memory capacity. In contrast, using the hardware neuron model is advantageous because even if a circuit scale becomes large, the nonlinear operation can perform at high speed and process in continuous time. Therefore, the construction of a hardware model that can generate oscillatory patterns is desired. The hardware ring coupled oscillators have already been studied as a system which can demonstrate the various oscillatory patterns and the synchronization phenomenon [8, 9]. The neural networks need various oscillatory patterns. For this reason, the ring coupled oscillators is expected to be a structural element of the cellular neural networks. However, most of the hardware models contain the inductor in circuit architecture [8-11]. If the system contains the inductor on the circuit system, it is difficult to implement the system to a CMOS IC chip.

We are studying about implementation of hardware neural networks controlling system to robot system. Previously, we proposed the pulse-type hardware neural networks which could generate the locomotion patterns to actuate the micro robot [12].

This paper presents the pulse-type hardware neural networks circuit (P-HNNC) which can control pulse width modulation (PWM) servo motor of robots. P-HNNC generates oscillatory patterns of electrical activity such as living organisms. P-HNNC is constructed by MOSFETs without inductor can be integrated by CMOS technology.

2 PWM SERVO MOTOR

Fig. 1. shows the example of pulse waveform to actuate the PWM servo motor. It is necessary to output the pulse waveform to control the servo motor.

Table 1. shows the pulse specifications of servo motor. The specifications were measured the control signal by oscilloscope.

It is shown that if the P-HNNC can output the waveform

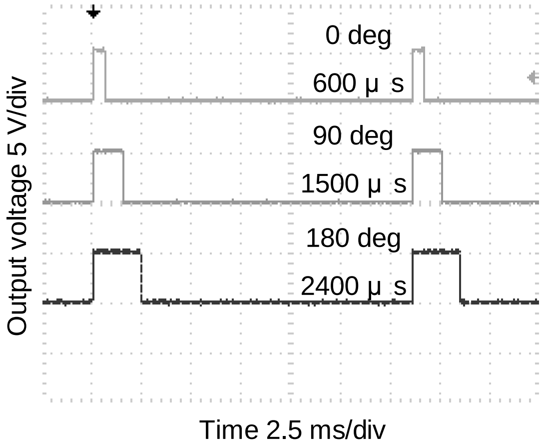

Fig. 1. Pulse waveform to actuate the servo motor

Table 1. Pulse specifications of servo motor (Hitec Multiplex Japan HSR-8498HB)

Pulse period	16040 μs
peak-to-peak voltage	5.04 V
motion range	0 to 180 degree
increase of pulse width per degree	10 μs
minimum pulse width (0 degree)	600 μs
maximum pulse width (180 degree)	2400 μs

such as shown in **Fig. 2.** satisfying the specifications of **Table 1.** the PWM servo motor can be control.

3 PULSE-TYPE HARDWARE NEURAL NETWORKS CIRCUIT

P-HNMs were used for the basic elements of the P-HNNC. P-HNMs consisted of a cell body model, synaptic model and axon model.

3.1 Neural networks

Fig. 2. shows the schematic diagram of P-HNNC. In the figure, C indicates cell body model, A indicates axon model and synapse indicates synaptic model. The cell body model were connected cascade, where *n* ($1 \leq n \leq 24$) was number of cell body model. In addition, the axon model were connected cascade, where *m* ($1 \leq m \leq 136$) was number of axon model. The cell body model and axon model were connected cascade such as ring neural networks. In the case of inputting the single external trigger pulse to C_1, the pulse propagated the ring neural networks with delay. If the delay of cell body model and axon model could set as 100 ms/number, 24 cell body model and 136 axon model could realize the pulse period (16040 μs) of PWM servo motor. In addition, *n*-th cell body model was connected to synaptic model. The synaptic model outputted the pulse waveform

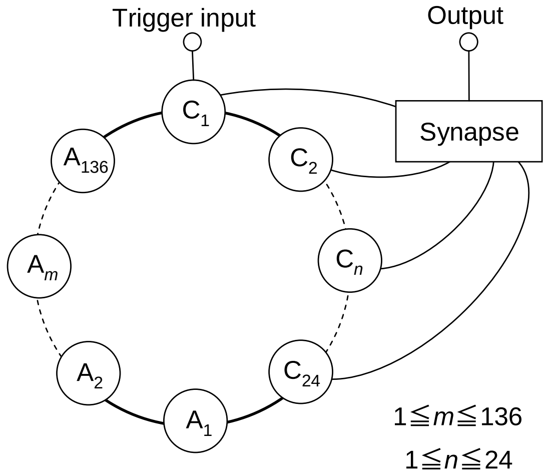

Fig. 2. Schematic diagram of pulse-type hardware neural networks circuit

which could control the PWM servo motor. The pulse width could vary from 600 μs to 2400 μs by switching the synaptic weights (1 or 0).

3.2. Pulse-type hardware neuron model

Fig. 3. shows the circuit diagram of *n*-th ($1 \leq n \leq 24$) stage of cell body model. The cell body model consisted of a voltage control type negative resistance and an equivalent inductance, membrane capacitor C_{Mn}. The voltage control type negative resistance circuit with equivalent inductance consisted of n-channel enchantment-mode MOSFET M_{C1n}, p-channel enchantment-mode MOSFET M_{C2n}, and voltage source V_A, resistors R_{Mn}, R_{Gn}, and a capacitor C_{Gn}. The cell body model had the negative resistance property which changed with time like a biological neuron, and enabled the generation of a continuous action potential v_{Cn} by a self-excited oscillation and a separately-excited oscillation. Moreover, the cell body model could switch between both oscillations by changing V_A. The separately-excited oscillation occurred by direct-current voltage stimulus or pulse train stimulus. The circuit parameters of cell body model were as follows: C_{Mn}=1.8 nF, C_{Gn}=0.8 nF, R_{Mn}=10 kΩ, R_{Gn}=390 kΩ, R_{an}=20 kΩ, R_{bn}=15 kΩ, $M_{C3n}, M_{C4n}, M_{C5n}$: W/L=1. The voltage source were V_A=3.3 V, V_{DD}=5 V. The input current of *n*-th stage of cell body model was i_{cn-1} which was the output of (*n*-1)-th stage of cell body model. The output voltage *n*-th stage of cell body model was v_{cn}

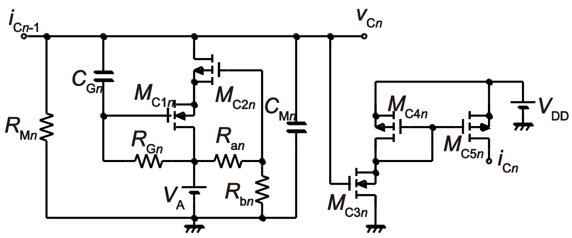

Fig. 3. Circuit diagram of cell body model

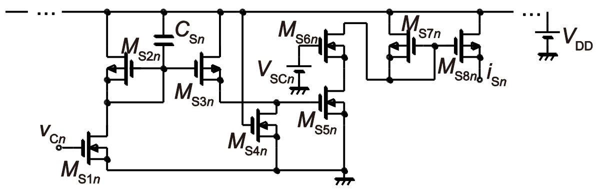

Fig. 4. Circuit diagram of synaptic model

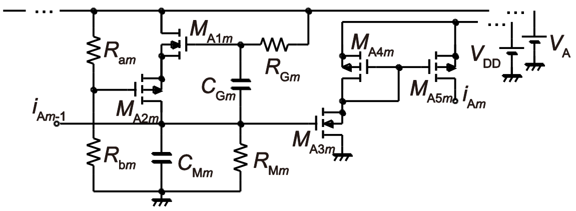

Fig. 5. Circuit diagram of axon model

which was the input voltage of synaptic model.

Fig. 4. shows the circuit diagram of n-th ($1 \leq n \leq 24$) stage of synaptic model. The synaptic model spatio-temporal summated the outputs of cell body models according with synaptic weights. Synaptic weights were controlled by the voltage source V_{SCn}. In this paper, the synaptic weights were set as 1 or 0. The circuit parameters of synaptic model were as follows: C_{Sn}=1 pF, M_{S1n}:W/L=3, M_{S2n}, M_{S3n}, M_{S7n}, M_{S8n}:W/L=1, M_{S4n}:W/L=0.25, M_{S5n}:W/L=5, M_{S6n}:W/L=0.2. The voltage source was V_{DD}=5 V.

Fig. 5. shows the circuit diagram of m-th ($1 \leq m \leq 136$) stage of axon model. The axon models were connected cascade. The axon model was active distributed constant line which had the threshold function and waveform shaping function. The input current of m-th stage of axon model was i_{Am-1} which was the output of (m-1)-th stage of axon model. The circuit parameters of axon model were as follows: C_{Mm}=1.8 nF, C_{Gm}=0.8 nF, R_{Mm}=10 kΩ, R_{Gm}=390 kΩ, R_{am}=20 kΩ, R_{bm}=15 kΩ, M_{A3m}, M_{A4m}, M_{A5m}: W/L=1. The voltage sources were V_A=3.3 V, V_{DD}=5 V.

Fig. 6. shows the example of output waveform of P-HNNC. The simulation results of output waveform were given by PSpice. In the figure, angles of the PWN servo motor were 0, 90, 180 degree where pulse period was 630, 1490, 2390 μs, respectively. The output waveform was generated by waveform generator inputting the output waveform given by PSpice. It is shown that P-HNNC can output the waveform to actuate the PWM servo motor such as **Fig. 1.**

Fig. 7. shows number of neurons vs. pulse width and angle of servo motor. In the figure, solid circles indicate the pulse width, open circles indicate angle of servo motor and solid line indicates the theoretical line. This figure shows

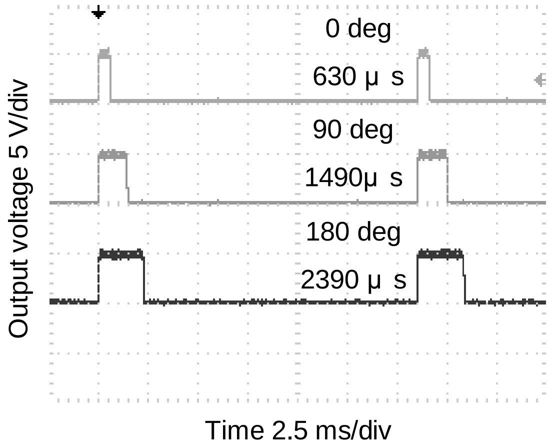

Fig. 6. Example of output waveform of P-HNNC

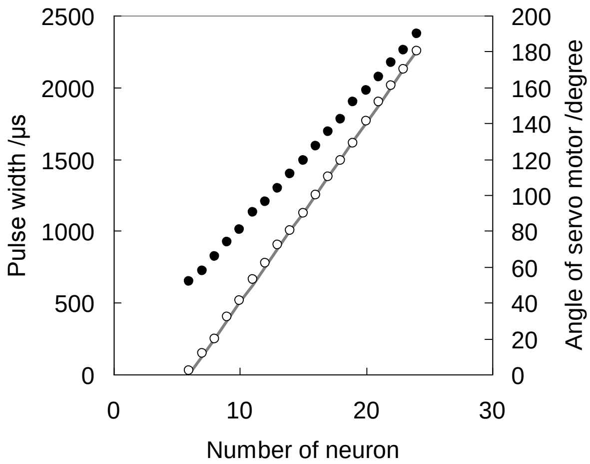

Fig. 7. Number of neuron vs. pulse width and angle of servo motor

that our P-HNNC can change the pulse width of output waveform by changing the number of neurons and controlled the PWM servo motor.

4 CONCLUSION

In this paper, we proposed pulse-type hardware neural networks circuit which could control pulse width modulation servo motor of robots. As a result, we showed that pulse-type hardware neural networks circuit could control the PWM servo motor. P-HNNC realized the PWM servo motor control without using any software programs, or A/D converters.

In the future, we will integrate pulse-type hardware neural networks circuit to the humanoid robot.

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