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(71) Applicant and
(72) Inventor: LANA, Alessandro [IT/IT]; Piazza della Vittoria, 2, I-50067 Rignano sull'Arno (IT).

(74) Agents: MANNUCCI, Michele et al.; Via della Scala, 4, I-50123 Firenze (IT).

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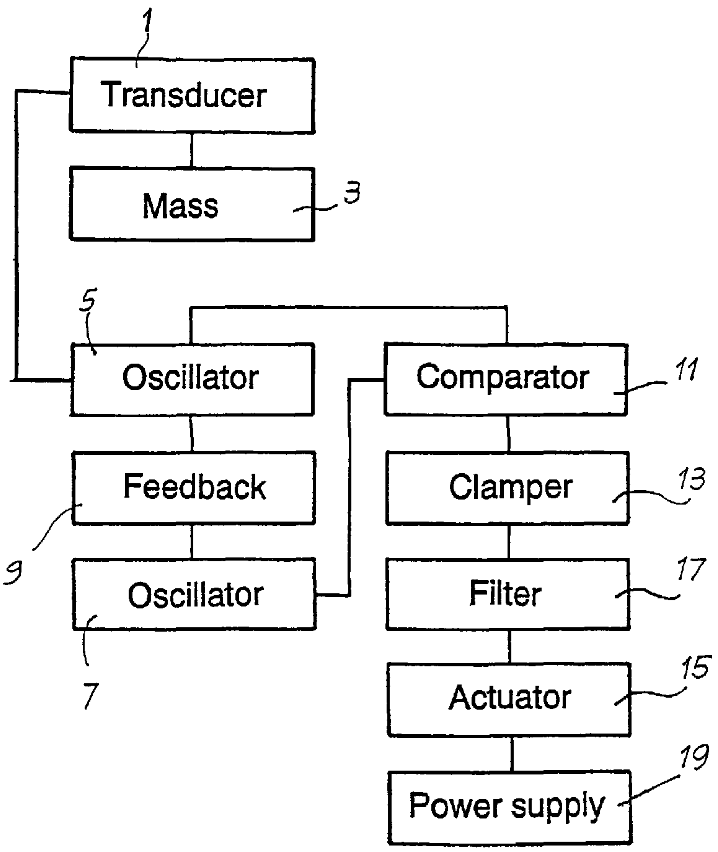
(54) Title: ELECTRONIC SENSOR WITH AN INERTIAL SYSTEM FOR DETECTING VIBRATIONS



(57) Abstract: The vibration sensor comprises an electronic circuit and a deformable transducer element (1) mechanically connectable to an object whose vibrations are to be detected and fixed to an inertial system (3). The vibrations to be detected cause a perturbation of the inertial system (3) which causes a deformation of the transducer element. The deformation is electrically detected by the electronic circuit.

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ELECTRONIC SENSOR WITH AN INERTIAL SYSTEM FOR DETECTING VIBRATIONS

Technical Field

The present invention relates to an electronic sensor for detecting vibrations in general, varying from subsonic frequencies to frequencies of several hundred hertz.

Background Art

The most common systems used in this field range from a simple acoustic indicator (a bell with a spring and clamp) through a sprung rocker contact, which opens by inertia in case of vibration, to more complex selective microphones, generally calibrated to detect frequencies of hundreds or thousands of hertz.

Objects and Brief Description of the Invention

The object of the present invention is to provide a new type of sensor which combines the following set of characteristics: reliability, small size, and low production cost.

These and further objects and advantages, which the following text will make clear to those skilled in the art, are essentially achieved with a sensor of the type comprising an electronic circuit which can be fixed to the object whose vibrations are to be detected, with a deformable transducer element fixed to an inertial system. The vibrations of the object to which the sensor is mechanically fixed cause a perturbation of the resting state of the inertial system, which in turn causes the deformation of the transducer. This deformation is detected electrically by means of an electronic circuit in which the transducer is connected. In practice, the inertial system comprises, for example, a mass of suitable weight. A metal mass, for example one consisting of lead, can be used for this purpose.

In practice, the transducer can advantageously consist of a capacitive component whose capacitance varies as a function of the mechanical deformation to which it is subjected. It can be formed, for example, by a capacitor with at least one elastically deformable plate connected mechanically to the inertial system. The oscillation of the latter causes a temporary deformation of the plate, resulting in a temporary variation of the capacitance of the transducer. Essentially, the deformation is such that the two plates are temporarily moved away from and/or towards each other, thus generating said variation of capacitance in the transducer.

To produce a particularly reliable sensor having a low cost and small size, it is advantageous to use a piezoelectric transducer. These transducers are commonly used for the production of microphones which in certain cases are also used as sensors of mechanical vibrations. However, in these known applications the transducer is used as it stands, and therefore cannot detect vibrations which are not in the high frequency range, particularly in the audible range. Moreover, in the known applications the piezoelectric transducer is used as a voltage generator, owing to the capacity of these components to generate a voltage when they are subjected to a mechanical deformation. According to the invention, on the other hand, the piezoelectric transducer essentially forms an elastic or visco-elastic element of an inertial mechanical system including the mass.

According to the invention, on the other hand, the transducer is made to be capable of additionally detecting vibrations at low or very low frequency, by means of the combination with the inertial system. Moreover, according to the invention, the variation of capacitance induced in the piezoelectric transducer by the mechanical deformation is exploited.

In practice, the transducer is fixed at one of its ends to the inertial system and at its opposite end it is made integral, directly or indirectly, with the body whose vibrations are to be detected. The connection between the transducer and the body can be indirect, in the sense that the container within which the electronic circuit, on which the transducer is located, is applied to the body on which the detection is to be carried out.

In general terms, the invention can be applied by connecting the transducer element in an electronic circuit configured in any way, provided that it is capable of detecting the variation of capacitance caused by the mechanical deformation of the transducer.

In a particularly advantageous embodiment of the invention, the transducer element is connected in an oscillator of the RC type, of which the transducer element forms a part of the capacitive component at least. Thus a variation of the conditions of oscillation of the oscillator occurs as a result of the mechanical deformation of the transducer. In practice, the transducer element can form the single capacitive element of the RC oscillator.

It is possible to make a sensor according to the invention with a single RC oscillator within which the transducer associated with the inertial system is connected; however, in a preferred embodiment of the invention, which is inexpensive and particularly reliable, the electronic circuit has a first and a second oscillator. The transducer element is connected, as a capacitive element, in the first oscillator, while the second oscillator has a fixed configuration, in other words one in which its oscillations are not affected by the vibration to be detected. In this case, it is advantageous to provide for the use of comparator means which receive at their input the signals generated by the first and by the second oscillator, and compare them. A vibration which causes the deformation of the transducer element modifies the relative position in time of the waveforms generated by the two oscillators. More particularly, it is possible to make the vibrations induce a beat or a phase difference, which can be detected by comparator means, between the two signals. The two oscillators are advantageously connected by a stabilizer which synchronizes the first and second oscillator in such a way that the two oscillators generate signals in phase quadrature in rest conditions, in other words in the absence of vibrations.

The comparator means can be associated with a clamper circuit which provides, if vibration is detected, a detection signal to activate an acoustic, optical or other type of indicator, for a sufficiently long period.

In a particularly advantageous embodiment of the invention, a unit can also be provided between the comparator means and/or the clamper circuit and the actuator which causes the acoustic, optical or other indicators to be switched on, this unit preventing the sensor from self-oscillating as a result of the mechanical vibrations generated by the acoustic indicator.

Advantageously, the oscillators can be constructed with the use of logical gates, in view of the quality which such electronic components provided for these applications. In practice, the logical gates can be made in MOS technology, these being characterized by low consumption. However, the possibility of using different embodiments of the circuits is not excluded.

Further advantageous characteristics and embodiments of the sensor according to the invention are indicated in the attached dependent claims.

Brief Description of the Drawings

The invention will be more clearly understood from the description and the attached drawing, which shows some practical, non-restrictive embodiments of the invention. More particularly, in the drawing,

Fig. 1 is a schematic block diagram of the sensor according to the invention;

Fig. 2 shows an embodiment of the circuit of the diagram in Fig. 1;

Fig. 3 is a diagram illustrating the waveform of the signal at various points of the circuit in Fig. 2;

Fig. 4 is a different embodiment of the sensor circuit according to the invention; and

Figs. 5 and 6 show, in lateral elevation and in plan view respectively, a schematic embodiment of the assembly formed by the transducer and the inertial system.

Detailed Description of Embodiments of the Invention

The operating principle of the sensor will be described initially in a general way with reference to the diagram in Fig. 1.

The sensor comprises a transducer 1, which in the illustrated example consists of a piezoelectric transducer, connected mechanically to a mass 3, which oscillates, deforming the transducer 1, when the sensor is caused to vibrate by the object to which the sensor is connected.

The transducer 1 is electrically connected to a first oscillator 5 of an electronic circuit which comprises a second oscillator 7. The first oscillator 5 generates a signal whose waveform is a function of the value of an electrical quantity associated with the transducer 1, which changes when the latter is deformed by the oscillation of the mass 3. The oscillator 7, on the other hand, oscillates at a fixed frequency, which can if necessary be set by the operator. The two oscillators 5 and 7 are interconnected by a feedback element 9 which connects the oscillator 5 to the oscillator 7, in such a way that the two oscillators oscillate at an essentially identical frequency and in phase quadrature when no vibrations are detected.

The outputs of the oscillators 5 and 7 are connected to a comparator 11, whose output takes a value which depends on the relative positions of the waveforms of the two oscillators 5 and 7, in the sense that, when the two signals at the outputs of the oscillators 5 and 7 are coincident with each other, the output of the comparator 11 changes its state, emitting a signal whose duration is proportional to the period of coincidence of the output signals of the oscillators 5, 7. The output of the comparator 11 is connected to a clamper circuit 13, whose output signals changes its state when it receives a pulse from the comparator 11 at its input, and remains in the changed conditions for an appropriate period, determined by the characteristics of the circuit components of the clamper 13. The signal at the output of the clamper circuit 13 activates an actuator 15 which emits a signal when the electronic circuit detects a vibration. The actuator 15 can be of the acoustic or optical or similar type, or a combination of these.

Between the clamper circuit 13 and the actuator 15 there is placed a filter circuit 17 which, when the actuator 15 is of the acoustic type, prevents the vibrations induced by the signal emitted by the actuator 15 from being detected as mechanical vibrations by the transducer 1, thus causing the blocking of the sensor.

The number 19 indicates in a general way a power supply unit for the whole electronic circuit.

Fig. 2 shows a circuit embodying the electronic circuit illustrated in block diagram form in Fig. 1. The same reference numbers are used to indicate the individual functional units. Accordingly, in Fig. 2 a first oscillator 5 and a second oscillator 7 are again identified, and are interconnected by a feedback element 9, which stabilizes the oscillations of the oscillators 5 and 7. In the illustrated example, the feedback element consists of a simple resistor.

Essentially, this forms a stabilizer which synchronizes the first and the second oscillators 5, 7 with each other. The number 11 indicates the comparator, 13 indicates the clamper circuit, 15 indicates the actuator which emits the signal when the sensor detects a vibration, 17 indicates the filter circuit and 19 indicates the power supply of the whole electronic circuit. The transducer 1 and the oscillating mass 3 are shown schematically within the unit 5.

In greater detail, the transducer 1 consists of a piezoelectric transducer with a capacitance variable as a function of the mechanical deformations which it undergoes, these deformations being induced by the oscillation of the mass 3. The piezoelectric transducer 1 is connected within an oscillation circuit of the RC type, comprising, in addition to the capacitance represented by the piezoelectric transducer 1, a first resistor 21 in series with a diode 22 and in parallel with a branch comprising a second resistor 23 and a third resistor 25, the last of these being of the variable type, to enable the oscillator to be calibrated. This calibration is made necessary by the fact that the commercially available piezoelectric transducers have electrical characteristics which differ greatly from one device to another, even for a single model; in other words, there is a wide dispersion of characteristics. The variable resistor 25 enables the device to be calibrated to compensate the variations of capacitance of the piezoelectric transducer which is used. The oscillating circuit of the oscillator 5 also comprises a NOT gate. The signal generated by the oscillator 5 is a square-wave signal with a duty cycle of less than 50% and a frequency dependent on the value of the constants RC and therefore, in particular, on the capacitance of the piezoelectric transducer 1.

The oscillator 7 is also an oscillator of the RC type, and comprises a capacitor 29 and a first resistor 31 in series with a diode 32, which, in turn, are in parallel with a branch comprising a resistor 33 in parallel with a variable resistor 35. The oscillation frequency of the oscillator 7 is fixed, and the signal generated is a square-wave signal with a duty cycle of less than 50%. The variable resistor 35 enables the sensitivity of the circuit to be varied in the way explained below. Finally, the oscillator 7 comprises a NOT gate 37.

With reference to Fig. 3, the signal generated by the oscillator 7 is represented by the diagram O7. It consists of a square wave signal at constant frequency. The diagram O5 shows the variation of the waveform of the oscillator 5. In the diagram in Fig. 3, the sensor does not detect vibrations until the time t0. As can be seen from a comparison of the diagrams O5 and O7, until the instant t0 the waveforms of the signals generated by the two oscillators 5, 7 have the same frequency and are in phase quadrature, or, more generally, the two signals are phased in such a way that there is no temporal coincidence of the two signals ON. At the instant t0 the sensor detects a vibration and this is reflected in an alteration of the frequency of the waveform of the oscillator 5, as can be observed from the variation of the diagram O5. This is due to the variation of the capacitance of the piezoelectric transducer 1, caused by the mechanical deformation induced by the oscillation of the mass 3 which is mechanically fixed to the piezoelectric transducer 1. The effect of this variation of capacitance is not constant in time, and causes a temporally variable alteration of the waveform due to the fact that the mechanical deformation induced in the piezoelectric transducer is affected by the mechanical behavior of the system consisting of the piezoelectric transducer itself and the mass 3, with the corresponding damping arrangements. When the detected vibrations are of sufficient intensity, the shift of the signals ON of the oscillator 5 with respect to the signal of the oscillator 7 is such that two signals ON are brought into temporal coincidence. This event is detected by the sensor circuit, which indicates that the vibration has been detected. The size of the mechanical vibration required to cause the coincidence of the signals 05 and 07 depends on the temporal spacing of the two signals in rest conditions and can be set by varying the resistance 35.

To obtain the detection signal, the outputs of the two oscillators 5, 7 are connected to the comparator 11, which comprises two diodes 41 and 43, by means of which the outputs of the oscillators 5, 7 are connected to the input of a NOT gate 45. The two diodes 41 and 43 are also connected through a resistor 47 to the power supply indicated in a general way by 19. When the two signals generated by the oscillators 5 and 7 are both high, in other words when there is a coincidence of the signals ON of the two oscillators, the two diodes 41 and 43 are simultaneously turned off, so that the input of the NOT gate 45 takes a high value (this input being connected to the power supply 19). Consequently, the output of the NOT gate 45 takes a low value. This is represented in Fig. 3 by the signal C. This signal has a high value until the instant t1, in other words the instant at which there is a temporal coincidence of the two output signals ON of the oscillators 5, 7. This is because the signal at the input of the NOT gate 45 remains at the low value until there is a coincidence of two signals ON of the two oscillators 5, 7, since in this condition at least one of the two diodes 41 and 43 is conducting and connects the input of the NOT gate 45 to earth.

As shown in the diagram in Fig. 3, the output signal of the NOT gate 45 remains at a low value for a very short time, corresponding to the temporal coincidence of two ON signals of the two oscillators 5, 7. The temporal duration of this output signal of the NOT gate 45 would not be sufficient to emit a vibration detection signal. For this purpose, therefore, the clamper circuit 13 is provided. This comprises a NOT gate 47 connected through a diode 49 to the output of the NOT gate 45 and through a resistor 51 to the power supply 19. A capacitor 53 connects the input of the NOT gate 47 to earth. The input signal of the NOT gate 47 remains at the high value as long as a high signal remains present at the output of the NOT gate 45. This is due to the fact that the diode 49 is non-conducting in this configuration. The capacitor 53 is charged, through the resistor 51, by the current provided by the power supply circuit 19. The voltage between the plates of the capacitor 53 keeps the value at the input of the NOT gate 47 high. Consequently, the output signal of the NOT gate 47 is low. This is represented by the curve D in the diagram in Fig. 3. At the instant t1, in other words at the position of the falling edge of the signal C at the output of the NOT gate 45, the diode 49 becomes conducting, thus instantaneously bringing the input signal of the NOT gate 47 to the low value. Since the output signal of the NOT gate 45 returns to the high value very rapidly, the diode 49 immediately becomes non-conducting again. However, the output signal of the NOT gate 47 remains at the high value until the instant t2 (Fig. 3) which is determined by the time taken for the capacitor 53 to be recharged through the resistor 51. Thus a driver signal for the actuator 15, having a duration (t2-t1) which can be set by the appropriate selection of the value of the capacitor 53 and/or of the resistor 51, and being suitable for controlling the actuator 15, is obtained at the output of the clamper circuit 13.

In the illustrated example, the actuator 15 comprises an acoustic indicator 61 and an optical indicator 63 in the form of an LED. These are switched on by means of a switch 64 consisting of a pair of transistors which are made conducting and non-conducting by the signal arriving from the output of the NOT gate 47 through a resistor 65.

The activation of the acoustic indicator 61 causes the generation of mechanical vibrations which may be propagated into the container in which the whole circuit is housed, and consequently induce oscillations in the mass 3, which are detected as vibrations, thus generating a false alarm. Essentially, this may cause the sensor to self-oscillate, emitting a constant detection signal. To prevent this phenomenon, the blocking or filter circuit 17 is provided. This comprises a logical NOT gate 71 whose input is connected through a resistor 73 to the output of the NOT gate 47, and through a capacitor 75 to earth. The output of the logical NOT gate 71 is connected through a diode 77 to the base of the first of the two transistors forming the switch 64. The input and output of the logical NOT gate 71 are interconnected by a resistor 79 in series with a diode 81.

With this arrangement, when the output of the logical NOT gate 47 is brought to the high value (at the instant t1 in the diagram in Fig. 3), the charging of the capacitor 75 through the resistor 73 commences. If the time for which the output signal of the logical NOT gate 47 remains at the high value is less than the time taken to recharge the capacitor 75 through the resistor 73, the output signal from the logical NOT gate 71 will remain at a high value, thus keeping the diode 77 non-conducting, so that there is no interaction with the switch 64. If the time for which the output signal of the logical NOT gate 47 remains at the high value exceeds the charging time of the capacitor 75, the value of the input signal of the logical gate 71 will become high, and consequently the output signal of this logical gate 71 will become low, making the diode 77 conducting. As a result of this, the switch 64 will be turned off and the acoustic indicator 61 and the optical indicator 63 will be switched off. Consequently, the acoustic vibration of the acoustic indicator 61 will cease to affect the piezoelectric transducer 1, which will continue to emit a vibration signal solely and exclusively in the presence of a real vibration imparted to the sensor from the outside. If this happens, this vibration condition will again by signaled by a new activation of the acoustic indicator 61 and the optical indicator 63. Conversely, if there are no external vibrations to be detected, the indicators 61 and 63 will remain inactive. The time interval during which the diode 77 remains conducting and consequently the switch 64 remains turned off is determined by the value of the capacitance of the capacitor 75 and by the value of the resistor 79. The time taken to discharge the capacitor 75 through the resistor 79 can be set in such a way that it has a different value from the charging time, by the selection of suitable values for the resistors 73 and 79.

Fig. 4 shows a different embodiment of the sensor circuit represented schematically by the block diagram in Fig. 1. Blocks and components which are identical to, or correspond to, those of Figs. 1 and 2 are indicated by the same reference numbers. The principal differences between the circuit of Fig. 4 and the circuit of Fig. 2 consist in the fact that the block 17 is not provided in the circuit of Fig. 4, since in this case the function of preventing self-excitation of the sensor due to vibrations induced by the acoustic indicator 61 is not provided. Additionally, the oscillators 5 and 7, as well as the clamper circuit 13, are constructed with logical NAND gates instead of logical NOT gates. The configuration of the power supply circuit 19 is slightly modified, only one RC cell being provided. Finally, the variable resistor 25 is replaced by a fixed-value resistor 25 with a switch 26 in parallel, which can short-circuit the resistor to vary the sensitivity of the circuit. In this case, calibration is carried out by means of the variable resistor 35 of the oscillator 7. The operation of the circuit of Fig. 4 will be evident to those skilled in the art from the description provided with reference to the circuit of Fig. 2, no detailed description being necessary.

Figs. 5 and 6 show schematically an embodiment of the mechanical system formed by the transducer and the mass 3. The transducer 1 is a piezoelectric transducer with a metal base plate 1A, forming a first plate, a crystal 1B, and a strip 1C forming a second plate. It is fixed mechanically to the electronic circuit board 2 on which the circuit described above is constructed. The mass 3, consisting in this case of a lead block, measuring 30 x 20 x 1 mm for example, is soldered to the base plate. The vibrations of the body to which the electronic circuit board is fixed induce a perturbation in the inertial system comprising the mass 3, with a consequent deformation of the crystal 1B of the transducer 1.

Because of the described characteristics, the sensor according to the invention can be applied in various fields. For example, this device, if made integral with a fishing rod, can be used to detect the moment at which a fish nibbles at or swallows the bait.

In the medical field, the same sensor, provided with a suitable feedback control system, can be used to determine the number of vibrations which a limb produces while an attempt is made to keep it immobile. In this case, the sensor is used as a tremor detection device.

On the other hand, if the sensor is suitably modified with respect to the actuator section (block 15), it may be possible to use it for the visual assessment of a vibration, as in the case of an explosion. In this connection, a device of this type has been found useful for the experimental determination of the explosive charge required to fracture blocks of marble in quarries. Essentially, it becomes an explosimeter.

Each specific application of the vibration sensor according to the invention may require the modification of one or more elements of the electronic circuit. These modifications fall within the scope of protection of the patent.

CLAIMS

1. A vibration sensor comprising an electronic circuit, characterized in that it includes a deformable transducer element (1) mechanically connectable to an object whose vibrations are to be detected and fixed to an inertial system (3), and in which the vibrations to be detected cause a perturbation of the inertial system which causes a deformation of the transducer element, said deformation being electrically detectable by said electronic circuit.

2. The sensor as claimed in claim 1, characterized in that said transducer element (1) has an electrical capacitance whose value is modified as a result of said deformation, the electronic circuit detecting the variation of capacitance of the transducer element.

3. The sensor as claimed in claim 1 or 2, characterized in that said inertial system comprises an oscillating mass (3).

4. The sensor as claimed in claim 2, characterized in that said transducer element is a piezoelectric transducer (1).

5. The sensor as claimed in claim 1 or 2 or 3, characterized in that said electronic circuit comprises at least a first RC oscillator (5) within which is connected said transducer element (1), which consists at least partially of the capacitive component of the oscillator, the vibrations causing a variation of the conditions of oscillation of said first oscillator.

6. The sensor as claimed in claim 5, characterized in that said electronic circuit comprises: a second oscillator (7) which oscillates at a predeterminable frequency; comparator means (11) for comparing the oscillations generated by said first and said second oscillator (5, 7), a signal being generated by said comparison if there is an alteration of the oscillations of the first oscillator (5) with respect to the oscillation of the second oscillator (7) caused by a vibration to be detected.

7. The sensor as claimed in claim 6, characterized in that said first and said second oscillator are connected by a stabilizer (9) which synchronizes said first and said second oscillator with each other.

8. The sensor as claimed in claim 6 or 7, characterized in that said

comparator means (11) are sensitive to the beat or phase shift between said first and said second oscillator (5, 7) due to a vibration which causes the variation of the capacitance of the first oscillator.

9. The sensor as claimed in one or more of claims 6 to 8, characterized in that said first and said second oscillator generate rectangular waveforms whose frequencies are close to each other when no vibrations are detected.

10. The sensor as claimed in claim 7 at least, characterized in that said stabilizer (9) connects the output of the second oscillator (7) to the input of the first oscillator (5), keeping said oscillators in phase quadrature when no vibrations are detected.

11. The sensor as claimed in claim 7 at least, characterized in that said stabilizer comprises a resistive component.

12. The sensor as claimed in one or more of claims 5 to 10, characterized in that the output of said comparator means (11) is connected to a clamper circuit (13).

13. The sensor as claimed in one or more of the preceding claims, characterized in that said electronic circuit comprises a variable calibrating component (25; 35) for calibrating the circuit in accordance with the characteristics of the transducer element (1).

14. The sensor as claimed in at least one of claims 5 and 13 or 6 and 13, characterized in that said variable calibrating component is connected in said first or in said second oscillator and makes it possible to vary the oscillation frequency of the oscillator in which it is connected.

15. The sensor as claimed in claim 14, characterized in that said variable calibrating component is a variable resistor.

16. The sensor as claimed in one or more of claims 13 to 15, characterized in that it comprises a further variable component for adjusting the sensitivity (35; 25) connected in one of said first or second oscillator.

17. The sensor as claimed in claim 16, characterized in that said further variable component for adjusting the sensitivity is a variable resistor.

18. The sensor as claimed in claims 15 and 17, characterized in that

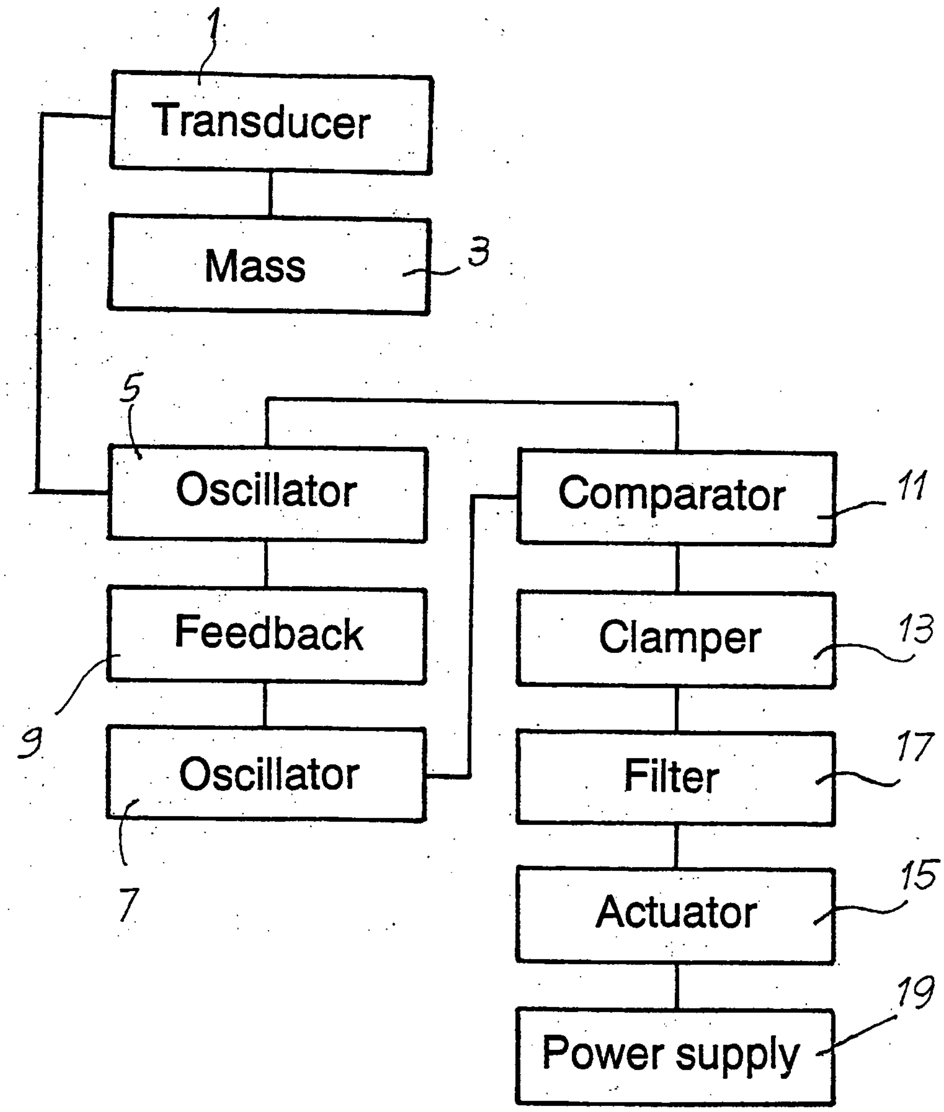
said variable calibrating resistor is connected in the first oscillator and said sensitivity adjustment resistor is connected in the second oscillator.

19. The sensor as claimed in one or more of claims 5 to 16, characterized in that said first and said second oscillator are oscillators of the logical gate type.

20. The sensor as claimed in one or more of the preceding claims, comprising in said electronic circuit indicator means of the acoustic and/or optical type.

21. The sensor as claimed at least in claims 10 and 18, characterized in that said indicator means of the acoustic type comprise an acoustic actuator driven by the output of said clamper circuit through a blocking circuit (17) which prevents the interaction between the vibrations produced by the acoustic indicator means and the vibrations which are to be detected by said sensor.

Fig. 1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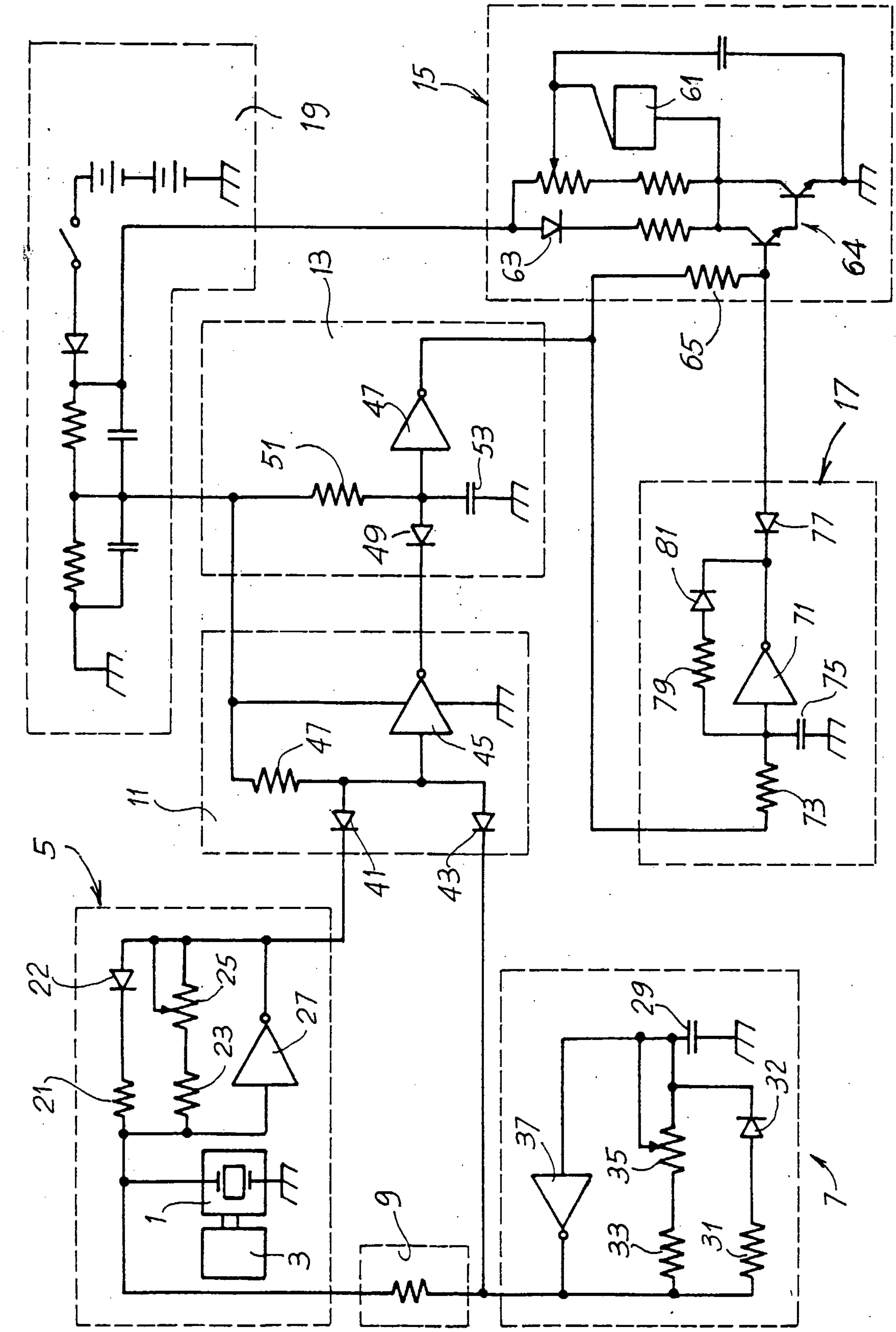
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Fig. 2

Fig. 3

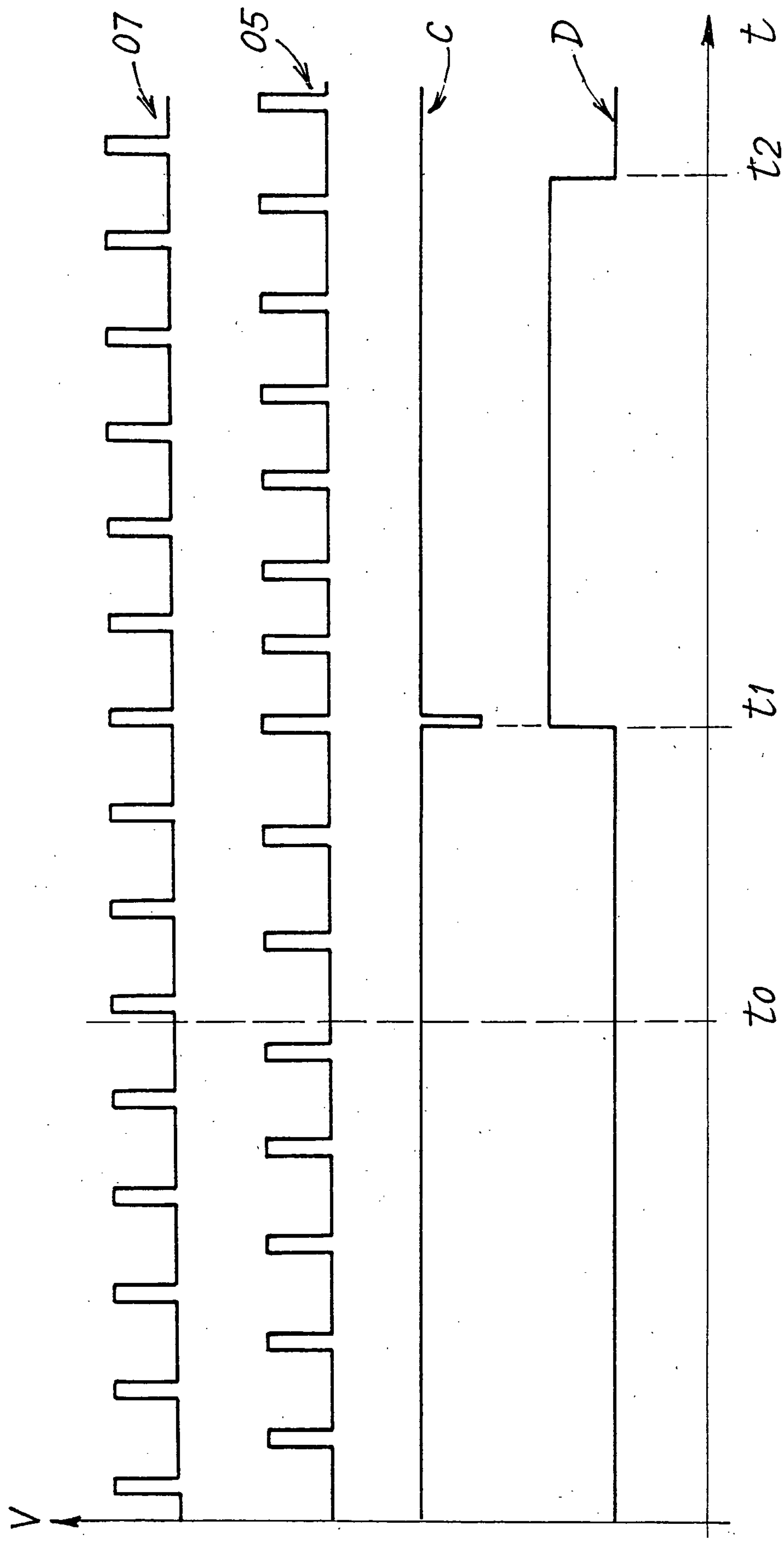


Fig. 4

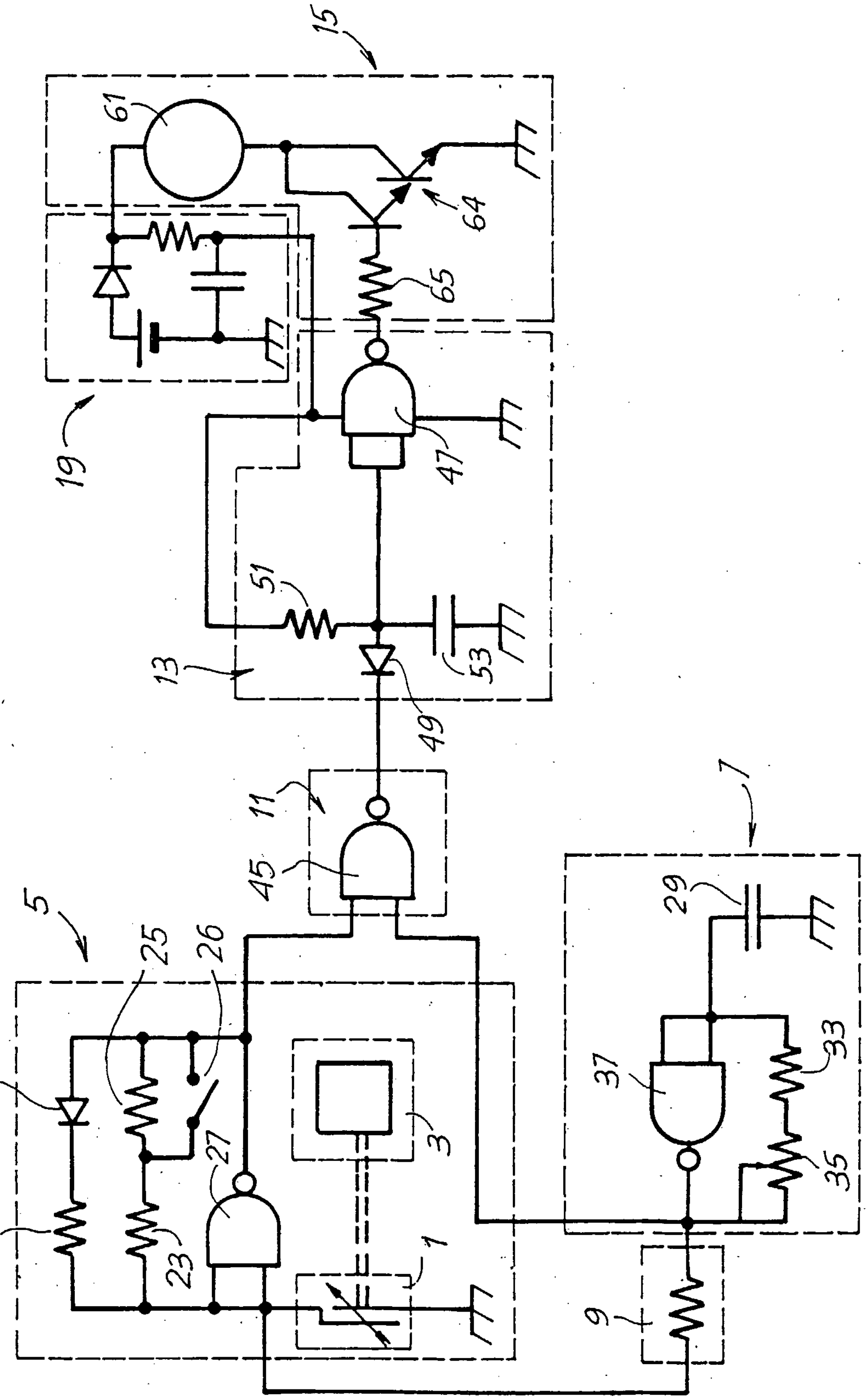


Fig.5

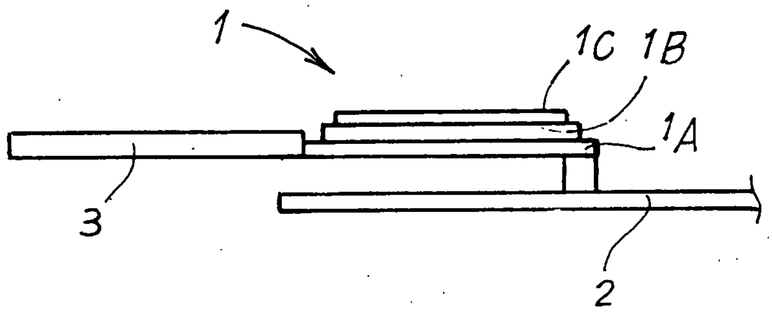
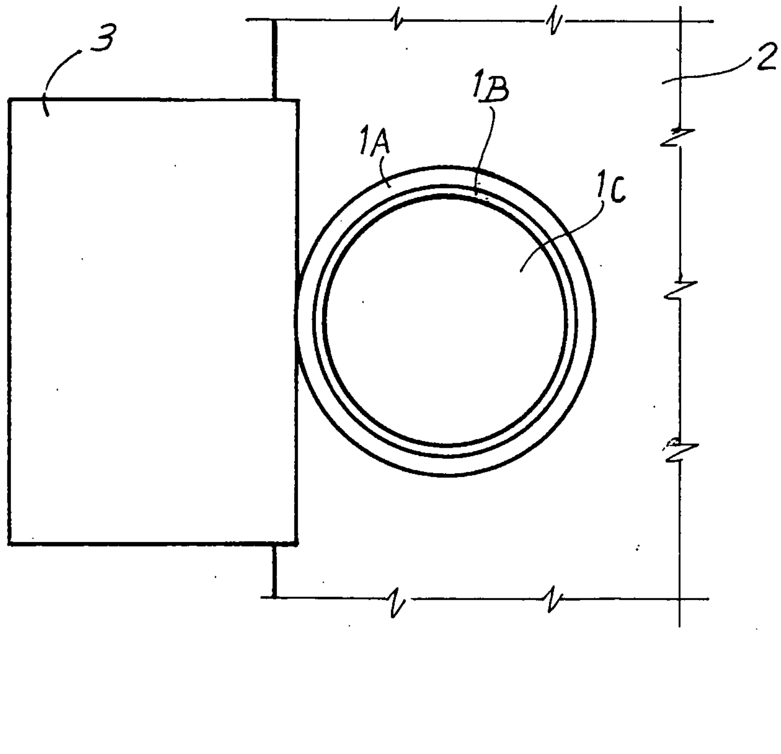


Fig.6



INTERNATIONAL SEARCH REPORT

International Application No
PCT/IT 00/00155

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01H11/08 G01P15/09

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)
IPC 7 G10K G01H G01P

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 practical, search terms used)

PAJ, 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 5 801 475 A (KIMURA MITSUTERU) 1 September 1998 (1998-09-01)	1,3,20
A	column 2, line 38 -column 3, line 8 column 4, line 39 - line 45; figure 2	4
X	GB 2 219 171 A (PENNWALT PIEZO FILM) 29 November 1989 (1989-11-29)	1,3,20
A	page 2, line 19 -page 4, line 20; figure 1	4
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 175 (P-1716), 24 March 1994 (1994-03-24) -& JP 05 340799 A (OMRON CORP), 21 December 1993 (1993-12-21) abstract; figures 1,2	2,5

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 November 2000	01/12/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Häusser, T

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INTERNATIONAL SEARCH REPORT

Interl nal Application No
PCT/IT 00/00155

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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