(12) UK Patent Application (19) GB (11) 2 282 450 (13) A

(43) Date of A Publication 05.04.1995

(21) Application No 9320047.5

(22) Date of Filing 29.09.1993

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(51) INT CL^6
G01P 15/09

(52) UK CL (Edition N)
G1N NAFD4 N3V5 N7Q

(56) Documents Cited
GB 1225799 A **GB 1078228 A** **GB 0668406 A**
EP 0374870 A2 **US 4816713 A**

(58) Field of Search
UK CL (Edition L) **G1N NACA NAFDR NAFD4 NAGBR NAGB4 NAGCR NAGC4 NAGDR NAGD4**
INT CL^5 **G01P 15/09**

(54) Improvements in or relating to accelerometers

(57) An accelerometer comprises an elongate sensor having a plurality of contiguous piezo-electric elements 4 - 9 extending between its two ends, conductive terminals 11, 12 on the two ends and further terminals 13 - 17 at regions of contiguity between the said elements, so that voltages are produced between the said terminals when the sensor is subjected to acceleration, and signal processor means arranged to be responsive to the said voltages for providing in dependence thereon a signal characteristic of the acceleration experienced.

The device is stated to have a higher than usual resonant frequency.

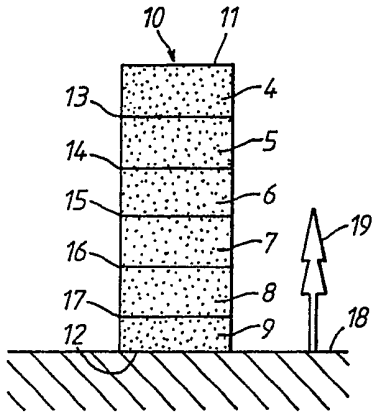

Fig. 2

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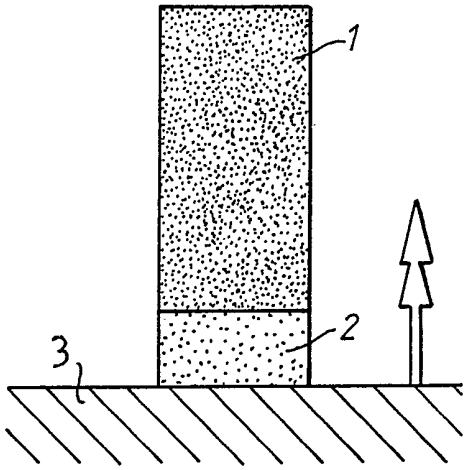

Fig. 1

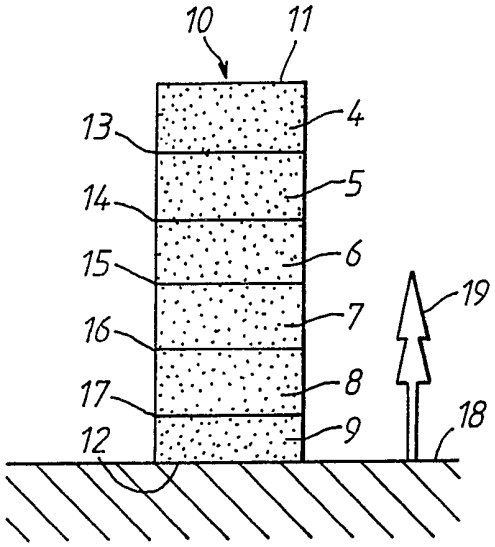

Fig. 2

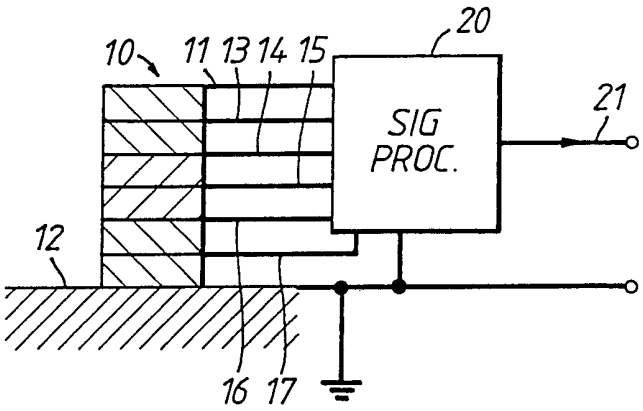

Fig.3

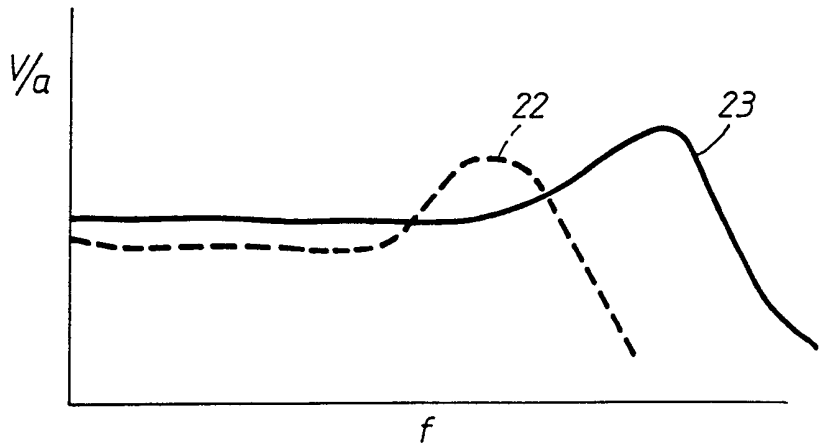

Fig.4

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IMPROVEMENTS IN OR RELATING TO ACCELEROMETERS

This invention relates to accelerometers and more especially it relates to piezo-electric accelerometers.

Accelerometers having a piezo-electric sensor are well known. Known piezo-electric accelerometers comprise an elongate piezo-electric sensor element which is loaded by means of a predetermined load mass which is secured thereto. When the sensor element and more particularly the load mass experience acceleration, a voltage is generated across the sensor element which is related to acceleration. This voltage is used in subsequent signal processing the precise nature of which is determined in accordance with the application in view.

One problem with known piezo-electric accelerometers is that the frequency of operation can be undesirably limited due to resonant effects which may also affect sensitivity as will hereinafter be explained.

It is an object of the present invention therefore to provide an improved piezo-electric accelerometer affording improved sensitivity and extended frequency operating range.

According to the present invention we provide an accelerometer which comprises an elongate sensor, comprising a plurality of contiguous piezo-electric elements extending between one end and the opposite end thereof, a conductive terminal being provided on each of the said ends and at regions of contiguity between the said elements, so that voltages are produced between

the said terminals when the sensor is subjected to acceleration, and signal processor means arranged to be responsive to the said voltages for providing in dependence thereon a signal characteristic of the acceleration experienced.

The conductive terminals may comprise layers of conductive material which are sandwiched between the said elements and which are arranged to cover each of the said ends.

The layers of conductive material may be fabricated by an electro-plating technique.

The material from which the layers are made may comprise silver.

The elements may be made of lead zirconium titanate.

One embodiment of the invention will now be described by way of example only with reference to the accompanying drawings in which:

FIGURE 1 is a generally schematic side view of a known piezo-electric accelerometer sensing device,

FIGURE 2 is a generally schematic side view of an accelerometer sensor according to one embodiment of the present invention,

FIGURE 3 is a somewhat schematic block diagram of an accelerometer according to one embodiment of the present invention, and

FIGURE 4 is a graph showing accelerometer operational characteristics.

Referring firstly to Figure 1, an accelerometer sensor comprises a mass 1 which is coupled to one end of a piezo-electric

element 2 the other end of which is anchored to a surface 3. When the mass 1 is subjected to acceleration in a direction as indicated by an arrow, a voltage is developed across the piezo-electric element 2 which is generally proportional to acceleration. As is well known to those skilled in the art however, this proportional relationship obtains below mechanical resonance only. The mechanical resonant frequency is generally proportional to the inverse square root of the mass 1. A high resonant frequency is to be desired because as the resonant frequency is increased the useful bandwidth of the sensor is extended.

Below the mechanical resonant frequency the sensitivity of the accelerometer to acceleration is independent of frequency and proportional to the mass used. High sensitivity is to be desired since this reduces the amplification required and is associated with lower noise which therefore permits a higher dynamic useful range. The sensitivity and resonant frequency are interdependent and when one is increased the other tends to reduce. Consequently the design of piezo-electric accelerometers tends to involve a compromise between sensitivity and resonant frequency.

Turning now to Figure 2, an accelerometer sensor according to one embodiment of the present invention comprises piezo-electric elements 4, 5, 6, 7, 8 and 9 which are serially stacked to define a piezo-electric sensor 10. Opposing end faces of each of the elements 4 to 9 are plated with silver so as to define terminals 11 and 12 on end faces of the sensor 10 and so as to define

terminals 13, 14, 15, 16 and 17 which are sandwiched between individual elements of the sensor 10. The terminal 12 on the bottom end face of the sensor is secured to a surface 18 so that when the sensor 10 is subjected to acceleration in a direction as indicated by an arrow 19, voltages are developed between the terminals 11 to 17. It will be apparent that the mass with which each of the elements 4 to 9 is loaded will be dependent on its position in the sensor. Thus the element 9 will be loaded by the mass of the sensors 4 to 8 which are positioned above it whereas the element 4 will be the most lighted loaded since it is positioned at the free end of the sensor 10.

Referring now to Figure 3, wherein parts corresponding to Figure 2 bear the same numerical designations, outputs signals from the terminals 11 to 17 are fed to a signal processor 20. The signal processor may simply be used to add the signals applied thereto so as to produce an output signal on a line 21. Alternatively however, the signals may be suitably processed or weighted so as to compensate for undesirable characteristics of the sensor. The sensor as shown in Figures 2 and 3 has the advantage that it is somewhat lighter than known accelerometers which commonly have a mass element made of heavy material such as tungsten for example. A lighter accelerometer sensor is an advantage since it tends to have a proportionately smaller loading effect on surfaces to which it is attached for measurement purposes.

An important additional advantage of the accelerometer sensors shown in Figure 2 and Figure 3 is that they provide a

higher resonant frequency than known piezo-electric accelerometer sensors of equivalent size. Comparative accelerometer characteristics are shown in Figure 4, wherein voltage per unit acceleration is plotted against frequency for a known accelerometer sensor as shown by a broken line 22 and for an equivalent sensor fabricated in accordance with one embodiment of the invention as shown by a line 23. A typical frequency range may be between 0 and 100 KHz and will be determined by design and in accordance with the application in view. The sensitivity of the sensor 10 as shown in Figure 2 and Figure 3 is determined largely by the number and arrangement of the piezo-electric elements and by the amplifier used. It has been found in practice that a sensor of the kind shown in Figure 2 or Figure 3 can be configured to have improved sensitivity and improved noise performance, size for size, than known accelerometer sensors.

A particular feature of the sensor shown is that signal processing techniques may be employed to modify resonance characteristics whereby useful bandwidth may be extended.

Various modifications may be made to the arrangement shown without departing from the scope of the invention and, for example, although the sensor shown comprises six serially stacked elements other arrangements are envisaged comprising two or more elements. It will also be apparent that signal processing techniques comprising weighting of the signals may be utilised as required by a particular application.

It will also be apparent that although, by way of example only, the piezo-electric sensor 10 is shown anchored at one end, in an alternative arrangement the sensor may be annular and mounted on a cylindrical rod which may itself be secured at one end to a mounting surface structure and may provide tension to hold the parts together.

CLAIMS

1. An accelerometer comprising an elongate sensor, comprising a plurality of contiguous piezo-electric elements extending between one end and the opposite end thereof, a conductive terminal being provided on each of the said ends and at regions of contiguity between the said elements, so that voltages are produced between the said terminals when the sensor is subjected to acceleration, and signal processor means arranged to be responsive to the said voltages for providing in dependence thereon a signal characteristic of the acceleration experienced.

2. An accelerometer as claimed in Claim 1, wherein the conductive terminals comprise layers of conductive material which are sandwiched between the said elements and which are arranged to cover each of the said ends.

3. An accelerometer as claimed in Claim 2, wherein the layers of conductive material are fabricated by an electro-plating technique.

4. An accelerometer as claimed in Claim 2 or Claim 3, wherein the material from which the layers are made comprises silver.

5. An accelerometer as claimed in an preceding claim, wherein the elements are made of lead zirconium titanate.

6. An accelerometer as claimed in any preceding claim and substantially as hereinbefore described with reference to the accompanying drawings.

7. For use in an accelerometer as claimed in any preceding claim, an elongate sensor, the said sensor comprising a plurality of contiguous piezo-electric elements extending between one end and the opposite end thereof, a conductive terminal being provided at each of the said ends and at regions of contiguity between the said elements, so that voltages are produced between the said terminals when the sensor is subjected to acceleration.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report) -9-	Application number GB 9320047.5
k evant Technical Fields (i) UK Cl (Ed.L) G1N (NACA, NAFD4, NAFDR, NAGB4, NAGBR, NAGC4, NAGCR, NAGD4, NAGDR) (ii) Int Cl (Ed.5) G01P 15/09	Search Examiner M G CLARKE Date of completion of Search 7 DECEMBER 93
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1, 2, 6, 7

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	**P:**	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	**E:**	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	**&:**	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1225799	(KISTLER INSTRUMENTS) See especially Figures 1-4	1, 7
X	GB 1078228	(KISTLER INSTRUMENTS) Whole document	1, 2, 7
X	GB 668406	(METROPOLITAN-VICKERS) Whole document	1, 2, 7
X	EP 0374870 A2	(MITSUBISHI DENKI) See especially Figure 3	1, 2, 7
X	US 4816713	(N D CHANGE JNR) See especially Figure 3	1, 2, 7

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).