

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
6 April 2006 (06.04.2006)

PCT

(10) International Publication Number
WO 2006/036097 A1

(51) International Patent Classification⁷: **G01B 7/14**,
B60N 2/02, G01D 5/165, B60N 2/00, 2/44, B60R 21/01,
G01B 7/02, 7/15, G01D 5/12, 5/16, 5/24

(21) International Application Number:
PCT/SE2005/001218

(22) International Filing Date: 18 August 2005 (18.08.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0418671.4 20 August 2004 (20.08.2004) GB

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

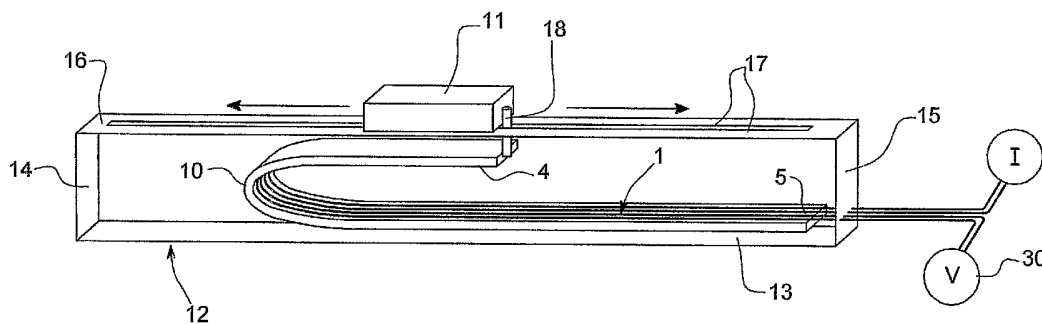
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A POSITION SENSOR



(57) Abstract: A sensor (1) for measuring the position of a first object, such as a seat of a vehicle, and a second object, such as a floor-mounted rail. The sensor (1) comprises a flexible bend-responsive element (2) whose width varies along the length of the sensor (1). The element (2) has an electrical property, such as resistance or capacitance, which varies according to the position of a bend in the element (2). The position of the first object relative to the second object is measured by securing the sensor (1) to both objects such that a bend is formed in the sensor (1) at some point between the two objects. As the objects move relative to one another, the position of the bend in the sensor is caused to move, creating a change in the electrical property of the sensor, which may be measured.

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“A POSITION SENSOR”

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THE PRESENT INVENTION relates to a sensor for measuring the position of a first object relative to a second object and to an arrangement employing such a sensor.

15 Various sensors are known for measuring the position of a first object moveable relative to a second object. One such sensor involves the use of a potentiometer having a sliding contact. However, a problem with this type of sensor is that the sliding contact can be worn with use and consequently measurements can become unreliable.

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There are sensors for which no contact is made by the sensor between the first and second objects, referred to hereafter as contactless sensors. Examples of such sensors include optical or magnetic sensors, which when secured to the first object respond to optical or magnetic markings on the
25 second object. Other contactless sensors include optical and acoustic transceivers for transmitting and receiving a signal between the two objects. Although contactless sensors do not normally suffer from the reliability problems normally associated with sliding contacts, they are generally complex and / or expensive.

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An additional problem with many sensors is that they are capable of measuring only a change in the position of the first object relative to the second object. The sensors are not therefore able to measure the absolute position of the first object relative to the second object and require re-calibrating with every reset, e.g. whenever the power is turned off and on.

It is therefore an object of the present invention to provide a sensor that overcomes one or more of the aforementioned problems.

Accordingly, in a first aspect, the present invention provides sensor for securing to a first object and to a second object and for measuring the position of the first object relative to the second object, the sensor comprising a flexible bend-responsive element characterised in that the width of the bend-responsive element is tapered along the length of the element so that one end of the element is wider than the other end of the element, the bend-responsive element having a characteristic that may be measured electrically and which varies as a function of a position of a bend in the element.

By securing the sensor to both the first and second objects, the sensor does not suffer from the reliability problems normally associated with sensors that employ sliding contacts. Additionally, owing to its relative simplicity, the sensor is generally less expensive and complex than many contactless sensors.

Preferably the cross-section and/or the thickness of the bend-responsive element varies along the length of the element. Moreover, the change in cross-section preferably varies linearly along the length of the element.

The characteristic of the bend-responsive element may be electrical resistance, with the resistivity of the element preferably varying along its length. This may be achieved, for example, by means of a layer of an

electrically conductive material whose resistance increases upon bending. Alternatively, the characteristic to be measured may be electrical capacitance, with the bend-responsive element comprising a dielectric sandwiched between a pair of electrically conductive layers. The dielectric is compressible such
5 that the electrical capacitance of the bend-responsive element increases upon bending. The thickness and/or the dielectric constant of the dielectric may vary along the length of the element.

The sensor preferably includes four bend-responsive elements arranged in a
10 Wheatstone bridge configuration, such that the sensitivity and accuracy of the sensor is improved.

In a second aspect, the present invention provides a sensor arrangement for measuring the position of a first object relative to a second object, the first and
15 second objects being moveable with respect to one another, the arrangement comprising: a sensor having a first portion secured to the first object, a second portion secured to the second object, and a bend formed in the sensor at a position between the first and second portions, wherein the sensor arrangement is configured such that position of the bend in the sensor is
20 caused to move as the first object moves relative to the second object, and the sensor comprises a flexible bend-responsive element having a characteristic that may be measured electrically and which varies as a function of a position of a bend in the sensor; and means for measuring the characteristic of the bend-responsive element to obtain information regarding
25 the position of the first object relative to the second object.

The bend formed in the sensor is preferably about 180°. Moreover, the sensor preferably comprises a U-shaped strip.

30 The sensor arrangement may be configured so that the position of the bend in the sensor is caused to move as the first object moves laterally relative to the

second object. As a result information regarding the lateral position of the first object relative to the second object is obtained. Alternatively, the sensor arrangement may be configured such that the position of the bend in the sensor is caused to move as the first object moves rotationally relative to the second object. Consequently, information regarding the angular position of the first object relative to the second object may be obtained.

In a preferred embodiment of the sensor arrangement, the first and second objects are components of a motor vehicle. In particular, the first and second objects may be components of a seat and its mounting, a swab and back rest of a seat, or a pillar loop of a seat belt mechanism and its mounting.

In a third aspect, the present invention provides a method of measuring the position of a first object relative to a second object, the first and second objects being moveable with respect to one another, the method comprising the steps of: providing a sensor comprising a flexible bend-responsive element having a characteristic that may be measured electrically and which varies as a function of a position of a bend in the sensor; securing a first portion of the sensor to the first object and securing a second portion of the sensor to the second object; configuring the sensor such that a bend is formed in the sensor between the first and second portions, and the position of the bend is caused to move as the first object moves relative to the second object; and measuring the characteristic of the bend-responsive element to obtain information regarding the position of the first object relative to the second object.

Embodiments of the present invention will now be described by way of example with reference to accompanying drawings, in which:

FIGURE 1 illustrates a sensor in accordance with the present invention;

FIGURE 2 illustrates the specific electrical resistance measured at various points along the length of the sensor of Figure 1;

- 5 FIGURE 3 illustrates the total electrical resistance measured across the sensor of Figure 1 as a function of bending position;

FIGURE 4 illustrates an alternative sensor in accordance with the present invention;

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FIGURE 5 is a circuit diagram of the sensor of Figure 4;

FIGURE 6 illustrates the total electrical resistance measured across the different junctions of the sensor of Figure 4 as a function of bending position;

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FIGURE 7 illustrates the potential difference measured across junctions C and D of the sensor of Figure 4 as a function of bending position;

FIGURE 8 is a cross-sectional view of a further alternative sensor in accordance with the present invention;

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FIGURE 9 is a circuit diagram of the sensor of Figure 8;

FIGURE 10 illustrates a sensor arrangement in accordance with the present invention;

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FIGURE 11 illustrates an alternative sensor arrangement in accordance with the present invention;

- 30 FIGURE 12 illustrates a further alternative sensor arrangement in accordance with the present invention, the sensor arrangement being in a first position;

FIGURE 13 illustrates the sensor arrangement of Figure 12 in a second position; and

5 FIGURE 14 illustrates the sensor arrangement of Figure 12 in a third position.

Figure 1 illustrates a sensor 1 in accordance with the present invention. The sensor 1 comprises a bend-responsive element 2 carried on a flexible substrate 3. The substrate 3 is generally rectangular having a length greater than that of the width, such that the sensor 1 resembles a strip. The bend-responsive element 2 comprises a thin layer of an electrically conductive material whose resistance increases upon bending. The sensor 1 also includes a pair of wires or conductive tracks 6 carried on the substrate 3 for connecting to a measuring device 30, such as an ohmmeter, each wire or track being connected to one end of the bend-responsive element 2. The measuring device 30 measures the electrical resistance across the bend-responsive element 2.

The width of the bend-responsive element 2 is tapered along the length of the sensor 1, such that the element 2 is wider at one end 4 of the sensor 1. Because the width of the bend-responsive element 2 varies along the length of the sensor 1, the electrical resistance of the sensor 1 (as measured by the wires or tracks 6) depends not only upon whether the sensor 1 includes a bend but also upon the location of the bend, as will now be demonstrated with reference to Figures 2 and 3.

Figure 2 illustrates the specific electrical resistance, dR/dx , of the sensor at a particular position, x , along the length of the sensor 1. The graph includes two plots, the first illustrating the specific electrical resistance when the strip is unbent and the second illustrating the same measurement when the strip is bent by some fixed amount. A plan view of the bend-responsive element 2 is

shown beneath the x axis, from which it can be seen that $x = 0$ corresponds to the end 4 of the sensor 1 for which the bend-responsive element 2 is widest. It can be seen from Figure 2 that the specific electrical resistance of the sensor 1, when bent and unbent, increases as the width of the bend-responsive element 2 at the location of the bend decreases. Importantly, the gradient of the change in specific electrical resistance along the length of the sensor 1 is greater when the sensor 1 is bent than when it is unbent. Accordingly, the total electrical resistance across the sensor depends not only upon whether the sensor 1 is bent but also upon the location of the bend, as illustrated in Figure 3.

Figure 3 illustrates the total electrical resistance, R , measured across the sensor 1 as a function of the location, x , of a bend in the sensor 1. Owing to the specific resistance behaviour of the sensor, as illustrated in Figure 2, the total resistance across the sensor 1 varies according to the location of the bend in the sensor 1. Consequently, the position of a bend in the sensor 1 may be determined by measuring the electrical resistance across the sensor 1.

The sensor 1 of the present invention may therefore be used to determine the position of a first object relative to a second object. This is achieved by securing one end 4 (or first portion) of the sensor 1 to the first object and the other end 5 (or second portion) of the sensor 1 to the second object. A bend is then formed in the sensor 1 between the two ends 4, 5 of the sensor 1, and the arrangement of the sensor 1 and objects is configured such that the position of the bend is caused to move when the first object is moved relative to the second object. As a result, movement of the first object brings about a change in position of the bend in the sensor 1, resulting in a change in the electrical resistance of the sensor 1. Thus the electrical resistance measured by the measuring device 30 can be used as a measure of the position of the first object relative to the second object.

Figures 4 and 5 illustrate an alternative embodiment of a sensor 1 in accordance with the present invention. In this embodiment, the sensor 1 includes four identical bend-responsive elements 2a, 2b arranged in a Wheatstone bridge configuration. The bend-responsive elements 2a, 2b are aligned parallel to one another on the substrate 3. However, two of the bend responsive elements 2a are arranged such that tapering occurs in a first direction, whilst the tapering of the other two elements 2b is an opposite direction. In providing four bend-responsive elements 2a, 2b arranged in a bridge configuration, the sensitivity and accuracy of the sensor is improved.

Figure 6 shows the total electrical resistance, R , across each of the four bend-responsive elements 2a, 2b of the sensor 1 of Figure 4 as a function of bending position, x . Since the bend-responsive elements 2a between junctions B-C and A-B are aligned in the same direction, they share the same resistance behaviour with bending position. Similarly, the bend-responsive elements 2b between junctions B-D and A-C also share the same resistance behaviour with bending position. As the bending position moves along the sensor 1 in a direction x indicated in Figure 4, the resistance across the bend-responsive elements between junctions B-C and A-B increases, while the resistance of the bend-responsive elements between junctions B-D and A-C decreases.

The potential difference across junctions C and D of the sensor 1 of Figure 4, V_{C-D} , as a function of bending position, x , is shown in Figure 7. As the bending position moves along the sensor 1 in a direction indicated in Figure 4, the potential difference across junctions C and D gradually decreases. Accordingly, the position of the bend in the sensor 1 can be determined by measuring the potential difference across this junction using a suitable measuring device 30, e.g. a Voltmeter.

The dashed lines in Figures 4 to 7 represent the position of a possible bend in the sensor 1. At this bending position, the potential difference at junction C is higher than that at junction B and therefore a positive V_{C-D} is measured by the measuring device 30 across the C-D junction.

In the embodiments of the sensor described thus far, the bend-responsive element 2 of the sensor 1 comprises an electrically conductive material whose resistance increases at a bend in the sensor 1. As a result, the total resistance across the sensor 1 varies as a function of bending position. Rather than a sensor 1 whose resistance varies as a function of bending position, the sensor 1 may alternatively be configured such that its capacitance or inductance varies as a function of bending position.

Figures 8 and 9 illustrate a further alternative embodiment of sensor 1 in accordance with the present invention, in which the capacitance of the sensor 1 varies as a function of bending position. As with the sensor 1 of Figure 4, the sensor 1 of Figure 8 comprises four bend-responsive elements 2 arranged in a bridge configuration. However, the sensor 1 may equally comprise a single bend-responsive element 2.

Each bend-responsive element 2 comprises a pair of conductive layers 7a, 7b which sandwich a dielectric 8. The dielectric 8 is made of a compressible material such that when the sensor 1 is bent, the separation of the conductive layers 7a, 7b decreases and therefore the capacitance of the bend-responsive element 2 increases. The widths of the conductive layers 7a, 7b are tapered along the length of the sensor 1 such that the specific capacitance of each bend-responsive element 2 varies along the length of the sensor 1. Consequently, the total capacitance of the sensor 1 varies as a function of bending position. The position of the bend in the sensor 1 may therefore be

determined by measuring the capacitance of the sensor 1 using a suitable measuring device 30, e.g. a Voltmeter.

The dielectric 8 serves as a carrier for the conductive layers 7a, 7b. Consequently, there is no need for the sensor 1 to include a separate substrate 3. Indeed, the same dielectric 8 is preferably common to all four bend-responsive elements 2 of the sensor 1 and is generally rectangular in shape such that the sensor 1 resembles a strip. Nevertheless, each bend-responsive element 2 may be formed individually and carried on a common substrate.

The sensor 1 further includes insulating layers 9 disposed over at least the conductive layers 7a, 7b of the bend-responsive elements 2. The insulating layers 9 serve to insulate the conductive layers 7a, 7b from the objects to which the sensor 1 is to be secured. Accordingly, should the objects, or at least the parts to which the sensor 1 is secured, be made of an insulating material then the insulating layers 9 may be omitted.

As shown in Figure 9, the sensor 1 of Figure 8 is wired to an alternating current source. Moreover, junctions A and B are wired to a first conductive layers 7a of the bend-responsive elements 2, whilst junctions C and D are wired to the second conductive layers 7b of the bend-responsive elements 2. A measuring device 30, e.g. a Voltmeter, measures the potential difference across the C-D junction to provide a measure of the capacitance of the sensor 1.

The variation in the width of the bend-responsive elements 2 of the sensors 1 of Figures 1, 4 and 8 is preferably linear along the length of the sensor 1. Accordingly, the total resistance or capacitance across the sensor 1 varies linearly with the bending position. Nevertheless, the variation in width of the bend-responsive element 2 need not be linear but may instead be tailored to

suit. For example, the width of the bend-responsive element 2 may vary exponentially such that the sensitivity of the sensor 1 to changes in bending position increases at one end of the sensor 1. Alternatively, the width of the bend-responsive element 2 may vary in discrete steps such that the resistance across the sensor 1 similarly varies in discrete steps. With this particular arrangement, the resistance of the sensor 1 would therefore only change when the bend in the sensor 1 is moved by a specific amount.

In the embodiments of the sensor 1 described thus far, the width of the bend-responsive element 2 varies along the length of the sensor 1 such that the resistance, capacitance or inductance across the element 2 varies with bending position. It will be appreciated, however, that the same technical effect may be achieved by having a bend-responsive element 2 whose thickness, rather than its width, varies along the length of the sensor 1. Indeed, changes in the thickness of the element 2 may be used in addition to changes in width so as to increase the sensitivity of the sensor 1.

Where the bend-responsive element 1 comprises a pair of conductive layers 7a, 7b which sandwich a dielectric 8, the thickness of the dielectric 8 may vary across the length of the sensor 1. Alternatively, or additionally, the dielectric constant of the dielectric 8 may vary across the length of the sensor 1.

Embodiments of a sensor arrangement employing the sensor 1 of the present invention will now be described with reference to Figures 10 to 14.

Figure 10 illustrates a first embodiment of a sensor arrangement in accordance with the present invention. The sensor arrangement is configured to measure the lateral position of a first object 11, which may be part of a vehicle seat, slideably mounted on a second object 12, which may be mounted on the floor of a vehicle.

The second object 12 comprises a base 13 to which are attached a pair of upright side walls 14, 15 which support a rail 16 positioned directly above the base 13. The rail 16 includes a pair of tracks 17 upon which the first
5 object 11, e.g. a carriage, is slideably mounted.

A sensor 1 is housed within the second object 12 and is secured at one end 5 to the base 13 of the second object 12. The end 5 of the sensor 1 is secured to the base 13 at a point adjacent one of the upright side walls 15. The
10 remainder of the sensor 1 extends along the base 13 towards the other side wall 14. Before reaching the other side wall 14, the sensor 1 is bent back upon itself so as to form a U-shaped bend 10. The other end 4 of the sensor 1 is secured to the first object 11 by means of a pin 18 which slots between the pair of tracks 17 of the rail 16.

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As the first object 11 is slid along the rail 16 of the second object 12, the end 4 of the sensor 1 secured to the first object 11 is caused to move laterally. As a result, the position of the bend 10 in the sensor 1 is also caused to move, resulting in a change in the resistance or capacitance of the sensor 1. By
20 measuring the resistance or capacitance of the sensor 1, the position of the bend 10 in the sensor 1 may be determined and consequently the position of the first object 11 relative to the second object 12 may be measured.

In this particular embodiment, the sensor 1 may be regarded as having a pair
25 of legs, each leg extending either side of the U-shaped bend 10. The first leg extends from the bend 10 to the end 4 of the sensor 1 secured to the first object 11. The second leg extends from the bend 10 to the end 5 of the sensor 1 secured to the second object 12. The two legs are substantially parallel and their respective lengths change as the first object 11 is slid
30 relative to the second object 12.

Figure 11 shows an alternative sensor arrangement in accordance with the present invention. As with the sensor arrangement of Figure 10, the arrangement of Figure 11 is configured to measure the lateral position of a first object 11 slideably mounted on a second object 12. Again, the second object comprises a base 13 attached to upright side walls 14, 15, which support a rail 16 above the base 13.

The sensor 1 is again housed within the second object 12 and is secured at one end 5 to a spring 19, or other resilient means. The end of the spring 19 remote from the end 5 of the sensor 1 is attached to the rail 16 of the second object 12 at a point adjacent a side wall 15. From the spring 19, the sensor 1 extends vertically downwards and passes around a roller 20 mounted within the second object. The roller may be mounted, as shown, by a pair of brackets to the base 13 of the second object 12. Alternatively, the second object 12 may include front and rear walls (not shown) and the roller 20 is mounted directly to these walls. The sensor 1 passes around the roller 20 to create a bend 10 in the sensor 1. After passing around the roller 20, the other end 4 of the sensor 1 is secured to the first object 11 by means of a pin 18, which again passes between the tracks 17 of the rail 16.

As the first object 11 is slid along the rail 16 of the second object 12, the end 4 of the sensor 1 is also caused to move. When the first object 11 is moved in a direction away from the roller 20, the length of the sensor 1 between the end 4 attached to the first object and the roller 20 increases, and the length of the sensor between the end 5 attached to the spring 19 and the roller 20 decreases. Additionally, the spring 19 is stretched. When the first object 11 is instead moved in a direction towards the roller 20 of the second object 12, the tension in the spring 19 ensures that length of sensor 1 between the end 4 secured to the first object and the roller 20 decreases, whilst the length of sensor 1 between the end 5 secured to the spring 19 and the roller 20

increases. Accordingly, as the first object 11 is moved along the rail 16 of a second object, the position of the bend 10 formed in the sensor 1 by the roller 20 is caused to move. This change in the position of the bend 10 is measured as changes in the resistance or capacitance of the sensor 1.

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Again, the sensor 1 may be regarded as having a pair of legs on either side of the bend 10, the first leg extending from the bend 10 to the first object 11 and the second leg extending from the bend 10 to the spring 19. As the first object 11 is moved along the rail 16 of the second object 12, the respective
10 lengths of the legs change.

Figures 12 to 14 illustrate a further embodiment of the sensor arrangement of the present invention. The sensor arrangement is configured to measure the angular position of a first object 11 which is rotatable relative to a second
15 object 12. The three figures illustrate the sensor arrangement in three different angular positions.

The first object 11 is a cylindrical element and the second object 12 is a tubular sleeve arranged co-axially around the first object 11. The first
20 object 11 is rotatable relative to the second object 12 about the coaxial axis.

Disposed between the first and second objects 11, 12 is a guiding means 21. The guiding means 21 comprises a substantially cylindrical collar arranged coaxially around the first object 11. The guiding means 21 is spaced from the
25 first object 11 so as to create an inner annular passage 22 between the guiding means 21 and the first object 11. The guiding means 21 is also spaced from the second object 12 so as to create an outer annular passage 23 between the guiding means 21 and the second object 12.

The guiding means 21 includes a channel 24 which communicates the inner annular passage 22 to the outer annular passage 23, the channel 24 including a radial portion 25 and a circumferential portion 26.

5 The radial portion 25 of the channel 24 extends radially from the surface 27 of the guiding means 21 adjacent the inner annular passage 22 towards the surface 28 of the guiding means 21 adjacent the outer annular passage 23. The circumferential portion 26 is formed in a direction substantially parallel to the inner and outer annular passages 22, 23 and extends from the radial
10 portion 25 to the surface 28 of the guiding means 21 adjacent the outer annular passage 23. The radial portion 25 of the channel 24 is therefore normal to both the inner annular passage 22 and the circumferential portion 26 of the channel 24.

15 The sensor 1 is secured at one end 4 to the first object 11 and extends along at least a portion of the inner annular passage 22. The sensor 1 then continues along the channel 24 of the guiding means 21 and extends along at least a portion of the outer annular passage 23 before being secured at the other end 5 to the second object 12.

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The sensor 1 extends along the inner annular passage 22 in a direction such that a U-shaped bend 10 is created in the sensor 1 by the guiding means 21 as the sensor 1 passes from the inner annular passage 22 to the circumferential portion 26 of the channel 24.

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The guiding means 21 can be rotated independently of the first and second objects 11, 12 and ensures that a single bend 10 is formed in the sensor 1 as the first object 11 is rotated relative to the second object 12. The guiding means 21 is resiliently biased to rotate in an anti-clockwise direction.

30 Although the sensor 1 is curved along the inner and outer annular passages 22, 23, as well as the circumferential portion 26 of the channel 24,

the degree of curvature is small compared to that of the bend 10 in the sensor 1. Consequently, changes in the resistance or capacitance of the sensor 1, as the first object 11 is rotated, are due primarily to changes in the position of the bend 10.

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Figure 12 illustrates the sensor arrangement in a first end position. In this position, the end 4 of the sensor 1 secured to the first object 11 is proximate the radial portion 25 of the channel 24, whilst ensuring that a bend 10 is maintained in the sensor 1. Were the first object 11 rotated anti-clockwise from this position, the bend 10 in the sensor 1 would be released. Consequently, anti-clockwise rotation of the first object 11 from this position is prohibited. Rotation of the first object 11 is, however, permitted in a clockwise direction.

15 As the end 4 of the sensor 1 secured to the first object is proximate the radial portion 25 of the channel 24, the length of sensor 1 which extends along the inner annular passage 22 is relatively short (and is at a minimum). Conversely, the length of sensor 1 which extends around the outer annular passage 23 is relatively long (and is at a maximum) in this first end position.

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Figure 13 shows the sensor arrangement after the first object 11 has been rotated clockwise by 360° from the position of Figure 12. As the first object 11 is rotated clockwise, the end 4 of a sensor 1 secured to the first object 11 is pulled around the inner annular passage 22. Consequently, the length of sensor 1 which extends along the inner annular passage 22 increases. Moreover, the position of the bend 10 in the sensor 1 moves along the sensor 1 in a direction away from the end 4 of the sensor 1 secured to the first object 11. The guiding means 21 has moved by 180° against the resilient bias.

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In this particular position, the sensor 1 may be regarded as having two legs on either side of the bend 10, the first leg extending from the bend 10 to the end 4 of the sensor 1 secured to the first object 11 and the other leg extending from the bend 10 to the end 5 secured to the second object 12. Although the
5 legs are curved, they may be regarded nevertheless as lying substantially parallel to one another. Again, as with the arrangements of Figures 10 and 11, the respective lengths of the legs vary as the first object 11 is rotated relative to the second object 12.

10 Figure 14 illustrates the sensor arrangement after the first object 11 has been rotated clockwise by a further 270° (i.e. roughly 630° from the first end position of Figure 12). The sensor 1 has been pulled further around the inner annular passage 22 and now extends completely around the inner annular passage 22. The guiding means 21 has also executed a further rotation
15 against its bias. Consequently, were the first object 11 to be rotated further in a clockwise direction, a short circuit would be created between the end 4 of the sensor 1 and a portion of the sensor 1 located at the bend 10. The sensor arrangement of Figure 13 therefore represents a second end position, whereby further clockwise rotation of the first object 11 relative to the second
20 object 12 is prohibited.

In this second end position, the length of sensor 1 which extends around the inner annular passage 22 is relatively long (and is at a maximum) whilst the length of sensor 1 extending around the outer annular passage 23 is relatively
25 short (and is at a minimum).

By employing a sensor that is secured to the objects whose relative positions are to be measured, the sensor arrangement of the present invention does not suffer from the reliability problems of sliding contacts. Additionally, the sensor
30 of the present invention is relatively simple in construction and is therefore generally less expensive and complex than many contactless sensors.

Owing to the versatility of the sensor, it is anticipated that the sensor will have practical applications in many different fields. For example, the sensor may be used to measure the position of hydraulic and pneumatic pistons as used,
5 for example, in the automation of production, as well as forest and construction machinery.

The sensor is intended to have applications in the automotive industry, and in particular as components of a vehicle interior. For example, in the sensor
10 arrangements illustrated in Figures 10 and 11, the first and second objects may be, respectively, components of a seat and a rail mounted to the floor of a vehicle interior. Additionally, in the sensor arrangement of Figures 12 14, the first and second objects may be respectively components of a back rest and squab of a seat. Alternatively, the first and second objects may be
15 respectively, components of a pillar loop of a seat belt mechanism and the mounting point within a vehicle. The sensor may also be used to measure the angular position of a steering wheel.

When used in this Specification and Claims, the terms "comprises" and
20 "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the presence of other features, steps or components.

CLAIMS:

- 5 1. A sensor for securing to a first object and to a second object and for measuring the position of the first object relative to the second object, the sensor comprising a flexible bend-responsive element (2) characterised in that the width of the bend-responsive element (2) is tapered along the length of the element (2) so that one end of the element (2) is wider than the other end of
10 the element (2), the bend-responsive element (2) having a characteristic that may be measured electrically and which varies as a function of a position of a bend (10) in the element (2).
2. A sensor as claimed in Claim 1, wherein the cross-section of the bend-
15 responsive element (2) varies along the length of the element (2).
3. A sensor as claimed in Claim 2, wherein the change in cross-section of the bend-responsive element (2) varies linearly along the length of the
20 element (2).
4. A sensor as claimed in any one of the preceding Claims, wherein the thickness of the bend-responsive element (3) varies along the length of the element (2).
- 25 5. A sensor as claimed in any one of the preceding Claims, wherein the characteristic which varies as a function of a position of a bend (10) in the element is electrical resistance.
6. A sensor as claimed in Claim 5, wherein the resistivity of the bend-
30 responsive element (2) varies along the length of the element (2).

7. A sensor as claimed in either Claim 5 or 6, wherein the bend-responsive element (2) comprises a layer of an electrically conductive material whose electrical resistance increases upon bending.

5

8. A sensor as claimed in any one of Claims 1 to 4, wherein the characteristic which varies as a function of a position of a bend (10) in the element (2) is electrical capacitance.

10 9. A sensor as claimed in Claim 8, wherein the bend-responsive element (2) comprises a dielectric (8) sandwiched between a pair of electrically conductive layers (7a, 7b), the dielectric (8) being compressible such that the electrical capacitance of the bend-responsive element (2) increases upon bending.

15

10. A sensor as claimed in Claim 9, wherein the dielectric constant of the bend-responsive element (2) varies along the length of the element (2).

11. A sensor as claimed in either Claim 9 or 10, wherein the thickness of
20 the dielectric layer (8) varies along the length of the bend-responsive element (2).

12. A sensor as claimed in any one of the preceding claims, wherein the sensor comprises four bend-responsive elements (2a, 2b) arranged in a
25 Wheatstone bridge configuration.

13. A sensor as claimed in any one of the preceding Claims, wherein the bend-responsive element (2) is carried by a flexible substrate (3).

14. A sensor arrangement for measuring the position of a first object (11) relative to a second object (12), the first and second objects (11, 12) being moveable with respect to one another, the arrangement comprising:

5 a sensor (1) having a first portion secured to the first object (11), a second portion secured to the second object (12), and a bend (10) formed in the sensor (1) at a position between the first and second portions, wherein the sensor arrangement is configured such that position of the bend (10) in the sensor (1) is caused to move as the first object (11) moves relative to the second object (12), the sensor (1) comprises a flexible bend-responsive
10 element (2) having a characteristic that may be measured electrically and which varies as a function of a position of the bend (10) in the sensor (1); and a measuring device (30) for measuring the characteristic of the bend-responsive element (2) to obtain information regarding the position of the first object (11) relative to the second object (12).

15

15. A sensor arrangement as claimed in Claim 14, wherein the bend (10) formed in the sensor (1) is about 180°.

16. A sensor arrangement as claimed in either Claim 14 or 15, wherein the
20 sensor (1) comprises a U-shaped strip.

17. A sensor arrangement as claimed in any one of Claims 14 to 16, wherein the cross-section of the bend-responsive element (2) varies between the first and second portions of the sensor (1).

25

18. A sensor arrangement as claimed in Claim 17, wherein the change in cross-section of the bend-responsive element (2) varies linearly between the first and second portions of the sensor (1).

19. A sensor arrangement as claimed in either Claim 17 or 18, wherein the width of the bend-responsive element (2) varies between the first and second portions of the sensor (1).

5 20. A sensor arrangement as claimed in any one of Claims 17 to 19, wherein the thickness of the bend-responsive element (2) varies between the first and second portions of the sensor (1).

10 21. A sensor arrangement as claimed in any one of Claims 14 to 20, wherein the characteristic which varies as a function of a position of a bend (10) in the sensor (1) is electrical resistance.

15 22. A sensor arrangement as claimed in Claim 21, wherein the resistivity of the bend-responsive element (2) varies between the first and second portions of the sensor (1).

20 23. A sensor arrangement as claimed in either Claim 21 or 22, wherein the bend-responsive element (2) comprises a layer of an electrically conductive material whose electrical resistance increases upon bending.

24. A sensor arrangement as claimed in any one of Claims 14 to 20, wherein the characteristic which varies as a function of a position of a bend (10) in the sensor (1) is electrical capacitance.

25 25. A sensor arrangement as claimed in Claim 24, wherein the bend-responsive element (2) comprises a dielectric (8) sandwiched between a pair of electrically conductive layers (7a, 7b), the dielectric (8) being compressible such that the electrical capacitance of the bend-responsive element (2) increases upon bending.

26. A sensor arrangement as claimed in Claim 25, wherein the dielectric constant of the bend-responsive element (2) varies between the first and second portions of the sensor (1).
- 5 27. A sensor arrangement as claimed in either Claim 25 or 26, wherein the thickness of the dielectric layer (8) varies between the first and second portions of the sensor (1).
- 10 28. A sensor arrangement as claimed in any one Claims 14 to 27, wherein the sensor comprises four bend-responsive elements (2a, 2b) arranged in a Wheatstone bridge configuration.
- 15 29. A sensor arrangement as claimed in any one of Claims 14 to 28, wherein the sensor arrangement is configured such that position of the bend (10) in the sensor (1) is caused to move as the first object (11) moves laterally relative to the second object (12) such that information regarding the lateral position of the first object (11) relative to the second object (12) is obtained.
- 20 30. A sensor arrangement as claimed in any one of Claims 14 to 28, wherein the sensor arrangement is configured such that position of the bend (10) in the sensor (1) is caused to move as the first object (11) moves rotationally relative to the second object (12) such that information regarding the angular position of the first object (11) relative to the second object (12) is
25 obtained.
31. A sensor arrangement as claimed in Claim 29, wherein the first (11) and second objects (12) are respectively a seat and a mounting.
- 30 32. A sensor arrangement as claimed in Claim 30, wherein the first (11) and second objects (12) are respectively a squab and a backrest of a seat,

and the sensor arrangement measures the angular position of the backrest relative to the squab.

33. A sensor arrangement as claimed in Claim 30, wherein the first (11)
5 and second objects (12) are respectively a pillar loop of a seat belt mechanism and a mounting within a vehicle, and the sensor arrangement measures the angular position of the pillar loop relative to the mounting.

34. A method of measuring the position of a first object (11) relative to a
10 second object (12), the first and second objects (11, 12) being moveable with respect to one another, the method comprising the steps of:

providing a sensor (1) comprising a flexible bend-responsive element (2) having a characteristic that may be measured electrically and which varies as a function of a position of a bend in the sensor (1);

15 securing a first portion of the sensor (1) to the first object (11) and securing a second portion of the sensor to the second object (12);

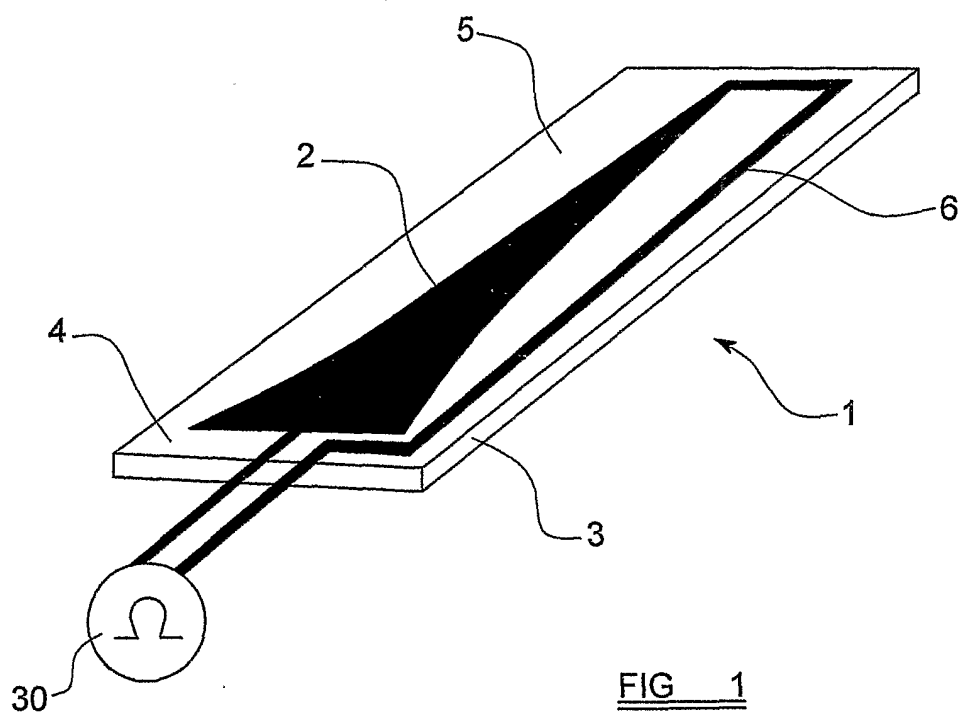
configuring the sensor (1) such that a bend (10) is formed in the sensor (1) between the first and second portions, and the position of the bend (10) is caused to move as the first object (11) moves relative to the
20 second object (12); and

measuring the characteristic of the bend-responsive element (2) to obtain information regarding the position of the first object (11) relative to the second object (12).

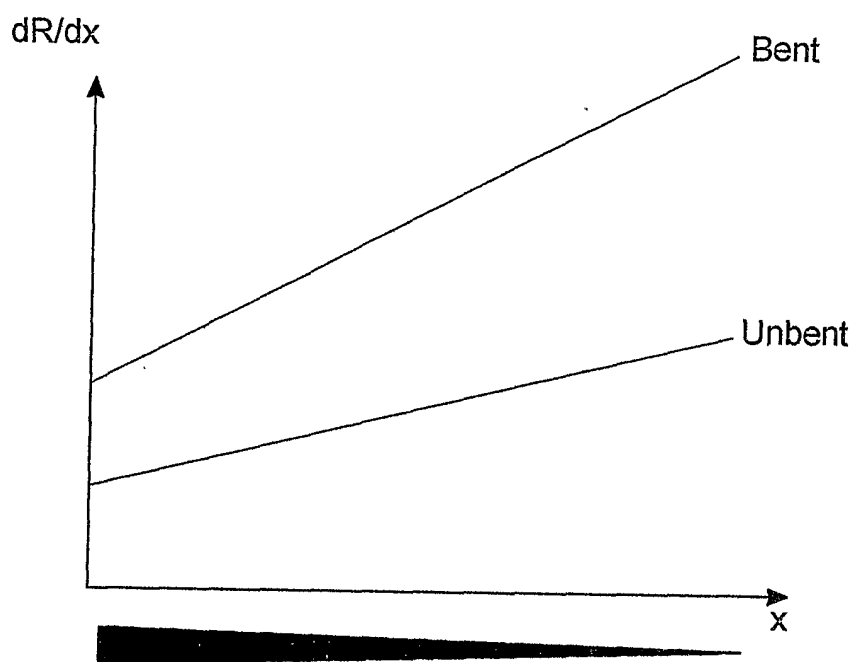
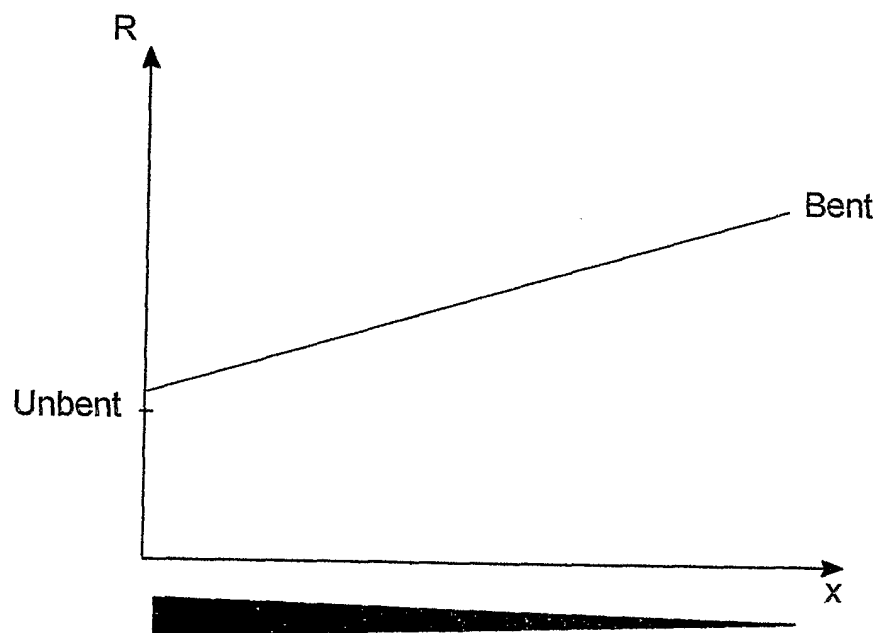
25 35. A sensor for securing to a first object and to a second object and for measuring the position of the first object relative to the second object, the sensor comprising a flexible bend-responsive element, the width of the bend-responsive element being tapered along the length of the element so that one end of the element is wider than the other end of the element, the bend-
30 responsive element having an electrical resistance which varies as a function of a position of a bend in the element, with the resistivity of the bend-

responsive element varying along the length of the element, the bend-responsive element comprising a layer of an electrically conductive material whose electrical resistance increases upon bending.

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FIG 2FIG 3

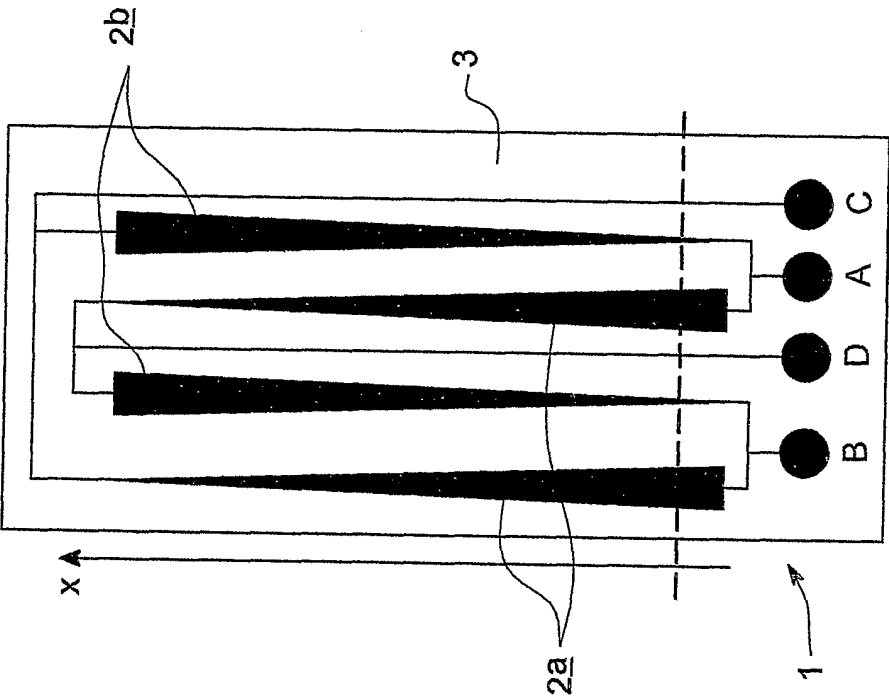


FIG 4

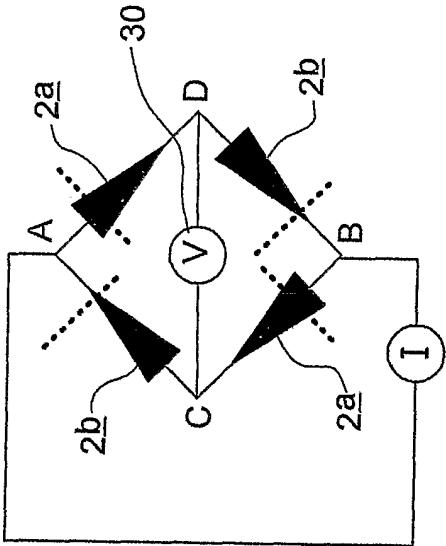
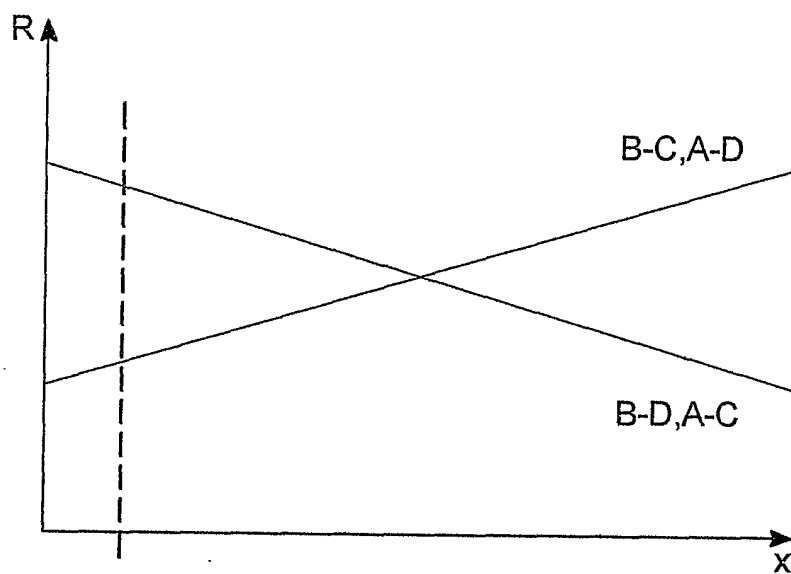
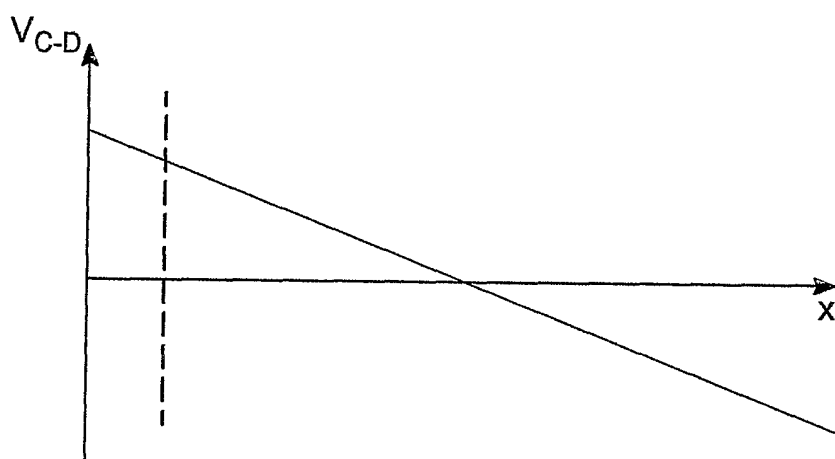


FIG 5

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FIG 6FIG 7

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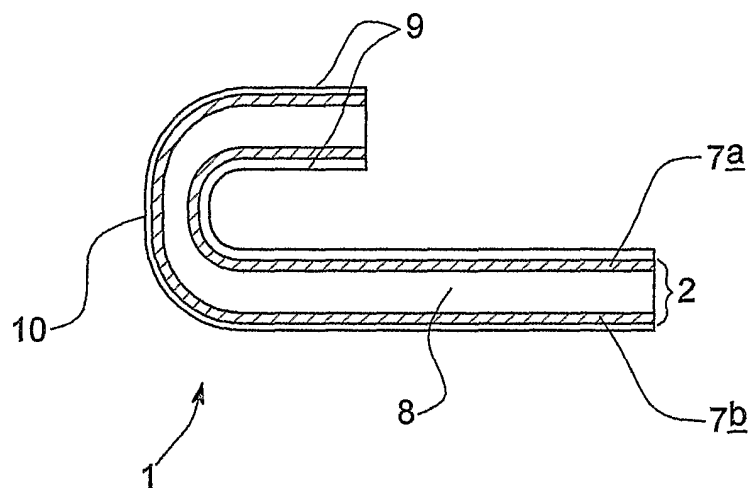


FIG 8

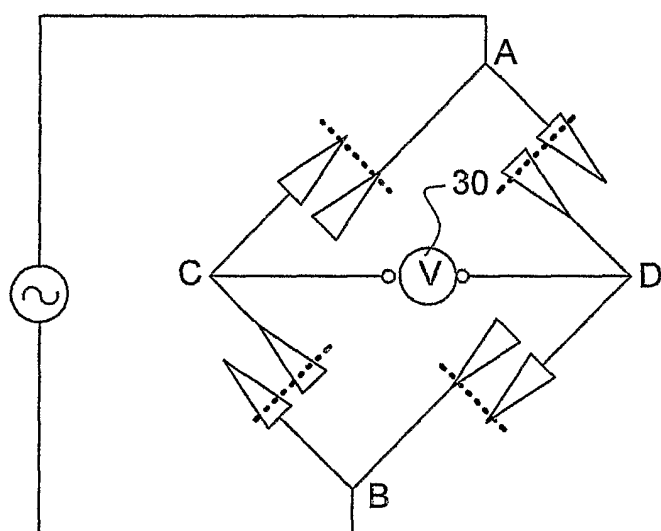
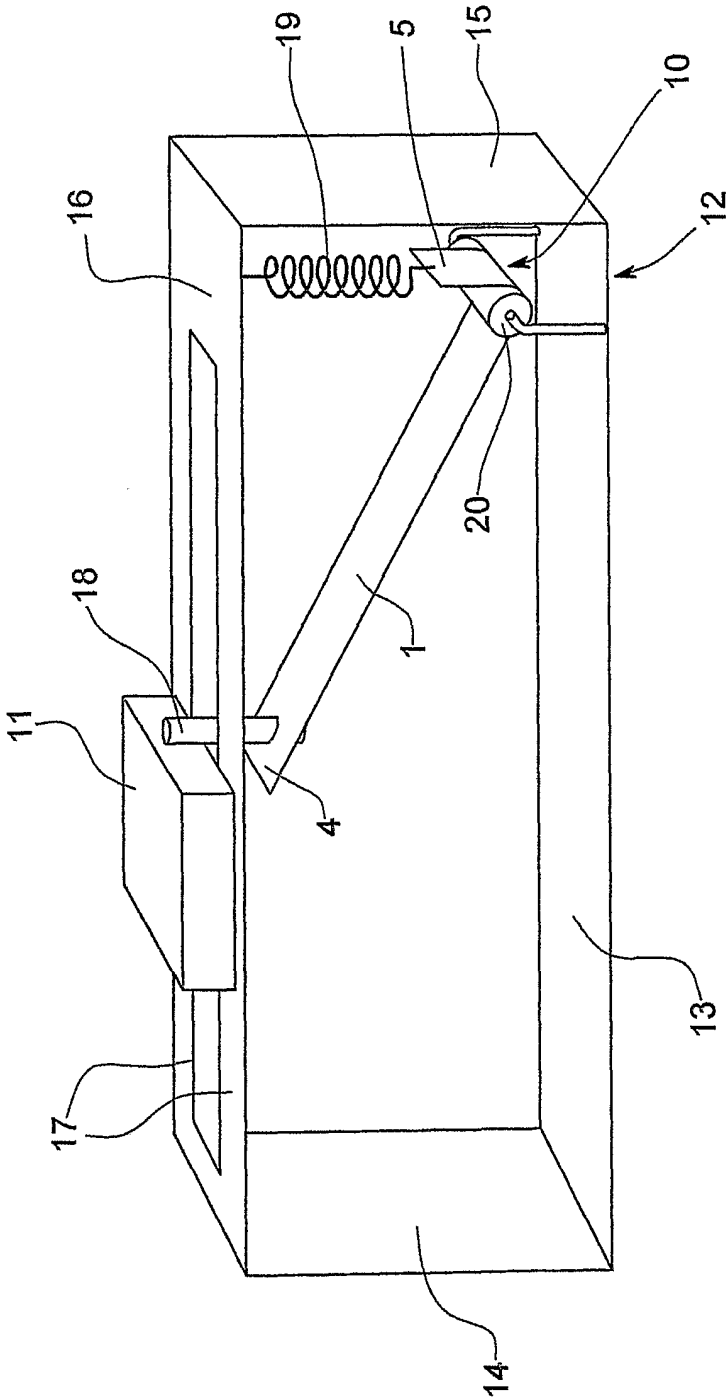


FIG 9



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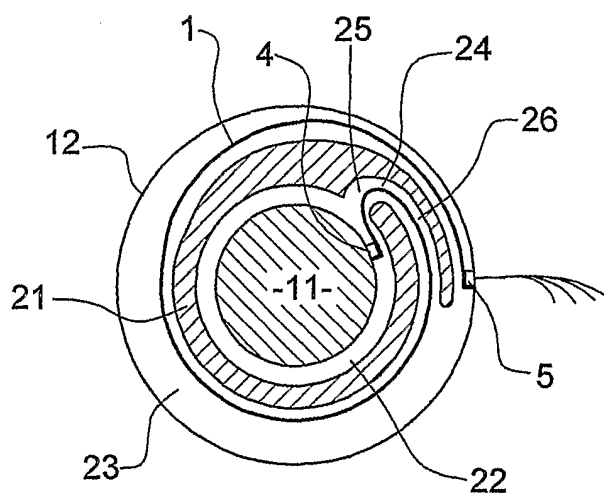


FIG 12

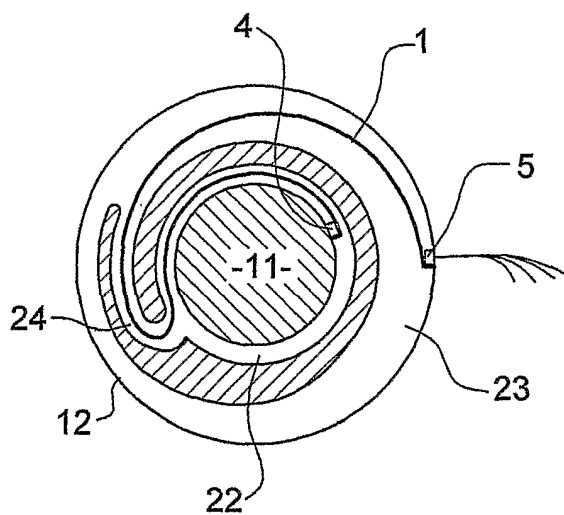


FIG 13

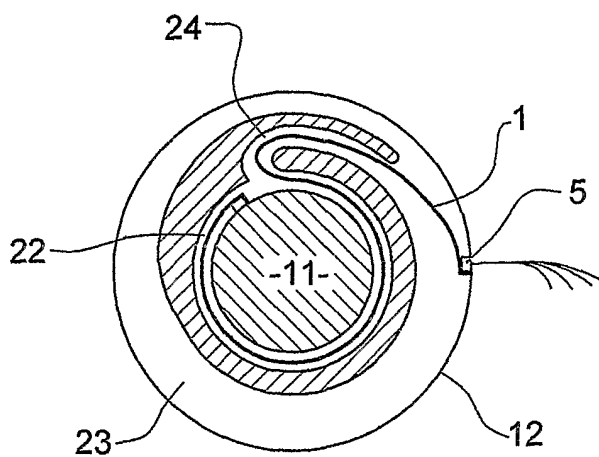


FIG 14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 2005/001218

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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: G01B, G01D, B60N, B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02087927 A1 (CONTROL DEVICES INC.), 7 November 2002 (07.11.2002), page 4, line 2 - line 17; page 6, line 10 - page 7, line 18, figure 1, claims 1,7,12	14-34
Y	--	1-13,35
X	GB 2239522 A (FORD MOTOR COMPANY LIMITED), 3 July 1991 (03.07.1991), see whole document	14-34
Y	--	1-13,35

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

23 November 2005

Date of mailing of the international search report

23-11-2005

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 2005/001218

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 3923042 A1 (MESSERSCHMITT-BÖLKOW-BLOHM GMBH), 24 January 1991 (24.01.1991), column 2, line 31 - line 50, figure 2, abstract	1-13,35
A	--	14-34
Y	EP 0447017 A1 (BORG-WARNER AUTOMOTIVE, INC.), 9 January 1991 (09.01.1991), column 4, line 35 - line 50, figure 2, abstract	1-13,35
A	--	14-34
A	EP 0421401 A1 (SARCOS GROUP), 4 October 1990 (04.10.1990), column 5, line 5 - line 54, figure 1	1-35
A	--	
A	WO 8800326 A1 (AUTOLIV DEVELOPMENT AKTIEBOLAG), 14 January 1988 (14.01.1988), figure 1, abstract	1-35
A	--	
A	US 5791603 A (MANFRED LÜCKING ET AL), 11 August 1998 (11.08.1998), abstract	1-35
A	--	
A	US 6015163 A (GORDON B. LANGFORD ET AL), 18 January 2000 (18.01.2000), abstract	1-35
A	--	
A	EP 0985909 A1 (CTS CORPORATION), 15 March 2000 (15.03.2000), abstract	1-35
A	--	
A	EP 0611061 A1 (FISHER-ROSEMOUNT LTD.), 24 January 1994 (24.01.1994), abstract	1-35
	--	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 2005/001218

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1108624 A2 (FORD GLOBAL TECHNOLOGIES, INC.), 20 June 2001 (20.06.2001), abstract -- -----	1-35

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2005/001218

Continuation of cover sheet

G01B 7/14 (2006.01)
B60N 2/02 (2006.01)
G01D 5/165 (2006.01)
B60N 2/00 (2006.01)
B60N 2/44 (2006.01)
B60R 21/01 (2006.01)
G01B 7/02 (2006.01)
G01B 7/15 (2006.01)
G01D 5/12 (2006.01)
G01D 5/16 (2006.01)
G01D 5/24 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/10/2005

International application No.

PCT/SE 2005/001218

WO	02087927	A1	07/11/2002	US	20030001748 A	02/01/2003
GB	2239522	A	03/07/1991	GB	8929212 D	00/00/0000
DE	3923042	A1	24/01/1991	NONE		
EP	0447017	A1	09/01/1991	CA	2033686 A	06/09/1991
				JP	4218702 A	10/08/1992
				US	5045785 A	03/09/1991
EP	0421401	A1	04/10/1990	AT	107019 T	15/06/1994
				AT	162619 T	15/02/1998
				CA	2026873 A,C	05/04/1991
				CA	2200106 A	05/04/1991
				CA	2200107 A	05/04/1991
				CA	2200108 A	05/04/1991
				CA	2200109 A	05/04/1991
				CA	2200110 A	05/04/1991
				CA	2200111 A	05/04/1991
				CA	2200112 A	05/04/1991
				CA	2200113 A	05/04/1991
				CA	2200114 A	05/04/1991
				CA	2200115 A	05/04/1991
				DE	69009653 D,T	15/12/1994
				DE	69031987 D,T	30/04/1998
				EP	0588383 A,B	23/03/1994
				JP	3023158 B	21/03/2000
				JP	3165215 A	17/07/1991
				US	5198740 A	30/03/1993
				US	5302886 A	12/04/1994
				US	5394070 A	28/02/1995
				US	5557185 A	17/09/1996
				US	5621318 A	15/04/1997
WO	8800326	A1	14/01/1988	AU	7589887 A	29/01/1988
				DE	3766694 D	00/00/0000
				EP	0271560 A,B	22/06/1988
				JP	1500617 T	01/03/1989
				SE	453689 B,C	22/02/1988
				SE	8602892 A	28/12/1987
				US	4958138 A	18/09/1990
US	5791603	A	11/08/1998	AU	1602197 A	22/09/1997
				CZ	9703240 A	17/03/1999
				DE	19609035 A	11/09/1997
				EP	0824666 A	25/02/1998
				JP	11504723 T	27/04/1999
				WO	9733138 A	12/09/1997
US	6015163	A	18/01/2000	NONE		
EP	0985909	A1	15/03/2000	JP	2000105132 A	11/04/2000

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/10/2005

International application No.

PCT/SE 2005/001218

EP	0611061	A1	24/01/1994	AU	5656994	A	04/07/1994
				GB	2275113	A,B	17/08/1994
				GB	9302530	D	00/00/0000
				US	5450764	A	19/09/1995

EP	1108624	A2	20/06/2001	SE	1108624	T3	
				DE	60015481	D,T	24/03/2005
				JP	2001191894	A	17/07/2001
				US	6581960	B	24/06/2003
