

INTERNATIONAL STANDARD



Semiconductor devices –

Part 18-5: Semiconductor bio sensors – Evaluation method for light responsivity characteristics of lens-free CMOS photonic array sensor package modules by incident angle of light

IECNORM.COM : Click to view the full PDF of IEC 60747-18-5:2023



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IECNORM.COM : Click to view the full PDF of IEC 60747-15:2023

INTERNATIONAL STANDARD



**Semiconductor devices –
Part 18-5: Semiconductor bio sensors – Evaluation method for light
responsivity characteristics of lens-free CMOS photonic array sensor package
modules by incident angle of light**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.080.99

ISBN 978-2-8322-6644-1

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	3
INTRODUCTION.....	5
1 Scope.....	6
2 Normative references	6
3 Terms and definitions	6
4 Measurement setup	7
4.1 General.....	7
4.2 Measurement system.....	7
5 Measurement.....	7
5.1 General.....	7
5.2 Case 1: Spectral responsivity with various incident light angles	8
5.2.1 General	8
5.2.2 Step 1: Measure dark offset.....	8
5.2.3 Step 2: Status check of monochromatic light source within test spectral range.....	8
5.2.4 Step 3: Measure responsivity to varying wavelengths of input light on optical axis	8
5.2.5 Step 4: Measure responsivity to varying wavelengths of input light off optical axis	8
5.2.6 Step 5: Measured data processing	9
6 Test report.....	10
Annex A (informative) Test report	11
Bibliography.....	12
Figure 1 – Measurement workflow.....	7
Figure 2 – Example of angular response measurement.....	8
Figure 3 – n trial data of frame capture	9
Figure 4 – Data processing for illuminated response.....	9
Table A.1 – Test environment specifications of CMOS photonic array sensors.....	11

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 18-5: Semiconductor bio sensors – Evaluation method for light responsivity characteristics of lens-free CMOS photonic array sensor package modules by incident angle of light

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60747-18-5 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

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

Draft	Report on voting
47E/779/CDV	47E/791/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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

IECNORM.COM : Click to view the full PDF of IEC 60747-18-5:2023

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 [3] defines the evaluation method of noise characteristics of lens-free CMOS photonic array sensors;
- IEC 60747-18-5 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 18-5: Semiconductor bio sensors – Evaluation method for light responsivity characteristics of lens-free CMOS photonic array sensor package modules by incident angle of light

1 Scope

This part of IEC 60747 specifies the evaluation method for light responsivity characteristics of lens-free CMOS photonic array sensor package modules by incident angle of light. This document includes the test setup, test procedure, test item, and test report for lens-free CMOS photonic array sensor package modules.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes the 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

angular response

light response characteristic of a photonic array sensor depending on the incident angle of light source

Note 1 to entry: The characteristic of angular response should be defined as the wavelength of light because the optical penetrating path into the lens-free CMOS photonic array sensor is different for each wavelength.

3.2

spectral responsivity

responsivity per unit wavelength interval at a given wavelength

[SOURCE: IEC 60050-731:1991 [5], 731-06-37]

4 Measurement setup

4.1 General

The input factors and environmental factors affecting sensor angular response are:

- 1) input component: light power (wavelength, intensity, incident angle) and its 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 performance of the lens-free CMOS photonic array sensor depends on the quantum efficiency, sensitivity, cross talk, etc.

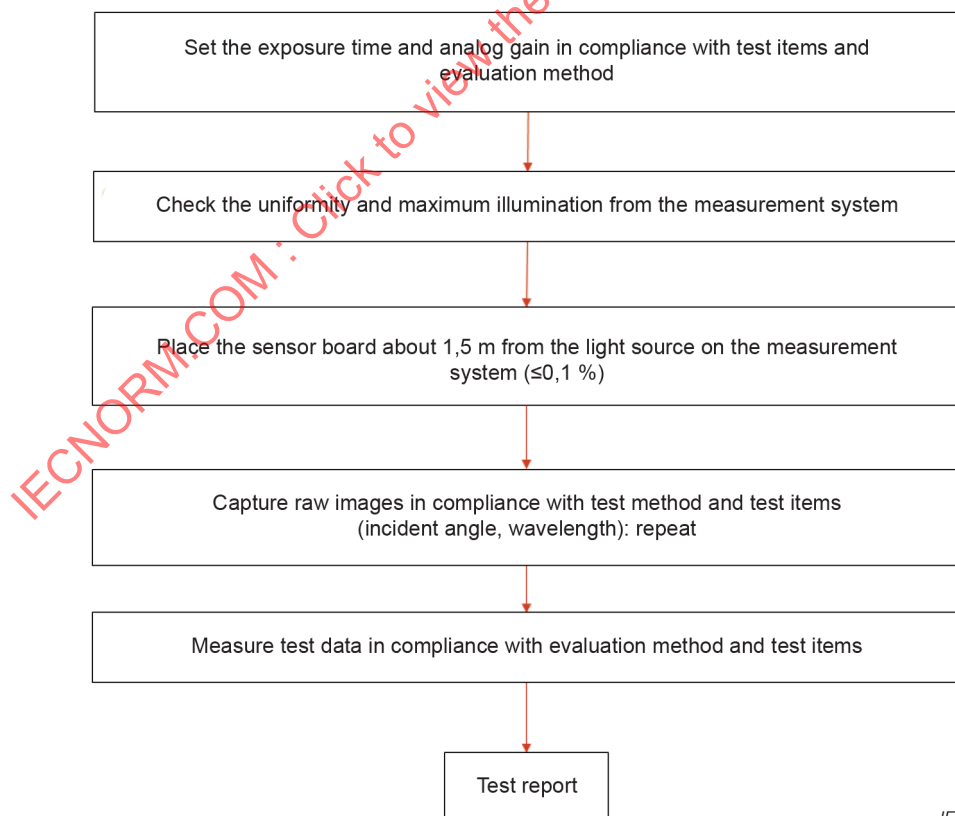
4.2 Measurement system

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 [6]. 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.



IEC

Figure 1 – Measurement workflow

5.2 Case 1: Spectral responsivity with various incident light angles

5.2.1 General

The response of photonic array sensor is a function of input light wavelength. This spectral responsivity varies with the incident light angle [7].

5.2.2 Step 1: Measure dark offset

Unwanted stray light and a dark signal of the detector could be source of measurement error. It should be eliminated by measuring before inputting the light source into the test ray path. To create dark conditions, use a mechanical shutter between the light source and DUT (device under test). After establishing dark conditions, measure the data of the reference detector and DUT.

5.2.3 Step 2: Status check of monochromatic light source within test spectral range

Light source characteristics should be measured before testing the DUT, and the intensity of the light with varying wavelengths should be measured by another reference detector. The reference detector should be calibrated by the target unit (for example: W/m^2).

5.2.4 Step 3: Measure responsivity to varying wavelengths of input light on optical axis

Store the data from the DUT after lighting up the DUT by taking away the shutter. Repeat the storing of DUT data by changing the wavelength of the light source every 5 nm. In this step, the angle should be perpendicular to the DUT (photonic array sensor).

5.2.5 Step 4: Measure responsivity to varying wavelengths of input light off optical axis

The storage of spectral responsivity data like that measured in 5.2.4, should be repeated after changing the angle of the light source as in Figure 2.

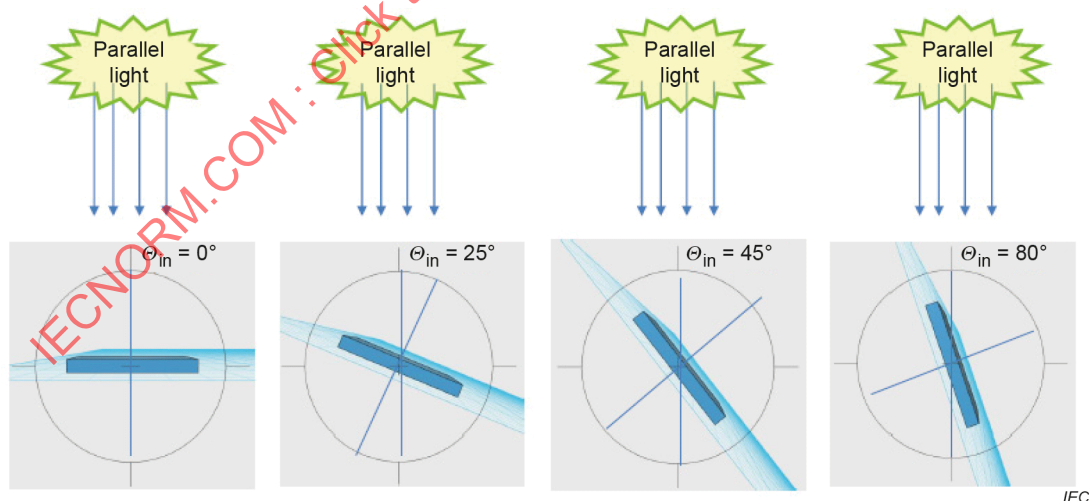
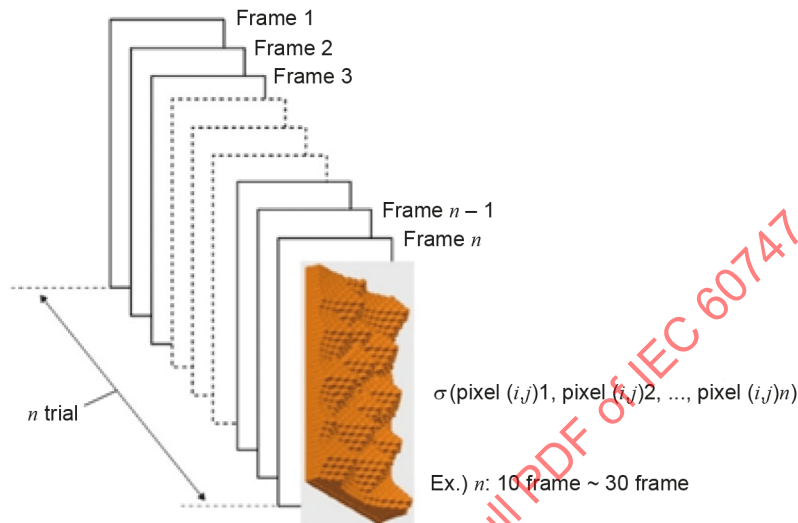


Figure 2 – Example of angular response measurement

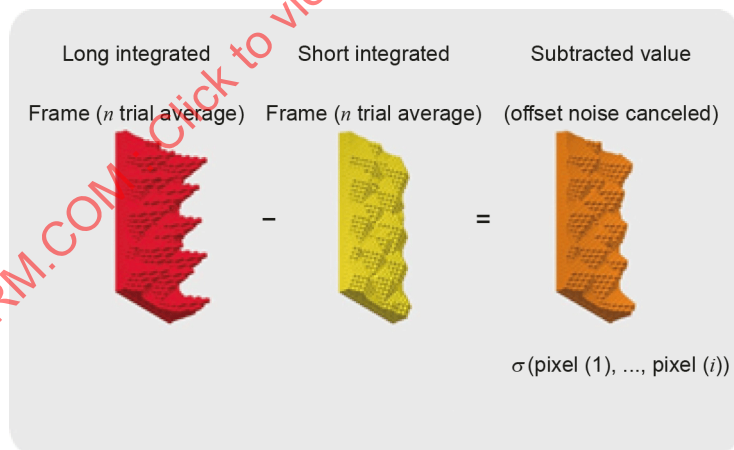
5.2.6 Step 5: Measured data processing

Stored data should be processed to ensure reliable test results. The first step is averaging multiple n trial frames of the $M \times N$ image size, which were captured as in Figure 3, in order to cancel temporal noise. The averaged pixel data is denoted as $\bar{p}(i, j, \lambda, \theta)$. After that, the dark frame is subtracted to eliminate fixed pattern noise and offset, as in Figure 4. The averaged dark pixel data is denoted as $\bar{p}_d(i, j, \lambda, \theta)$. This subtracted data should be normalized by reference detector data (dark cancelled) for every wavelength and incident angle in order to measure the spectral angular responsivity.



IEC

Figure 3 – n trial data of frame capture



IEC

Figure 4 – Data processing for illuminated response

This spectral angular responsivity can be described by the following equation with regards to certain angle of θ and wavelength λ :

$$R_{SA}(\theta, \lambda) = \frac{\frac{1}{M \cdot N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \{ \bar{P}(i, j, \lambda, \theta) - \bar{P}_d(i, j, \lambda, \theta) \}}{\{ \bar{R}(\lambda) - \bar{R}_d(\lambda) \}},$$

where R_{SA} is spectral angular responsivity, where $\bar{P}(i,j)$ is the averaged pixel value of light condition and $\bar{P}_d(i,j)$ is the averaged pixel value of dark conditions at the position i,j . M by N is the size of the image. $\bar{R}(\lambda)$ is the averaged value of the reference detector at certain wavelength of incident light on optical axis in light condition, and $\bar{R}_d(\lambda)$ is the averaged value of the reference detector in dark conditions.

6 Test report

The test report shall include the following information. An example of the test report is in Annex A (Table A.1).

- a) Environment factors:
 - temperature
 - humidity
- b) Specification of the lens-free CMOS photonic array sensor:
 - pixel size
 - ADC bit depth
 - resolution
 - responsivity
 - dynamic range
- c) Spectral angular responsivity:
 - dark state
 - wavelength [nm]

IECNORM.COM : Click to view the full PDF of IEC 60747-18-5:2023