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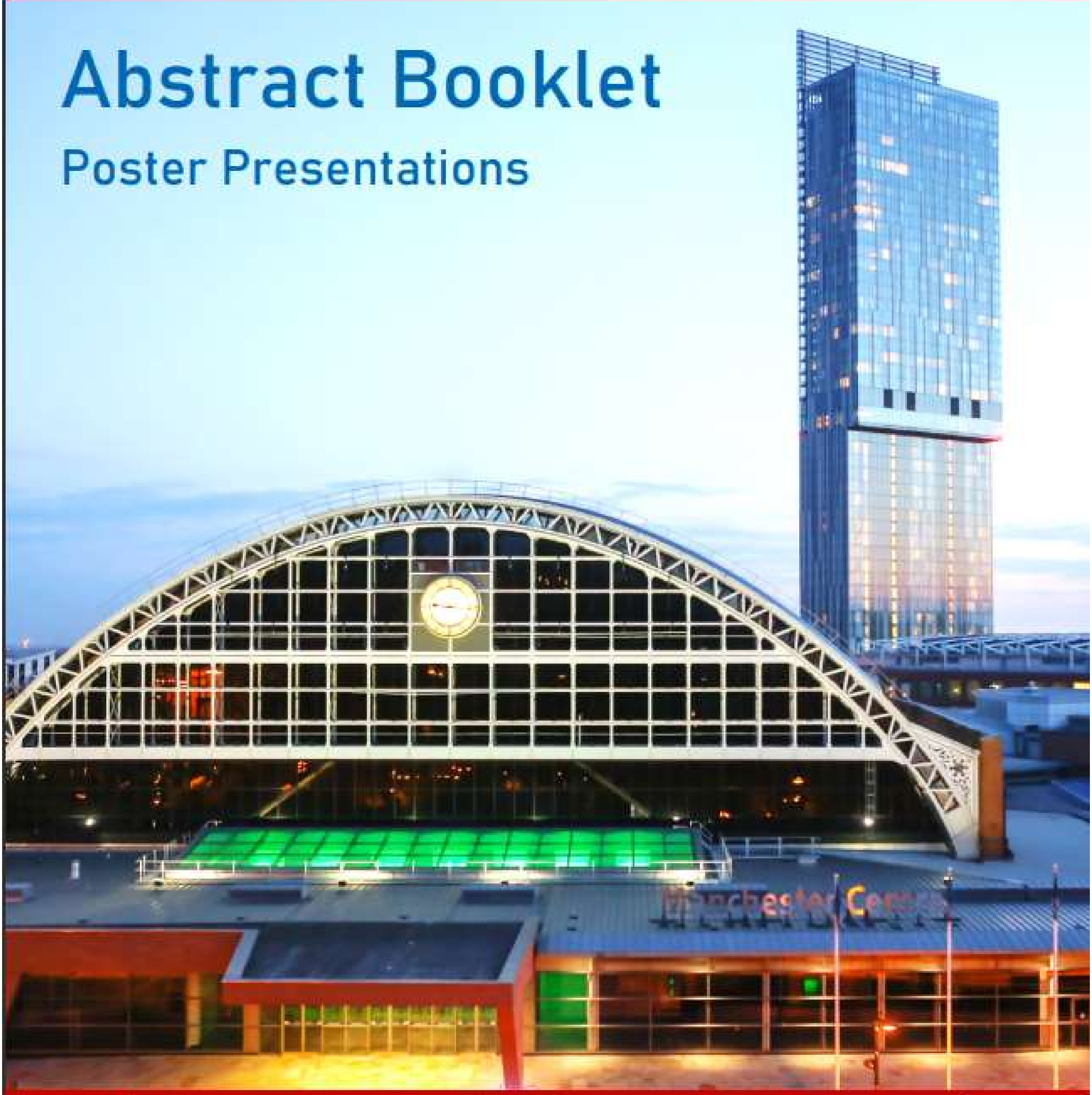
Abstract Booklet

Poster Presentations



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solid-state detectors. Responding to the expanding demand of APDs as particle detectors, the low-energy (120 keV and 1.2 MeV) foreground proton radiation effect was investigated for the first time to estimate the operation lifetime using two reach-through APDs with different drift region thicknesses. In contrast to the previous proton damage studies with penetrating particles, the primary damage depth can be controlled by tuning the incident proton energy in the investigated range. When the incident energy was adjusted to stop right at the avalanche region, a significant reduction of the gain was observed at 10^{10}-10^{11} protons/cm^2 total dose level, and the detector gain was completely lost over 10^{12} protons/cm^2 dose level. In other cases, in which proton damage was only in the drift region, only the increase of the leakage current was observed while the avalanche gain was stable over 10^{12} protons/cm^2 dose level. The increase of the leakage current was steeper for higher-energy proton damages, reflecting the more energy deposited in the detector crystal.

N-19-352 10:20 AM

Design of a Voltage Subtraction Bandgap Reference Circuit for Radiation Hardening (#2622)

M.Sc./M.A. student Minuk Seung[1,2], Prof. Wooyoung Choi[1], Dr. Seop Hur[2], Dr. Inyong Kwon[2]

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Content

The bandgap reference circuit applicable to instruments requiring radiation hardness is presented in this paper. In nuclear power plants, radiation detector and temperature sensor are generally used to observe a reactor state. Therefore, the bandgap reference circuit utilized in sensors should be required a radiation hardening technology for the harsh environments. The proposed bandgap reference circuit is used with the subtraction of the voltages induced from two identical bandgap circuits which have the same temperature curvature and the different voltage magnitude while two reference voltages are only the difference on the design. With statistical simulations, the proposed design achieves about the radiation error rate of 0.93% and the temperature coefficient of 56.2 ppm/°C in the range of -30 to 125° C, while the conventional bandgap circuit has 2.3% and 62 ppm/°C, respectively.

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Fifty Million CPS OCR with 7-Element Silicon Drift Detector (#1084)

M.Sc./M.A. Shaul Barkan, Dr. Valeri D. Saveliev, M.Sc./M.A. Eugene Tikhomirov, M.Sc./M.A. Yen-Nai Wang, M.Sc./M.A. Mengyao Zhang, M.Sc./M.A. Elena V. Damron, M.Sc./M.A. Del Redfern

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Content

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Minuk Seung[1, 2], Wooyoung Choi[1], Seop Hur[2], and Inyong Kwon[2*]

***Abstract*— The bandgap reference circuit applicable to instruments requiring radiation hardness is presented in this paper. In nuclear power plants, radiation detector and temperature sensor are generally used to observe a reactor state. Therefore, the bandgap reference circuit utilized in sensors should be required a radiation hardening technology for the harsh environments. The proposed bandgap reference circuit is used with the subtraction of the voltages induced from two identical bandgap circuits which have the same temperature curvature and the different voltage magnitude while two reference voltages are only the difference on the design. With statistical simulations, the proposed design achieves about the radiation error rate of 0.93% and the temperature coefficient of 56.2 ppm/˚C in the range of -30 to 125˚ C, while the conventional bandgap circuit has 2.3% and 62 ppm/˚C, respectively.**

***Index Terms*— bandgap reference, radiation hardening, subtracting reference voltage.**

I. INTRODUCTION

Today, the bandgap reference (BGR) is used in various applications, for instance, analog-digital converter (ADC), digital-analog converter (DAC), temperature sensor, and voltage regulator [1, 2, 3]. These circuits require high accurate voltage and stability. However, the output voltage of a BGR slightly changes when variation of temperature, supply voltage, and process are occurred. Therefore, it does always have an error of several mV.

In some specific environment such as radiation measurement, military and space field, the BGR circuit is affected by another variation due to incident radiation. When radiations penetrate into oxide region of MOSFET, it generates hole-electron pairs. Some carriers are promptly recombined but other carriers are trapped in the SiO_2-Si interface [3]. This effect occurs the threshold voltage variation at CMOS devices. It leads to change the output voltage of the BGR circuit [4]. Therefore, it is necessary to minimize the influence of radiation.

This paper shows the concept of the BGR circuit to prevent radiation effects. First, we will explain the concept of radiation hardened by design (RHBD) topology. Second, we are going to show the result of the simulation of bandgap reference circuit. Finally, the conclusion and future work are shown.

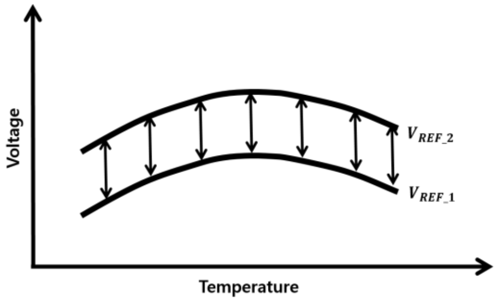

Fig. 1. Concept of operating method

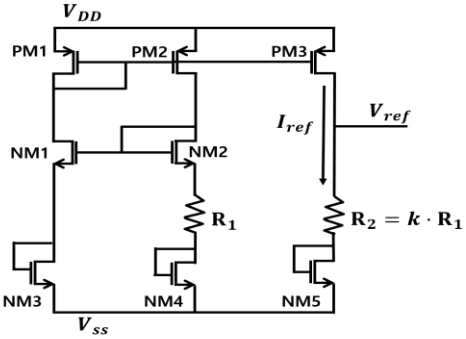

Fig. 2. Traditional bandgap reference circuit

II. CONCEPT OF PROPOSED DESIGN

The proposed BGR circuit is combined by two conventional BGR circuits having the same Temperature Coefficient (TC) but different output references as shown in Fig. 1. The final reference voltage of the proposed circuit is calculated by the difference between the two conventional reference voltages. Therefore, the final reference voltage is defined like (1).

$$V_{REF} = V_{ref\,2} - V_{ref\,1} \tag{1}$$

Generally, a reference voltage of a traditional BGR changes depending on the supply voltage. In Fig. 2, PM1, PM2, NM1 and NM2 are the current reference circuit providing constant current to the whole system. As supply voltage decreased, current decreased either because of the channel-length modulation effect.

Fig. 3 shows the schematic of the proposed design by using the voltage subtracting radiation hardened bandgap reference. The two identical BGR circuits with different supply voltages are effected by radiation uniformly, then the each reference voltage, V_{ref1} and V_{ref2} is increased due to increased leakage current in single transistors induced by incident radiation. The final output, V_{REF} as a temperature indicator, is eventually obtained by the subtraction of each reference voltage of the two identical BGRs.

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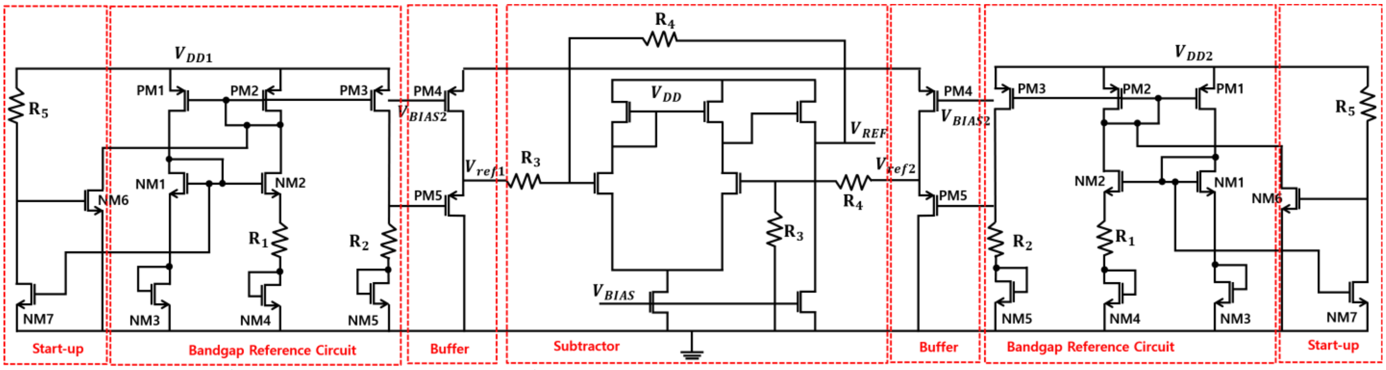

Fig. 3. Proposed design of the radiation hardened bandgap reference

III. SIMULATION RESULT

Fig. 4 shows the simulation of radiation effects in BGR. Since cumulated total ionizing dose (TID) lead to leakage current of MOSFET, we put current sources as radiation circuit models to every NMOS transistors [3]. We assume that every radiation model is the same amount of leakage current. When the V_{gs} is 500 mV and dose is 500 krad, the leakage generally presents several hundred of nanoampere [5]. It shows that the two identical conventional BGRs have about the radiation error rate of 2.3% while the proposed BGR has 0.93%.

Fig. 5 shows the output voltages versus temperature change. Each conventional BGR has the temperature error of 0.95% and 0.99%, and the proposed BGR has 0.87% in the range of -30 to 125 ˚C. Table I shows the comparison with the conventional BGRs and the proposed BGR. The simulation results show that the proposed BGR has more stable for radiation effects and temperature variation than the conventional BGRs.

IV. CONCLUSION

The radiation hardened bandgap reference circuit is designed in this paper. The key idea is that the circuit can mitigate the radiation variation by subtracting reference voltages of two identical BGRs, resulting in supplying constant output voltages. The whole circuit was designed in a 180 nm standard CMOS process. With statistical simulations, the proposed design achieves about the radiation error rate of 0.93% and the temperature coefficient of 56.2 ppm/˚C in the range of -30 to 125˚ C, while the conventional bandgap circuit has 2.3% and 62 ppm/˚C, respectively. Therefore, the proposed design BGR is more stable for radiation dose. If the circuit is more optimized and developed, it can be implemented into many electronics operating in harsh radiation environments. After the chip is manufactured, the irradiation test will be proceeded.

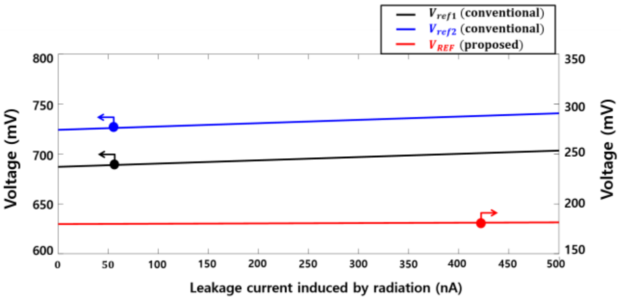

Fig. 4. Output reference voltages of the conventional BGRs and the proposed BGR versus the radiation effects

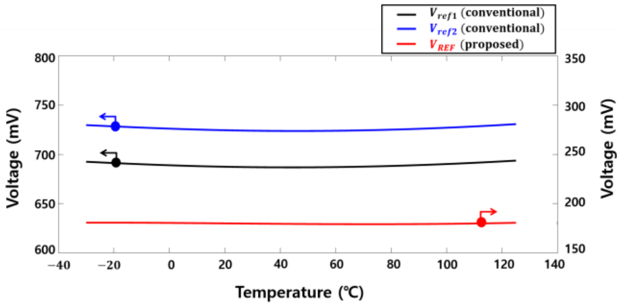

Fig. 5. Output reference voltages of the conventional BGRs and the proposed BGR versus temperature

TABLE I
COMPARISON WITH CONVENTIONAL BGR AND PROPOSED BGR

	Conventional BGR1	Conventional BGR2	Proposed BGR
Supply voltage (V)	2.8	1.5	-
Voltage reference @ 25℃ *(mV)*	724	687	179.7
Error (*due to temperature*)	0.95%	0.99%	0.87%
Temperature coefficient (PPM/˚C)	62	64.6	56.2
ΔV_{out} *(due to radiation)*	16.6 mV	16 mV	1.67 mV
Error *(due to radiation)*	2.3%	2.32%	0.93%

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