Uncooled amorphous silicon ¼ VGA IRFPA with 25 µm pixel-pitch for High End applications

A. Crastes, J.L. Tissot, M. Vilain, O. Legras, S. Tinnes,
C. Minassian, P. Robert, B. Fieque

ULIS - BP27 - 38113 Veurey Voroize, France

ABSTRACT

The high level of accumulated expertise by ULIS and CEA/LETI on uncooled microbolometers made from amorphous silicon layer enables ULIS to develop 384 x 288 (¼ VGA) IRFPA formats with 25 µm pixel-pitch designed for high end applications.
This detector ROIC design relies on the same architecture as the full TV format ROIC one (detector configuration by serial link, user defined amplifier gain, windowing capability …). The detector package is identical as the 384 x 288 / 35 µm and 640 x 480 / 25µm ones, enabling an easier system update or less non recurrent cost for different systems developments.
This paper will give results of the IRFPA characterization. NETD in the range of 30mK (f/1, 300 K, 60 Hz) and operability higher than 99.99 % are routinely achieved.

Keywords: uncooled microbolometer, amorphous silicon, NETD, IRFPA.

1. INTRODUCTION

For more than 10 years now, uncooled detectors have given new opportunities in the IR field of applications by picking up rather than completing or developing dormant applications. Compared to cooled technology, the uncooled detector offers many interesting advantages: high reliability, lower cost, no need to conjugate the optical pupil stop with the cold shield (additional degree of freedom for the optical designer), … whereas the performance is high enough for a lot of applications where the "targeting" range is relatively close to the sensor (typical range around 1km): thermography application, automotive, military: thermal weapon sight, low altitude UAV sensor…. For such applications, ULIS developed a new 384 x 288 / 25 µm detector (320 x 240 easily configurable).
The sensor is available in same package (Figure 1) as 384 x 288 / 35 µm or 640 x 480 / 25 µm ones in order to simplify system integration.

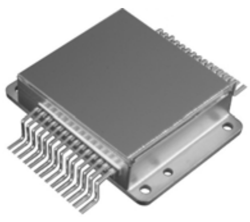


Figure 1: UL 03 19 1

2. FPA ARCHITECTURE AND READOUT CIRCUIT DESIGN

2.1 Design challenge

Relying on the proven and reliable package, the challenge was only at the technology level and was to keep the same level of 35µm pixel-pitch performance while the pitch was reduced down to 25 µm. For different reasons: cost reduction, improved spatial resolution…, it is essential to reduce the size on the microbolometer pixels as much as possible. Nevertheless, there are some limitations for this size reduction: the smaller the pixel is, the less active area is available for radiation absorption (50% less from 35 µm to 25 µm) and more critically, less space is available for thermal insulation. The amorphous silicon technology has a great advantage due to the low thermal time constant which gives the possibility to increase the thermal insulation while keeping a single level microbolometer pixel design. Moreover, a low thermal time constant design is a huge benefit [1] whatever the targeted application is.

Parameters	**Values**
Pixel dimension	25 µm x 25 µm
Thermal time constant	3.8 to 9 ms (pixel design depending)
Optical fill-factor	> 80%
Spectral response	8-14 µm
Absorption	> 85 %
Thermal coefficient resistance (TCR)	> 2.2%/K
Resistance non uniformity	< 2%

Table 1 : 384 x 288 (320 x 240) 25µm characteristics for ULIS advanced 25µm a-Si microbolometer

2.2 ROIC architecture

This 384 x 288 25µm array was designed for very high-performance operations. The readout integrated circuit design includes a serial programmable interface, which allows the operation of the device to be optimized for a wide range of conditions and provides a large degree of flexibility. The array operates in non-interlaced mode (row by row), forward or reverse scan in both row and column directions. Integration is controlled by a specific clock, and data is sampled and held, and read out during the next row time. Moreover, the ROIC has an on-chip programmable gain, which allows, with integration time and active microbolometer bias, optimization of performance over a wide range of operating conditions. These settings can also be used to optimize or to manage the trade off between scene dynamic range and sensitivity, according to different applications (figure 3).

Moreover, three options for the array size can be controlled with this serial interface to adapt the video format or make a user defined windowing in order to only select the region of interest, and then be able to refresh this specific area faster.

In addition to the previous mentioned improvements, on 25µm pitch, the new implemented features are:

- the electrical dynamic range is wider (3.2V),
- the supply voltage rejection is the lowest ever achieved,
- analog and/or digital outputs are available.

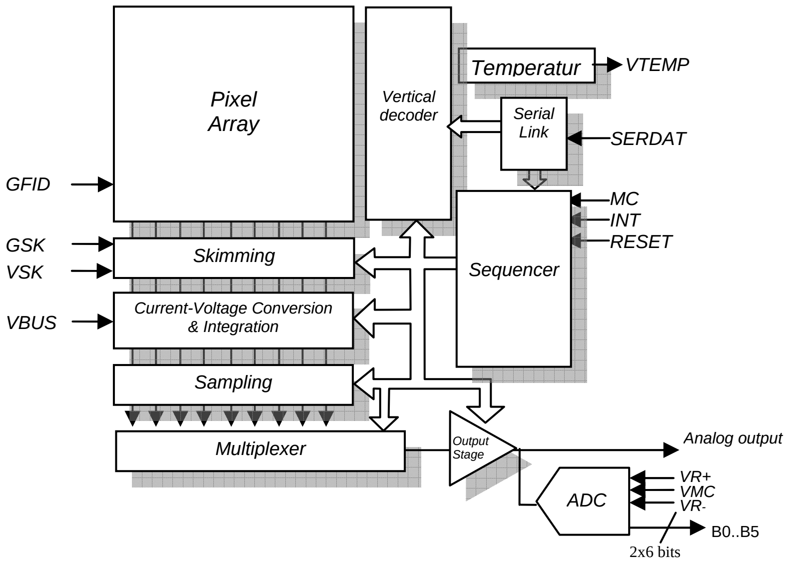


Figure 2: ROIC scheme

This last improvement consists of the implementation of an on-chip analog to digital converter (ADC) providing a high degree of EMI noise immunity in the output connector. This ADC [3] has 12 efficient bits (ENOB) going through the output multiplexed in 2 x 6 bits in order to limit the package I/O number and hence package size. The user has to use either the analog or the digital output at its own convenience. The design is a pipeline architecture where three specific biases (VR+, VR- and VMC) allow driving the output dynamic range and then optimizing the quantization.

2. ELECTRO-OPTICAL RESULTS

The NETD improvement leads to NETD around 30 mK, F/1, 60 Hz in 384 x 288 (figure 3). This can be improved by operating the detector in 320 x 240 format which leads the possibility to increase the integration time for a given frame rate. The figure 4 gives the typical NETD Gaussian distribution with a standard deviation under 7 mk.

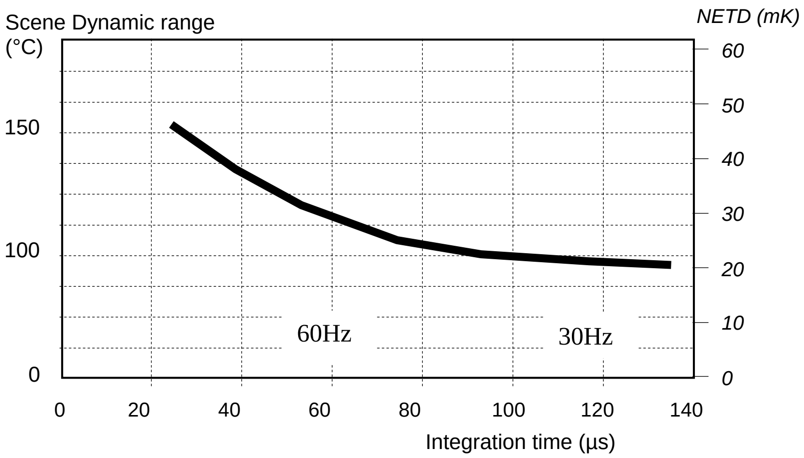


Figure 3: NETD & Scene Dynamic Range versus integration time

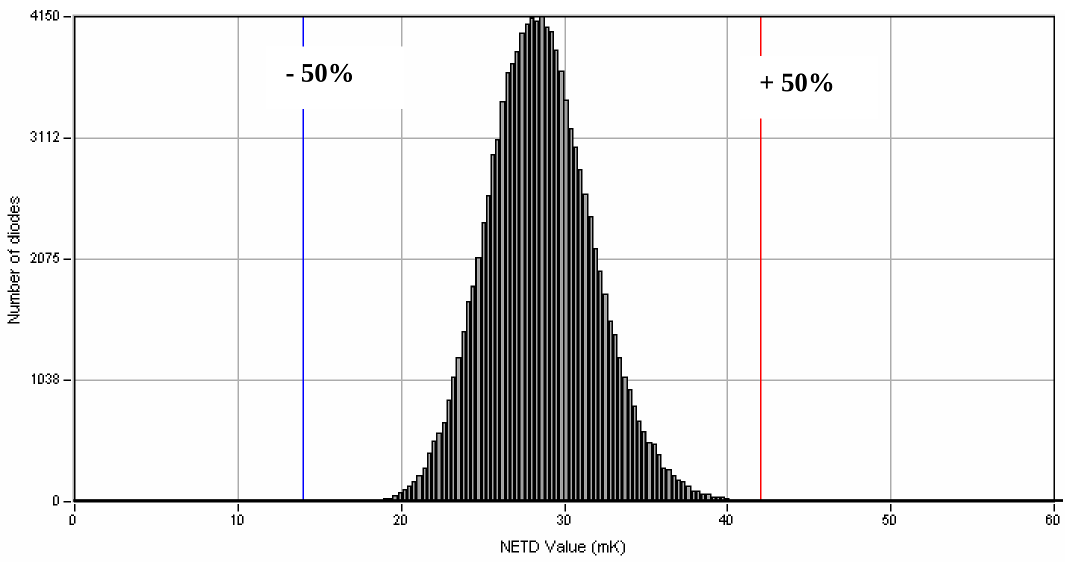
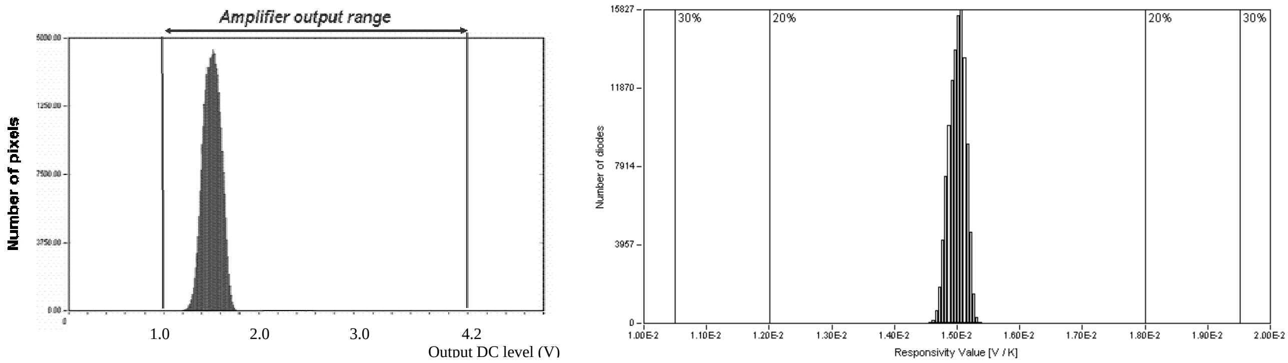


Figure 4: Typical NETD distribution for a typical array

The integrated figure of merit as expressed by M. Kohin & al. [2], will give in that case a value of 230 mK.ms for the product NETD x τ, which is one of the best published results at the production level.

Another significant advantage of amorphous silicon technology is its outstanding uniformity compared to other material. Indeed, the two histograms below show the AC and DC level dispersion without any compensation. These two characteristics represent the raw data in terms of DC level and responsivity coming from the detector output. Such a detector does not need any additional and complicated non-uniformity compensation device (typically 10 to 12 bits correction).



Typical DC level dispersion

Typical responsivity dispersion

Figure 5: AC and DC level pixel distribution

In addition, keeping the responsivity level at moderate values (around 12 to 15 mV/K with σ/m: 1.1%), affords a wide scene dynamic range (see figure 5). Moreover, this low pixel-to-pixel dispersion greatly facilitates the two point calibration, and above all the temporal stability of the residual non uniformity noise.
Figure 6 below shows the NETD evolution with the focal plane array temperature. All the parameters influencing the NETD (integration time, microbolometer biases, current to voltage conversion gain…) are kept constant and adapted to 30°C operation. Therefore, the low temperature range NETD may be improved by adjusting the parameters accordingly.

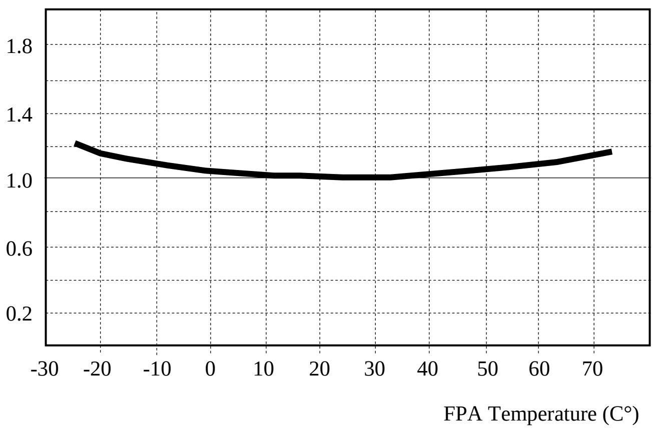


Figure 6: Normalized NETD @ 27°C versus FPA temperature

Another important behaviour regarding TEC-less operation is to be able to keep the output signal variation within the output amplifier range whatever the ambient temperature (see figure 7). This mode of operation is fully described in reference [4].

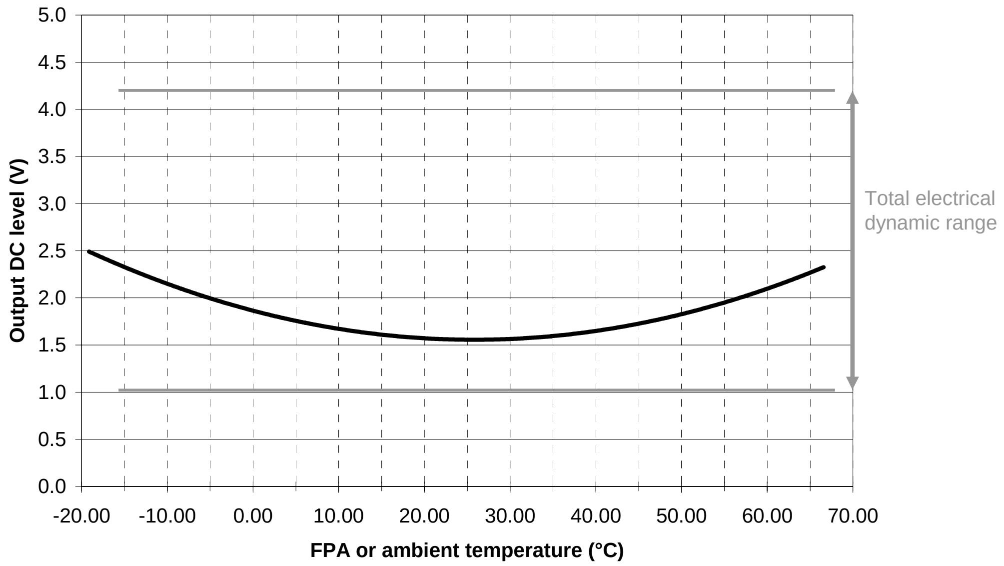


Figure 7: DC level versus ambient temperature (thermal chamber measurement)

3. MANUFACTURABILITY

Since the end of 2006, ULIS has delivered few thousand components. The NETD pixel distribution, with fixed set of bias parameters, are given below (Figure 8) for some delivery batches.

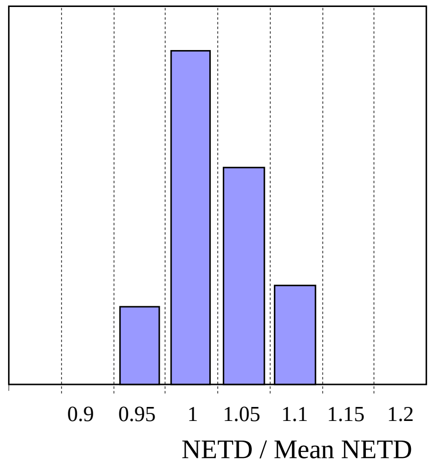


Figure 8: Average FPA NETD distribution over more than 1000 detectors

5. CONCLUSION

We have made a significant breakthrough in the development of 25 µm pixel-pitch technology to address high end applications. This detector shows performance comparable to that of 35 µm arrays with outstanding pixel operability and uncorrected responsivity non-uniformity (σ/m: 1.1%). This paper gives an overview of the technical features implemented on the 384 x 288 / 25 µm detector. Some new important functionalities have been added in comparison to the 35 µm product (same format), leading to an easier detector operation. A complete summary of the electro-optical performances has been reviewed, showing a top performance better than 30 mK, F/1, 60 Hz full format. The trade off between NETD and scene dynamic range has also been addressed. The manufacturing aspect shows that amorphous silicon technology remains a competitive one mainly due to its remarkable simplicity, uniformity and repeatability, facilitating the detector mass production needed by the market.

Such a sensor with state of the art performances and reliable proven package will fit most of high end applications.

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