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INTERNATIONAL STANDARD

colour inside

Semiconductor devices –
Part 18-4: Semiconductor bio sensors – Evaluation method of noise characteristics of lens-free CMOS photonic array sensors

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FOREWORD

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The text of this International Standard is based on the following documents:

Draft	Report on voting
47E/778/CDV	47E/790/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60747 series, published under the general title *Semiconductor devices*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

The IEC 60747-18 series on semiconductor bio sensors is composed of the following parts:

- IEC 60747-18-1 defines the test method and data analysis for calibration of lens-free CMOS photonic array sensors;
- IEC 60747-18-2 [1] [1] defines the evaluation process of lens-free CMOS photonic array sensor package modules;
- IEC 60747-18-3 [2] defines the fluid flow characteristics of lens-free CMOS photonic array sensor package modules with fluidic system;
- IEC 60747-18-4 defines the evaluation method of noise characteristics of lens-free CMOS photonic array sensors;
- IEC 60747-18-5 [3] defines the evaluation method for light responsivity characteristics of lens-free CMOS photonic array sensor package modules by incident angle of light.

The IEC 60747-18 series [4] includes subjects such as noise analysis, long-term reliability tests, test methods for lens-free CMOS photonic array sensor package modules under patchable environments, test methods under implantable environments, etc.

1 Numbers in square brackets refer to the Bibliography.

SEMICONDUCTOR DEVICES –

Part 18-4: Semiconductor bio sensors – Evaluation method of noise characteristics of lens-free CMOS photonic array sensors

1 Scope

This part of IEC 60747 specifies the evaluation method for noise characteristics of lens-free CMOS photonic array sensors. This document includes the measurement setup, test procedure, test items, evaluation method, and test report for noise characteristics of lens-free CMOS photonic array sensors.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60747-18-1:2019, *Semiconductor devices – Part 18-1: Semiconductor bio sensors – Test method and data analysis for calibration of lens-free CMOS photonic array sensors*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
noise
unwanted variations in the response of an imaging system

Note 1 to entry: Spatial noise is unwanted variations that are consistent for every exposure. Temporal noise is unwanted time variance in the response of an imaging system. Noise of imaging systems also includes photon shot noise and analogue processing and quantization noise, which varies from one image to the next.

[SOURCE: ISO 21550:2004 [5], 3.14 and ISO 15739:2017 [6], 3.9, modified – The note has been added.]

3.2
spatial noise
spatial variation in pixel output of photonic array sensor

Note 1 to entry: The location and time of occurrence is not predictable. Dark Fixed Pattern Noise (FPN) is static variation of the offset in the dark signal from pixel to pixel. Photo-response non-uniformity is non-uniformity in the spatial variation of pixel values for a specific illumination level (e.g., 50 % saturation level) and lighting condition.

3.3
temporal noise
random variation in the signal that fluctuates over time

Note 1 to entry: Occurrence is location-based due to the underlying structure. Considering the full pipelines from photon to final image data, temporal noise can mostly be removed by image signal processors from the system. Dark current shot noise is a result of thermally random generation of electron-hole pairs in dark conditions. In contrast, photo-electron shot noise is due to the statistical variation of generated/excited electron-hole pairs due to random arrival of impinging photons under illumination. It obeys a Poisson statistic. Read noise is the result of various noise sources, such ADC noise, temporal row noise, and other noise sources, due to in-pixel transistors [7].

4 Measurement setup

4.1 General

The major input factors and environmental factors affecting sensor noise characteristics are:

1) input component: light power and its two-dimensional distribution as well as stability over time, electric inputs;
2) environmental factor: temperature. The evaluation environment provides a method that allows to control these factors and to obtain numerical results with the necessary accuracy. The noise characteristic of the lens-free CMOS photonic array sensor depends on the image lag, black level, dark signal, temporal noise, fixed-pattern noise, cross talk, etc.

4.2 Measurement system

All measurements shall be performed under the standard conditions, according to 4.2 of IEC 60747-18-1:2019.

5 Measurement

5.1 General

Each pixel of the CMOS photonic array sensor experiences noise from multiple noise sources and there are responsivity variations between pixels in the array sensor. Therefore, multiple measurements with the same input and environment factors should be made and these should be statistically processed in order to cope with such noise and spatial variations in responsivity. The measurement workflow may be carried out in accordance with Figure 1.

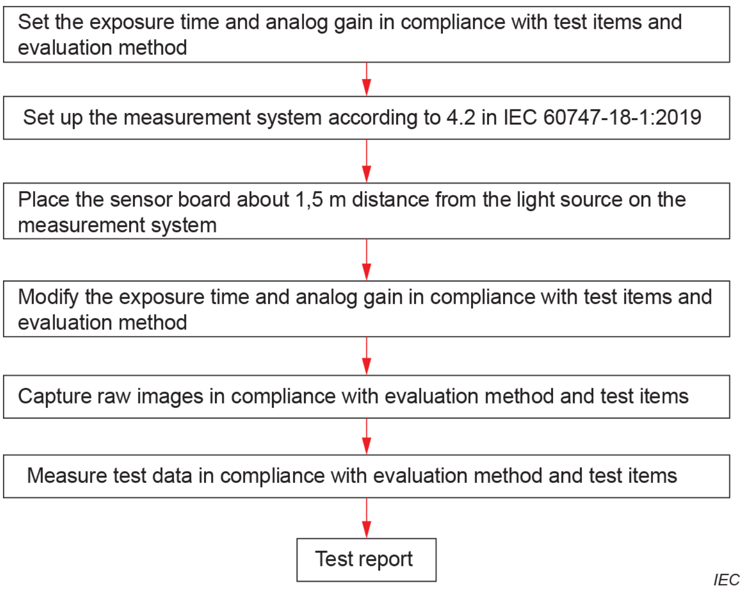

Figure 1 – Measurement workflow

5.2 Spatial noise

5.2.1 DFPN: Dark fixed pattern noise (without illumination)

5.2.1.1 General

The dark signal and offset values are different for each pixel of a photonic array sensor. Those two factors are the main source of DFPN. In general, the dark signal is a function of temperature because the generation and recombination rate of semiconductors are strongly related to temperature. Integration time is also an important condition because the dark signal increases when the integration time gets longer. Therefore, these two conditions should be accounted for when measuring FPN (fixed pattern noise).

5.2.1.2 Step 1: *n* trial of frame capture

The data of a single frame is measured, and the same measurement is repeated n times to get the statistics of the frame, as shown in Figure 2.

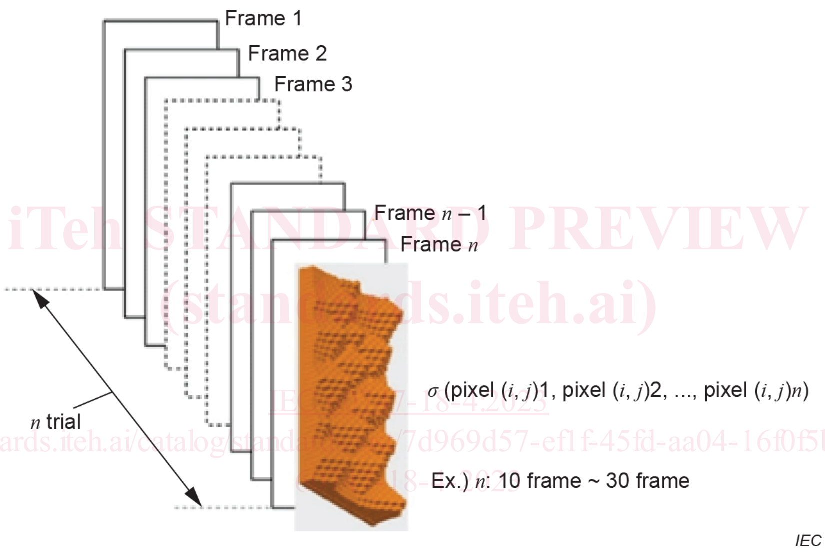

Figure 2 – *n* trial data of frame capture

5.2.1.3 Step 2: Averaging *n* trial captured frames varying integration time

The n trial captured data should be used to cancel temporal random noise. The noise level induced by a dark signal depends on integration time. Thus, this item should be measured with various integration times at a fixed temperature. And the integration time should be chosen with considering the device operating range and application operating speed.

5.2.1.4 Step 3: Subtraction of offset frame data (offset cancelled data)

As shown in Figure 3, the averaged dark frame data with the shortest integration time is used to remove the offset variation. Because the dominant source of dark fixed pattern noise is the offset variation not the dark signal with shortest integration time. In contrast, the longest integrated data includes more dark signal compared to the offset. So, in order to measure DFPN without offset variation, subtract the short-integrated data from the long-integrated data, as shown in Figure 3. The shortest integration time and the longest integration time are the values those are defined by device manufacturer.