A novel self-adaptive background current compensation technique is proposed.

Proposed ROIC could operate in two modes.

Proposed ROIC achieves high precision, wide application and high intelligence.

**Abstract**

A novel self-adaptive background current compensation circuit applied to infrared focal plane array is proposed in this paper, which can compensate the background current generated in different conditions. Designed double-threshold detection strategy is to estimate and eliminate the background currents, which could significantly reduce the hardware overhead and improve the uniformity among different pixels. In addition, the circuit is well compatible to various categories of infrared thermo-sensitive materials. The testing results of a $4 \times 4$ experimental chip showed that the proposed circuit achieves high precision, wide application and high intelligence. Tape-out of the $320 \times 240$ readout circuit, as well as the bonding, encapsulation and imaging verification of uncooled infrared focal plane array, have also been completed.

**1. Introduction**

The background current of uncooled infrared detector consists of the background radiation current generated by the background infrared radiation and the dark current of the detector in radiation-free biasing condition [1–3]. Conventional readout circuits generally integrate the total current of the detector, including background current and signal current. Due to large background current, the readout circuit must be equipped with huge integration capacitor, so that the weak signal hidden in the high background current can be detected over sufficient integration time [4,5]. However, huge integration capacitor occupies a large chip area, which will be a challenge in integrated circuit design [6,7]. Background current is a sensitive issue especially in long wavelength infrared detector, because long wavelength infrared detector generally operates in high background radiation, and its background current is even greater than the signal current. When the readout circuit is drawing current from the detector, the integration capacitor gets saturated easily, greatly reduces the signal to noise ratio (SNR) and dynamic range (DR), and even leads to blooming effect during operation [8]. Background current suppression is a widely accepted technique to release the above mentioned problem, which can suppress the background current and integrate the signal only. As a result, the SNR can be significantly improved with small-sized on-chip capacitors.

The existing background current suppression mainly includes following types: (1) single transistor compensation [9]; (2) current compensation [10–14]; (3) blind-pixel resistor compensation [15–19]; (4) current memory compensation [20–23]; (5) BGMI or BDI compensation [24,25]; One transistor acting as a controllable current source is adopted in single transistor compensation, which enjoys the advantage of simplicity and suitable for small area applications; however, the compensation error is considerable due to process and temperature variations. In order to obtain high precision compensation, the single transistor can be replaced by high-precision current source, which named current compensation. This method has advantages of flexibility and controllable. However, high...
temperature coefficient current source usually incurs serious non-uniformity, which will cause fixed pattern noise. Blind-pixel resistor can agree well with active pixels and ensure the consistent characteristics in different conditions. However, the blind-pixel resistor will introduce greater resistor thermal noise, and reduce its compatibility with transferring thermal film materials (such as vanadium oxide, SiGe/Si multi-quantum well), so it is difficult to ensure the compensation precision. The current memory compensation could copy the background current accurately and record it in a storage unit, but the capacitor leakage will cause relatively high deviation, making this circuit not suitable for an uncooled IRFPA. Although the current skimming based on a BGMI or BDI circuit can perform background current skimming per row or column, the generated dc current is difficult to control because it exhibits significant dependence on the temperature and threshold variations. In recent years, some other compensation methods have also been applied in practice, such as Wheatstone bridge compensation method [26,27] and its improved structure [28]. Currently, all these methods cannot realize automatic compensation for various background currents, and complex calibration algorithms are required.

Based on current compensation technology, we proposed a new background current skimming technique with high precision and low temperature coefficient in 2015 [29]. This method has been successfully applied in SiGe/Si multi-quantum well IRFPA, which achieved satisfied effects in high/low temperature condition. However, similar with existing compensation methods, this method requires calibration according to varied temperature and background radiation. Frequent manual calibration adds inconvenience to its application, and it is difficult to guarantee the precision of manual calibration. Based on previous research, this paper proposes a ROIC with self-adaptive background current compensation technique. The proposed method is an improvement based on current compensation method, by adding a self-adaptive digital module, which can perform automatic compensation for varied currents in different conditions, making the compensation intelligent and with the features of high accuracy, great flexibility and wide adaptability. This method is compatible with a variety of thermo-sensitive materials (such as vanadium oxide, amorphous silicon and SiGe/Si multi-quantum well) and it is of great practical significance.

2. Circuit structure

2.1. Structure descriptions

The block diagram of ROIC is shown in Fig. 1, which operates in two modes: the compensation mode and the readout mode. The compensation mode provides the function of calculating the background current automatically and storing the results in the pixel register, so that the results can be retrieved in the readout mode. In the compensation mode, the difference between the background current and the compensation current will be integrated, and then the results will be analyzed and estimated by the double-threshold module, the compensation current will be adjusted according to the feedback subsequently, making the compensation current and the background current highly consistent and realizing the accurate calculation of the background current.

This method only requires an integrator to estimate the mismatch between the background current and the compensation current instead of employing the ADC to calculate the background current, thus reducing hardware overhead and improving the accuracy. In addition, the ROIC can adaptively compensate background currents generated by different infrared thermo-sensitive materials, so the circuit is well compatible to various materials.

2.2. Implementation

Fig. 2 shows the schematic diagram of readout circuit with self-adaptive background current compensation module, which mainly consists of three parts: the current source compensation module (analog part), the self-compensation control module (digital part) and the double-threshold module. The current source compensation module is controlled by digital to analog converter (DAC), which generates compensation current according to background current; the self-compensation control module calculates the background current according to specific algorithm, and drives the DAC module to generate voltage at optimal value; the double-threshold module comprises two comparators, which encodes the compensation error. The self-compensation control module completes feedback regulation according to the output value of the comparators. Operation modes (compensation mode and readout mode) are selected by external pin MODE. If MODE = 1, the chip operates in the compensation mode, the self-compensation module occupies the bus, otherwise, the chip operates in the readout mode.

Fig. 3 is the flow chart of self-compensation control circuit. After initialization, the operation mode shall be determined by the level at MODE pin (to be selected by the user). In the compensation mode, compensation flag CMODE is set to high level, the self-compensation control module will hand over its control of the bus. Then the self-compensation module acquires the right to operate pixels and the integrator, and calculate the background current of all pixels subsequently. Once the calculation of the background current of all pixels is completed, the flag READY shall be
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