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Simple Analog-Digital Circuit for Motion Detection and Its Application to Target Tracking System

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***Abstract*:** We proposed in this study an analog-digital circuit for detecting the motion of the object. The proposed unit circuit is simple structure since the digital part of the proposed circuit is only constructed with one NOT circuit and one NOR circuit. The proposed circuit was simulated with the simulation program with integrated circuit emphasis(SPICE). The simulation results showed that the proposed circuit can operate normally. The test circuit was fabricated on the breadboard. The measured results of the fabricated test circuit showed that the proposed circuit can output the pulsed voltage (motion signal) when the object moves on the circuit. We proposed in this study the system for tracking the target. Since the array of the proposed analog-digital circuit was introduced at the first stage of the system, the circuit for tracking the target became simple structure. It was clarified from the measured results of the fabricated test system and the simulation results that the proposed system and the simulation results can track the target and capture the target on the center of the input part.

Keywords: analog circuit, digital circuit, motion detection, target tracking, vision chip

I. INTRODUCTION

It is necessary for the monitoring system, robotics vision and other systems to perform the high speed image processing. However, it is difficult for typical image processing system using Neumann-type computer to realize the high speed image processing. On the other hand, the biological vision system can perform the high speed processing since the nerve cells in the vision system perform information processing in parallel.

Analog complementary metal oxide semiconductor (CMOS) circuits for motion detection were proposed based on the biological vision system [1]-[8]. These circuits are characterized by the high speed processing, low power consumption and simple structure. Researchers tried to use these circuits as the input part of the target tracking system [6]-[8]. However, these circuits have a problem of incorrect operation by device mismatches due to use the analog technology. Thus, it is difficult to use these analog circuits to the application systems such as the target tracking system.

Digital circuits for motion detection were proposed based on the biological vision system [2]. These circuits do not have a problem of incorrect operation. However, the circuit by using digital technology has the problem of the complex structure. If the simple digital circuit for motion detection is proposed, it is able to use it to various application systems.

In this study, we tried to propose the simple analog-digital circuits for motion detection by mimicking the information processing of the vertebrate retina. Particularly, we tried to realize the simple digital circuit. The simulation results of the proposed circuit with the simulation program with integrated circuit emphasis (SPICE) showed that the proposed circuit can operate normally. The test circuit is fabricated on the breadboard. The measured results of the test circuit showed that the proposed simple circuit can generate the motion signal. The target tracking system was proposed by applying the simple analog-digital circuits. The measured results of the fabricated test system for tracking the target and the simulation results showed that the proposed system can operate normally.

II. MOTHION DETECTION CIRCUIT

The proposed unit circuit for motion detection based on the vertebrate retina in this study is shown in Fig. 1. By arranging the circuits in one- or two-dimensionally, it is able to detect the motion velocity and direction of the object. The circuit is constructed with the analog part and the digital part. The analog circuit detects the object (light) or the edge of the object. The digital circuit generates the motion signal when the object moves on the photodiode PD.

When the object is projected on PD, the current I_p which is proportional to light intensity is generated. The voltage V_{DD}-V_p is proportional to I_p, where V_{DD} is the supply voltage. The constant voltage V_{con1} is set to the circuit. The voltages V_a and V_b are given by the following equation.

$$V_a = V_b \cong \frac{V_{DD} - V_p}{(V_{DD} - V_p) + V_{con1}} V_{DD} \qquad (1)$$

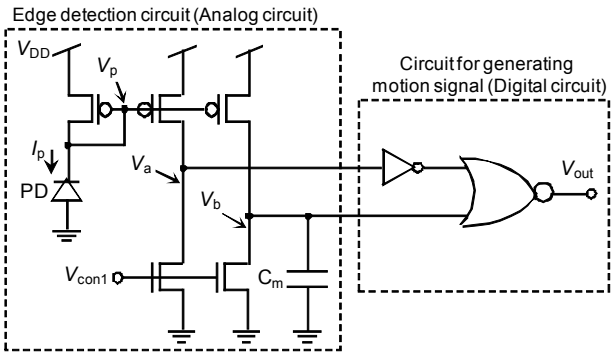

Fig. 1. Unit circuit for motion detection.

Table 1. A Truth table of proposed digital circuit.

V_a	V_b	V_{out}
0	0	0
0	1	0
1	0	1
1	1	0

At first, the object is not projected on PD. In this case, V_a is equal to about 0 since V_{DD}-V_p is smaller than V_{con1}. When the object is projected on PD, V_a becomes about V_{DD} because V_{DD}-V_p is larger than V_{con1}. At the moment that V_a becomes V_{DD}, V_b is 0. After time t_d, V_b becomes V_{DD} since the capacitor C_m is connected at the terminal of V_b.

A truth table of the proposed digital circuit is shown in table 1. When V_a is 0 and V_b is V_{DD}, V_{out} becomes V_{DD}. Therefore, the circuit outputs the pulsed voltage when the object moves on PD. The width of the pulsed voltage is t_d. The pulsed voltage is the motion signal since the voltage is generated when the object moves on PD.

The proposed digital circuit is constructed with a NOT circuit and a NOR circuit. The NOT circuit consists of two metal oxide semiconductor (MOS) transistors. The NOR circuit consists of four MOS transistors. The proposed circuit is simple structure since the circuit consists of only six MOS transistors.

III. Target Tracking System

In this study, we tried to apply the proposed motion detection circuits to the target tracking system. The model for tracking the target is shown in Fig. 2.

At the first stage, the one-dimensional array of the proposed circuits is introduced. When the target moves on the array, the circuits output the motion signals. The output signals input to the integrator.

The integrator of the right side outputs the signal I_{right}. I_{right} becomes large when the target moves to the right side. The integrator of the left side outputs the signal I_{left}. I_{left} becomes large when the target moves to the left side. The circuit in the center generates the signal V_{cent}. V_{cent} is large when the target located on the center of the array.

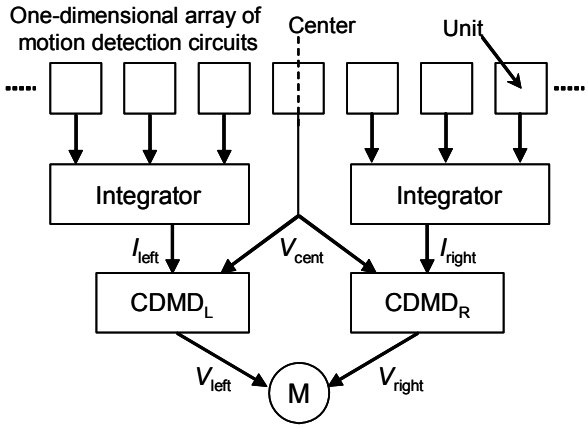

Fig. 2. The model for tracking the target.

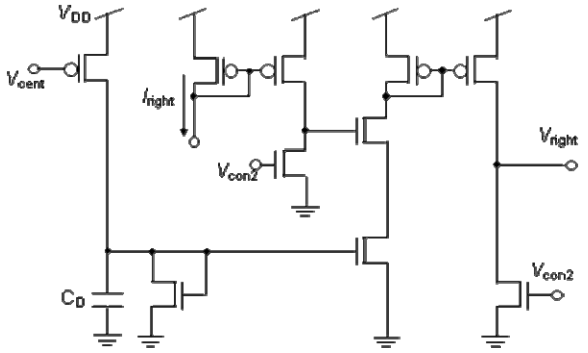

Fig. 3. Circuit for detecting the motion direction ($CDMD_R$).

I_{left} and V_{cent} are input to the circuit for detecting the motion direction ($CDMD_L$). I_{right} and V_{cent} are input to $CDMD_R$. The output signals V_{left} and V_{right} become 0 when the target does not move on the input array. V_{left} becomes about V_{DD} when the target moves toward the left side. V_{right} becomes about V_{DD} when the target moves toward the right side.

The motor M rotates when V_{right} is V_{DD} and V_{left} is 0. Then, the system can track the target toward the right side. The motor rotates inversely when V_{right} is 0 and V_{left} is V_{DD}. Then, the system can track the target toward the left side.

After tracking the target, V_{cent} becomes large when the target is captured on the center of the input array. Then, V_{left} and V_{right} become 0 (reset) by using V_{cent}. When both V_{left} and V_{right} are 0 or V_{DD}, the motor is stopped. Thus, using the model and system, it is able to track the target and capture the target

Figure 3 shows the proposed CDMDR. The circuit is proposed based on the correlation model [9]. The circuit is constructed with nine MOS transistors and 1

capacitor. Thus, the proposed circuit is simple structure.

IV. EXPERIMENTAL RESULTS

1. Motion detection circuit

The proposed circuit for motion detection circuit was simulated with SPICE. Input current I_p was set to 100 nA when the object was projected on PD. C_m was set to 100 nF, The upply voltage V_{DD} was set to 5 V. Figure 4 shows the simulation result of the proposed circuit. I_p was shown in Fig. 4(a). Figure 4(b) shows the transient response of V_{out}. At the moment that the light was projected on PD, V_{out} become 5 V. The circuit output the pulsed voltage. Thus, it was clarified from the simulation results that the proposed circuit can generate the motion signal.

The test circuit of the unit circuit was fabricated on the breadboard. The analog part in Fig. 1 was fabricated by using discrete MOS transistors (nMOS:2SK1398, pMOS:2SJ184). The digital part in Fig. 1 was fabricated by the field programmable gate array (FPGA) (Xilinx, Spartan III). V_{DD} was set to 5 V. V_{con1} was set to 1.6 V. C_m was set to 4.7 μF. Thus, it was clarified that the proposed circuit can generate the signal for rotating the motor of the tracking system.

Figure 5 shows the transient response of V_{out}. At the moment that the light was projected on PD, V_{out} became 5 V. The circuit output the pulsed voltage. Thus, it was clarified from the measured results that the fabricated test circuit can generate the motion signal.

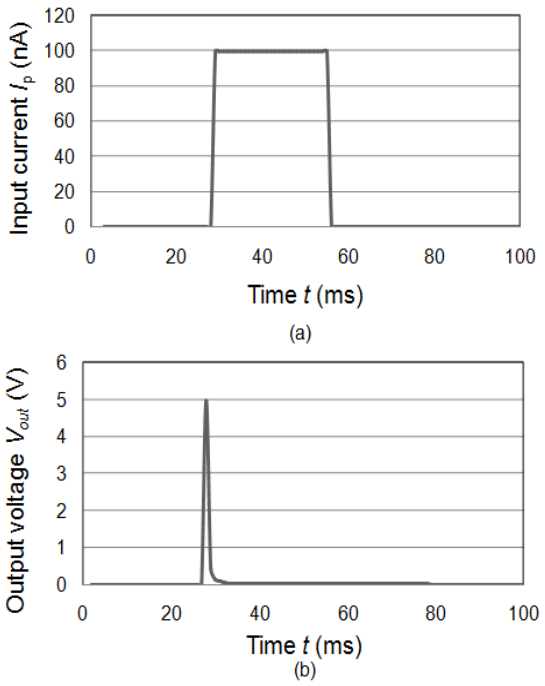

Fig. 4. Simulated results of the proposed circuit. (a) Input current I_p. (b) Transient response of V_{out}.

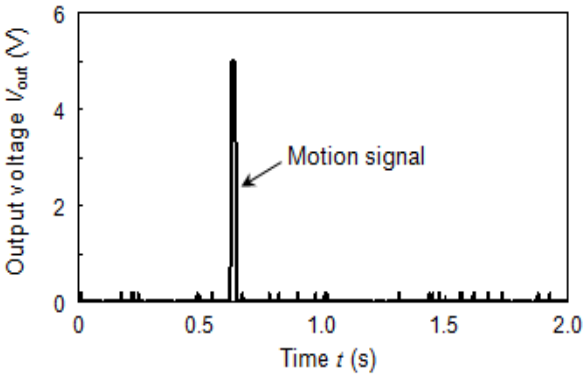

Fig. 5. Measured results of the test circuit.

2. Target tracking system

The proposed circuit for tracking the target based on the model in Fig. 2 was simulated with SPICE. Five unit circuits were utilized to each input part.

C_m was set to 300 nF. V_{DD} was set to 5 V. V_{con1} was set to 3.5 V. V_{cont2} was set to 0.5 V. V_{th} was set to 1.58 V. Figure 6 shows the transient response of V_{right} obtained by SPICE. In this simulation, the object moved toward the right side. V_{right} showed about 4 V when the object moved.

The test system for tracking the target was fabricated based on the model in Fig. 2. The photograph of the fabricated tracking system is shown in Fig. 7. The current I_{left} was generated by PD_L. The current I_{right} was generated by PD_R. The voltage V_{cent} was generated by PD_C.

V_{DD} was set to 5 V. V_{con2} was set to 1.27 V. C_D was set to 100 μF. The light was provided as the object. The motor was controlled by the motor driver (TA7257P, TOSHIBA).

Figure 7 shows the measured results. The light moved toward the right side from t=0 to t=1.2 s. At t=1.2 s, the light was stopped. To t=2 s, the system tracked the target. At t=2 s, the system captured the target on the center of the input array.

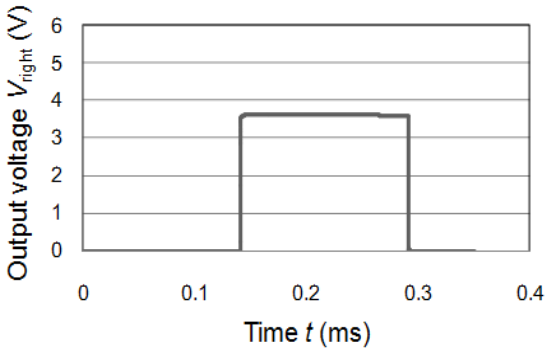

Fig. 6. Simulated results of the proposed circuit transient response of output voltage V_{right}.

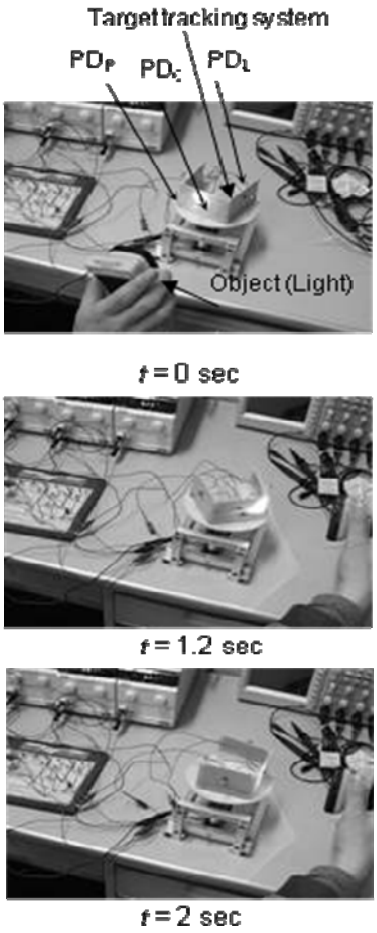

Fig. 7. Measured results of the target tracking system.

V. CONCLUSION

The simple analog-digital circuit for generating the motion signal was proposed in this study. Particularly, the digital part for motion detection is constructed with a NOT circuit and a NOR circuit. The test circuit is fabricated based on simulated results. The measured results and the simulation results showed that the proposed circuit can generate the motion signal. The target tracking system was proposed by using the array of the proposed analog-digital circuit for motion detection. The circuit for tracking the target is simple structure. It was clear from the measured results and the simulation results that the proposed system can track the target and capture the target on the center of the input array. The realization of the advanced image processing system for the robotics vision, the security system and other systems can be expected by applying the proposed circuit and system.

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