



(51) International Patent Classification:

H03F 1/08 (2006.01) *H03G 3/30* (2006.01)
H03F 3/195 (2006.01) *H04B 10/61* (2013.01)
H03F 3/45 (2006.01) *H04B 10/69* (2013.01)

(21) International Application Number:

PCT/EP2024/053119

(22) International Filing Date:

08 February 2024 (08.02.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

10 2023 104 356.0

22 February 2023 (22.02.2023) DE

(71) Applicant: **AMS-OSRAM AG** [AT/AT]; Schloß Premstät-
ten, Tobelbader Str. 30, 8141 Premstaetten (AT).

(72) Inventors: **VISCONTI, Andrea**; Hansjakobstrasse 81B,
81673 Munich (DE). **RACHUPALLI, Gurumahan**;
Schellenbergstr. 9, 82110 Germering (DE). **MEMBRET-
TI, Giorgio**; Ginhardtstraße 5, 80639 Munich (DE).

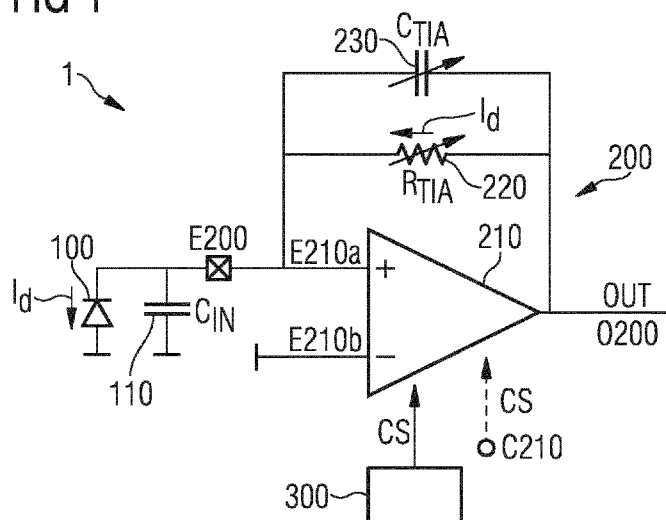
(74) Agent: **EPHING HERMANN FISCHER PATENTAN-
WALTSGESELLSCHAFT MBH**; Schlossschmidstr. 5,
80639 München (DE).

(81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG,
KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY,
MA, MD, MG, MK, MN, MU, 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, ST, SV, SY, TH,
TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS,
ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, CV,
GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST,
SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ,
RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ,
DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT,
LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE,
SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN,
GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: OPTICAL SENSOR DEVICE WITH OPTIMIZED POWER AND NOISE

FIG 1



(57) Abstract: An optical sensor device (1) comprises a photodetector (100) to provide a current input signal (I_d) in response to light detected by the photodetector (100). The optical sensor device (1) further comprises a transimpedance amplifier (200) having an input side (E200) being coupled to the photodetector (100) to receive the current input signal (I_d) and having an output side (O200) to provide a voltage output signal (OUT) in response to the current input signal (I_d). The transimpedance amplifier (200) comprises a controllable amplifier (210), wherein a current consumption of the controllable amplifier (210) is controllable in response to a control signal (CS) applied to the controllable amplifier (210).

Published:

— *with international search report (Art. 21(3))*

- 1 -

Description

OPTICAL SENSOR DEVICE WITH OPTIMIZED POWER AND NOISE

5 Technical Field

The disclosure relates to an optical sensor device configured to detect light with low noise and optimized power over a wide range of an input signal.

10

Background

Optical sensors are widely used on personal electronic devices for monitoring ambient light or to enable
15 applications in the field of distance measurement or in the field of measurement of biological signals. An optical sensor device is generally implemented with a photodetector, for example a photodiode, that outputs a current proportional to the detected light. The current generated by the
20 photodetector is transferred as a current input signal to a subsequently arranged front-end circuitry for further processing.

The front-end circuitry may be configured to directly convert
25 the current input signal of the photodetector in the digital domain by a current input ADC. According to another possible configuration, the front-end circuitry may comprise a transimpedance amplifier which translates the current input signal of the photodetector into an output voltage signal.
30 The transimpedance amplifier comprises an operational amplifier with a feedback path between its input and output side. The feedback path comprises a feedback resistor being arranged in parallel to a feedback capacitor.

- 2 -

Depending on the external illumination and ambient light, the current input signal to be read by the front-end circuitry may vary by several orders of magnitude, requiring the
5 adjustment of the full-scale range of the input signal path over a wide range. In the configuration of a front-end circuitry comprising a transimpedance amplifier, this translates into changing the value of the feedback resistor and therefore the noise it generates and the noise transfer
10 functions. Since the main two noise contributors are the feedback resistor and the amplifier, the noise of the latter may vary from being dominant to be negligible.

In a standard conventional design, the amplifier will have to
15 be sized for the case in which its noise is dominant to provide a sufficient signal to noise ratio in the signal bandwidth. The implementation of the amplifier thus results in an overdesign and a waste of power in the case in which its noise is negligible.

20 There is a desire to provide an optical sensor device with low noise, independent from the detected illumination level, and thus over a wide range of an input signal received by a transimpedance amplifier from a photodetector of the optical
25 sensor.

Summary

An optical sensor device capable of detecting different
30 brightnesses of the light incident on the sensor while having low noise, independent from the level of the incident light, is given in claim 1.

- 3 -

The optical sensor device comprises a photodetector to provide a current input signal in response to light detected by the photodetector. The optical sensor device further comprises a transimpedance amplifier having an input side
5 being coupled to the photodetector to receive the current input signal and having an output side to provide a voltage output signal in response to the current input signal. The transimpedance amplifier comprises a controllable amplifier, wherein a current consumption of the controllable amplifier
10 is controllable in response to a control signal applied to the controllable amplifier.

Since a major market for optical sensors is its use for personal electronic devices, which are usually powered from a
15 battery, the power consumption of an optical sensor is a very critical parameter. According to the proposed approach of an optical sensor, the transimpedance amplifier is designed with the possibility of varying its current consumption, and therefore its noise, so as to optimize the power for a
20 specific application or environmental condition. In conclusion, the optical sensor device allows to optimize the noise-power trade-off in a transimpedance amplifier used in the optical sensor, and to save power when the controllable amplifier would not be anyway the dominant noise source.

25

According to an embodiment of the optical sensor device, an operational current flowing through the controllable amplifier is controlled in response to the control signal. The current consumption of the controllable amplifier is
30 dependent on the operational current. The control signal can be selected such that the power consumption of the controllable amplifier is adapted to the light conditions to be detected in a specific application, and thus to the

- 4 -

expected full-scale of an input signal of the transimpedance amplifier.

The transimpedance amplifier comprises a controllable
5 (feedback) resistor and a controllable (feedback) capacitor. The controllable resistor and the controllable capacitor are arranged in a feedback path of the controllable amplifier.

10 An optical sensor device is usually limited at the level of the voltage output signal. When low light conditions are present, the resistance of the feedback resistor can therefore be chosen to be high, as the current input signal is low and the voltage output signal of the transimpedance amplifier is thus within a certain range or does not exceed a
15 certain value.

If, on the other hand, there is a strong light incidence on the sensor, for example the sensor is exposed to direct incident of light from a light source, the photodetector
20 provides a high input current for the amplifier. In this case, the resistance of the feedback resistor is set low because otherwise the level of the output voltage of the transimpedance amplifier would be outside a predefined range or exceed a predefined threshold.

25 With a low resistance of the feedback resistor, the noise of the amplifier of the transimpedance amplifier is largely independent of the operational current of the amplifier. In this case, the amplifier of the transimpedance amplifier does
30 not represent the dominant noise source. Therefore, at a low resistance of the feedback resistor, the operational current of the amplifier and, consequently, the current consumption of the controllable amplifier can be reduced without

- 5 -

significantly increasing the noise contribution of the controllable amplifier at the total noise. In particular, the operational current or current consumption of the controllable amplifier can thus be decreased with a low value
5 of the feedback resistor than when the resistance of the feedback resistor has a large value without increasing the noise contribution of the controllable amplifier of the transimpedance amplifier.

10 On the other hand, with a high resistance of the feedback resistor, the noise of the controllable amplifier of the transimpedance amplifier is the dominant noise source in the total noise. A decrease in the operational current of the controllable amplifier of the transimpedance amplifier and
15 thus a decrease in the current consumption of the controllable amplifier would lead to a significant increase in the noise component of the controllable amplifier and thus to a significant increase in the total noise. The operational current or current consumption of the controllable amplifier
20 of the transimpedance amplifier will thus be set larger when the resistance of the feedback resistor has a large value than when the resistance of the feedback resistor has a low value to reduce the noise contribution of the amplifier of the transimpedance amplifier at the total noise.

25 According to a possible embodiment, the optical sensor device may comprise a control circuit to provide the control signal to set the operational current of the controllable amplifier of the transimpedance amplifier or the current consumption of
30 the controllable amplifier of the transimpedance amplifier. The control circuit is configured to provide the control signal in dependence on the resistance of the controllable (feedback) resistor. According to this embodiment, the

- 6 -

operational current of the controllable amplifier can be changed automatically by the control circuit in dependence on the resistance of the controllable (feedback) resistor.

5 According to another possible embodiment, the optical sensor device may comprise an external control terminal to apply the control signal to set the operational current of the controllable amplifier of the transimpedance amplifier and thus the current consumption of the controllable amplifier of
10 the transimpedance amplifier. In this case, the operational current/current consumption of the controllable amplifier can be set externally, for example manually by an operator.

In the following, possible implementations of the optical
15 sensor device, particularly of the controllable amplifier of the transimpedance amplifier of the optical sensor device, are given.

According to a possible embodiment of the optical sensor
20 device, the controllable amplifier includes a current branch comprising a transistor pair. The current branch comprises a first current path and a second current path being respectively connected to a common node. The transistor pair comprises a first transistor and a second transistor. The
25 first transistor is arranged in the first current path, and the second transistor is arranged in the second current path. The controllable amplifier is configured such that the operational current flows through the first transistor and the second transistor.

30

The controllable amplifier is embodied as an operational amplifier, particularly an operational differential

- 7 -

amplifier. The first and second transistor are arranged as a differential transistor pair of the controllable amplifier.

According to a possible embodiment of the optical sensor device, the controllable amplifier may further comprise a controllable current generator being configured to provide the operational current in response to the control signal. The current branch of the optical sensor device may comprise a third current path being arranged between the supply potential and the common node. The controllable current generator is arranged in the third current path.

The controllable current generator can be trimmed to provide different current levels of the operational/biasing current of the controllable amplifier. The controllable current generator may be controlled by the control signal which is automatically provided by the control circuit, for example, in dependence on the resistance of the feedback resistor, or which is set manually by an operator.

In both cases, the operational current or the current consumption of the controllable amplifier of the transimpedance amplifier can be varied based on the selected feedback network and therefore based on the product full-scale of the input signal. In conclusion, by selecting a proper power consumption of the amplifier for each expected full-scale of the input signal provided by the photodetector, it is possible to optimize the noise-power consumption trade-off for a specific application of the optical sensor device. Thus, the proposed configuration of a transimpedance amplifier enables power to be saved when the controllable amplifier of the transimpedance amplifier would not be the dominant noise source anyway.

- 8 -

According to another possible embodiment of the optical sensor device, the controllable amplifier includes a current branch comprising a transistor pair. The current branch
5 comprises a first current path and a second current path being respectively connected to a common node. The transistor pair comprises a first transistor and a second transistor. The first transistor is arranged in the first current path. The second transistor is arranged in the second current path.
10 The first and second transistor of the controllable amplifier are arranged as a first differential transistor pair.

The controllable amplifier may comprise a current generator, wherein the current generator is configured to provide at
15 least a portion of the operational current flowing through the first transistor and the second transistor. The current branch of the optical sensor device may further comprise a third current path being arranged between the supply potential and the common node. The current generator is
20 arranged in the third current path.

According to a possible embodiment of the optical sensor device, the controllable amplifier includes at least a second current branch comprising a second transistor pair. The at
25 least one second current branch comprises a fourth current path and a fifth current path being respectively connected to a second common node. The second transistor pair comprises a third transistor and a fourth transistor. The third transistor is arranged in the fourth current path, and the
30 fourth transistor is arranged in the fifth current path.

The controllable amplifier may comprise a second current generator. The second current generator is configured to

- 9 -

provide at least a second portion of the operational current flowing through the third transistor and the fourth transistor. The at least one second current branch may comprise a sixth current path being arranged between the supply potential and the second common node. The second current generator is arranged in the sixth current path.

According to a possible embodiment of the optical sensor device, the second current generator is configured as an activatable current source to be switched on and off. The third transistor and the fourth transistor are arranged as a second differential transistor pair which is connected in parallel to the first differential transistor pair. The second differential transistor pair can be enabled or disabled by switching the second current generator on or off.

By adding the second differential transistor pair, i.e. the third and fourth transistor, in parallel to the first differential transistor pair, i.e. the first and second transistor, in that the second current generator is activated, i.e. switched on, the operational current and thus the current consumption of the controllable amplifier of the transimpedance amplifier can be varied.

A lower operational current and thus a lower current consumption can be provided when the second current generator is switched on, and the operational current of the controllable amplifier is just provided by the current generator arranged in the third current path. On the other hand, if a larger current has to be used to reduce the noise contribution of the controllable amplifier, for example when the feedback resistor has a large resistance, the current

- 10 -

generator in the third current path and the current generator in the sixth current path are switched on.

The second current generator can be activated or deactivated
5 by the control signal which can be applied automatically by the control circuit in dependence on the resistance of the controllable feedback resistor or which can be applied externally to the optical sensor device by an operator. The proposed structure of the second embodiment of the optical
10 sensor device thus allows the power of the transimpedance amplifier to be scaled based on the selected feedback network and therefore the product full-scale of the input signal. In particular, it is thus possible to save power when the amplifier of the transimpedance amplifier would not be the
15 dominant noise source anyway.

Additional features and advantages of the optical sensor device are set forth in the detailed description that follows. It is to be understood that both the foregoing
20 general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework for understanding the nature and character of the claims.

25 Brief Description of the Drawings

The accompanying drawings are included to provide further understanding, and are incorporated in, and constitute a part of, the specification. As such, the disclosure will be more
30 fully understood from the following detailed description, taken in conjunction with the accompanying figures in which:

- 11 -

Figure 1 shows an embodiment of an optical sensor device comprising a photodetector and a transimpedance amplifier;

5 Figure 2 shows noise transfer functions, respectively for a feedback resistor and for an amplifier of a transimpedance amplifier;

10 Figure 3 illustrates the course of a frequency of the zero in the amplifier noise transfer function;

Figure 4 shows a normalized noise density of an optical sensor device for different values of an operational current of an amplifier of a transimpedance
15 amplifier and different resistances of a feedback resistor of the transimpedance amplifier;

Figure 5 shows a first possible embodiment of an optical sensor device comprising a transimpedance amplifier with a controllable amplifier having a trimmable
20 current generator; and

Figure 6 shows a second embodiment of an optical sensor device comprising a transimpedance amplifier with a
25 controllable amplifier having an additional differential pair and an activatable current generator.

Detailed Description of the Embodiments

30

An optical sensor device 1 for detecting light incident on the sensor is shown in Figure 1. The optical sensor device 1 comprises a photodetector 100 to provide a current input

- 12 -

signal I_d in response to light detected by the photodetector 100. The optical sensor device further comprises a transimpedance amplifier 200 having an input side E200 which is coupled to the photodetector 100 to receive the current input signal I_d , and an output side O200 to provide a voltage output signal OUT in response to the current input signal I_d . The photodetector 100 has an input capacitance 110. The photodetector 100 is connected with its input capacitance 110 to the input terminal E200 of the transimpedance amplifier 200.

The transimpedance amplifier 200 comprises a controllable amplifier 210. The controllable amplifier 210 has an input terminal E210a which is connected to the input side E200 of the transimpedance amplifier, and an input terminal E210b which is connected to a reference potential. The transimpedance amplifier 200 comprises a controllable (feedback) resistor 220 and a controllable (feedback) capacitor 230 which are arranged in a feedback path of the controllable amplifier 210. The controllable amplifier 210 provides the voltage output signal OUT in response to the current input signal I_d provided by the photodetector 100.

Referring to the optical sensor device 1 shown in Figure 1, the controllable feedback resistor 220 determines the gain of the transimpedance amplifier 200 and therefore the full-scale of the input signal I_d of the sensor. The resistance of the controllable resistor 220 can have a value selected between a wide range R_{TIA_MIN} to R_{TIA_MAX} .

The noise of the controllable resistor 220 present at the output side O200 of the optical sensor is:

- 13 -

$$v_{n_out_RTIA} = \sqrt{\frac{4kT}{R_{TIA}}} \cdot \frac{R_{TIA}}{1+sC_{TIA}R_{TIA}} = \frac{\sqrt{4kTR_{TIA}}}{1+sC_{TIA}R_{TIA}}$$

The noise of the controllable amplifier 210 present at the
 5 output side O200 of the transimpedance amplifier 200 is:

$$v_{n_out_AMP} = v_{n_in_AMP} \cdot \frac{1+sR_{TIA} (C_{IN} + C_{TIA})}{1+sC_{TIA}R_{TIA}}$$

C_{IN} is the total parasitic capacitance at the input node E200
 10 and C_{TIA} is set by the bandwidth requirement and is linked to
 the resistance R_{TIA} of the controllable resistor 220 by the
 relation:

$$BW = \frac{1}{2\pi C_{TIA}R_{TIA}}$$

15

These constraints fix the position of the zero and the pole
 in the noise transfer functions shown in Figure 2.

In particular, as shown in Figure 3, the frequency of the
 20 zero in the amplifier noise transfer function shifts to lower
 frequencies for higher R_{TIA} values, resulting in a noise
 amplification that could affect the signal-to-noise ratio in
 the signal bandwidth.

25 Such an effect is clearly visible in Figure 4, where the
 noise density of a real transimpedance amplifier system is
 plotted versus the operational current used in the input
 transistor pair of an amplifier of a transimpedance amplifier

- 14 -

for different values of the resistance of the feedback resistor.

In particular, as shown in Figure 4, for lower values of the resistance of the controllable resistor 220, the operational current/bias current of the controllable amplifier of the transimpedance amplifier can be significantly reduced without any appreciable affect on the noise. In this case, the amplifier contribution to the total noise is not dominant.

For higher values of the resistance of the controllable amplifier 220 instead, a reduction of the operational current/bias current of the controllable amplifier of the transimpedance amplifier leads to a significant increase of the total noise. In conclusion, sizing the controllable amplifier 210 to meet the noise specification for higher values of the resistance of the controllable resistor 220 will most likely result in a large overdesign and power inefficiency for lower values of the resistance of the controllable resistor 220.

Referring to Figure 1, according to the proposed approach of the optical sensor device 1, the controllable amplifier 210 is designed so that a current consumption of the controllable amplifier 210 is controllable in response to a control signal CS applied to the controllable amplifier 210. In particular, an operational/bias current flowing through the controllable amplifier 210 is controlled in response to the control signal CS. The current consumption of the controllable amplifier 210 is dependent on the operational current.

According to the proposed approach of a transimpedance amplifier of an optical sensor device, the controllable amplifier 210 is designed with the possibility to vary its

- 15 -

current consumption, i.e. its operational/bias current, and therefore its noise, so as to optimize the power for a specific application or environmental condition. By selecting a proper amplifier power consumption for each available full-scale of the input signal, it is possible to optimize the noise/power consumption trade-off of the transimpedance amplifier 200.

In a low light condition, when the resistance of the controllable resistor 220 is set to have a large value, the controllable amplifier 210 is the dominant noise source of the optical sensor device. In this case, the operational current/current consumption of the controllable amplifier 210 is set to a large value in order to reduce the noise contribution of the controllable amplifier at the total noise. On the other hand, when a huge amount of light is expected to be detected by the optical sensor, the resistance of the controllable feedback resistor 220 is set to a low value. In this case the controllable amplifier 210 is not the dominant noise source of the optical sensor, and the operational/bias current or the current consumption of the controllable amplifier 210 can be reduced.

Two possible embodiments on how to implement the design of the controllable amplifier 210 are shown in Figures 5 and 6. The first embodiment of the controllable amplifier 210 shown in Figure 5 is based on a controllable/programmable current source providing the operational current I_{bias} , and thus the biasing for the input transistor pair. The second embodiment of the controllable amplifier 210 shown in Figure 6 is based on having separate input transistor pairs in parallel that can be enabled or disabled.

- 16 -

Referring to the first possible embodiment of the controllable amplifier 210 of the transimpedance amplifier 200 shown in Figure 5, the controllable amplifier 210 includes a current branch 10 comprising a transistor pair. The transistor pair is arranged between a supply potential VDD and the following stage of the amplifier, for example a load current generator, a current mirror and a subsequent stage. The current branch 10 comprises a first current path 11 and a second current path 12. The first current path 11 and the second current path 12 are respectively connected to a common node N1.

The transistor pair of the controllable amplifier 210 comprises a first transistor 211 and a second transistor 212. The first transistor 211 is arranged in the first current path 11. The second transistor 212 is arranged in the second current path 12. The first and second transistor 211, 212 are thus arranged as a differential transistor pair. The controllable amplifier 210 is configured such that an operational current I_{bias} of the controllable amplifier 210 flows through the first transistor 211 in the first current path 11 and through the second transistor 212 in the second current path 12.

The controllable amplifier 210 comprises a controllable current generator 215. The controllable current generator 215 is configured to provide the operational current I_{bias} in response to the control signal CS. The current branch 10 comprises a third current path 13 that is arranged between the supply potential VDD and the common node N1. As illustrated in Figure 5, the controllable current generator 215 is arranged in the third current path 13 between the supply potential VDD and the common node N1.

- 17 -

According to the proposed approach of the controllable amplifier 210 shown in Figure 5, the operational/biasing current I_{bias} of the controllable amplifier 210 and thus the current consumption of the controllable amplifier 210 can be varied by trimming the controllable current generator 215 in response to the control signal CS.

Referring to the second embodiment of the controllable amplifier 210 shown in Figure 6, the controllable amplifier 210 includes a current branch 10 comprising a first transistor pair. The first transistor pair is arranged between a supply potential VDD and the following stage of the amplifier, for example a load current generator, a current mirror and a subsequent stage. The current branch 10 comprises a first current path 11 and a second current path 12. The first current path 11 and the second current path 12 are respectively connected to a common node N1.

The first transistor pair of the controllable amplifier 210 comprises a first transistor 211 and a second transistor 212. The first transistor 211 is arranged in the first current path 11, and the second transistor 212 is arranged in the second current path 12. The first and second transistor 211, 212 are thus arranged as a first differential transistor pair.

The controllable amplifier 210 comprises a current generator 216. The current generator 216 is configured to provide at least a portion of an operational/biasing current I_{bias1} which flows through the first transistor 211 in current path 11 and through the second transistor 212 in current path 12. The current branch 10 comprises a third current path 13 that

- 18 -

is arranged between the supply potential VDD and the common node N1. The current generator 216 is arranged in the third current path 13 between the supply potential VDD and the common node N1.

5

The controllable amplifier 210 further includes at least a second current branch 20 comprising a second transistor pair. The second transistor pair is arranged between the supply potential VDD and the following stage of the amplifier, for example a load current generator, a current mirror and a subsequent stage. The at least one second current branch 20 comprises a fourth current path 21 and a fifth current path 22. The fourth current path 21 and the fifth current path 22 are respectively connected to a second common node N2.

10

The second transistor pair of the controllable amplifier 210 comprises a third transistor 213 and a fourth transistor 214. The third transistor 213 is arranged in the fourth current path 21. The fourth transistor 214 is arranged in the fifth current path 22.

15

The controllable amplifier 210 comprises a second current generator 217. The second current generator 217 is configured to provide at least a second portion of the operational/biasing current I_{bias2} which flows through the third transistor 213 and the fourth transistor 214. The at least one second current branch 20 comprises a sixth current path 23 that is arranged between the supply potential VDD and the second common node N2. The second current generator 217 is arranged in the sixth current path 23 between the supply potential VDD and the second common node N2.

20

25

30

- 19 -

The second current generator 217 is configured as an activatable current source to be switched on and off. The second current generator 217 can be switched on and off by the control signal CS. According to the proposed concept of the second embodiment of the controllable amplifier 210, the third and the fourth transistor 213, 214 are configured as a second (differential) input transistor pair which is connected in parallel to the first input pair comprising the first transistor 211 and the second transistor 212. The second input transistor pair can be enabled or disabled by switching the second current generator 217 on or off, which allows the operational current or the current consumption of the controllable amplifier 210 to be varied.

Referring to Figures 1, 5 and 6, the control signal CS to trim the operational current provided by the controllable current generator 215 (Figure 5) or to enable/disable the current generator 217 (Figure 6) may be provided automatically by a control circuit 300 or manually by an operator. The configuration of the optical sensor device 1 comprising the control circuit 300, and the other configuration of the control circuit 300, where the control signal CS is externally applied to the controllable amplifier 210 is illustrated in Figure 1. The latter configuration is shown in dashed lines in Figure 1.

According to the first configuration, the control circuit 300 may be configured to provide the control signal CS in dependence on the resistance of the controllable resistor 220. According to the second configuration, the optical sensor device may have an external control terminal C210 to apply the control signal CS. The control signal CS may thus be generated automatically by the control circuit 300, for

- 20 -

example in dependence on the selected feedback network, i.e. the resistance of the controllable resistor 220, or the control signal CS can be externally applied to the optical sensor device by an operator.

5

The embodiments of the optical sensor device disclosed herein have been discussed for the purpose of familiarizing the reader with novel aspects of the optical sensor device.

Although preferred embodiments have been shown and described,
10 many changes, modifications, equivalents and substitutions of the disclosed concepts may be made by one having skill in the art without unnecessarily departing from the scope of the claims.

15 In particular, the design of the optical sensor device is not limited to the disclosed embodiments, and gives examples of many alternatives as possible for the features included in the embodiments discussed. However, it is intended that any modifications, equivalents and substitutions of the disclosed
20 concepts be included within the scope of the claims which are appended hereto.

Features recited in separate dependent claims may be advantageously combined. Moreover, reference signs used in
25 the claims are not limited to be construed as limiting the scope of the claims.

Furthermore, as used herein, the term "comprising" does not exclude other elements. In addition, as used herein, the
30 article "a" is intended to include one or more than one component or element, and is not limited to be construed as meaning only one.

- 21 -

This patent application claims the priority of German patent application with application No. 102023104356.6, the disclosure content of which is hereby incorporated by reference.

References

	1	optical sensor device
	10	first current branch
5	11, 12, 13	current path
	20	second current branch
	21, 22, 23	current path
	100	photodetector
	110	input capacitor
10	200	transimpedance amplifier
	210	controllable amplifier
	211 - 214	transistor
	215	controllable current generator
	216, 217	current generator
15	300	control circuit
	CS	control signal

- 23 -

Claims

1. An optical sensor device, comprising:

- a photodetector (100) to provide a current input signal (Id) in response to light detected by the photodetector (100),
- a transimpedance amplifier (200) having an input side (E200) being coupled to the photodetector (100) to receive the current input signal (Id) and having an output side (O200) to provide a voltage output signal (OUT) in response to the current input signal (Id),
- wherein the transimpedance amplifier (200) comprises a controllable amplifier (210), wherein a current consumption of the controllable amplifier (210) is controllable in response to a control signal (CS) applied to the controllable amplifier (210).

2. The optical sensor device of claim 1,

- wherein an operational current (Ibias) flowing through the controllable amplifier (210) is controlled in response to the control signal (CS),
- wherein the current consumption of the controllable amplifier (210) is dependent on the operational current (Ibias).

3. The optical sensor device of claim 2,

- wherein the controllable amplifier (210) includes a current branch (10) comprising a first transistor pair,
- wherein the current branch (10) comprises a first current path (11) and a second current path (12) being respectively connected to a common node (N1),
- wherein the transistor pair comprises a first transistor (211) and a second transistor (212),

- 24 -

- wherein the first transistor (211) is arranged in the first current path (11),
- wherein the second transistor (212) is arranged in the second current path (12).

5

4. The optical sensor device of claim 3,
wherein the controllable amplifier (210) is configured such
that the operational current (I_{bias}) flows through the first
transistor (211) and the second transistor (212).

10

5. The optical sensor device of claim 4,
wherein the controllable amplifier (210) comprises a
controllable current generator (215) being configured to
provide the operational current (I_{bias}) in response to the
control signal (CS).

15

6. The optical sensor device of claim 5,
- wherein the current branch (10) comprises a third current
path (13) being arranged between the supply potential (VDD)
and the common node (N1),
- wherein the controllable current generator (215) is
arranged in the third current path (13).

20

7. The optical sensor device of claim 3,
- wherein the controllable amplifier (210) comprises a
current generator (216),
- wherein the current generator (216) is configured to
provide at least a portion of the operational current
(I_{bias1}) flowing through the first transistor (211) and the
second transistor (212).

25

30

8. The optical sensor device of claim 7

- 25 -

- wherein the current branch (10) comprises a third current path (13) being arranged between the supply potential (VDD) and the common node (N1),

- wherein the current generator (216) is arranged in the
5 third current path (13).

9. The optical sensor device of claim 8,

- wherein the controllable amplifier (210) includes at least a second current branch (20) comprising a second transistor
10 pair,

- wherein the at least one second current branch (20) comprises a fourth current path (21) and a fifth current path (22) being respectively connected to a second common node (N2),

15 - wherein the second transistor pair comprises a third transistor (213) and a fourth transistor (214),

- wherein the third transistor (213) is arranged in the fourth current path (21),

- wherein the fourth transistor (214) is arranged in the
20 fifth current path (22).

10. The optical sensor device of claim 9,

- wherein the controllable amplifier (210) comprises a second current generator (217),

25 - wherein the second current generator (217) is configured to provide at least a second portion of the operational current (I_{bias2}) flowing through the third transistor (213) and fourth transistor (214).

30 11. The optical sensor device of claim 10,

- wherein the at least one second current branch (20) comprises a sixth current path (23) being arranged between the supply potential (VDD) and the second common node (N2),

- 26 -

- wherein the second current generator (217) is arranged in the sixth current path (23).

12. The optical sensor device of claim 11,

5 wherein the second current generator (217) is configured as an activatable current source to be switched on and off.

13. The optical sensor device of any of the claims 1-12, wherein the transimpedance amplifier (200) comprises a

10 controllable resistor (220) and a controllable capacitor (230) arranged in a feedback path of the controllable amplifier (210).

14. The optical sensor device of claim 13, comprising:

15 - a control circuit (300) to provide the control signal (CS),
- wherein the control circuit (300) is configured to provide the control signal (CS) in dependence of the resistance of the controllable resistor (220).

20 15. The optical sensor device of any of the claims 1-14, comprising:

an external control terminal (C210) to apply the control signal (CS).

FIG 1

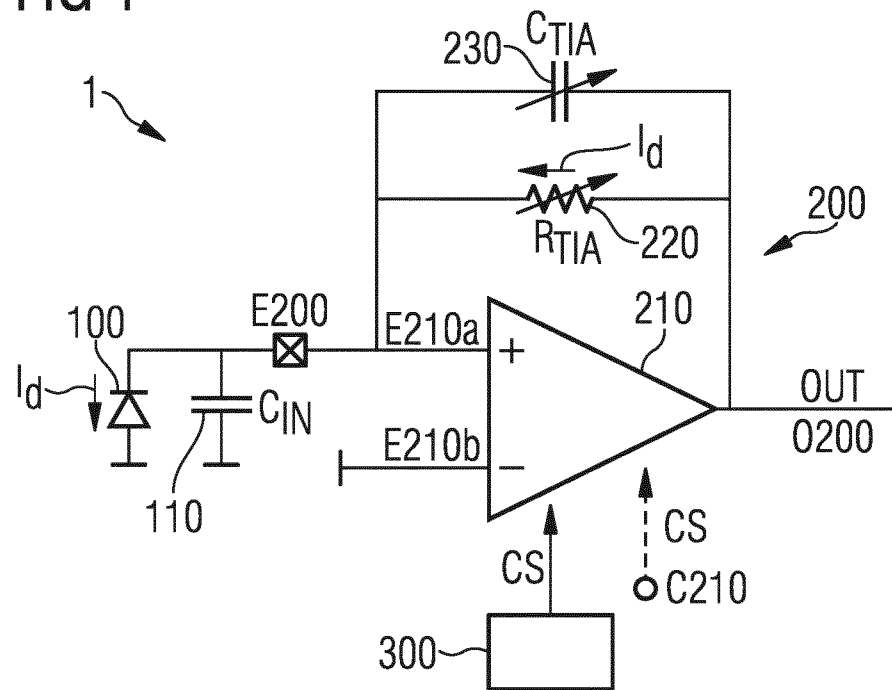


FIG 2

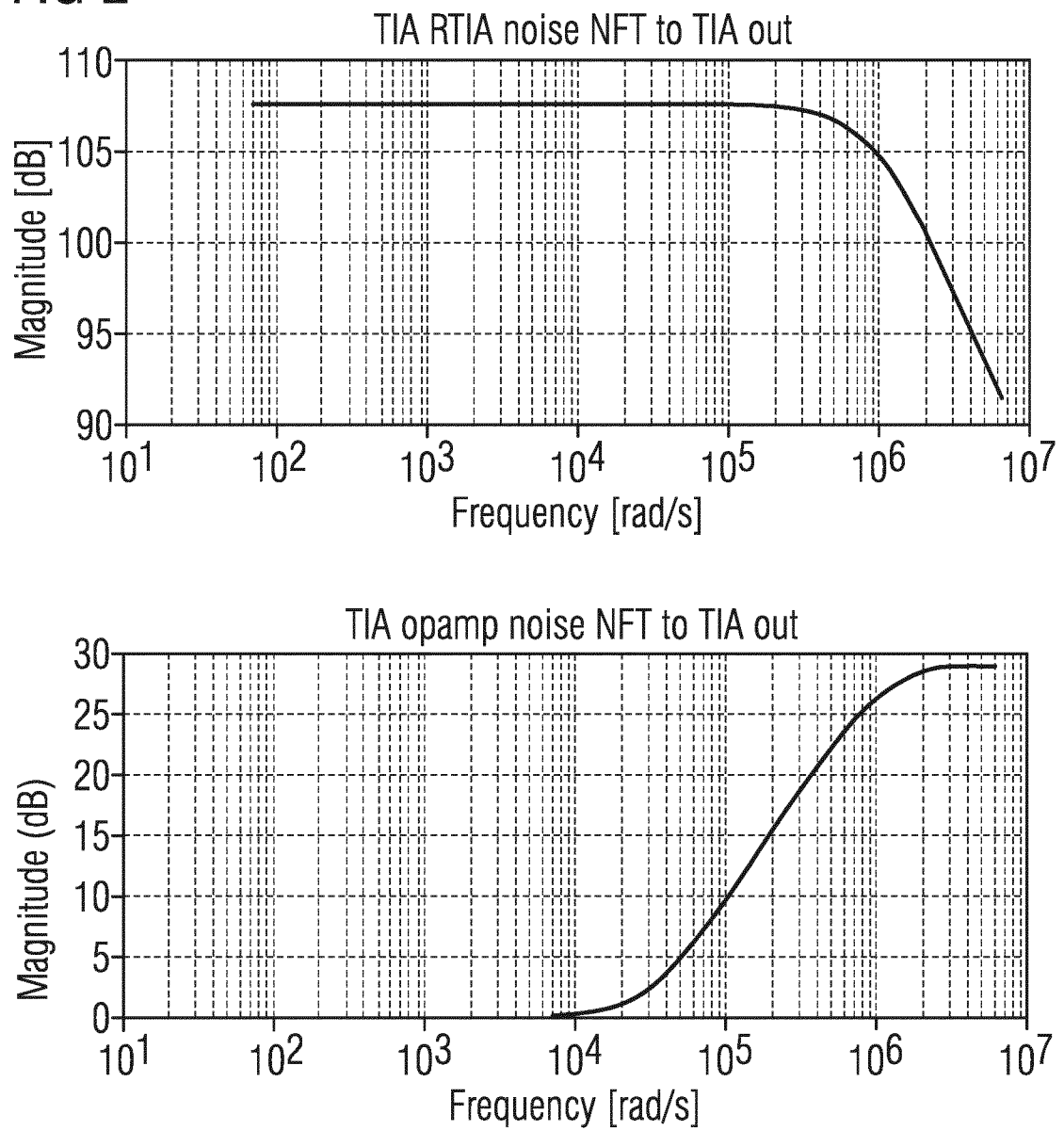


FIG 3

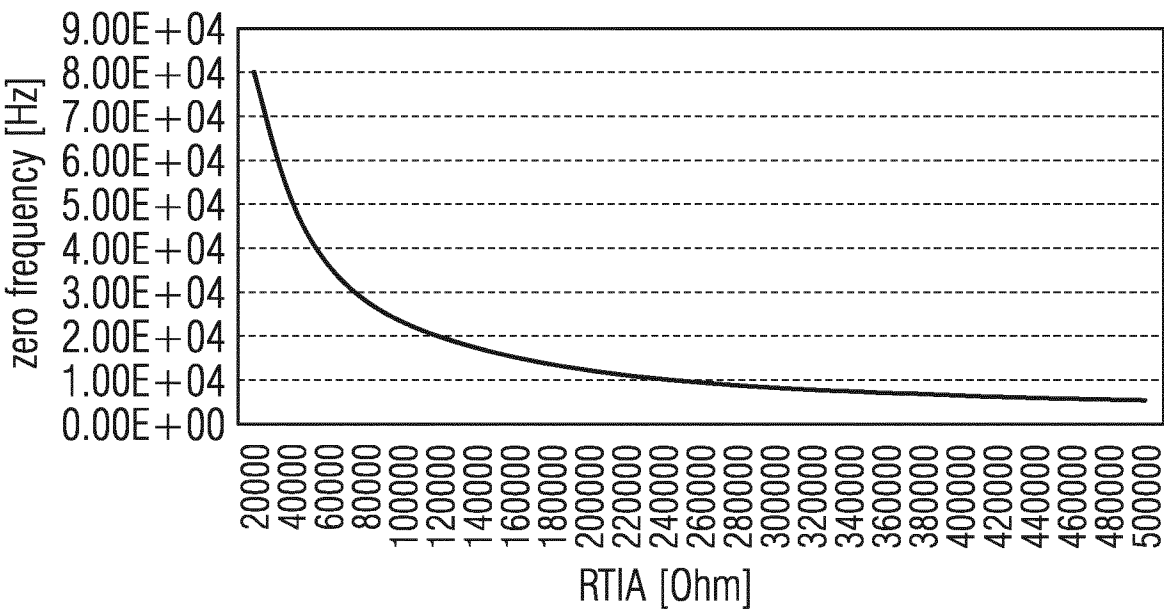


FIG 4

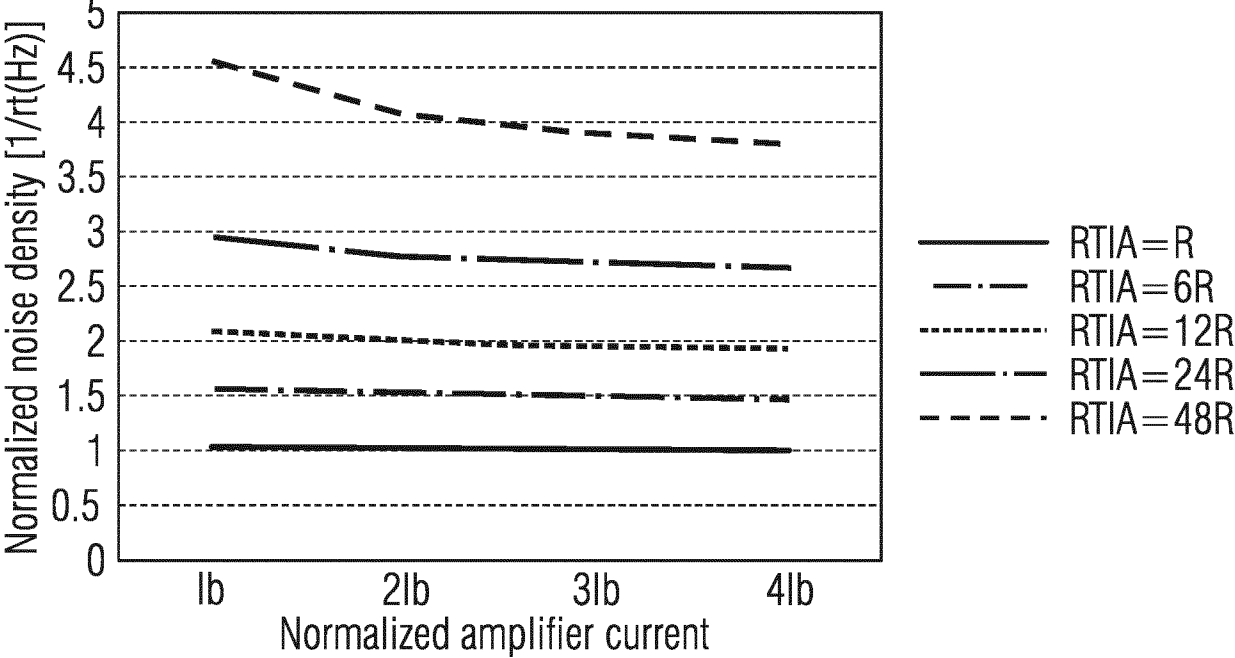


FIG 5

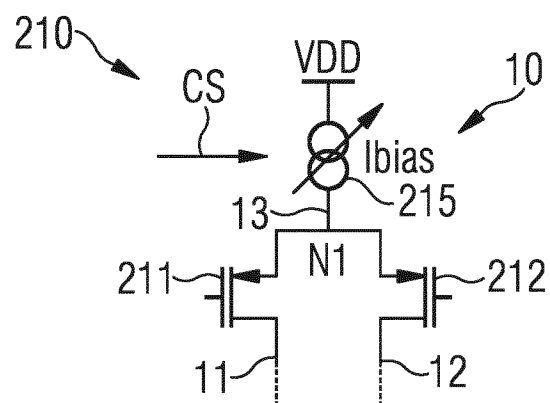
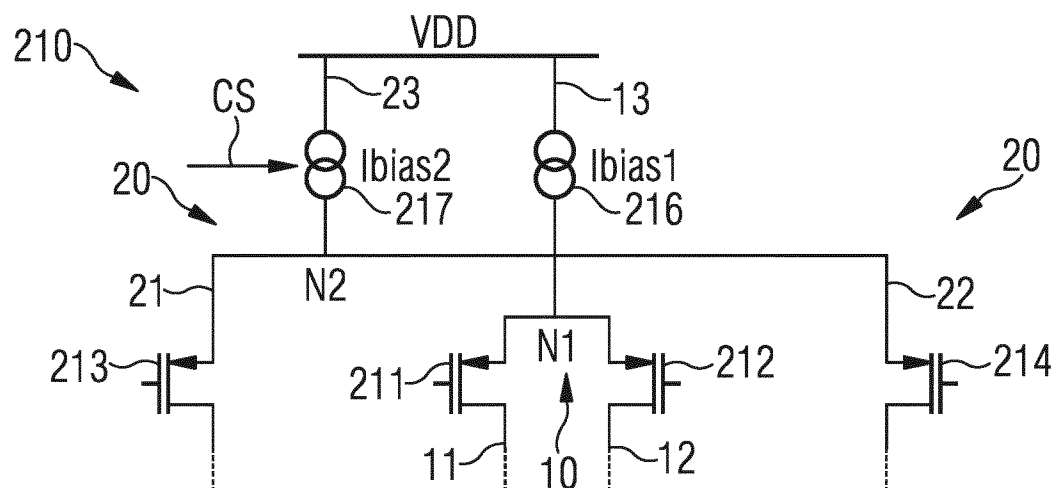


FIG 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/053119

A. CLASSIFICATION OF SUBJECT MATTER		
INV.	H03F1/08	H03F3/195
	H03F3/45	H03G3/30
	H04B10/69	H04B10/61
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)		
H03F H04B H03G		
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, 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 2020/235705 A1 (VERA VILLARROEL ARIEL LEONARDO [US] ET AL) 23 July 2020 (2020-07-23) paragraph [0040] - paragraph [0042]; figure 1 paragraph [0044] - paragraph [0045]; figures 3A, 3B paragraph [0049]; figure 5 -----	1-15
X	US 2017/104545 A1 (SHIRAISHI TAKASHI [JP]) 13 April 2017 (2017-04-13) paragraph [0046] - paragraph [0049]; figure 6 paragraph [0051] - paragraph [0070]; figure 7 ----- -/--	1-8, 15
☒ 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		Date of mailing of the international search report
25 April 2024		13/05/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Aouichi, Mohamed

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/053119

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/226455 A1 (FRANK MATTHEW B [US] ET AL) 4 August 2016 (2016-08-04) paragraph [0021] - paragraph [0023]; figure 2 paragraph [0026] - paragraph [0029]; figure 4 -----	1, 2
X	US 2006/202766 A1 (KWA HOCK T [SG] ET AL) 14 September 2006 (2006-09-14) paragraph [0028] - paragraph [0033]; figure 2 paragraph [0035] - paragraph [0054]; figure 3 -----	1, 2
A	US 5 977 828 A (HU XIAOYUN [CA] ET AL) 2 November 1999 (1999-11-02) column 3, line 55 - column 4, paragraph 51; figures 3, 4 -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/053119

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020235705 A1	23-07-2020	US 2020083846 A1 US 2020235705 A1	12-03-2020 23-07-2020
US 2017104545 A1	13-04-2017	JP 6507980 B2 JP 2017073677 A US 2017104545 A1	08-05-2019 13-04-2017 13-04-2017
US 2016226455 A1	04-08-2016	CN 105846787 A US 2016226455 A1 US 2016226457 A1	10-08-2016 04-08-2016 04-08-2016
US 2006202766 A1	14-09-2006	CN 1832338 A GB 2424138 A JP 4896547 B2 JP 2006254462 A US 2006202766 A1	13-09-2006 13-09-2006 14-03-2012 21-09-2006 14-09-2006
US 5977828 A	02-11-1999	NONE	