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Smart Infrared Detector

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Abstract

Turning passive infrared detectors into smart detectors is the goal of this work. The expected advantages are more flexibility in the design of the detectors opening the door to new performance and the integration of smart functionalities simplifying the use of future imaging systems.

1. Introduction

Infrared (IR) detectors can be referred to as a booming market with an annual growth around 23%. This growth is mainly driven by the demand for safety application in automotive industry and thermal survey of buildings for environmental concern. Uncooled resistive bolometer based IR imaging system is the dominant technology of this market with more than 95% of the sales [1].

The technology of resistive bolometer is mature and has almost reached the performance limits related to the technological process. The current developments focus on materials and micro-fabrication optimization but still face up to some intrinsic sensitivity-time constant tradeoff and fabrication discrepancies issues.

Based on this technology our aim is to derive existing passive bolometer infrared pixels into smart-pixels. Bringing smartness into the pixel overcomes the intrinsic limits related to technological process since the performance of the system becomes almost independent of the pixel characteristics. Such independence overtaking the traditional tradeoff between sensitivity and time constant introduces new flexibility in the design of the pixels and consequently new achievable performance. Besides, extra smart functionalities can be added that facilitate the use of the imaging system and release constraints on post-processing. Self-test, self-identification or configurability are some examples of such smart functionalities to monitor and compensate aging effects during operation life of imaging system.

After a presentation of the operating principle of a bolometer infrared pixel, the paper illustrates some of the smart functionalities achievable when a bolometer pixel is derived into a smart pixel using heat feedback.

2. Bolometer infrared detector

Principle

Bolometers are part of the thermal detectors category. They consist of a membrane thermally insulated from the substrate by suspension legs. Infrared optical power incoming onto the surface is absorbed and converted into heat. Consequently, the temperature of the membrane rises. The monitoring of this temperature through the variation of a resistive sensing element is the basic principle of resistive bolometers illustrated in Fig. 1.

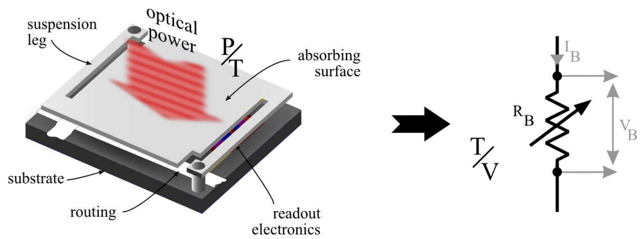

Fig. 1 Schematic of a bolometer pixel and equivalent circuit.

The performance of the bolometer is characterized by figures of merit such as its responsivity (R), the temperature coefficient of resistance (TCR denoted α) of the temperature sensing resistor, its specific detectivity (D*) and its effective time constant ($\tau_{eff}=C_{th}/G_{eff}$, G_{eff} is the effective thermal conductance that depends on G_{th} the geometrical thermal conductance and that takes into account the electro thermal effect [2]). The responsivity describes the variations of the output voltage signal (V_B) depending on the IR input radiation (P_{opt}) and it is expressed as follows

$$R(s)[V/W] = \frac{V_B(s)}{P_{opt}(s)} = \frac{\alpha \eta I_B R_B}{G_{eff}\left(1 + s\tau_{eff}\right)} \quad (1)$$

where η is the absorption coefficient of the absorbing surface. From the dependence of both the responsivity and the time constant on G_{eff} arises the tradeoff guiding the design of bolometer pixels. Low G_{eff} increases the responsivity but also the time constant. The thermal capacitance C_{th} is usually minimized by reducing the thickness of the membrane down-to mechanical self-supporting limits. Then the thermal conductance is adjusted through the length of the suspension legs or through particular pressure conditions to meet time constants suitable for imaging.

The infrared optical measure is based on resistance measurement. Considering imaging systems, discrepancies during the fabrication process can lead to typical ±5% resistance values variations among the same matrix. Such variations can represent 10 times the useful signal. This phenomenon is known as spatial noise. At the present time, spatial noise is compensated by calibration with reference scenes and post-treatment of the infrared image.

Heat balanced bolometer

Operating a system in closed-loop mode classical enables to operate it almost independently of its intrinsic characteristics. The operating performance is then set by control electronics inserted into the system and the operating point can be determined by the user. The heat stimuli means implied by feedback operation can also be used for the implementation of smart functionalities [3]. Self-test is then straightforward. Through heat pulse stimuli applied to the sensor, the right operation of the sensor can be monitored. The stimuli means can also serve for self-identification of the system and allow adjusting to aging effects during the operating life.

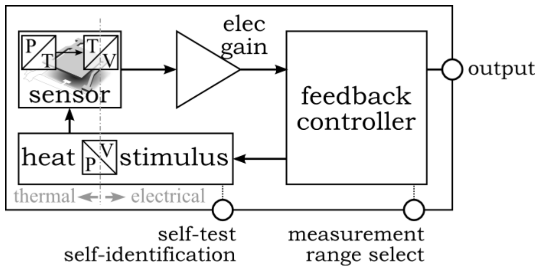

Fig. 2 Block diagram of a heat balanced bolometer.

3. Illustration of smart functionalities

Fig. 3 illustrates experimental results involving the configurability functionality that can be achieved with the closed-loop operation of the bolometer. Both the gain and the working point can be selected, here 2 gains and 2 working points.

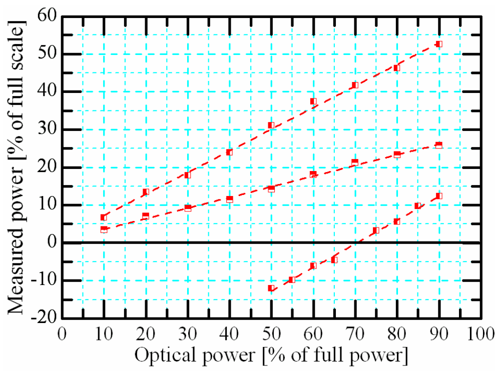

Fig. 3 Illustration of configurability.

Fig. 4 illustrates experimental self-test feature. The build-in heat stimulus enables stimulation of the sensor and the observation of the response answers the crucial question: “is the sensor working or not ?”. The fig. 5 illustrates a bit more complex diagnostic feature: self-identification. In that case, pseudo-random sequence is applied to the sensor by the heat stimuli input and from the output, parameters are evaluated in real time using least mean square estimation algorithm. In this experiment, a variation of pressure is used to simulate parameters evolution in time and to evaluate the performance of the self-identification procedure.

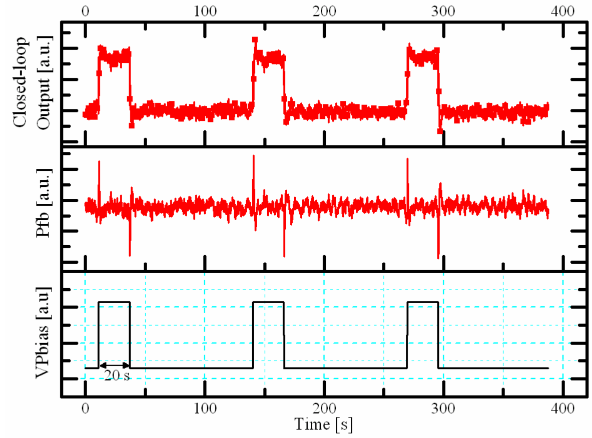

Fig. 4 Illustration of self-test.

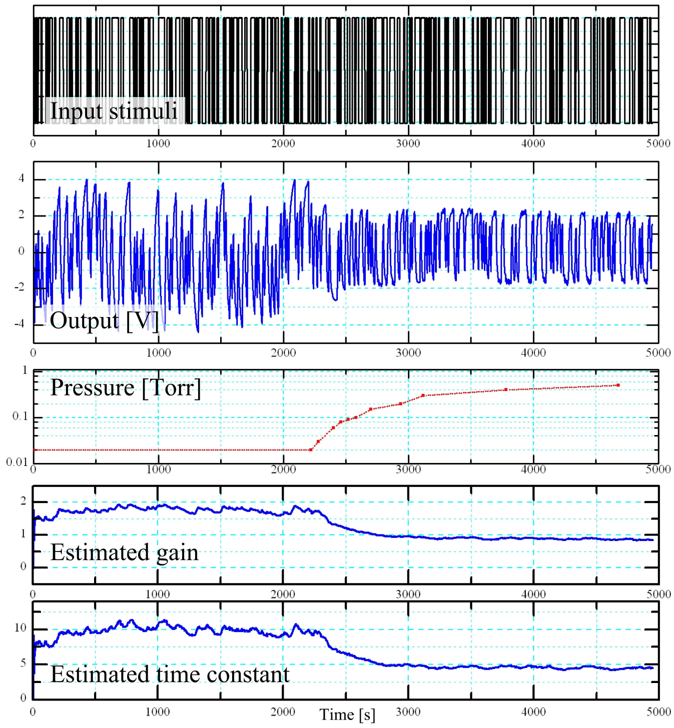

Fig. 5 Illustration of self-identification.

4. Conclusions

Bringing smartness into infrared detector pixel promises more efficient and more flexible infrared imaging systems. After successful demonstration with mono-pixel prototypes, the actual challenge is the integration of matrixes of smart-pixels.

Acknowledgements

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