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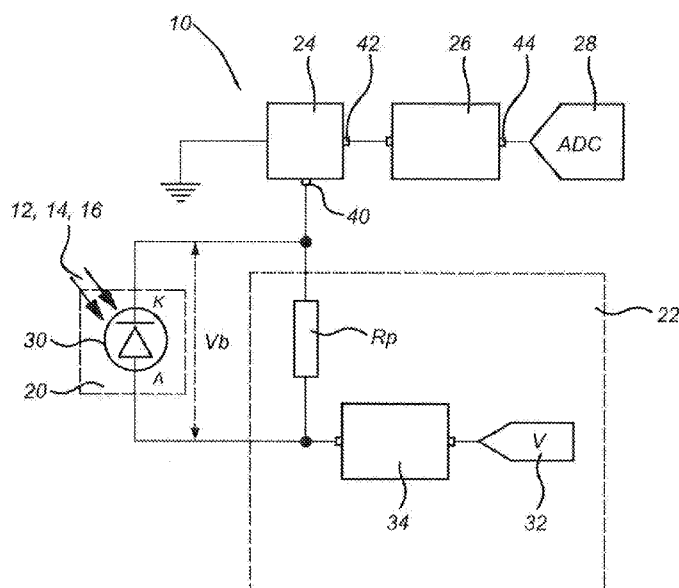
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P.O.Box 29720, 2502 LS The Hague (NL).(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
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DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
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(54) Title: SENSOR FRONT END

Fig. 3A



(57) **Abstract:** A sensor circuit (10), including a silicon photomultiplier, SiPM, sensor (20), a voltage source (32), a current-to-voltage converter (24), and a limiting bias circuit (34). The SiPM sensor (20) has avalanche photodiode, APD, elements (30) connected in parallel between a cathode (K) and an anode (A). The voltage source (32) is configured to apply a reversed bias voltage (V_b) across the SiPM sensor, so that each APD element operates in reverse-biased Geiger mode, and the APD elements operate in integration mode. The bias circuit (34) is connected between the voltage source (32) and the anode, and is configured to limit currents through the APD elements, and to present an AC load impedance for an alternating current within a predetermined operating frequency range (f_0) generated by the APD elements at the anode (A) as well as a DC load impedance, such that said AC load impedance is lower than said DC load impedance.



MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2018/050468

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L31/02 H01L31/107 H04B10/11 H04B10/112 H04B10/116
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/030769 A1 (CLEMENS KLAUS [DE] ET AL) 2 February 2017 (2017-02-02)	1-13, 20-22
Y	figures 1, 3b, 4a, 4b, 5-12	14,15
A	paragraphs [0001] - [0006], [0010], [0016], [0056] - [0061], [0064] - [0067], [0070] - [0077], [0085], [0087] - [0089]	16-19
A	----- US 6 654 215 B2 (BOEING CO [US]) 25 November 2003 (2003-11-25) the whole document	1-13, 20-22
A	----- JP 2017 041782 A (LAMP SERVE CORP) 23 February 2017 (2017-02-23) the whole document	1-13, 20-22
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 March 2019

Date of mailing of the international search report

20/03/2019

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2018/050468

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DONATI SILVANO ET AL: "Single-Photon Detectors: From Traditional PMT to Solid-State SPAD-Based Technology", IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 20, no. 6, 1 November 2014 (2014-11-01), pages 1-8, XP011558789, ISSN: 1077-260X, DOI: 10.1109/JSTQE.2014.2350836 [retrieved on 2014-09-11] the whole document	1-13, 20-22
A	----- Anonymous: "Si APD, MPPC", 28 August 2014 (2014-08-28), XP055469058, Retrieved from the Internet: URL:http://www.hamamatsu.com/resources/pdf/ssd/e03_handbook_si_apd_mppc.pdf [retrieved on 2018-04-20] the whole document	1-13, 20-22
Y	US 8 395 127 B1 (FRACH THOMAS [DE] ET AL) 12 March 2013 (2013-03-12)	14,15
A	column 16, lines 19-67 columns 17-19 figure 15	16-19
Y	----- US 2005/205759 A1 (WANG WENLU [CA]) 22 September 2005 (2005-09-22)	14,15
A	figures 2, 3, 4, 5A, 5B, 5C paragraphs [0027] - [0040]	16-19
A	----- US 2013/248720 A1 (KIM YOUNG [KR] ET AL) 26 September 2013 (2013-09-26)	14-19
	paragraphs [0098] - [0104] figures 6A, 6B, 6C	
A	----- GIL A ET AL: "Programmable power supply system for SiPM bias", NUCLEAR SCIENCE SYMPOSIUM AND MEDICAL IMAGING CONFERENCE (NSS/MIC), 2011 IEEE, IEEE, 23 October 2011 (2011-10-23), pages 787-790, XP032121560, ISSN: 1082-3654, DOI: 10.1109/NSSMIC.2011.6154298 ISBN: 978-1-4673-0118-3 the whole document	14-19

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NL2018/050468

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-13, 20-22

A SiPM sensor including an array of APDs, a voltage source, a current-to-voltage converter and a limiting bias circuit.

2. claims: 14-19

A SiPM sensor including an array of APDs, a voltage source, a current-to-voltage converter and a limiting bias circuit, said SiPM sensor comprising an active electronic component for generating current limiting schemes.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2018/050468

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2017030769	A1	02-02-2017	EP 3124992 A1 01-02-2017
			JP 6212605 B2 11-10-2017
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