Measuring device comprising a normalization circuit.

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RADIO FERNSEHEN ELEKTRONIK, vol. 37, no. 2, 1988, Berlin, DE, pages 85-87; THOMAS GÜNTHER: "Einsatzmöglichkeiten positionsempfindlicher Si-Fotodiode"

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Description

The invention relates to a measuring device, comprising at least two units provided with a sensor for sensing an input quantity \( A \) and for producing a signal which is dependent on the input quantity, and also comprising a normalization circuit which receives the signals produced by the transducer units (2) and which subsequently determines the ratio of a linear combination of input quantities to the sum of the input quantities.

The invention also relates to a normalization circuit suitable for use in a measuring device in accordance with the invention.

A measuring device of this kind is known from the publication "Optical position sensing using silicon photodetectors" by Bill Light in Lasers and Applications, April 1986, pp. 75-79. The cited article describes some position-sensitive detectors (PSD) which are constructed using photodiodes in a bi-cell, quadrant and lateral configuration. Such detectors enable, for example determination of the position of a laser spot. The signals required for the X and Y displacement of the spot can be found by suitably summing or subtracting the diode currents, followed by normalization to the total intensity. To this end, the detectors described in the cited publication comprise two or four current-voltage converters for first converting the signals to the voltage domain, a number of subtraction and summing circuits, and two analog dividers. They have the drawbacks that the procedure is rather complex and that a variety of errors is introduced by the various components.

It is an object of the invention to provide a measuring device of the kind set forth in which said drawbacks are mitigated.

To achieve this, the measuring device in accordance with the invention is characterized in that each transducer unit comprises converter means for converting the input quantities \( A \) into signals \( V \), which are proportional with proportionality constant

\[
V = \frac{kT}{q}
\]

to the logarithm of the input quantities \( A \), normalization circuit comprising a number of first, identical bipolar transistors which corresponds to the number of input quantities, said transistors comprising a base, an emitter and a collector, an output signal \( I \) of the converter means being applied to the base of a first transistor, the emitters of the first transistors being collectively connected to a constant current source via an emitter junction. As a result of the described step, the diode currents are directly converted into a logarithmic voltage, followed by further processing by means of a normalization circuit, so that the procedure is substantially simplified and fewer errors are introduced.

A preferred embodiment of the measuring device in accordance with the invention is characterized in that the converter means form part of the sensor. When the sensor already incorporate a logarithmic relationship between the quantity to be measured and the output voltage, the normalization circuit can be connected directly to the sensors.

An alternative preferred embodiment of the measuring device in accordance with the invention is characterized in that the signal produced by the sensor is linearly proportional to the detected input quantity sensed, the converter means comprising a logarithm is converter which is included in the transducer unit. The signals applied to the normalization circuit, originally being linearly proportional to the input quantities, thus also exhibit a logarithmic relationship with the corresponding input quantities.

A further preferred embodiment of the measuring device in accordance with the invention is characterized in that the measuring device comprises a series of photodiodes which are accommodated on the same substrate as the normalization circuit and whose anodes are connected to the base of the first transistors, their cathodes being collectively connected together.

Another preferred embodiment of the measuring device in accordance with the invention is characterized in that the measuring device comprises a series of photodiodes which are accommodated on the same substrate as the normalization circuit, the cathodes of said photodiodes being collectively connected to a voltage source, their anodes being connected to the collector of second transistors whose emitters are collectively connected to a point of constant potential, their base being connected to the collector and to the base of a first transistor.

Another preferred embodiment of the measuring device in accordance with the invention is characterized in that the measuring device comprises a series of sensor circuits which are accommodated on the
same substrate as the first transistors and which are connected to the base of the first transistors whose
emitters are collectively connected to a constant current source and whose collectors are interconnected via
a series of resistance elements, which series comprises two contact points. In the latter three embodiments
the compactness of the measuring device is increased, being of advantage for applications where the
dimensions of the components are preferably minimized for example, in optical disc recording.

Another preferred embodiment of the measuring device in accordance with the invention is character-
ized in that the measuring device is constructed as a quadrant detector comprising four photodiodes and an
appropriate number of transistors. Both series of photodiodes integrated with a normalization circuit can be
constructed as a quadrant detector.

The invention will be described in detail hereinafter with reference to the drawing.

Figure 1 diagrammatically shows a measuring device in accordance with the invention;
Figures 2a and 2b show two embodiments of a logarithmic converter for use in a measuring device in
accordance with the invention;
Figure 3 shows a third embodiment of a logarithmic converter;
Figure 4 shows an alternative embodiment of the logarithmic converter shown in Figure 3;
Figure 5 diagrammatically shows a part of a measuring device suitable for use in a device in accordance
with the invention;
Figure 6 shows a first embodiment of a series of photodiodes integrated with a normalization circuit;
Figure 7 shows a second embodiment of a series of photodiodes integrated with a normalization circuit;
and
Figure 8 shows a further embodiment of a measuring device in accordance with the invention.

The measuring device 1 which is diagrammatically shown in Figure 1 comprises a number of
transducer units 2 for sensing input quantities $A_i$, a normalization circuit 5 for normalizing these input
quantities, and an arithmetic unit 7. Generally speaking, the normalization circuit 5 comprises a number of
first, identical bipolar transistors 9 which corresponds at least to the number of input quantities, said
transistors comprising a base 11, an emitter 13 and a collector 15, and also comprising a constant current
source 17. Normalization is substantially simplified when it is ensured that the output signals of the
transducer units 2 are proportional to the logarithm of the corresponding input quantities $A_i$. To this end,
each transducer unit 2 comprises a sensor 3 and a logarithmic converter 4. In some cases it may be that
the output signals of the sensors 3 are already proportional to the logarithm of the input quantities $A_i$. In that
case the logarithmic converters 4, denoted by a broken line, can be omitted. The output signal of each
transducer unit 2 is then applied to the base 11 of the corresponding transistor 9, the emitters 13 of all
transistors 9 being collectively connected to the constant current source 17 via an emitter junction 19. The
output quantity $I_i$ supplied by a collector 15 can subsequently be applied to the arithmetic unit 7 for further
processing, if necessary. The logarithmic relationship between the input quantities $A_i$ and the output signals
of the transducer units 2, for example output voltages $V_i$, can be written as follows

$$V_i = V_o \ln(A_i)$$  \hspace{1cm} (1)

Therein, $V_o$ is a proportionality constant yet to be determined. An arbitrary collector current $I_i$ of a transistor
9 having a base-emitter voltage $V_{be}$ satisfies:

$$I_i = I_o \exp(V_{be}/V) = I_o \exp(V - V_o)/V_i$$  \hspace{1cm} (2)

Therein, $I_o$ is the reverse current of each transistor, $V_o$ is the voltage across the If:
current of the transistors is assumed to be negligibly small. Moreover:

$$I_e = \sum_{i=1}^{n} I_i = I_o \cdot \exp(-V_e/V_i) \cdot \left(\sum_{i=1}^{n} \exp(V_i/V_i)\right)$$  \hspace{1cm} (3)

If:

$$V_o = V_i$$  \hspace{1cm} (4)

it follows, considering (1) and (3) that:
\[ I_i \cdot \exp\left[ -\frac{V_e}{V_i} \right] = I_i / \left( \sum_{i=1}^{n} A_i \right) \]

(5)

Substitution in (2) produces:

\[ I_i = \frac{A_i}{A_1 + A_2 + \ldots + A_n} \cdot I_i \]

(6)

The latter expression represents the desired relationship between an input quantity \( A_i \) and the associated output current \( I_i \). It is important that the relation (4) is satisfied. To this end, it is necessary to compensate for the temperature dependency of \( V_i \). This can be realized, for example, by keeping the transistors 9 of the normalization circuit 5 and the logarithmic converter 4 at a constant temperature. The logarithm of the sum of the input quantities can also be expressed by means of the voltage \( V_e \) across the emitter junction. (5) can be rewritten as:

\[ \exp\left[ \frac{V_e}{V_i} \right] = \frac{I_i \sum_{i=1}^{n} A_i}{I_i} \]

or

\[ V_e = V_i \ln\left( \frac{I_i}{I_i} \right) + V_i \ln\left( \sum_{i=1}^{n} A_i \right) \]

The first term is a constant, provided that the temperature is constant. This term is in the order of magnitude of -0.6 V.

The logarithmic relationship between the input quantities \( A_i \) and the output signals of the transducer units 2 can be achieved by means of a number of circuits which are known per se. One possibility consists in that the relationship between the input quantities to be normalized and the output signals of the sensors 3 is linear. In that case the transducer unit 2 is formed by a sensor 3, followed by a logarithmic converter 4, so that the signals applied to the normalization circuit 5 are proportional to the logarithm of the input quantities.

A first embodiment thereof consists of a diode 18 or a transistor 20 which is connected as a diode as shown in the Figures 2a and 2b, respectively. The output signal \( V \) is then given by:

\[ V = \frac{kT}{q} \ln \left( \frac{I_i}{I_i} \right) \]

An operational amplifier 21 having a transistor 23 connected in the feedback path 25 as shown in Figure 3 represents a second embodiment. Such a circuit is described in detail in the publication "A circuit with logarithmic transfer response over 9 decades" by J.F. Gibbons and H.S. Horn in IEEE Transactions on Circuit Theory, pp. 378-384, September 1964. The output voltage is then negative:

\[ V = -\frac{kT}{q} \ln \left( \frac{I_i}{I_i} \right) \]
An alternative version thereof, in which a positive output voltage is generated, is shown in Figure 4. The relationship between the input current and the output voltage is again given by:

\[ V = \frac{kT}{q} \ln \frac{I_i}{I_r} \]

In the above embodiment, the relationship between the input current \( I_i \) and the output voltage \( V \) is generally given by:

\[ V = V_i \ln \frac{I_i}{I_r} \]

Therein, \( I_r \) is the reverse current of the diode or the transistors and \( V_i = kT/q \). The relation \( V_o = V_i \) is then automatically satisfied, provided that all transistors have the same temperature.

Application of a logarithmic converter 4 of the type shown in Figure 4 provides a circuit of which the performance as regards speed, dynamic range and resolution are more than one order of magnitude better than that of the conventional circuit comprising an analog divider as described in the cited publication by B. L. Light (dynamic range 1:1000, inaccuracy 0.05%, bandwidth 150 kHz.).


A fifth embodiment concerns logarithmic converters based on the exponential relationship between time and the voltage across a capacitor which is charged or discharged by a resistor. This is described in the publication "A simple low-frequency logarithmic converter using logarithmic pulse width modulation technique" by S.D Marougi in IEEE Transactions on Instrumentation and Measurement, Vol. IM-34, No. 3, pp. 473-475, September 1985.

Converters of the kind such as the fourth and the fifth embodiment produce an output voltage which generally need be amplified or attenuated in order to satisfy the relation \( V_o = V_i \).

Another possibility consists in that the output signals are already proportional to the logarithm of the input quantities, so that the normalization circuit 5 can be connected directly to the converters.

A first embodiment in this respect is formed by a photodiode in which the photovoltaic effect occurs. The output quantity, being a voltage, is a logarithmic representation of the input quantity, being the light intensity. When the temperature of the photodiodes and the normalization circuit is the same:

\[ V_o = \frac{kT}{q} \]

so that the relation \( V_o = V_i \) is satisfied.

Another embodiment in which the relationship between light intensity and output voltage is logarithmic is formed by a photodetector as described in the patent specification US-A 4,473,838.

An entirely different class of sensors is formed by the ion concentration meters, for example, PH meters. The output voltage is logarithmically dependent on the ion concentration. An embodiment in this respect is a hydrogen ion concentration measuring device 100 as shown in Figure 5. The measuring device 100 consists of a container 102 in which a porous partition 104 is arranged. To the left of the porous partition 104 there is introduced an electrolyte 106 having a known H\(^+\) ion concentration \( C_N \). To the right of the porous partition 104 there is introduced an electrolyte 108 with the H\(^+\) ion concentration \( C_x \) to be measured. No H\(^+\) ions are exchanged through the porous partition 104. A hydrogen electrode 110, 112 is immersed in both electrolytes 106, 108. These electrodes 110, 112 may consist of, for example, platinum which has absorbed hydrogen. The voltage \( \Delta V_N \) between the electrode 110 and the electrolyte 106 satisfies Nernst's relation:
\[ \Delta V_N = \frac{kT}{q} \ln \frac{C_N}{C_X} \]

The same holds good for the voltage \( \Delta V_x \) between the electrode 112 and the electrolyte 108:

\[ \Delta V_x = \frac{kT}{q} \ln \left( \frac{C_X}{C_X} \right) \]

Therein, \( C_N \) is the \( \text{H}^+ \) ion concentration to be measured, \( C_X \) is the known \( \text{H}^+ \) ion concentration, and \( C_X \) is the boundary concentration on the electrodes 110, 112, so that the voltage between the two electrodes 110, 112 is given by:

\[ \Delta V = \Delta V_x - \Delta V_N = \frac{kT}{q} \ln \frac{C_X}{C_N} \]

In order to make the measuring device more compact, a series of photodiodes 27 can be accommodated, together with the normalization circuit 5, on the same substrate. Figure 6 shows an embodiment in this respect. The anodes 29 of the photodiodes 27 are connected to the base 11 of the first transistors 9, the cathodes 31 being collectively connected to a point 35 of constant potential. The emitters 13 are collectively connected to the constant current source 17 via the emitter junction 19. When a current \( I_p \) is extracted from the common emitter junction of the transistors 9 (junction 19), any collector current of the transistors 9 will be proportional to the quotient of the photocurrent of the associated photodiode 27 and the sum of the photocurrents. The scale factor is \( I_p \). Normalization can also be de-activated by means of the external circuit by connecting the junction 19 to a fixed voltage (not shown). If this voltage is lower than the voltage at the point 35, the photocurrent is amplified by the transistor 9.

Figure 7 shows another embodiment of a detector integrated with the normalization circuit 5. The cathode 31 of the photodiodes 27 are collectively connected to a voltage source 37, via a junction 39, the anodes 29 being connected to the collectors 41 of second transistors 43. The emitters 45 of the transistors 43 are collectively connected to a point 47 of constant potential. The base 49 of each transistor 43 is connected to the collector 41 of the same transistor 43 and to the base 11 of the corresponding first transistor 9. Furthermore, the emitters 13 of the first transistors 9 are collectively connected to the constant current source 17, via the emitter junction 19. In the present embodiment the photodiodes 27 have a reverse bias voltage, so that the output current is linearly proportional to the light intensity (photo-amperage effect). The logarithmic converter 4 is of the same type as shown in Figure 2b. This detector can be comparatively simply realised. One of the possibilities in this respect is a monolithic structure where a compromise must be found between the quality of the photodiodes on the one hand and the quality of the transistors on the other hand. A further possibility consists in a hybrid structure, for example, in a thick-film or thin-film technique.

The latter circuits can in principle both be composed using an arbitrary number of photodiodes in different configurations, for example, bi-cell, quadrant, circular or linear array. Bi-cell and quadrant photodiode configurations are often used to detect the position of a light spot which spreads across the surface of diodes. Using the arithmetic unit 7, the signals required for the X and Y displacement of the spot can be found by suitably summing or subtracting the diode currents. This technique is used inter alia in optical disc recording, for example, in CD/VLP players, and for sensing distance and location in the measuring technique. In many cases the intensity-dependency of these sensors is undesirable, thus necessitating normalization of the diode currents.

When the number of collector connections 51 of a transistor array, as shown in Figure 6 and Figure 7, is reduced to two, such a circuit can be used, for example, for optical centre of gravity determination. Figure 8 shows an example in this respect. The collectors 15 are no longer separated but interconnected via resistance elements 53. Only the ends 55, 57 of the transistor array are contacted. The resistance elements 53 may consist of, for example, a resistance layer as in the present embodiment. However, they can
alternatively be formed by discrete resistors. Under the influence of the resistance elements 53, the
currents I_A and I_B to the two contacts 55, 57 differ. They represent the centre of gravity of the current
distribution I_1, I_2, ..., I_n. The sensor circuits 59, being connected to the bases 11 of the first transistors 9 and
supplying the input signal, may consist of a diode 27 as shown in Figure 6 or of a diode 27 with a transistor
43 as shown in Figure 7. Furthermore, the emitters 13 of the transistors 9 are collectively connected to a
constant current source 17 for a current I_o.

Claims

1. A measuring device (1), comprising at least two transducer units (2) provided with a sensor (3) for
sensing an input quantity A_i and for producing a signal which is dependent on the input quantity, and
also comprising a normalization circuit (5) which receives the signals produced by the transducer units
(2) and which subsequently determines the ratio of a linear combination of input quantities to the sum
of the input quantities, characterized in that each transducer unit (2) comprises converter means (4) for
converting the input quantities A_i in signals V_i which are proportional with proportionality constant

\[ V_o = \frac{kT}{q} \]

to the logarithm of the input quantities A_i, the normalization circuit (5) comprising a number of first,
identical bipolar transistors (9) which corresponds to the number of input quantities, said transistors (9)
comprising a base (11), an emitter (13) and a collector (15), an output signal I_i of the converter means
(4) being applied to the base (11) of a first transistor (9), the emitters (13) of the first transistors (9)
being collectively connected to a constant current source (17) via an emitter junction (19).

2. A measuring device as claimed in Claim 1, characterized in that the converter means (4) form part of
the sensor (3).

3. A measuring device as claimed in Claim 1, characterized in that the signal produced by the sensor (3)
is linearly proportional to the input quantity sensed, the converter means (4) comprising a logarithmic
converter which is included in the transducer unit (2).

4. A measuring device as claimed in Claim 2, characterized in that the measuring device (1) comprises a
series of photodiodes (27) which are accommodated on the same substrate as the normalization circuit
(5) and whose anodes (29) are connected to the base (11) of the first transistors (9), their cathodes (31)
being collectively connected together.

5. A measuring device as claimed in Claim 3, characterized in that the measuring device (1) comprises a
series of photodiodes (27) which are accommodated on the same substrate as the normalization circuit
(5), the cathodes (31) of said photodiodes (27) being collectively connected to a voltage source (37),
their anodes (29) being connected to the collector (41) of second transistors (43) whose emitters (45)
are collectively connected to a point (47) of constant potential, their base (49) being connected to the
collector (41) and to the base (11) of a first transistor (9).

6. A measuring device as claimed in Claim 1, 2 or 3, characterized in that the measuring device (1)
comprises a series of sensor circuits (59) which are accommodated on the same substrate as the first
transistors (9) and which are connected to the base (11) of the first transistors (9) whose emitters (13)
are collectively connected to a constant current source (17) and whose collectors (15) are interconnected
via a series of resistance elements (53), which series comprises two contact points (55, 57).

7. A measuring device as claimed in Claim 4, 5 or 6, characterized in that it is constructed as a quadrant
detector comprising four photodiodes and an appropriate number of transistors.
Patentansprüche

1. Meßeinrichtung (1) mit mindestens zwei Wandereinheiten (2), die mit einem Sensor (3) zum Aufnehmen einer Eingangsgröße $A_i$ und zum Erzeugen eines von der Eingangsgröße abhängigen Signals versehen ist, und auch mit einem Normierungsschaltkreis (5), der die von den Wandereinheiten (2) erzeugten Signale empfängt und anschließend das Verhältnis einer linearen Kombination von Eingangsgrößen zu der Summe der Eingangsgrößen bestimmt, dadurch gekennzeichnet, daß jede Wandereinheit (2) Umsetzermittel (4) zum Umsetzen der Eingangsgrößen $A_i$ in den Logarithmus der Eingangsgrößen $A_i$ proportionale Signale mit der Proportionalitätskonstante $V_e = kT/q$ umfaßt, wobei der Normierungsschaltkreis (5) eine Anzahl erster, identischer Bipolartransistoren (9) umfaßt, die der Anzahl Eingangsgrößen entspricht, wobei die Transistoren (9) eine Basis (11), einen Emitter (13) und einen Kolektor (15) umfassen, wobei ein Ausgangssignal $I$, der Umsetzermittel (4) der Basis (11) eines ersten Transistors (9) zugeführt wird und die Emitter (13) der ersten Transistoren (9) über einen Emitterknotenpunkt (19) gemeinsam mit einer Konstantstromquelle (17) verbunden sind.

2. Meßeinrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Umsetzermittel (4) Teil des Sensors (3) sind.

3. Meßeinrichtung nach Anspruch 1, dadurch gekennzeichnet, daß das von dem Sensor (3) erzeugte Signal linear proportional zu der aufgenommenen Eingangsgröße $A_i$ ist, wobei die Umsetzermittel (4) einen in der Wandereinheit (2) enthaltenen Umsetzer umfassen.

4. Meßeinrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Meßeinrichtung (1) eine Reihe von Photodioden (27) umfaßt, die sich auf dem gleichen Substrat befinden wie der Normierungsschaltkreis (5) und deren Anoden (29) mit der Basis (11) der ersten Transistoren (9) verbunden sind, wobei ihre Kathoden (31) gemeinsam miteinander verbunden sind.

5. Meßeinrichtung nach Anspruch 3, dadurch gekennzeichnet, daß die Meßeinrichtung (1) eine Reihe von Photodioden (27) umfaßt, die sich auf dem gleichen Substrat befinden wie der Normierungsschaltkreis (5), wobei die Kathoden (31) dieser Photodioden (27) gemeinsam mit einer Spannungsquelle (37) verbunden sind, ihre Anoden (29) mit dem Kolektor (41) zweiter Transistoren (43) verbunden sind, deren Emitter (45) gemeinsam mit einem Punkt (47) konstanten Potentials verbunden sind, wobei deren Basis (49) mit dem Kolektor (41) und der Basis (11) eines ersten Transistors (9) verbunden ist.

6. Meßeinrichtung nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß die Meßeinrichtung (1) eine Reihe von Sensorschaltungen (59) umfaßt, die sich auf dem gleichen Substrat befinden wie die ersten Transistoren (9) und die mit der Basis (11) der ersten Transistoren (9) verbunden sind, deren Emitter (13) gemeinsam mit einer Konstantstromquelle (17) verbunden sind und deren Kolektoren (15) untereinander über eine Reihe von Widerständen (53) verbunden sind, welche Reihe zwei Kontaktpunkte (55, 57) umfaßt.

7. Meßeinrichtung nach Anspruch 4, 5 oder 6, dadurch gekennzeichnet, daß sie als Quadrantendetektor mit vier Photodioden und einer geeigneten Anzahl Transistoren ausgeführt ist.

Revendications

1. Dispositif de mesure (1) comprenant au moins deux unités de transducteurs (2) pourvus d’un capteur (3) pour détecter une quantité d’entrée $A_i$ et pour produire un signal qui dépend de la quantité d’entrée, et comprenant également un circuit de normalisation (5) qui reçoit les signaux produits par les unités de transducteurs (2) et qui détermine ensuite le rapport d’une combinaison linéaire de quantités d’entrée à la somme des quantités d’entrée, caractérisé en ce que chaque unité de transducteur (2) comprend des moyens de conversion (4) pour convertir les quantités d’entrée $A_i$ en signaux $V_i$ qui sont proportionnels avec une constante de proportionnalité $V_e = kT/q$ au logarithme des quantités d’entrée $A_i$, le circuit de normalisation (5) comprenant un nombre de premiers transistors bipolaires identiques (9) qui correspond au nombre de quantités d’entrée, les dits transistors (9) comprenant une base (11), un émetteur (13) et un collecteur (15), un signal de sortie $I_i$ des moyens de conversion (4) étant appliqué à la base (11) d’un premier transistor (9), les émetteurs (13) des premiers transistors (9) étant collectivement connectés à une source de courant constant (17) via une jonction d’émetteur (18).
2. Dispositif de mesure selon la revendication 1, caractérisé en ce que les moyens de conversion (4) font partie du capteur (3).

3. Dispositif de mesure selon la revendication 1, caractérisé en ce que le signal produit par le capteur (3) est proportionnel linéairement à la quantité d'entrée détectée, les moyens de conversion (4) comprenant un convertisseur logarithmique qui est inclus dans l'unité de transducteur (2).

4. Dispositif de mesure selon la revendication 2, caractérisé en ce que le dispositif de mesure (1) comprend une série de photodiodes (27) qui sont reçues sur le même substrat que le circuit de normalisation (5) et dont les anodes (29) sont connectées à la base (11) des premiers transistors (9), leurs cathodes (31) étant connectées collectivement les unes aux autres.

5. Dispositif de mesure selon la revendication 3, caractérisé en ce que le dispositif de mesure (1) comprend une série de photodiodes (27) qui sont reçues sur le même substrat que le circuit de normalisation (5), les cathodes (31) desdites photodiodes (27) étant collectivement connectées à une source de tension (37), leurs anodes (29) étant connectées au collecteur (41) de deuxièmes transistors (43) dont les émetteurs (45) sont connectés collectivement à un point (47) de potentiel constant, leur base (49) étant connectée au collecteur (41) et à la base (11) d'un premier transistor (9).

6. Dispositif de mesure selon la revendication 1, 2 ou 3, caractérisé en ce que le dispositif de mesure (1) comprend une série de circuits de détection (59) qui sont reçus sur le même substrat que les premiers transistors (9) et qui sont connectés à la base (11) des premiers transistors (9) dont les émetteurs (13) sont connectés collectivement à une source de courant constant (17) et dont les collecteurs (15) sont interconnectés via une série d'éléments résistants (53), ladite série comprenant deux points de contact (55, 57).

7. Dispositif de mesure selon la revendication 4, 5 ou 6, caractérisé en ce que le dispositif de mesure est conçu sous la forme d'un détecteur à quadrants comprenant quatre photodiodes et un nombre approprié de transistors.