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Uncooled amorphous silicon IRFPA with 25 µm pixel-pitch for large volume applications

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ABSTRACT

This paper reviews the specifications and performances of uncooled infrared focal plane array made from amorphous silicon microbolometers with a pixel-pitch of 25 µm, integrated into a LCC TEC-less package. 160 x 120 and 384 x 288 IRFPA have been specifically designed for large volume production, while keeping the main features of high end developments, at detection pixel level, as well as at ROIC level, like detector configuration by serial link in order to minimize the number of electrical inputs, low power, large dynamic range…). The main particular features of this achievement are the miniaturized very low weight package, along with easy TEC-less operation naturally afforded via amorphous silicon behavior and the readout architecture, which lead to very low consumption levels, making these devices well adapted to low end hand held cameras. We present in the last part of this paper the main electro-optical characteristics and TEC-less operation principle.

1. Introduction

Uncooled infrared detectors are now available for various applications. Their simple operating conditions are similar to those of digital CMOS Active Pixel Sensor (APS) for visible applications. They have already shown their potentiality to fulfill many commercial (automotive, medical, fire-fighter…) and military (thermal weapon sight, Enhanced Driver Vision…) applications. Amorphous silicon material is well known for many applications and its use for uncooled infrared detector production benefits from a simple technology easier to master than other technologies making use of different material. The advantage of amorphous silicon is to be easily integrated onto silicon CMOS substrate at temperature compatible with readout integrated circuit using well mastered deposition and etching technologies.

NETD as low as 30 mK is routinely measured on 25 µm pixel pitch detectors for high end application. However for low end application for which the competition is harder, the price is more important than the sensitivity. Therefore a new detector family has been developed to address these new market needs which are mainly oriented on reduced size and cost.

2. Package DESIGN FOR HIGH PRODUCTION VOLUME

Due to the reduced pixel pitch, the 160 x 120 and 384 x 288 arrays are integrated under vacuum in specifically designed ceramic packages (figure 1). These packages are sealed under vacuum without the need of the traditional pinch-off tube, leading to a more compact package with reduced impact on the proximity electronics design.

The package size is reduced by suppressing the thermo-electric cooler usually used to stabilize the focal plane temperature. As a consequence, the detector has to be operated in TEC-less mode with a feed-back of the focal plane temperature variation on the non-uniformity correction coefficients. Moreover, these packages are compliant with the RoHs regulation.

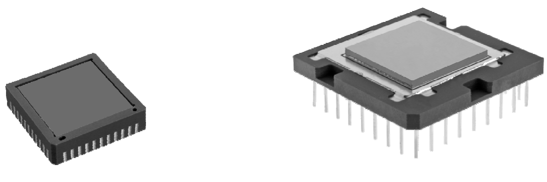

Fig. 1: *Ceramic package for 160 x 120 / 25 µm and 384 x 288 / 25 µm*

3. Architecture and readout circuit design

A new readout circuit (ROIC) design has been especially developed for 25 µm IRFPA (see figure 2). It enables the circuit to extract a small signal from a large background current. The bolometer signal detection is performed in two steps. First, the rejection of the common mode signal is made by subtracting a current delivered by a blind bolometer circuit from the current delivered by the active bolometer itself. Secondly, the current to voltage conversion is performed by an integrator (CTIA). The bolometer signal is sampled and held row by row and then, multiplexed to the output.

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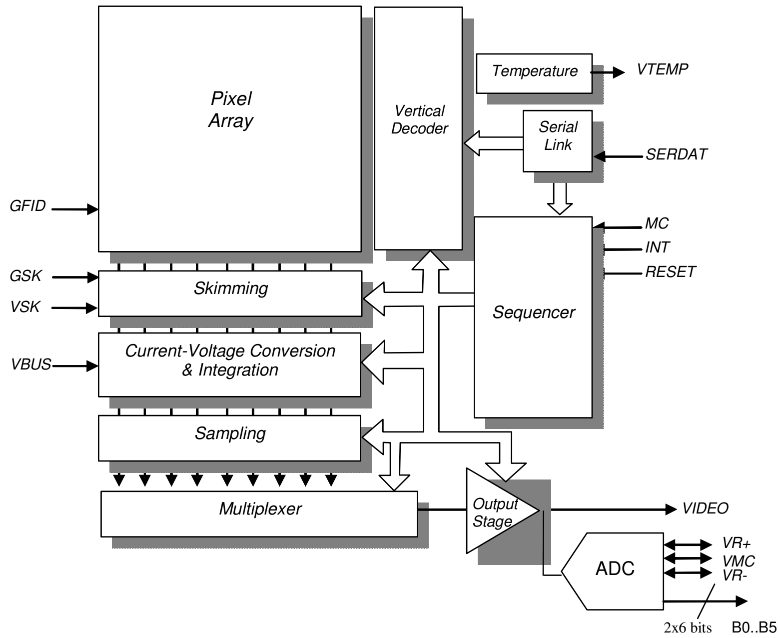

Fig. 2: *Readout circuit block diagram and Silicon CMOS chip*

The readout integrated circuit includes a sequencer and a bias generation module in order to simplify the electrical interfaces. Therefore, the detector implementation requires only four clocks (MC, INT, RESET, SERDAT), and six analog biases. The component can be operated at a 60 Hz frame rate in both digital and analog output modes.

Parameters such as blind bolometer reading mode, ADC standby, gain, image flip, and window selection can be controlled via a serial link (SERDAT). These programmable parameters are acknowledged at the next frame after the parameter command has been sent and will remain active until a new parameter command is sent, or until the array is switched off.

In order to simplify the electronic board, an ADC has been included into the chip. The converter is based on an internal 13 bits resolution design and only the12 effective bits are available at the output in a multiplexed mode of two times 6 bits. ADC power consumption has been reduced down to 170 mW for 384 x 288 IRFPA and 100 mW for 160 x 120 IRFPA despite a high speed 13 bits conversion. The signal to noise ratio (SNR) reaches -72.4 dB leading to an ENOB of 11.7 bits. Consequently, the digital and analog video signals lead approximately to the same performances. Indeed, the use of the on-chip ADC makes the ROIC electrical interfaces simpler.

4. Performance data

The characterization is carried out using the analog and the digital outputs. The following table shows the equivalent results which could be obtained respectively using these two options (see table 1). The FPA power consumption is reduced down to 40 mW when the on-chip analog to digital converter is switch off.

Table 1: *Performance comparison using analog or digital output at 60 Hz frame rate for 160 x 120 IRFPA*

Parameter	Analog output	Digital output
Responsivity	7.53mV/K	7.55mV/K
Rms Noise	654µV	693µV
NETD (T1=293 K , T2=308 K)	86mK	91mK
Temperature dynamic range	200°C	200°C
FPA Power consumption	40mW	140mW

5. Tec-less operation

Principle of Operation

To be able to operate a detector in TEC-less mode, it is necessary to calculate gain and offset correction coefficients for any current focal plane temperature. The proposed solution is to interpolate not the gain and offset tables obtained at different focal plane temperatures during a calibration phase but to interpolate the DC output voltage tables. Therefore, the starting point is to calibrate the detector for different ambient temperatures (Tamb) to acquire the DC output voltage of each pixel of the detector in front of two blackbodies: one at the ambient temperature (DCL) and one at higher temperature (DCH) (see figure 3).

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The number of tables is depending on the system requirement in term of image quality. In our example a new set of tables has been acquired every 15 °C. TEC-less operation is enabling by DCL and DCH calculations for each pixel with a polynomial interpolation between DC tables for any current focal plane temperature and to calculate gain correction to apply at the current ambient temperature Tcurrent (see figure 4). The gain coefficients are then calculated from:

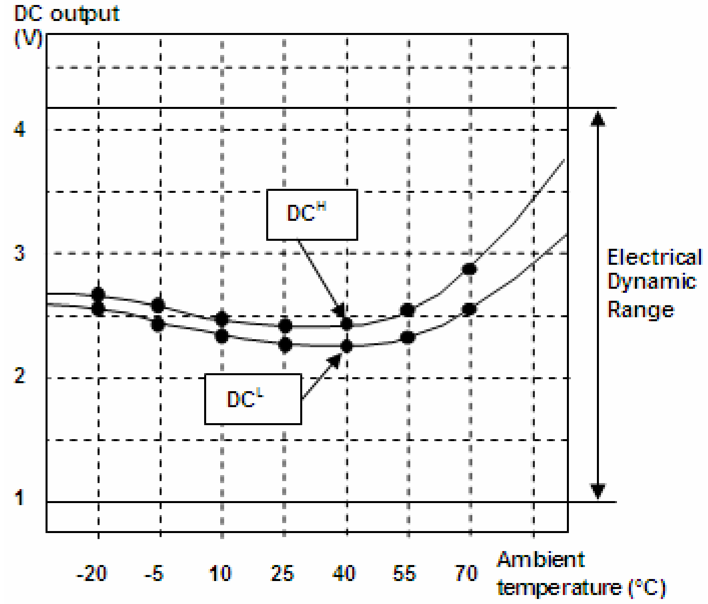

Fig. 3: *Acquisition of DCL and DCH tables*

$$G_{i,j}(T_{current}) = \frac{\overline{DC^H(T_{current})} - \overline{DC^L(T_{current})}}{DC^H(T_{current})_{i,j} - DC^L(T_{current})_{i,j}}$$

The offset coefficients are obtained in a more efficient way by an interpolation process from three tables one of which is measured on the shutter (see figure 5). This method enables a more precise offset coefficient evaluation as the shutter temperature is usually closer to the focal plane temperature.

TEC-Less Results

To test the algorithm validity, the ambient temperature has been driven along a temporal profile, designed to cover large ambient temperature amplitude between minus 15°C and plus 60°C, comprising several stabilization plateaus (see figure 6). A new gain and offset interpolation is done every 0.2 °C ambient temperature change. During the whole ambient temperature profile, the detector is in front of 40°C blackbody, without optics. In this experiment the shutter is activated every 15 minutes but it is important to notice that other activation strategies could be applied.

The ration of fixed pattern noise (FPN) on rms temporal noise results are presented in figure 7. It's important to notice that the ratio is close to 1 during the whole profile, except during temperature transients during which it should be necessary to increase the shutter activation frequency. Indeed, this is an excellent result which shows that the image quality is good for every ambient temperature. It's important to point out that the same kinds of result can be obtained both in analog and digital modes.

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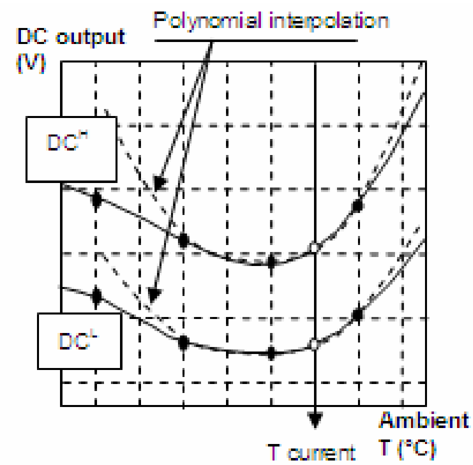

Fig. 4: *interpolation of DCL and DCH tables at Tcurrent for gain calculation*

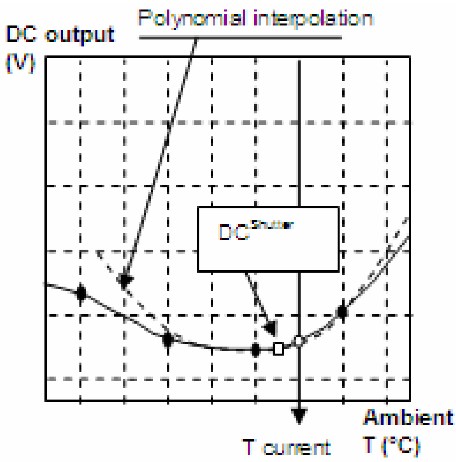

Fig. 5: *Offset interpolation of DCL and Shutter tables at Tcurrent for offset calculation*

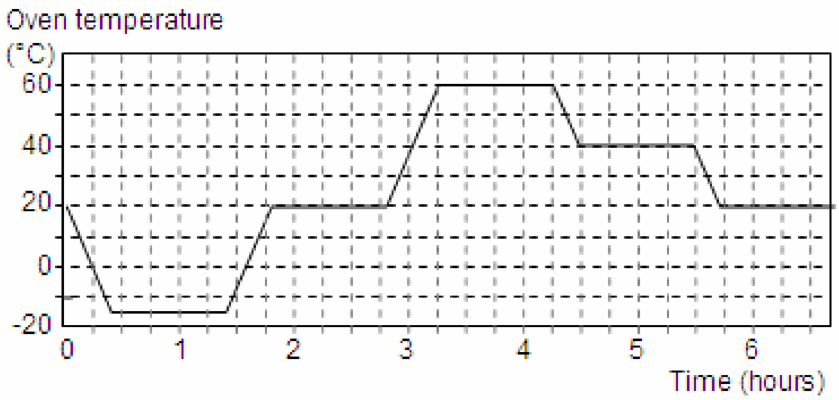

Fig. 6: *Experimental ambient temperature profile*

The current developments consist in reducing the number of tables. Particularly the possibility to use a unique gain table for all ambient temperatures is evaluated. The first results are very encouraging.

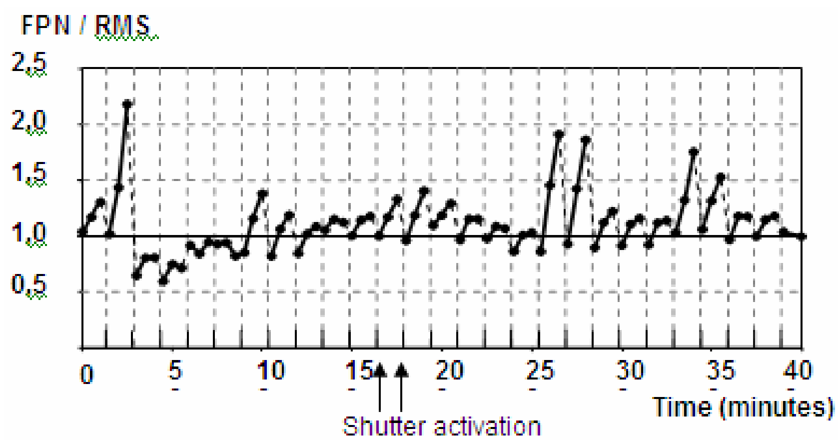

Fig. 7: *FPN/rms noise ratio behavior in TEC-less mode*

6. Conclusion

Uncooled IR detector with pixel-pitch of 25 µm offers numerous advantages in the design of uncooled IR imaging systems. The size of the infrared optics can be drastically reduced enabling the possibility to develop miniature systems for low end radiometric camera or for surveillance, fire-fighters or predictive maintenance. A small LCC package and a dedicated read out integrated circuit structure have been designed for these detectors. The possibility to operate readily the detector in a TEC-less mode by the means of simple and robust algorithms opens the way to reduced power consumption systems needed for man-portable applications.

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REFERENCES

[1] "35 µm pitch at ULIS, a breakthrough", C. Trouilleau, A. Crastes, O. Legras, J.L. Tissot, J.P. Chatard, Infrared Technology and Applications XXXI, Proc. of SPIE Vol. 5783, (2005), pp 578-585

[2] "320x240 microbolometer uncooled IRFPA development", J.L. Tissot et al, Infrared technology and Applications XXVI, proc. of SPIE Vol. 4130, (2000), pp. 473-479

[3] "Microbolometer development and production at Indigo Systems", W. Terre et al, Infrared Technology and Applications XXIV, proc. of SPIE Vol. 5074 (2003), pp. 518-526

http://dx.doi.org/10.21611/qirt.2008.14_04_04