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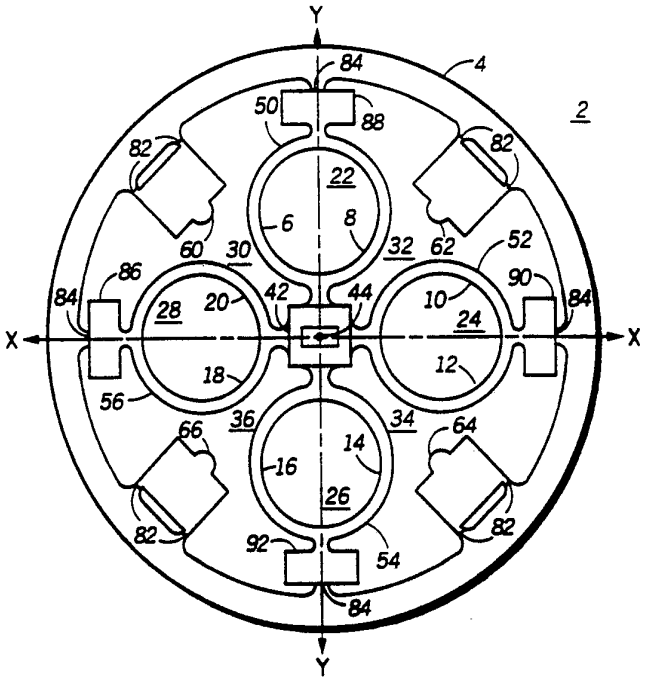
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With international search report.

(54) Title: PIEZO-ELECTRIC RESONANT VIBRATOR FOR A SELECTIVE CALL RECEIVER



(57) Abstract

A piezo-electric resonant vibrator (206) comprises a resonant armature (2) including a plurality of planar spring members (22, 24, 26, 28) which are coupled centrally therewith and further detachably coupled to a perimetric rim (4). The planar spring members (22, 24, 26, 28) provide a restoring force normal to the movement of the armature (2). A weight (604) is centrally coupled to the armature (2). A housing (622, 624) encloses and supports the armature (2). A piezo-electric actuator (602) is coupled to the planar spring members (22, 24, 26, 28) for inducing movement of the armature (2) at a predetermined resonant frequency which is established when the rim (4) is detached from said planar spring members (22, 24, 26, 28).

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PIEZO-ELECTRIC RESONANT VIBRATOR FOR A SELECTIVE CALL RECEIVER

Field of the Invention

This invention relates in general to the field of vibrators, and more particularly to piezo-electric resonant vibrator motors for selective call receivers that provide a tactile (sensory) response to indicate a received message.

Background of the Invention

Selective call receivers, including pagers, typically alert a user of a received message by producing an audio alerting signal. However, the audio signal may be disruptive in various environments, and therefore, vibrators have been utilized to provide a "silent" alerting signal.

Referring to FIG. 1, a conventional vibrator motor 100 comprises a cylindrical body 102, a longitudinal, rotating shaft 104, and an unbalanced, rotating counterweight 106. The cylindrical body 102 is held in place on a printed circuit board 108 by motor bracket 110. The counterweight 106 is attached to the protruding end of the shaft 104 on the vibrator motor 100. Operationally, the motor 100 is energized by a power source causing the shaft 104 and the counterweight 106 to rotate, resulting in the motor 100 vibrating and, consequently, the selective call receiver vibrating, thereby alerting the user.

With the trend to miniaturization, the vibrator motor has become one of the largest components in silent alert type pagers. It is, therefore, difficult to realize further reductions in the size of a silent alert pager unless the vibrator motor itself is reduced in size. However, it is important that the vibration level not be significantly reduced, since this would defeat the advantage of size reduction if the tactile operation was ineffective.

Thus, what is needed is a miniaturized vibrator suitable for use in a selective call receiver for generating a tactile alert.

Summary of the Invention

In carrying out the invention in one form, there is provided an apparatus for effecting a vibrating motion comprising a resonant armature including a plurality of planar spring members which are coupled centrally therewith and further detachably coupled to a perimetric rim. The planar spring members provide a restoring force normal to the movement of the armature. A weight is centrally coupled to the armature. A housing encloses and supports the armature. A piezo-electric actuator is coupled to the planar spring members for inducing movement of the armature at a predetermined resonant frequency which is established when the rim is detached from said planar spring members.

Brief Description of the Drawings

FIG. 1 is a perspective view of a conventional vibrator attached to a printed circuit board.

FIG. 2 is a block diagram of a selective call receiver in accordance with the present invention.

FIG. 3A is a top view of an armature in accordance with the preferred embodiment of the present invention.

FIG. 3B is a top view of the armature of FIG. 3A positioned within a housing in accordance with the preferred embodiment of the present invention.

FIG. 4A is a cross sectional view taken along line X-X of FIG. 3.

FIG. 4B is a cross sectional view taken along section A-A of FIG. 3.

FIG. 5 is an exemplary side view of the armature in a vibratory motion.

Detailed Description of the Invention

Referring to FIG. 2, a selective call receiver (e.g., a pager) comprises an RF receiver 200 for receiving and demodulating a selective call signal, a decoder 202 for decoding the signal, and a controller 204 for presenting an alert and a message when the message is contained within the signal. The alert is presented via one of a plurality of output devices 206, 208, and 212, such as, but not limited to, an audible alerting device (e.g., beep or tone) 212, a tactile alerting device (i.e. message indicator) 206, and a visual alerting device 208. Additionally, the alert may be presented in response to selection of a user control 210 (e.g., pushing a button or moving a slide switch). This basic function of a selective call receiver is well known to those skilled in the art.

Referring to FIG. 3, an armature 2 manufactured in accordance with the preferred embodiment of the present invention comprises a substantially circular body section,or rim, 4 including positioning tabs 60, 62, 64 and 66, and mounting tabs 86, 88, 90 and 92 contiguously attached thereto. Curved, substantially planar springs 50, 52, 54, and 56 are integrally positioned therein, and having first portions contiguous to the mounting tabs 88, 90, 92 and 86, respectively, and a second portion contiguous with an optional etched surface 42, having an opening 44. The armature 2 is preferably manufactured from a single piece of sheet metal, which may be chemically etched, or stamped, using known techniques to form the following configuration in the preferred embodiment. Each of the springs 50, 52, 54, and 56 comprise two substantially semicircular members 6 and 8, 10 and 12, 14 and 16, and 18 and 20, respectively. The springs 50, 52, 54, and 56 are formed having substantially circular openings 22, 24, 26, and 28 and curved openings 30, 32, 34, and 36, respectively. At locations 84 ,where the springs 50, 52, 54, and 56 attach to the rim 4, and at locations 82, where the mounting tabs 86, 88, 90 and 92 attach to the

rim 4, the sheet metal material thickness is preferably reduced, such as by stamping, etching, or other suitable means, to facilitate separation of the rim 4 from the positioning tabs 60, 62, 64 and 66, and mounting tabs 86, 88, 90 and 92, as will be described in detail below.

In the preferred embodiment, the armature 2 is made of international nickel alloy 902, or equivalent, which has been preferably heat treated to achieve a tensile strength of 190,000 p.s.i. The springs 50, 52, 54, and 56, are formed from a .004 inch thick sheet metal, which may be chemically etched to a membrane thickness of typically 0.003 inches or less depending upon the resonant frequency of vibration. This material is preferably a constant modulus alloy so as to reduce temperature induced frequency changes and force impulse changes. The preferred design of the armature 2 provides a linear spring rate due to the elastic bending of the members 6, 8, 10, 12, 14, 16, 18, and 20. Final frequency tuning is preferably accomplished by adjusting the inside edges of the springs 50, 52, 54, and 56 by any suitable etching, trimming, or grinding process known in the art. The substantially circular ring geometry makes it possible to elongate each of the members 6, 8, 10, 12, 14, 16, 18, and 20 (by approximately 0.0015 inches) without exceeding the required maximum fatigue stress level (30,000 psi) for the material selected in the preferred embodiment. It will be appreciated that ring geometries other than circular can be utilized as well to form the spring members. It should be understood that the shapes and dimensions may vary without deviating from the intent of the invention.

The unique feature of the restoring force and spring force, of the preferred embodiment of the present invention, is that it is generated from the plane of the axes X-X and Y-Y (FIG. 3), which are 90° out of phase with the operational mode of the axis Z-Z. In addition, the force is balanced equally by the position of the mounting

tabs 86, 88, 90 and 92 along the outer diameter of the armature 2 supporting structure.

The tactile alerting device 206 of FIG. 2, manufactured using the armature 2, provides a linear spring rate in the axis Z-Z which is accomplished by the elastic bending of the outside edges of springs 50, 52, 54, and 56 due to tension in the armature 2 in the plane of the axes X-X and Y-Y (FIG. 3A) during the operational mode of the axis Z-Z. This makes the frequency of response independent of the amplitude of deflection and the driving signal. The tactile alerting device 206 manufactured using the armature 2, also provides a frequency of response that is independent of the mass of the pager, or device in which the vibrator is operated. Therefore, the present invention provides a more efficient tactile vibrator, requiring less power than the conventional cylindrical housing vibrator while producing a similar sensory level of vibration.

Referring to FIG. 3B is a top view of the armature of FIG. 3A positioned within a lower housing section 622 in accordance with the preferred embodiment of the present invention. The weight 604 is first attached to the armature 2 as described below, followed by attaching the piezo-electric driver mechanism 602 to mounting tabs 86, 88, 90 and 92. and to positioning tabs 60, 62, 64 and 66, after which the rim 4 is detached from the armature 2, leaving stubs (the size of which are shown exaggerated) at locations 82 and 84. To facilitate rim detachment, the armature 2 with weight and piezo-electric driver mechanism 602 is preferably placed in a fixture which allows detachment of the rim by such methods as shearing, flexing, or other suitable means. The armature 2 is then located within the lower housing section 622 using positioning tabs 60, 62, 64 and 66 which are positioned on mounting bosses 72, 76, 78 and 74, respectively. A weight 604 is attached to the center of the armature, as will be described below. Electrical contact to the vibrator is provided by

conductors 80 and 80', as will be further described in detail below.

Referring to FIG. 4A, the tactile alert device 206 preferably comprises the armature 2, positioned within a housing 614 and coupled substantially around the perimeter of the armature 2 to the housing 614 at positioning tabs 60, 62, 64 and 66, as described above. The housing 614 comprises the lower housing section 622 and an upper housing section 624, both of which are formed using suitable means, such as molding, from a non-magnetic material, such as Zytel™ 71633L, or other suitable material. The preferred embodiment of the present invention comprises the piezo-electric driver mechanism 602 which is formed as a circular ring from a piezo-electric material such as B2023 ceramic material manufactured by the NTK Corporation for vibrating the tactile alert device 206. At least one piezo-ceramic ring 602 is coupled to the armature 2, and as shown in the preferred embodiment, a pair of circular rings are affixed to the top and bottom of the armature 2. The piezo-ceramic rings 602 are metallized on the top and bottom surfaces to provide attachment to the perimeter of the armature 2 at mounting tabs 86, 88, 90 and 92. and to positioning tabs 60, 62, 64 and 66 using a high Q mechanical adhesive, such as Armstrong 702. The armature 2 is coupled to a member (i.e. weight) 604 having an upper portion 606 and a lower portion 608, which are preferably constructed of a non-magnetic, high density metal, such as Kennertium W-2 which is tungsten based, or equivalent. The upper portion 606 and the lower portion 608 of the weight 604 engage through the opening 44 in the armature 2 (FIG. 3A). Thus, the weight 604 is attached to the armature 2 using a solder, such as All-State #509 or equivalent material, such as an epoxy adhesive.

As can be seen in FIG. 4B, the armature 2 is positioned within the upper housing section 624, and the lower housing section 622 at four points 60, 62, 64, and 66 (one of which is depicted in FIG. 4B). This arrangement of the armature

2 and the housing 614 allows the armature 2 to more freely expand in size along the axis X-X and Y-Y, in response to a force applied outwardly around the perimeter of the armature 2 by the piezo-electric driver mechanism 602. The armature 2 returns to its original dimensions when the force is removed. The lower portion 608 of the weight 604 is also coupled to a magnet 610. The magnet 610 attracts a fixed metal shield 612 which is affixed to the lower housing section 622 using a solder, such as All-State #509 or equivalent material, such as an epoxy adhesive.

According to the preferred embodiment of the invention, an alternating voltage is applied to the piezo-ceramic rings 602 through conductor 80 which is coupled to the armature 2, and through conductor 80' which is coupled to the metallized surfaces of the piezo-ceramic rings 602, to cause the piezo-ceramic ring 602 to alternately expand in size and return to equilibrium. Conductors 80 and 80' are preferably soldered using a low temperature solder, such as All-State #509 or equivalent, to the armature 2 and the piezo-ceramic rings 602. The induced movement in the armature 2 is along the axis X-X and Y-Y (FIG. 3A). The resulting movement of the weight 604 is along the axis Z-Z. The magnetic force between the magnet 610 and the shield 612 maintains tension on the armature 2 while the piezo-ceramic ring 602 expands and returns. Therefore, the piezo-electric mechanism 602 comprises an actuator for causing the weight 604 to move in response to the alternating voltage applied to the piezo-ceramic ring 602.

The weight 604 and the armature 2 are mechanically tuned to naturally resonate at a sub-audible frequency of approximately 70 Hz. The armature 2 is coupled to the housing 614 for transferring movement of the weight 604 to the housing 614 to generate a tactile alert. Since 70 Hz comprises a sub-audible frequency, no substantial audible sound will be heard. Therefore, the present invention provides a tactile alert by generation of a sub-audible signal.

At mechanical resonance, the energy required to move the armature 2 and weight 604 is substantially reduced, as compared to a rotating motor driven weight, which increases the selective call receiver's battery life. In addition, a maximum amplitude and impulse is provided at a relatively small power consumption. This is due chiefly to the restoring force created by tension in the springs 50, 52, 54, and 56 as each member 6, 8, 10, 12, 14, 16, 18, and 20 of the springs 50, 52, 54, and 56, extends (approximately 0.0015 inches). The restoring force is balanced along the perimeter of the armature 2 by the piezo-electric driver element 602 at mounting tabs 86, 88, 90 and 92, which is also coupled to the housing 614 at positioning tabs 60, 62, 64 and 66. The driving force (unbalanced) is in the axis Z-Z and is typically 10% of the balanced restoring force, which is in the axis X-X and Y-Y. Therefore, the system uses approximately 10% of the stored energy to move the message indicator 206 (and thus the selective call receiver) each cycle, which increases the system's battery life.

According to the invention, the indicator 206 generates an impulse toward the user in one direction as compared to the prior art motor 100 which generates an impulse in all radial directions within the plane of rotational motion of the external unbalanced counterweight 106. Therefore, much of the force generated by contemporary motors 100 are not felt in a tactile sense by the user. However, an equivalent tactile sensory response is obtained by the present invention while using less power and space than the conventional motor 100.

Referring to FIGS. 4A and 4B and 5, the armature 2 is in its stationary (equilibrium) position within message indicator 206 with a mass 500 comprised of the weight 604, and the magnet 610. The armature 2 is held substantially rigid to the housing 614 along the perimeter. As the indicator 206 begins to vibrate, the armature 2 and mass 500 will move from its stationary position, along axis Z-Z,

to its maximum amplitude as represented by armature 2' and mass 500'. Due to the spring force provided by springs 50, 52, 54, and 56 along the Z-Z axis and the actuating signal applied to the piezo-electric driver 602, the armature 2' and mass 500' will oscillate to the opposed extreme as represented by armature 2'' and mass 500''. In the preferred embodiment of the present invention, these oscillations produce the tactile alert at the frequency of approximately 70 Hz.

One advantage of the tactile alerting device 206 is that it generates an impulse toward the user in one direction while the conventional cylindrical motor 100 generates an impulse in all directions; therefore, much of the force generated by the motor 100 is not felt. An equivalent tactile sensory response is then obtained using the tactile alerting device 206 while using less power and space than the conventional motor 100. In addition, the gravity effect of the tactile alerting device 206 is relatively small as compared to the conventional motor 100 since the armature 2 is balanced whereas the conventional motor 100 utilizes an unbalanced counterweight 106. The gravity effect on the conventional motor is then dependent on the relationship between the shaft 104 and the unbalanced counterweight 106. Therefore, a further advantage of the tactile alerting device 206 is that the gravity effect will result in a smaller reduction in impulse force than the conventional motor 100 due to the resonant nature of the system.

What is claimed is:

Claims

1. A piezoelectric resonant vibrator, comprising:
a resonant armature including a plurality of planar spring members coupled centrally therewith and further detachably coupled to a perimetric rim, said planar spring members providing a restoring force normal to the movement of the armature;

a weight, centrally coupled to said armature;

a housing, for enclosing and supporting said armature; and

actuator means, coupled to said planar spring members, for inducing movement of said armature at a predetermined resonant frequency which is established when said rim is detached from said planar spring members.

2. The piezoelectric resonant vibrator of claim 1, wherein said plurality of planer spring members are coupled to a plurality of mounting members which are detachably coupled to said perimetric rim, said mounting members for mounting said actuator means to said planar spring members.

3. The piezoelectric resonant vibrator of claim 1, wherein said perimetric rim is further detachably coupled to a plurality of positioning members, for positioning and supporting said resonant armature within said housing.

4. The piezoelectric resonant vibrator of claim 1, wherein said actuator means is a piezo-ceramic ring driver which radially expands to produce an impulse to the armature at the resonant frequency when electrically excited.

5. The piezoelectric resonant vibrator of claim 1, wherein said armature includes at least four planar spring members.

6. The piezoelectric resonant vibrator of claim 5, wherein said planar spring members are arranged orthogonally about said centrally positioned weight.

7. The piezoelectric resonant vibrator of claim 5, wherein said planar spring members have a substantially circular geometry.

8. The piezoelectric resonant vibrator of claim 1, further comprising:

a ferromagnetic member coupled to said housing; and

a magnetic member coupled to said armature, and magnetically coupled to said ferromagnetic member, for maintaining tension on said armature.

9. The piezoelectric resonant vibrator of claim 1, wherein said armature is fabricated from sheet metal.

10. The piezoelectric resonant vibrator of claim 1, wherein said weight is fabricated from a high density, non-magnetic material.

11. The piezoelectric resonant vibrator of claim 7, wherein the resonant frequency is tunable by adjusting the inside edges of said planar spring members.

12. A selective call receiving device, comprising:
a receiver for receiving and detecting transmitted selective call messages;

a decoder, responsive to the received selective call messages, for generating an alert control signal in response thereto; and

a vibrator, responsive to said alert control signal, for generating a vibratory alert, said vibrator comprising

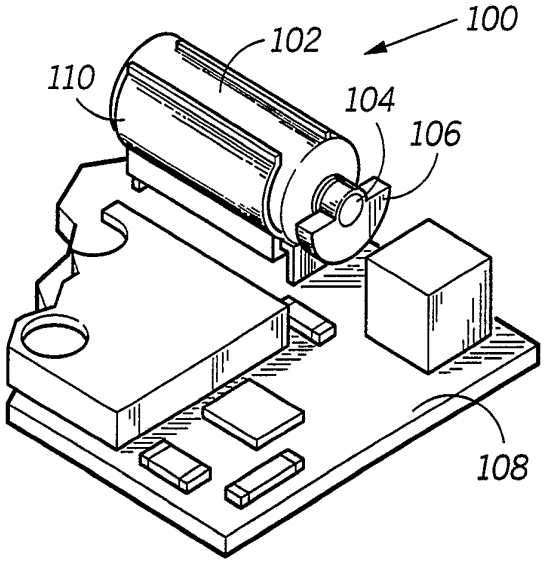
a resonant armature including a plurality of planar spring members coupled centrally therewith and further detachably coupled to a perimetric rim, said planar

spring members providing a restoring force normal to the movement of the armature;

a weight, centrally coupled to said armature;

a housing, for enclosing and supporting said armature; and

actuator means, coupled to said planar spring members, for inducing movement of said armature at a predetermined resonant frequency which is established when said rim is detached from said planar spring members.



— PRIOR ART —

FIG.1

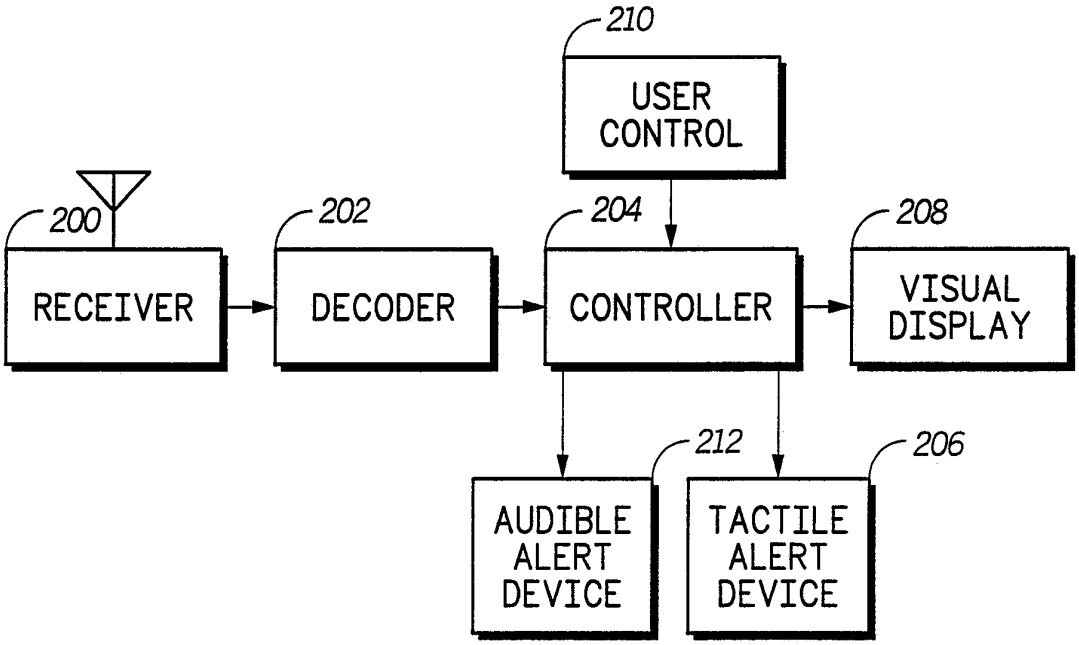


FIG.2

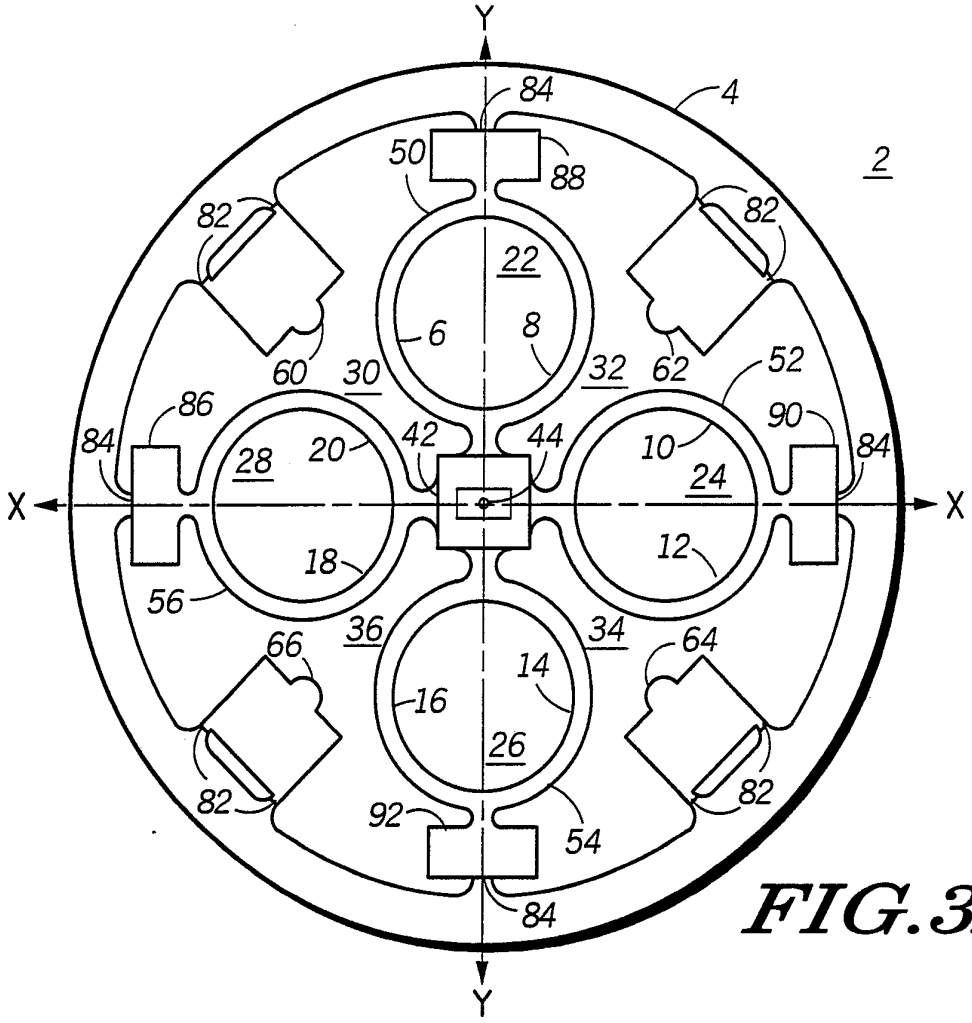

Y
84
4
50
88
2
82
82
22
6
8
60
30
32
62
52
86
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84
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28
20
42
44
10
24
X
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34
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82
92
54
84
Y

FIG.3A

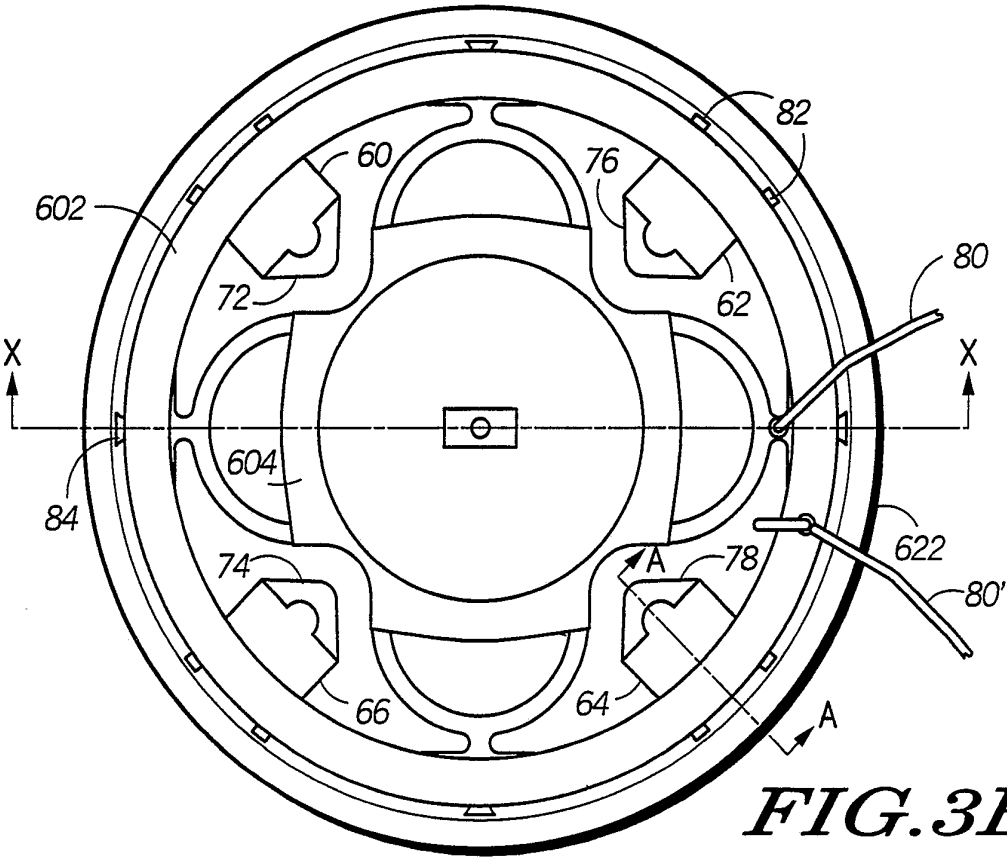

82
60
76
602
80
72
62
X
X
604
84
622
74
A
78
80'
66
64
A

FIG.3B

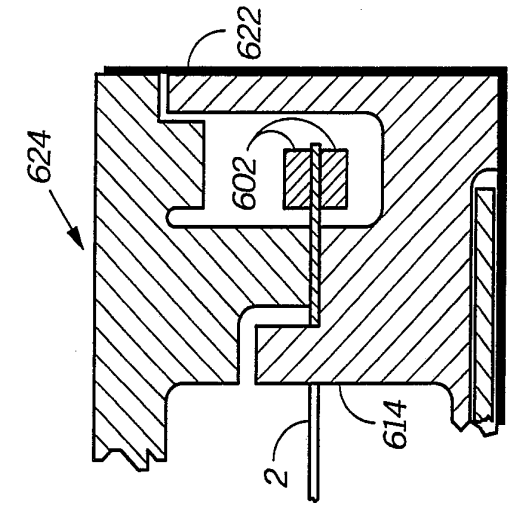


FIG.4B

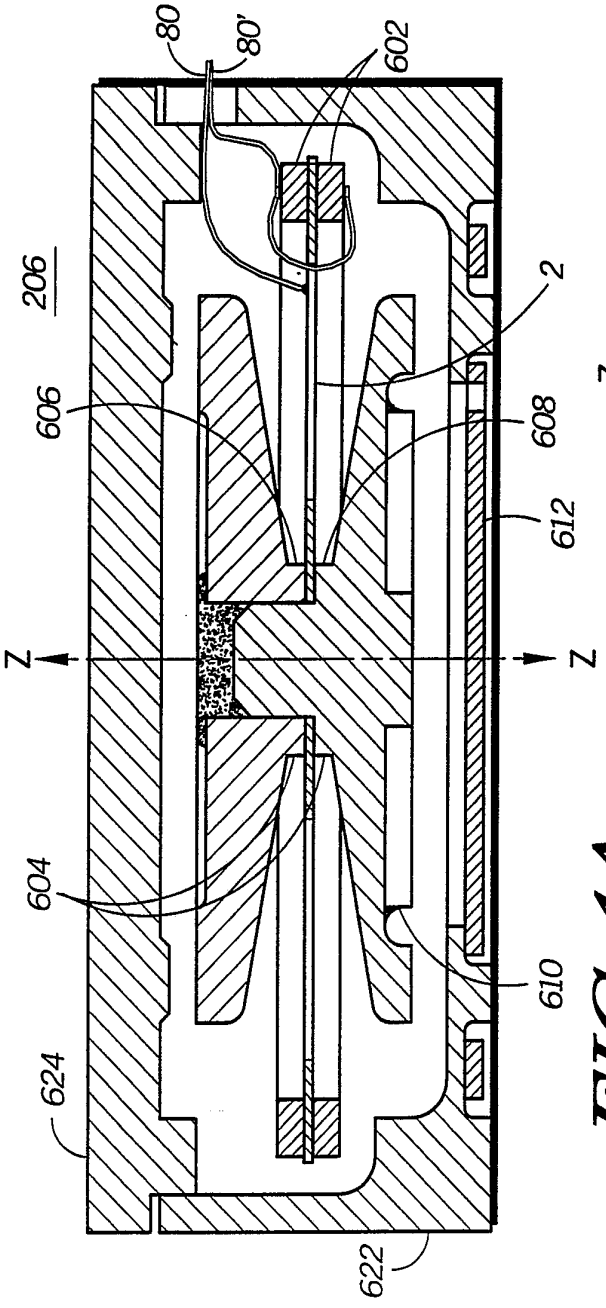


FIG.4A

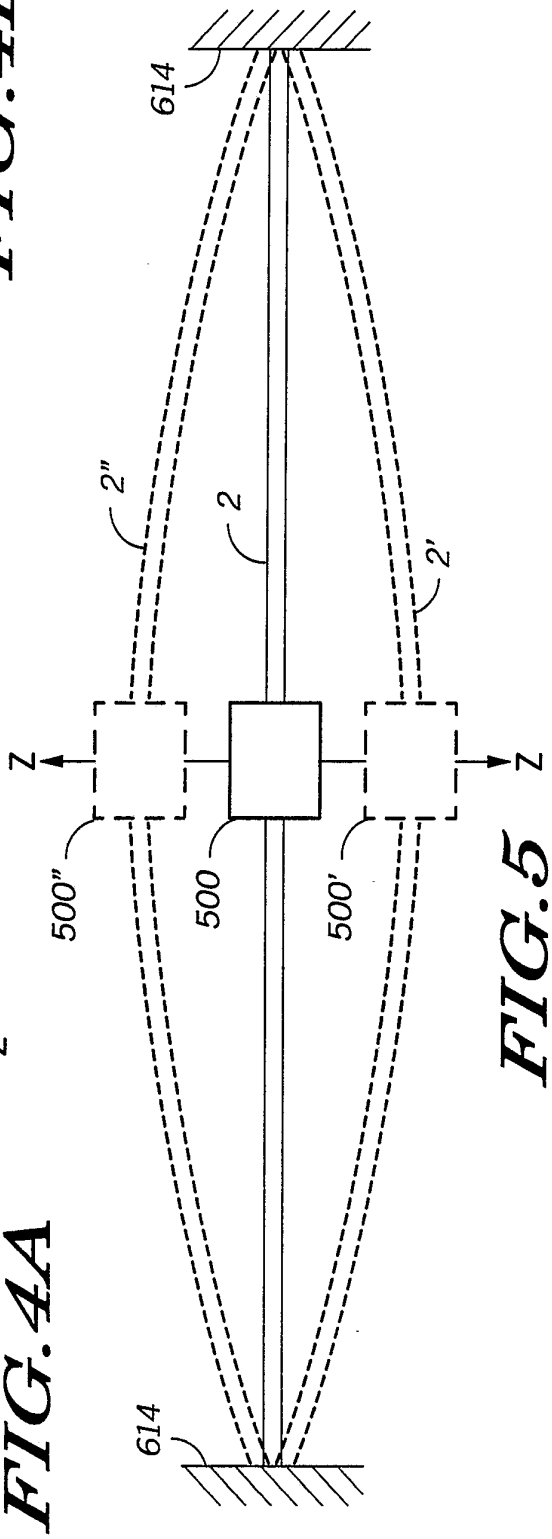


FIG.5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US91/04034

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): H01L 41/04; U.S. Cl. 310/322,268;340/825.44,825.46

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System [5]	Classification Symbols
U.S.	310/321,322,323,328,15,17,268; 240/825.44,825.46

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [6]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A,P	US, A, 5,023,504 (MOONEY ET.AL.) 11 JUNE 1991 See entire document.	1-12
A,P	US, A, 5,063,321 (CARTER) 5 NOVEMBER 1991 See entire document.	1,12
A,P	US, A, 5,008,580 (MASUDA ET AL.) 16 APRIL 1991 See entire document.	1,12
A	US, A, 4,720,710 (AKAHORI ET. AL.) 19 JANUARY 1988 See entire document.	12
A	US, A, 4,918,438 (YAMASAKI) 17 APRIL 1990 See entire document.	12
A	US, A, 4,491,759 (KUUZ ET. AL.) 1 JANUARY 1985 See entire document.	1

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]

18 NOVEMBER 1991

Date of Mailing of this International Search Report [2]

13DEC 1991

International Searching Authority [1]

ISA/US

Signature of Authorized Officer [20]

NGUYEN NGOC HO
INTERNATIONAL DIVISION
Thomas M. Dougherty

Form PCT/ISA/210 (second sheet) (May 1986)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US, A, 4,439,640 (TAKAYA) 27 MARCH 1984 See entire document.	1
A	US, A, 4,132,910 (KISS et. al.) 2 JANUARY 1979 See entire document.	1
A	US, A, 1,882,394 (PIERCE) 11 OCTOBER 1932 See entire document.	1,12
A	CA, A, 855,821 (MACBLANE) 10 NOVEMBER 1970	1,12

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers . because they relate to subject matter [1] not required to be searched by this Authority, namely:

2. ☐ Claim numbers . because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [1], specifically:

3. ☐ Claim numbers_____, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees