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Dual Data Pulse Width Modulator for RFID Biosensor Signal Modulation

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1. Introduction

Recently radio frequency identification (RFID) complementary metal oxide semiconductor (CMOS) biosensor has been reported for biomedical applications. For small, inexpensive, and easy sensing system, the biomedical information (DNA [1], electronic conductivity [2], temperature [1-2], etc) were wirelessly measured by combining RFID and CMOS biosensor. As shown in Fig. 1(a), conventional RFID biosensor adopts analog digital converter (ADC) for analog-to-digital conversion of biosensor signal. However, ADC requires large power consumption for sampling clock. The power consumption can be reduced by applying pulse width modulation (PWM) for sensor signal modulation, because this method requires only low frequency clock. Moreover, digital signal processor (DSP) in reader for demodulation is not necessary because it is analog-to-analog conversion (Fig. 1(b)). In this study, PWM circuit is proposed and demonstrated for RFID biosensor signal modulation. We also propose the dual data PWM circuit that the dual data can be transmitted in a single measurement. Using this circuit, temperature was measured wirelessly.

2. Pulse Width Modulation for RFID Biosensor

Figure 2 shows block diagram of basic PWM circuit that consists of triangle wave generator and operational amplifier (OA). When the direct current (DC) sensor signal V_{in} and triangle wave V_{tri} are entered to the OA, input signals are compared and converted to pulse signal V_{OA}. The low level width of V_{OA} (ΔT_{out}) changes in proportion to the input signal V_{in}. The conventional PWM adopts not OA but comparator. However, comparator needs high frequency clock for high accuracy. In contrast, since OA's settling time is constant and clock is not necessary, the better accuracy and power saving can be obtained.

Evolving the PWM circuit, we propose the dual data PWM that dual analog DC data can be transmitted and identified in a single period of clock. The block diagram of the dual data PWM circuit that consist of OA, triangle wave generator, pulse generator, and exclusive OR (XOR) is shown in Fig. 3. Input signal is determined by clock and the pulse V_{pulse} is generated at the raising edge and falling edge of clock. The OA's output including two sensors value is divided by XOR of V_{pulse} and V_{OA}.

3. Experimental Results

Measurement result of dual data PWM circuit is shown in Fig. 4. When the clock level is high or low, OA's input is switched to V_{in1} or V_{in2}. The lower graph of Fig. 4 shows output signal V_{out} when V_{in1} and V_{in2} are set to 0.5 V and -0.5V, respectively. When the clock is high, only V_{in1} is converted to pulse width value by shifting T_{a} in proportion to V_{in1}. Conversely, T_{b} is shifted in proportion to V_{in2}, when clock is low. In brief, pulse width ΔT_1 and ΔT_2 is changed in proportion to independent signal V_{in1} and V_{in2}, respectively. The pulse width can be distinguished by PULSE. Figure 5 shows the measurement result of (a) ΔT_1 and (b) ΔT_2 when V_{in1} and V_{in2} are swept in the range from -2.4V to 2.2V. In the range of -2.3 ~ 1.5 V, pulse width ΔT_1 and ΔT_2 are changed in proportion to V_{in1} and V_{in2}, respectively. Input range is restricted by headroom of OA's input stage. Measured modulation sensitivities are 131.15 μs/V and 128.05 μs/V, respectively, and this values are determined by the slope of triangle wave. Next, wireless measurement is carried out using dual data PWM and previously reported on-chip spiral inductor tag antenna [3]. The block diagram of wireless measurement circuit with dual data PWM is shown in Fig. 6. Since biosensor's output signal is weak, two instrumentation amplifier are set on the input stage. Measurement result is shown in Fig. 7. When the external input signal CH1 is swept in the range of -0.04 ~ 0.35 V, the change of ΔT_1 is observed as shown in Fig. 7(a). Measured modulation sensitivity (624.99 μs/V) becomes 4.7 times higher than the result of Fig. 5(a). The result of wireless temperature measurement is shown in Fig. 7(b). In the range of 25 ~ 40 °C, measured temperature sensitivity is 13.385 μs/°C. Figure 8 shows the micrograph of dual data PWM circuit fabricated using 1.2 μm standard CMOS process. The chip area and power consumption are 0.36 mm^2 and 650 μW, respectively.

4. Conclusions

The PWM circuit for RFID biosensor signal modulation has been proposed and demonstrated. For integration of two sensor circuits in single RFID tag chip, we have proposed dual data PWM. Measured modulation sensitivity of two inputs were 131.15 μs/V and 128.05 μs/V, respectively. The temperature was wirelessly measured by dual data PWM circuit.

Acknowledgments

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References

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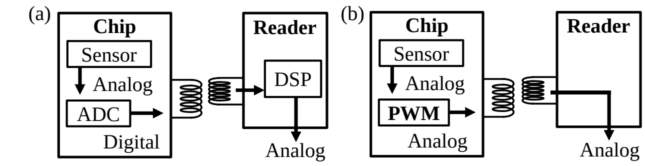

Fig. 1 (a) Block diagram of conventional RFID biosensor. (b) Block diagram of RFID biosensor with PWM.

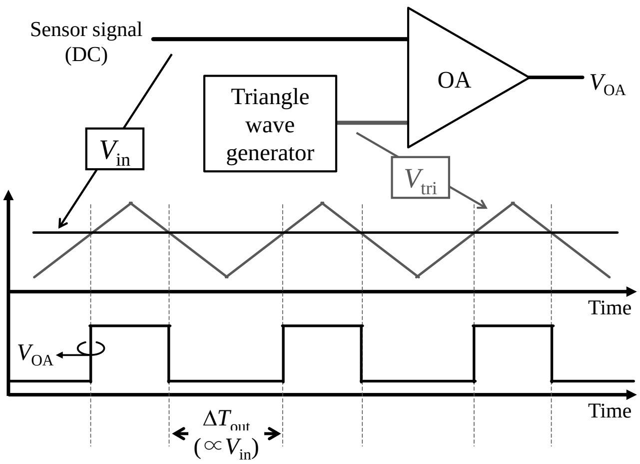

Fig. 2 Basic PWM circuit. The pulse width ΔT_{out} is proportional to input signal V_{in}.

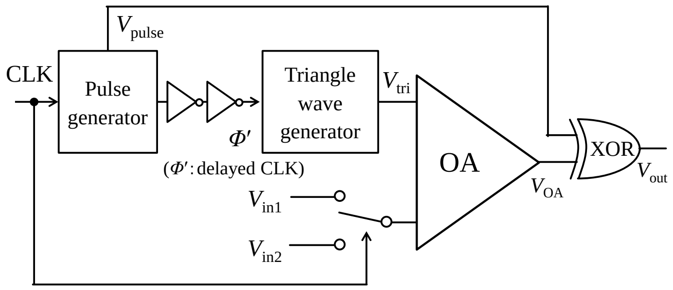

Fig. 3 Block diagram of dual data PWM circuit that consist of pulse generator, triangle wave generator, OA, and XOR.

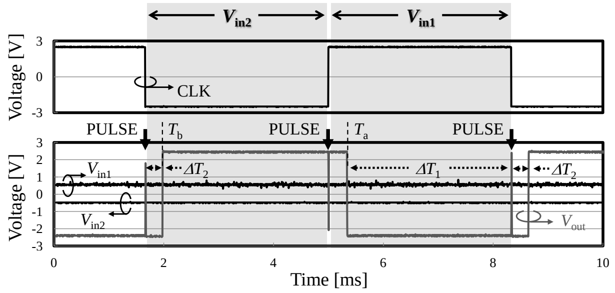

Fig. 4 Measurement result of dual data PWM circuit. The pulse width ΔT_1 and ΔT_2 is changed in proportion to independent signal V_{in1} and V_{in2}, respectively.

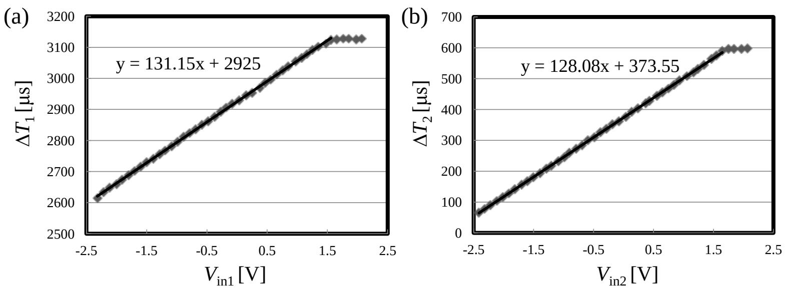

Fig. 5 (a) Measurement result of dual data PWM when V_{in1} and V_{in2} are swept in the range from -2.4V to 2.2V. (a) ΔT_1. (b) ΔT_2.

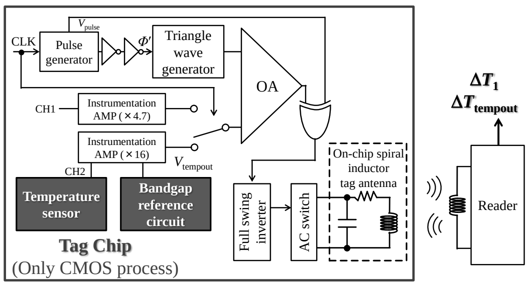

Fig. 6 Block diagram of wireless measurement circuit with dual data PWM.

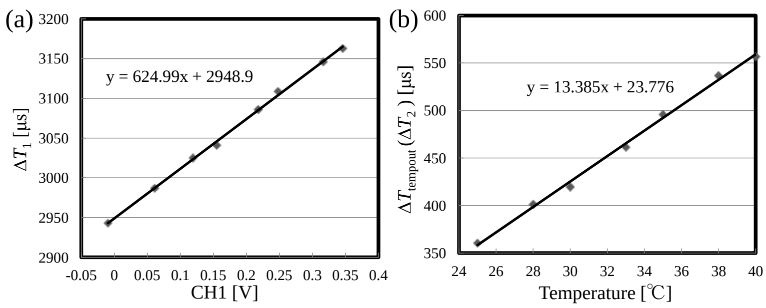

Fig. 7 Wireless measurement using dual data PWM. (a) Result of external input CH1. (b) Result of temperature measurement.

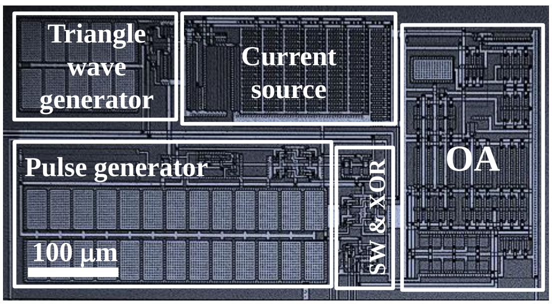

Fig. 8 Micrograph of dual data PWM circuit.