



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 1 439 499 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.07.2004 Bulletin 2004/30

(51) Int Cl.7: **G07D 5/08**

(21) Application number: **03001095.3**

(22) Date of filing: **20.01.2003**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT SE SI SK TR**
Designated Extension States:
AL LT LV MK RO

(72) Inventor: **De Feo, Carlo**
1223 Cologny (CH)

(74) Representative: **Wenger, Joel-Théophile**
Leman Consulting S.A.
62 route de Clementy
1260 Nyon (CH)

(71) Applicant: **IPM International SA**
1211 Genève 16 (CH)

(54) Method and device to recognize coins in a validation unit

(57) The present invention propose a method to recognize coins in a coin validation unit comprising a runway for coin passage where is placed at least one inductive sensor in form of a pair of coils between which a coin is going through, to said coils are applied input electric signals which responses represent, after calculation, values proportional respectively to the sensor

conductance and to the sensor susceptance, said values are an image of the coin characteristics.

This invention describes also the coin validation device able to recognize coins according to the method.

The objective is to provide a coin recognition method and device which main features lead to a high reliability, stability, and repeatability with the lowest manufacturing costs.

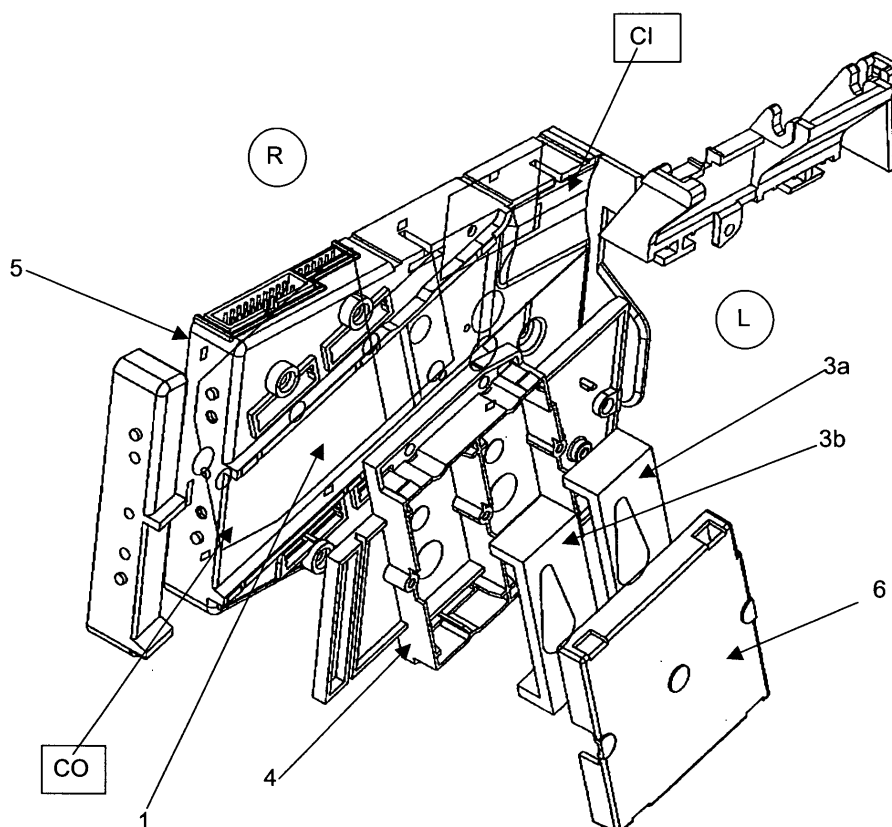


Fig. 4

EP 1 439 499 A1

Description

[0001] The present invention relates to a method and a device to recognize coins in a validation unit. Such a unit is a part of a coin-handling device which function is to determine if an inserted coin is acceptable or not.

[0002] A coin-handling device is an apparatus, which validates and accepts coins used as payment mean usually integrated in a vending machine or a payphone. The coin-handling device comprises a housing equipped with several openings including the coin entry slot, which is accessible from the front panel of the machine. A coin inserted in this slot gets into a runway generally inclined downwards before reaching a specific region or part called validation unit or validator where the coin is analysed according different parameters such as the dimensions and the material. In function of the analysis results, the coin comes through another opening into an escrow and finally in a cashbox (coin accepted), otherwise it is deviated to a coin return receptacle (coin rejected).

[0003] The invention concerns in particular a coin analysis method carried out by an electromagnetic sensor specially designed for applying this method.

[0004] In the prior art, the coin passes close by a sensor made of coils mounted in the wall of the runway which impedance is measured by a microprocessor driven unit. In fact the coil impedance is influenced by the nature of the coin metallic alloy and its volume (thickness and diameter). In some devices, the diameter could also be measured with optic cells, which are masked the time of the coin passage.

[0005] Other sensors are based on a variable frequency oscillator, which provides a signal through a coil. The presence of the coin changes the signal shape in function of its characteristics. This response could also be collected by another coil coupled to the first one like in a transformer.

[0006] In both type of sensors, the response signals are compared to references stored in a non-volatile memory (EPROM, Flash memory). When the comparison results are within or out of a predetermined window the coin is respectively accepted or rejected.

[0007] The sensor devices need a high precision mechanical and electronic hardware, which is driven by programs loaded in a non-volatile memory. A coin validation unit has usually to recognize several kinds of coins and to distinguish them from other ones with similar characteristics. For example, a coin of a defined value in a country must not be confused with another coin from another country having very close dimensions and alloy, but with a different value. In order to minimise such errors, the device becomes rather complex and requires high performances.

[0008] The aim of the present invention is to propose a coin recognition method and device which main features lead to a high reliability, stability, and repeatability with the lowest manufacturing costs.

[0009] The reliability is defined here as the capacity to have a small failure rate. The stability is the resistance to environmental parameters changes such as temperature, humidity and pressure. The repeatability is the ability to provide results as close as possible on measures made successively on series of same coins.

- The aim is achieved by a method to recognize coins in a coin validation unit comprising a runway for coin passage where is placed at least one inductive sensor in form of a pair of coils between which a coin is going through, to said coils are applied input electric signals which responses are analysed by an electronic circuit, characterized in that

- the input electric signals comprises a sum of single sinusoidal signals with frequencies having each a value $f_1, f_2, f_3, f_4, \dots, f_n$ according to the formula $f_2/f_1 = f_3/f_2 = \dots = f_n/f_{n-1} = 2m$ or $(2m+1)/2$ where m is a positive integer, the first value f_1 is determined by the measurement cycle period,

- the responses corresponding to each input signal frequency represent after calculation, values of the sensor conductance and of the sensor susceptance, said values are an image of the coin characteristics.

[0010] The method is essentially based on calculations made on signal responses received in presence of a coin traversing the area controlled by the sensor.

[0011] An advantage of such method is that the influence of the hardware components variation is reduced. In fact, the generally used high precision analog or digital filters are no more necessary therefore they are replaced by various mathematical operations performed on signals.

[0012] The invention will be better understood with the help of the following detailed description, which makes reference to the annexed figures, which are given as nonlimiting examples, and describe the structure in which the method of the invention is implemented:

Figure 1 represents a block schematic of the device operation

Figure 2 illustrate the signals used in calculation

Figure 3 represents the sensor admittance complex diagram

Figure 4: exploded view of the validator

5 Figure 5: view of the validator right chassis

Figure 6: view of the validator right chassis with the sensor mounted

Figure 7: view of the right halves of the sensors

10 Figure 8: view of the printed circuit supporting the sensors

Figure 9: view of the left chassis with sensors mounted, without cover

15 **[0013]** The figure 1 shows the principle of operating of the coin-validating device. A quadratic sinusoidal oscillator QO generates a pair of 90 degrees phase shifted sinusoidal signals V1 and V2 of frequency f.

[0014] The first signal V1 is applied to the coil of the sensor SE via a power amplifier PA in order to create a current in it. The current-voltage converter IUC converts this current into a voltage V3. The oscillator output signals V1, V2 enter into a comparator CP one after the other through a switch SW to provide a rectangular signal according to the sign of each sinusoidal signal V1 and V2. The converter IUC output V3 is multiplied respectively, through the synchronous detector SD, by each sign signal issued from V1 and V2. Finally, the resulting signal is integrated during the input signal period 1/f providing a number proportional respectively to the conductance g and to the susceptance b of the sensor SE.

25 **[0015]** The conductance g is the real part of the complex number representing the admittance $\underline{Y}$ (inverse of the impedance $\underline{Z}$, $\underline{Y}=1/\underline{Z}$) of the sensor, while the susceptance b represents the imaginary part.

[0016] Both values are directly influenced by the presence of the coin travelling on the runway between the coils of the sensor. Each kind of coin differentiated by the dimensions and the material will provide a specific pair of conductance and susceptance values.

30 **[0017]** The figure 2 shows the different signals at each step of the calculation. The oscillator QO output V1 and V2 have the same frequency f but 90° phase shifted. The rectangular signals SGN(V1) and SGN(V2) are provided by the comparator CP following the switch SW. These signals have fixed positive and negative amplitudes in function of the sign of the input signals V1 and V2.

35 **[0018]** The signal V3 is an image of the current flowing in the coil of the sensor SE. Its phase, relatively to the input signal V1, which is a voltage, depends on the admittance of the sensor in presence of a coin. It is known that a current in an inductance is phase shifted compared to the voltage applied at its ends. The admittance has then the same phase compared to the voltage than the current, according to the Ohm law.

[0019] This signal is then multiplied once by the sign signal determined by the first input signal V1 and once by the second signal V2 determined by the second signal V2.

40 **[0020]** The value proportional to the sensor conductance g is then calculated by the integrating analog / digital converter ADC providing the average of the produce of V3 by the sign of the input signal V1 (SGN(V1)).

45
$$\overline{V3 \cdot \text{sign}(V1)} = \int_0^T [V3 \cdot \text{sign}(V1)] dt = g$$

[0021] The integration is made on one period $T = 1/f$ corresponding to the frequency f of the input signals V1 or V2.

50 **[0022]** In a similar way, the value proportional to the sensor susceptance b is calculated with the second input signal V2.

55
$$\overline{V3 \cdot \text{sign}(V2)} = \int_0^T [V3 \cdot \text{sign}(V2)] dt = b$$

The calculation of the sensor admittance Y components (g , b) brings more possibilities to define the admittance than the simple determination of the admittance modulus as it is usually performed in the prior art. In fact, for a same modulus value, there is infinity of pairs of real and imaginary part (g , b) combination.

[0023] This can be observed in the complex diagram of figure 3 representing a quarter of circle (positive conductance and susceptance values) for a same admittance modulus value Y , but with different arguments Φ (or phase) from 0° to 90° . The components (g , b) are the projections of the vector Y representing the complex admittance respectively on the real axis (Re) and on the imaginary axis (Im) of the diagram.

[0024] In order to guarantee high precision coin measurements, the number of parameters has to be adapted so that the results obtained can be differentiated with the ones of other coins measurements. This is realised by the measuring of the sensor admittance components g and b with several input signal $V1$, $V2$ frequencies $f1$, $f2$, ... fn . Each coin passing close to the sensor provides a set of conductance and susceptance values (g , b), one pair for each frequency. These values (g , b) are stored in a memory and compared with a reference table or with a reference diagram showing each value of the sensor admittance components g and b in function of the frequency.

[0025] In such case, the calculation circuitry needs n quadratic oscillators, $2n$ comparators CD, $2n$ synchronous detectors SD and $2n$ integrating analog digital converters ADC.

[0026] One can demonstrate that when each frequency value $f1$, $f2$, $f3$, $f4$... fn of the input signal ($V1$, $V2$) comply to the formula $f2/f1=f3/f2=...=fn/fn-1=2m$ or $(2m+1)/2$ where m is a positive integer, the circuitry can be drastically simplified. The number of the mathematical operations as well as the number of calculation circuit elements such as comparators, detectors and integrators are reduced.

[0027] For example for the $fn/fn-1=2m$ case, if the integration period is one quarter of the period of maximum frequency and the integration is made on the signals that is the response to the sum of input frequency, the combination of the integration's results allows the separation of the different frequencies contribution. This is due when contributions of a frequency are summed for a time equal or multiple of its period, the result is equal to 0. For example in a case of 4 frequencies ($f1$, $f2$, $f3$, $f4$) used, the summing of the first 8 integrations results with its sign, will eliminate frequency $f3$ and $f4$ and remain only contributions of frequency $f1$ and $f2$; in the same way it is possible to eliminate contributions of $f2$ and then obtain only $f1$ response.

[0028] The first value $f1$ (minimum value) is determined by appropriate response of the sensor during the coin passage; maximum value is determined on the circuit accuracy, i.e. Analog / Digital converter (ADC) speed.

[0029] The amplitude of the oscillators output signal varies in function of each frequency because the current flowing in a coil decreases when the frequency increase. In the aim to adapt the signal amplitude values used for calculations to the measuring range, the oscillator signals are generated with an amplitude proportional to the frequency, according to f^β where β is a parameter depending on the sensor design.

[0030] The present invention relates also to a coin validation device comprising a coin runway, at least one sensor constituted by two symmetrical halves forming a support disposed on each lateral side of the coin runway, a coil is mounted on each said half in the way that one is facing the other and let a gap between the coils faces having a width allowing the passage of a maximum thickness coin, calculation electronic circuitry characterized in that

- both halves of the support form a closed magnetic circuit surrounding the runway, the coils of the sensor are connected in serial mode,
- the electronic circuitry has means to calculate the sensor conductance and susceptance at different frequencies in presence of a coin passing through the gap between the coils of said sensor

[0031] The sensor constitutes the heart of the validator that is specially designed to recognize coins according to above described method.

[0032] The figure 4 shows an exploded view of a coin validation device or coin validator comprising two sensors placed one beside the other. Each sensor is made by two symmetric support halves ($3a$, $3a'$, $3b$, $3b'$), carrying each one a coil, and mounted on the right and left lateral side of the coin runway (1). The validator is disposed vertically inside the host automate. Left (L) and right (R) sides are defined here as viewed from the front part of the validator near the coin input. The coins enter into the runway (1) through a slot on the topside (coin input CI) of the validator and leave the validator through another slot at its rear side (coin output CO). The validator is constituted mainly by a right chassis (5) supporting the coin runway (1) and the right sensor halves (not visible on the figure), a left chassis (4) mounted above the coin runway (1) supporting the left sensor halves ($3a$, $3b$). The sensor area of the left chassis (4) is protected by a cover (6).

[0033] The figure 5 represents the right chassis (5) alone comprising the coins runway (1). On both edges of the runway, openings ($7a$, $7b$) are provided for the junction of the right and left halves of each sensor.

[0034] Figure 6 shows the right chassis (5) with the sensors mounted in position. The coil ($2a$, $2b$) is mounted on each support half ($3a$, $3b$) in the way that a coil is facing the other mounted on the other half of the sensor located

behind the runway wall. The coin passes on the runway through a gap between the two coils having a width allowing the passage of the maximum thickness coins. Both support halves of each sensor thus assembled form a closed magnetic circuit surrounding the runway. The material used for these coil supports is in general ferrite.

[0035] Figure 7 shows the right sensor halves (3a', 3b') along with the coil (2a', 2b') formed by an ovoid shaped kernel where the larger part is directed to the bottom edge of the runway. This specific shape is adapted to the diameter range of the coins to be validated.

[0036] Figure 8 shows a printed circuit board (8) supporting the two complete sensors. This board is placed behind the runway wall of the right chassis (5) so that the runway (1) passes at the level of the junction of each sensor support halves (3a, 3a', 3b, 3b').

[0037] Figure 9 shows the left chassis (4) with the mounted left sensor halves (3a, 3b). This chassis (4) forms the left wall of the runway and supports the left halves (3a, 3b) of each sensor by maintaining them facing respectively each corresponding right half (3a', 3b').

[0038] The two coils of one sensor are connected in serial mode, i.e. one end of the first coil is connected to one end of the second coil. The two other ends are connected to the measuring circuitry in order to be supplied by the signals coming from the oscillator as described above.

[0039] In a preferred embodiment of the validator according to the present invention, the two sensors are connected in a balanced or differential mode. The aim of such configuration is to compensate the output signal measurement errors due to environmental parameters changes as temperature or electronic component ageing.

[0040] When two sensors are connected in a balanced mode and environmental parameters have the same influence on both sensors, the steady state response does not change with environmental parameters. Thus, this configuration allows automatic compensation of temperature changes or component's ageing.

Claims

1. Method to recognize coins in a coin validation unit comprising a runway for coin passage where is placed at least one inductive sensor in form of a pair of coils between which a coin is going through, to said coils are applied input electric signals which responses are analysed by an electronic circuit, **characterized in that**

- the input electric signals comprises a sum of single sinusoidal signals with frequencies having each a value $f_1, f_2, f_3, f_4, \dots, f_n$ according to the formula $f_2/f_1 = f_3/f_2 = \dots = f_n/f_{n-1} = 2^m$ or $(2m+1)/2$ where m is a positive integer, the first value f_1 is determined by the measurement cycle period,
- the responses corresponding to each input signal frequency represent, after calculation, values proportional respectively to the sensor conductance and to the sensor susceptance, said values are an image of the coin characteristics.

2. Method according to claim 1, **characterised in that** multiple sinusoidal input signals are generated where all the frequencies start with a well known phase relation, said signal is applied to the coil of the sensor creating a current in said coil, this current is converted into a voltage by a current - voltage converter,

3. Method according to claim 1 and 2, **characterised in that** active and reactive current components for each frequency is obtained by integrating on a time interval that is a multiple of a quarter of the period ($T/4$) for each frequency and combination of the partial results.

4. Method according to claim 1 to 3 **characterised in that** the relation between the frequencies is chosen according $f_n/f_{n-1} = 2$, the output signal is integrated on a quarter of the period $T_k/4$ corresponding to the maximum value of the frequency f_k for a duration corresponding to the period of lowest frequency f_1 .

5. Method according to claims 1 to 4 **characterized in that** the integration on a quarter of period $T_k/4$ is numerically controlled, an analog / digital converter converts integration results in numbers proportional to real and imaginary parts of conductance for all input frequencies after calculation, these values are modified by the coin passage through the sensor generating a diagram

6. Method according to claims 1 to 5, **characterised in that** the amplitude of each input signals at used frequency is proportional to the frequency, according to f^β where β is a parameter depending on the sensor design, the output signal amplitude being inside a determined measuring range.

7. Method according to claims 1 to 6, **characterised in that** each pair of conductance and susceptance values cal-

culated with each input signal frequency are introduced respectively in a diagram, particular points on each said diagram are compared with previously memorised reference values corresponding to coins accepted by the validation unit, a coin is then validated when the particular points on each diagram match with their reference values.

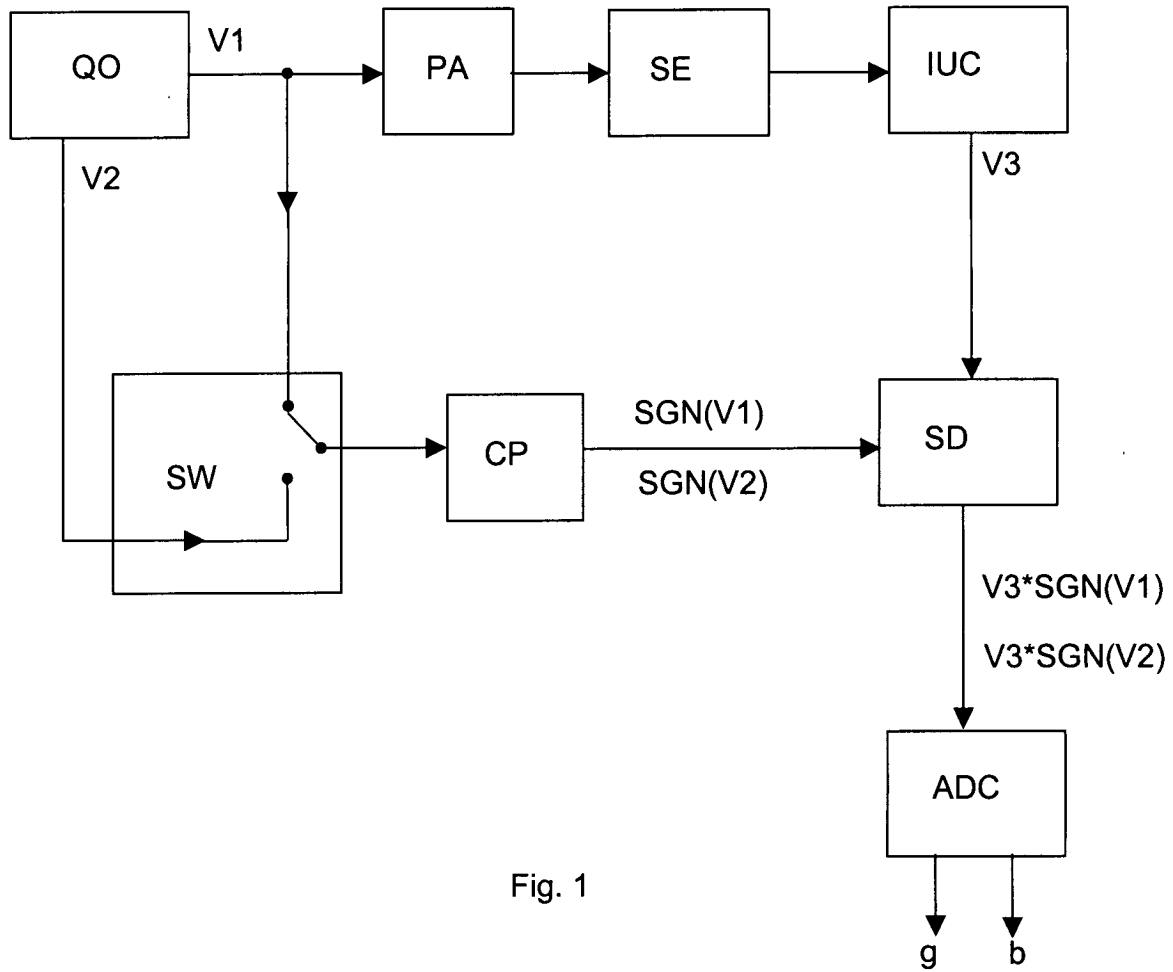
5 **8.** Coin validation device comprising a coin runway (1), at least one sensor constituted by two symmetrical halves forming a support (3a, 3b, 3a', 3b') disposed on each lateral side of the coin runway (1), a coil (2a, 2b, 2a', 2b') is mounted on each said half in the way that one is facing the other and let a gap between the coils faces having a width allowing the passage of a maximum thickness coin, calculation electronic circuitry **characterized in that**

- 10
- both halves of the support (3a, 3b, 3a', 3b') form a closed magnetic circuit surrounding the runway (1), the coils (2a, 2b, 2a', 2b') of the sensor are connected in serial mode,
 - the electronic circuitry has means to calculate the sensor conductance and susceptance at different frequencies in presence of a coin passing through the gap between the coils (2a, 2b, 2a', 2b') of said sensor.

15 **9.** Coin validation device according to claim 8 **characterised in that** each coil (2a, 2b, 2a', 2b') of the sensor is formed by an ovoid shaped kernel with the larger part directed to the bottom edge of the runway (1), said shape being adapted to the diameter range of the coins.

20 **10.** Coin validation device according to claims 8 and 9 **characterised in that** both halves of the coil support (3a, 3b, 3a', 3b') of the sensor are made in ferrite material.

25 **11.** Coin validation device according to claims 8 to 10 **characterised in that** it comprises two sensors connected in a balanced or differential configuration and means to provide automatic compensation of temperature changes or component's ageing.



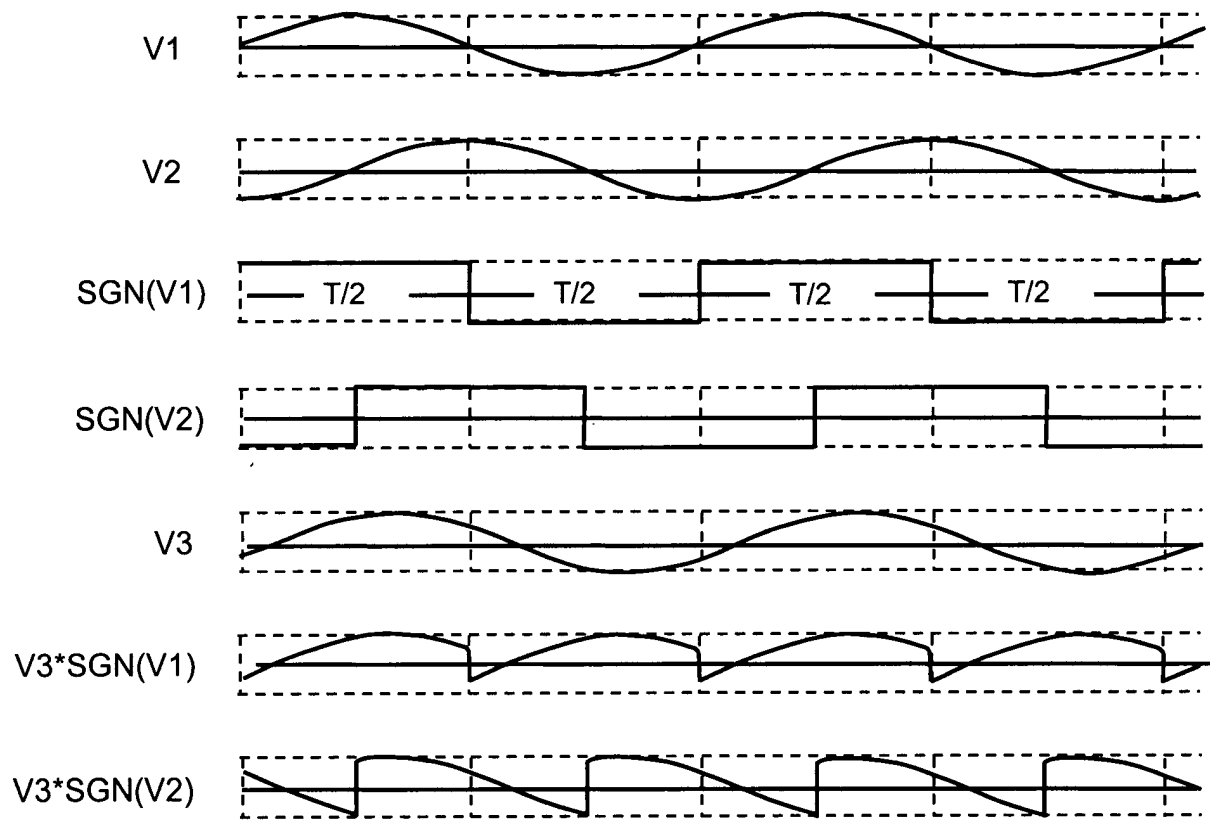


Fig. 2

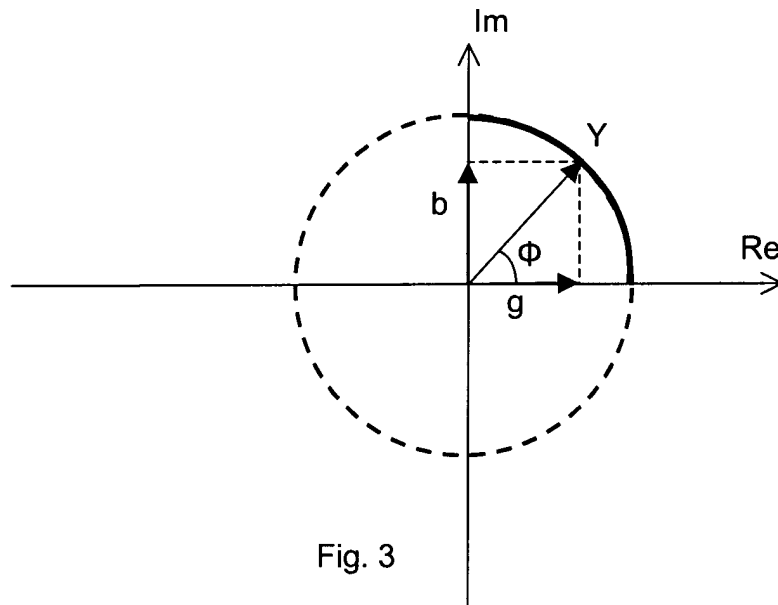


Fig. 3

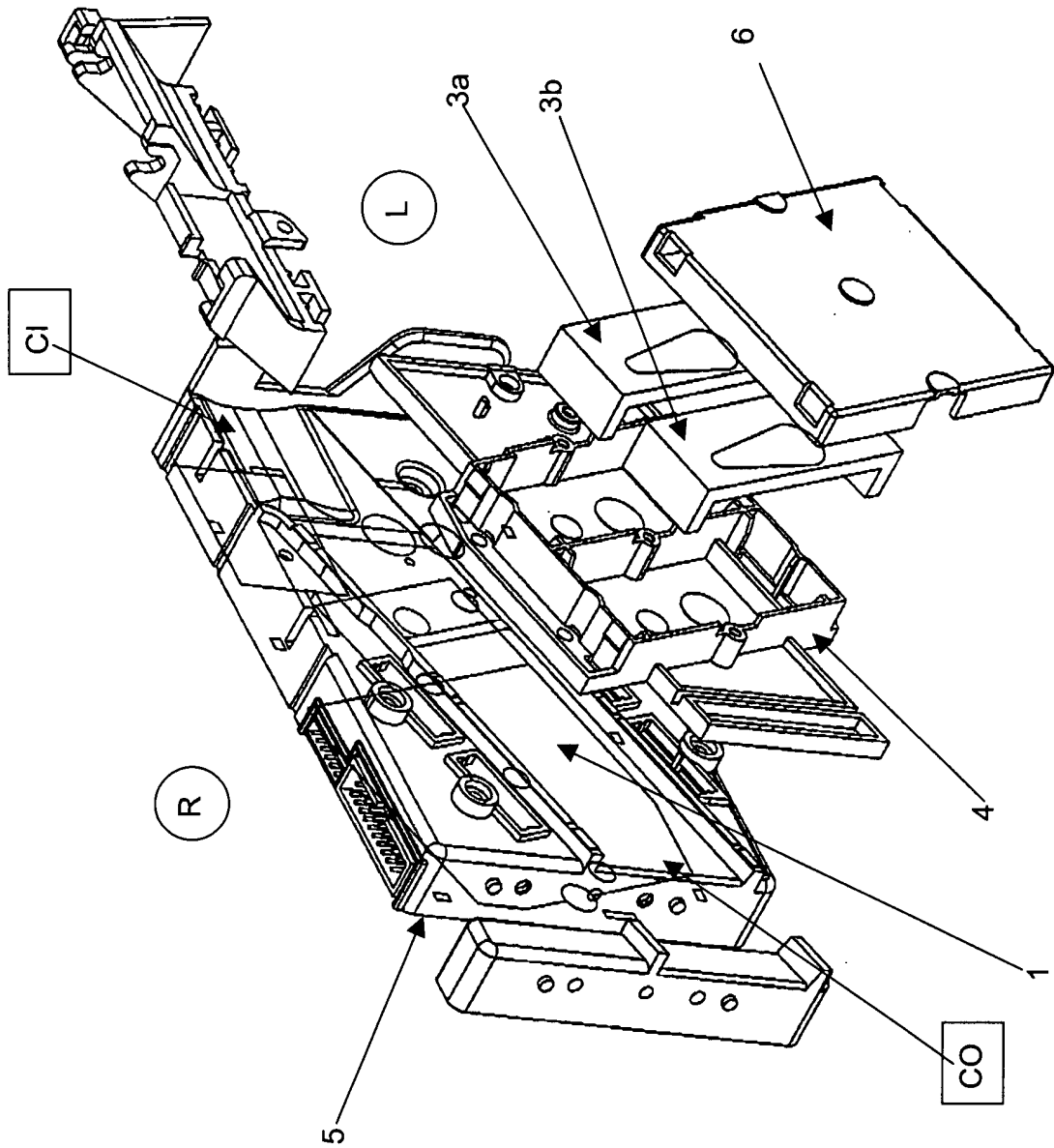


Fig. 4

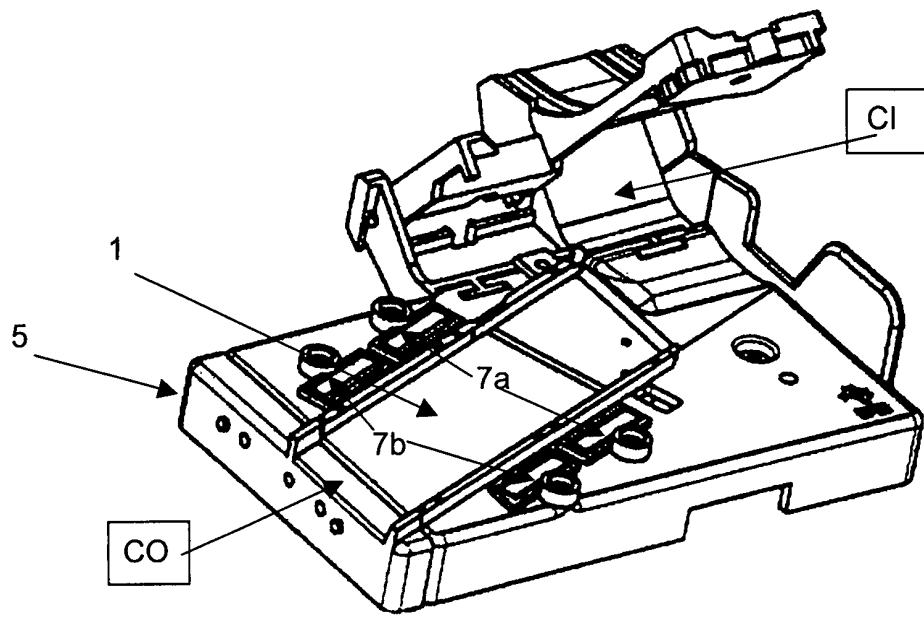


Fig. 5

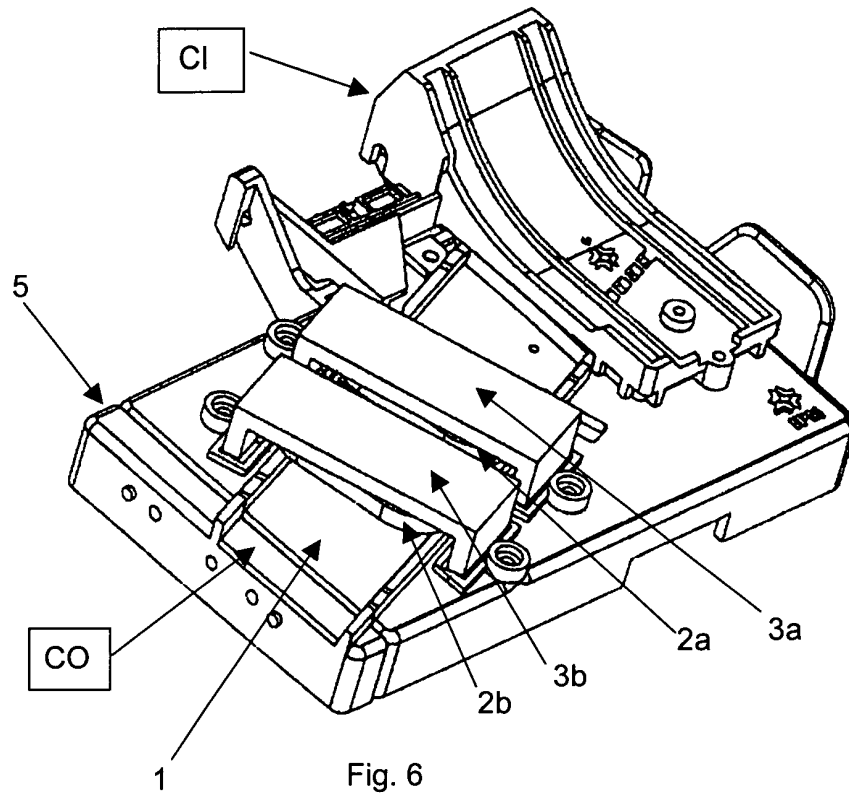


Fig. 6

Fig. 7

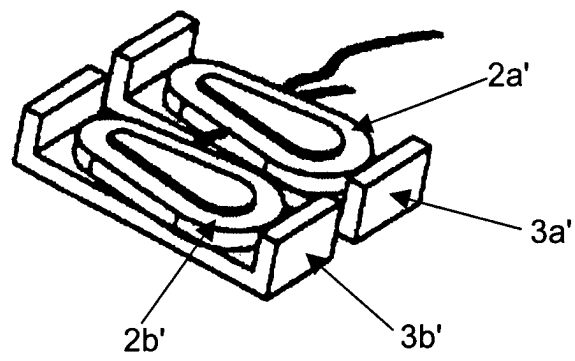


Fig. 8

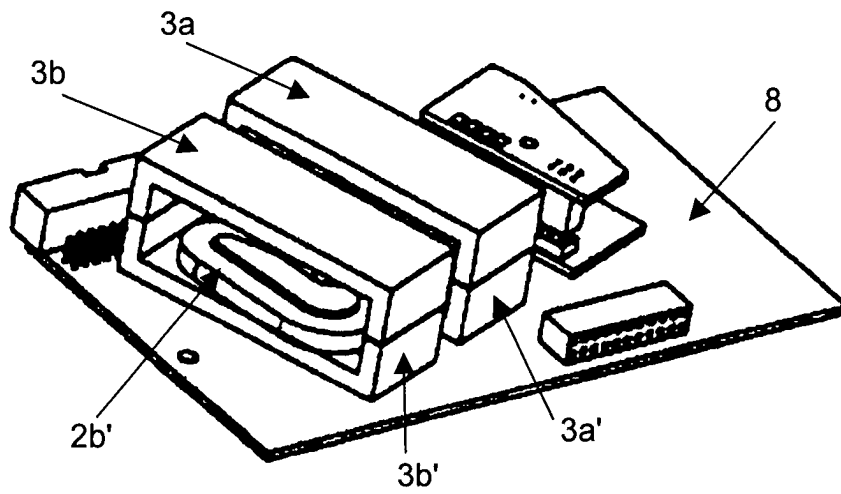
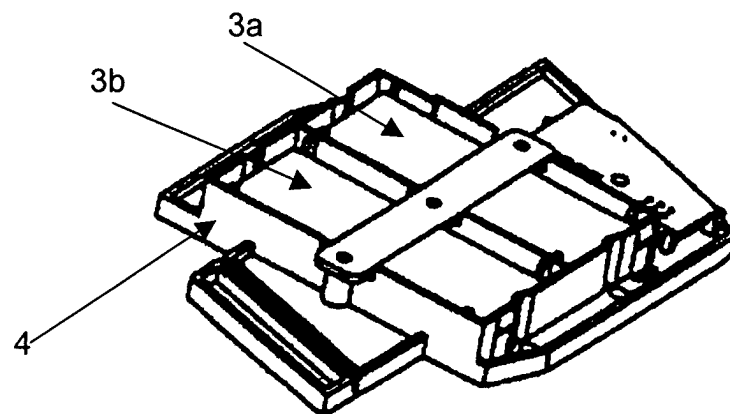


Fig. 9





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 00 1095

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 1 172 772 A (AZKOYEN MEDIOS DE PAGO S A) 16 January 2002 (2002-01-16)	1,6	G07D5/08 G07F3/02
Y	* page 3, line 40 - page 5, line 6; figures 1-3 *	2-5,7	

Y	US 6 340 082 B1 (HOUSE LARRY J ET AL) 22 January 2002 (2002-01-22)	5,7	
	* column 10, line 15 - line 35; figures 7-10 *		

Y	DE 100 49 390 A (NIPPON CONLUX CO LTD) 12 April 2001 (2001-04-12)	3,4	
	* column 8, line 32 - line 41 *		

Y	JP 53 084453 A (FUJITSU LTD) 25 July 1978 (1978-07-25)	2	
	* figures 1-5 *		

A	US 5 199 545 A (TAKAMISAWA KAIHEI ET AL) 6 April 1993 (1993-04-06)	3,4	
	* column 4, line 28 - line 35 *		
	* column 7, line 20 - line 25 *		
	* column 8, line 28 - line 31 *		

A	EP 0 392 110 A (NIPPON CONLUX CO LTD) 17 October 1990 (1990-10-17)	1-11	
	* figure 15 *		

The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 30 April 2003	Examiner Lavin Liermo, J
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 03 00 1095

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

30-04-2003

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1172772 A	16-01-2002	ES 2170678 A1	01-08-2002
		EP 1172772 A2	16-01-2002
US 6340082 B1	22-01-2002	CN 1339144 T	06-03-2002
		DE 10083658 T0	31-01-2002
		WO 0129785 A1	26-04-2001
		JP 2001126103 A	11-05-2001
		TW 418372 B	11-01-2001
DE 10049390 A	12-04-2001	DE 10049390 A1	12-04-2001
		GB 2357883 A ,B	04-07-2001
		JP 2001174438 A	29-06-2001
JP 53084453 A	25-07-1978	NONE	
US 5199545 A	06-04-1993	JP 2117733 C	06-12-1996
		JP 6084040 A	25-03-1994
		JP 8023898 B	06-03-1996
		GB 2253298 A ,B	02-09-1992
		KR 9503207 B1	04-04-1995
		US 5353906 A	11-10-1994
EP 0392110 A	17-10-1990	JP 2268391 A	02-11-1990
		JP 2767278 B2	18-06-1998
		AU 629842 B2	15-10-1992
		AU 3916389 A	18-10-1990
		CA 1309635 A1	03-11-1992
		DE 68921608 D1	13-04-1995
		DE 68921608 T2	18-01-1996
		EP 0392110 A2	17-10-1990
		ES 2069587 T3	16-05-1995
		KR 9205653 B1	11-07-1992
		US 5078252 A	07-01-1992

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82