Design of Readout IC for Uncooled Infrared Bolometer Sensor using Bias Offset Correction Technique

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오프셋 보정 기술을 이용한 비냉각형 적외선 센서용 신호검출 회로 설계

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Abstract : Infrared bolometer sensor's variation is detected by voltage drop between reference resistor and bolometer resistor in this architecture. One of the serious problems in this architecture is that these resistors value has a process variation. So common-mode level could be different from expectation in room temperature. Different common-mode level could lead to wrong output at the end of readout circuit. We suggest useful method to solve this problem. Difference correction using capacitor has reduced CM level difference to 86% for 1 MΩ bolometer and reference resistor's 10% variation.

Key Words : Bolometer sensor, Common-mode level, Reference resistor

1. INTRODUCTION

The operating principle of bolometer detectors is that the temperature change caused by the absorption of IR radiation leads to a change in electrical resistance of the material. Unlike the photo-conductive detectors, the resistance change in bolometer detectors is caused directly by the heating of material instead of direct photon-lattice interaction and carrier generation. In different applications of IR image systems, there are certain specific requirements for the design of IR FPA's. In general, the requirements involve a broad range of electrical circuit and detector array parameters like detector bias control, injection efficiency, charge storage capacity, integration time, noise, dynamic range, readout rate, array size and pitch, power, and operating temperature. Infrared bolometer sensor's variation is detected by voltage drop between reference resistor and bolometer resistor in this architecture. One of the serious problem in this architecture is that both of resistors values have process variation. And bolometer resistance could be changed by additional MEMS process. So common-mode level could be different from expectation in room temperature. The dark current, injection efficiency, detector 1/f noise, and responsivity are affected by the detector common mode bias. Moreover, operation ability and linearity of spectral response are also affected directly by the common mode level. Therefore, a strict and stable detector bias control is necessary in IR FPA's.

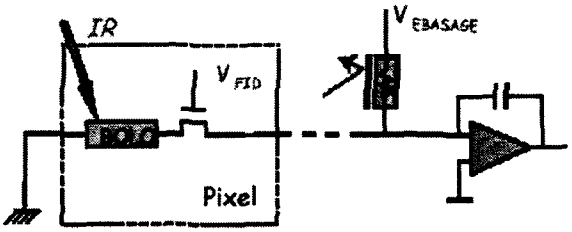

Figure 1. Bolometer pixel scheme

In this paper, we suggest a bias offset reduction technique that difference of bias and CM voltage is added to CM voltage using capacitor and switches. This method has been simulated for 1 MΩ bolometer and reference resistor's 10% process variation.

2. CIRCUIT OPERATION

Fig. 2 shows the proposed scheme of a simple concept of offset reduction tech. using capacitor and switches. At first, a capacitor is charged with the difference of the bias and CM voltage before the operation start. We expect that CM voltage between reference and bolometer resistor become

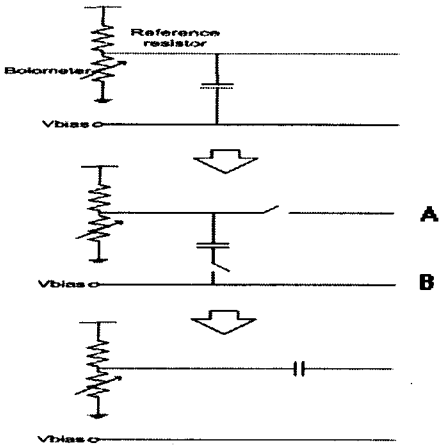

Figure 2. Simple concept of offset reduction

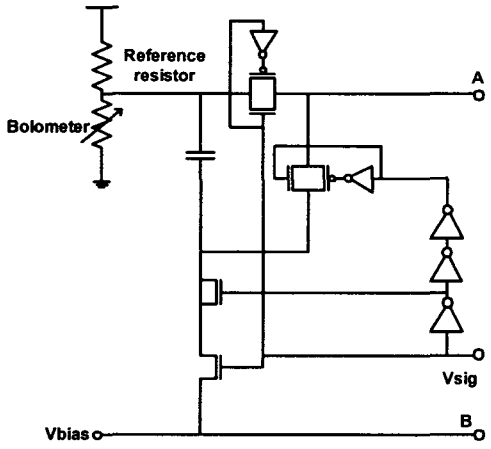

Figure 3. Applied schematic of offset reduction

$0.5V_{DD}$. But CM level could be different as I mentioned above. So the difference is charged in capacitor. Secondly switches are opened and the floated capacitor node moves from node B to node A. So stored charge become added to CM voltage. Fig. 3 shows applied schematic for concept of offset reduction. The reason of using three series inverter is to make delay for turning on and off switches one by one. Dummy switch has been used for avoiding charge injection problem when switch is turned off.

Consideration is that this offset reduction operation should be performed before column signal is applied. Because column signal is made by integration signal in column decoder. When column signal and integration signal are applied at the same time, readout circuit operation starts. So difference between CM voltage and bias voltage is detected and integrated. Therefore offset reduction operation should be accomplished before column signal applied.

Another consideration is that our suggestion needs additional signal to turn on and off switches. We can choose which signal between external or internal will be applied to the circuit. Internal signal could be made by different

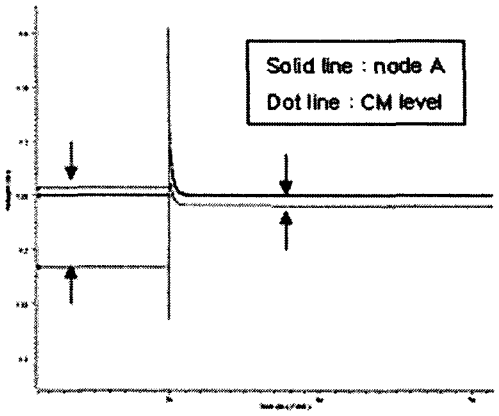

Figure 4. Simulation result of offset reduction for several resistor values.

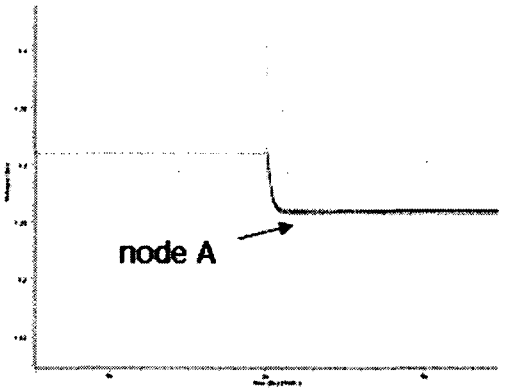

Figure 5. Simulation result for temperature variation to 1100 kΩ bolometer resistor.

Table 1. CM voltage shift for different bolometer resistor.

resistor(kΩ)	900	999	1000	1010	1100
before operation(V)	1.18417	1.24942	1.24998	1.25619	1.30950
after operation(V)	1.24082	1.24993	1.24998	1.25079	1.25825

architecture. External or internal signal has to turn on and off switches per 1 frame at least. Because capacitor could lose their charged value. Capacitor size has to be smaller than cell pitch.

3. SIMULATION RESULT

Fig. 4 and table 1 show simulation results of offset reduction circuit. We assume that reference resistor has no process variation and bolometer resistor has up to 10% process variation for 1 MΩ reference resistor. From 900 kΩ to 1100 kΩ , several values are adopted for bolometer resistor and these resistors have different voltage drop. In fig. 4, a solid line shows node A voltage change from uncorrected CM voltage to corrected value. A dot line shows that CM

voltage has extreme voltage difference and still stays at previous value after switching. As above diagram and table, various voltage value(node A) gathers to 1.25 V($0.5V_{DD}$) after switching the circuit. Node A is the input of the readout circuit. So shrank CM voltage difference enter to the readout IC. Difference of CM voltage have reduced to 86% for 1 MΩ bolometer resistor's 10% variation.

Because infrared bolometer is thermal resistor, temperature characteristic should not to be overlooked. Fig. 5 and table 2 shows simulation result for temperature variation to 1100 kΩ bolometer resistor. Circuit's internal temperature has been changed From 0 ℃ to 100 ℃. The switching operates before IR incidence. So we don't consider about bolometer resistance changing for IR absorption. The value of node A moves from 1.30953 V to 1.25723 V at 0 ℃. In the low internal temperature, we can get a closer result to $0.5V_{DD}$. Therefore thermoelectric stabilizer and thermistor should be mounted in the sealed bolometer vacuum packaging for stable and low temperature preservation.

Table 2. CM voltage shift for temperature variation to 1100 kΩ bolometer resistor.

temperature(℃)	0	20	40	60	100
before operation(V)	1.30953	1.30953	1.30953	1.30953	1.30953
after operation(V)	1.25723	1.25832	1.25912	1.25973	1.26068

4. CONCLUSION

Correction for unaccuracy of the input stage's CM voltage should be perform in the uncooled infrared bolometer sensor array for dark current, injection efficiency, detector 1/f noise, and responsivity. This paper suggests a bias offset reduction technique that difference of the bias and CM voltage is added to CM voltage using capacitor and switches. Without changing to any complex architecture and additional dummy pixel, each pixel's different CM voltage level can be reduced up to 86% of the expected CM voltage.

ACKNOWLEDGMENTS

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