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(54) **Elrendezés és eljárás egy forgó elem forgómozgásának kapacitív mintavételezésére**

Arrangement and method for capacitive sensing of the rotary movement of a rotary element

The invention relates to an arrangement and a method for capacitive sensing of the rotary movement of a rotary element, said arrangement having four electrodes arranged in a plane, an evaluation unit connected to the electrodes and an electrically conductive coupling surface. The coupling surface is arranged on the rotating element opposite the electrodes and is used for the capacitive coupling of the electrodes.

The electrodes comprise a central excitation electrode, around which the rest of the electrodes are arranged, wherein in each rotational position of the surface the coupling surface lies opposite the excitation electrode and substantially covers the latter. The coupling surface also covers a part of the area formed by the remaining electrodes and sweeps over different areas of the surface formed by the remaining electrodes during rotation of the rotary element. This means that, in each rotational position of the coupling surface an effect of a like capacitor is formed between the excitation electrode and the electrically conductive coupling surface, on which the charge is distributed after being coupled in by the excitation electrode. This charge distributed on the coupling surface is transferred onto the electrodes arranged around the excitation electrode and lying opposite the coupling surface depending on the rotational position. A capacitor is therefore formed between the electrodes that are opposite the coupling surface in a particular rotational position. Electrons are induced, which can be detected by a voltage signal at the electrodes.

In order to be able to identify the rotational position of the rotary element having the coupling surface in a time-resolved manner, the evaluation unit comprises an excitation circuit connected to the excitation electrode, for generating excitation pulses with a specified frequency (frequency circuit), and an evaluation circuit connected to the remaining electrodes for detecting the voltage signals existing at the electrodes and for comparing these voltage signals.

Such arrangements for capacitive sensing are frequently used in consumption meters, in particular water meters, but also electricity or gas meters, in which the consumption of the media being consumed is transformed into a rotary movement by means of a sensing element. This rotary motion is then transferred via a clutch, a set of gears and/or a shaft to the rotary element of the arrangement, on which the coupling surface is arranged.

In the case of a water meter, an impeller is usually used for detecting the flow. The rotary motion of the impeller in the flow meter is a measure of the volume flow, and can be detected via the electrical properties of the rotary element in the arrangement according to the invention. This is effected by means of a half-sided electrically conductive metal coating of the rotary element, which represents a particularly suitable coupling surface and which is capacitively coupled to the electrodes on the sensor arrangement, which are arranged stationary.

An example of such a capacitive sensing is described in EP 1 785 732 A1, which comprises an arrangement for detecting a rotation of a rotary element, having an electrically conductive partial surface provided on a substantially planar surface of the rotary element, and a fixed sensor element having an excitation electrode and at least two receiver electrodes adjacent to the excitation electrode. The electrodes are opposite to the electrically conductive partial surface and a distance apart from it, and during rotation of the rotary element can be capacitively coupled to the excitation electrode via the electrically conductive partial surface.

The detection means provided for in the arrangement comprises a voltage means for applying a voltage pulse to the excitation electrode, the voltage of the voltage pulse being greater than the voltage of a battery that provides the operating voltage of the arrangement, and an evaluation means for tapping off receiver signals of at least two receiver electrodes, which are generated by capacitive coupling as a result of the voltage pulse. A comparison means is also provided for generating a signal, which is based on the receiver signals, indicating the position of the partial surface with respect to the receiver electrodes. By the level of the voltage pulse which is applied to the excitation electrode interference effects from external electric fields, or field fluctuations, can be reduced. This enables a compensation electrode, described in a similar arrangement in accordance with EP 1 033 578 B1, to be eliminated, along with its corresponding electronics.

According to the teaching of EP 1 785 732 A1, by using two electrodes two different positions of the rotary element can be identified. To be able to detect the direction of rotation however, four different positions of the rotary element have to be identified. Four receiver electrodes are therefore necessary for this purpose.

The detection of the voltage signals of these four electrodes requires higher complexity in the electronics and a comparatively large amount of installation space for the electrodes and the connecting cables leading to the evaluation electronics. This amount of space is often not available when the arrangement according to the invention is used in a consumption meter, since the installation space in consumption meters is limited.

Another capacitive position sensor of similar design is shown in EP 0459118 A1.

The object of the present invention therefore is to propose an advantageous means for capacitively sensing the rotary motion of a rotary element, in which the complexity required for the evaluation is reduced and the installation space for the electrode arrangement can be designed to be particularly small overall.

This object is achieved in accordance with the invention in an arrangement of the type referred to above, by the fact that the remaining electrodes surrounding the excitation electrode are formed by two sensor electrodes and a common reference electrode, wherein at least the common reference electrode is designed differently from the sensor electrodes. In addition, the evaluation circuit is designed in such a way that in each case, a difference is formed in the voltage signal between one of the two sensor electrodes and the common reference electrode. There are therefore two difference signals formed, both between the first of the two sensor electrodes and the common reference electrode and also between the second of the two sensor electrodes and the common reference electrode.

In contrast to the prior art, in the present invention therefore there are only three electrode signals that need to be evaluated, which are collated to form two difference signals. This simplifies the circuit and allows the available installation space to be used for fewer electrodes, which therefore - despite smaller space requirements - can nevertheless comprise a larger electrode surface and thereby achieve a higher capacitive coupling with increased voltage signals. Overall, this reduces the susceptibility of the arrangement to interference, and also reduces the space requirements.

By virtue of the common reference electrode being designed differently from the sensor electrodes, the difference signals formed according to the invention result in two phase-shifted signals, from which the direction of rotation of the rotary element can be derived. The different design of the reference electrode from that of the sensor electrodes gives rise in particular to an asymmetric arrangement, in which the angular range covered by the reference electrode in relation to a central point of the excitation electrode, which is preferably coincident with the rotational axis of the coupling surface, is different from the angular range covered by a sensor electrode or each of the sensor electrodes. This ensures that the size of the phase shift between the two signals is neither 0 nor 180°, and therefore with the appropriate dimensioning and positioning of the remaining electrodes around the excitation electrode, a differentiation of the direction of rotation is possible due to the asymmetry of the arrangement.

In order to obtain a low interference sensitivity of the voltage signals of the sensor electrodes or of the reference electrode, the pulse height of the excitation or voltage pulse which is fed into the excitation electrode is preferably about 30 to 35 V, i.e. it roughly corresponds to 10 to 15 times the battery voltage of a supply battery of the arrangement according to the invention, which is typically on the order of 3 volts.

In extending the arrangement according to the invention, the design and arrangement of the two sensor electrodes and the common reference electrode can preferably be optimized in such a way that the phase shift between the two voltage signals of the first sensor electrode and the second sensor electrode, measured at the rotary position of the coupling surface, is on the order of 90°, i.e. in particular between 80° and 100°.

A preferred arrangement for this purpose provides that, in relation to the excitation electrode, the sensor electrodes and the reference electrode there is an axis of symmetry, relative to which the shape and position of the said electrodes in the arrangement are mirror-symmetric. Preferably, the axis of symmetry passes through a central point of the excitation electrode, e.g. the centre of a circular or square excitation electrode, wherein the axis of symmetry preferably additionally bisects the reference electrode mirror symmetrically and passes through a gap between the two sensor electrodes. Such an arrangement enables a phase difference between the voltage signals of the two sensor electrodes in the order of 90° to be easily obtained.

A particularly effective arrangement is one in which the remaining electrodes substantially surround the excitation electrode in a circular manner, wherein a gap exists between the two sensor electrodes and between each sensor electrode and the reference electrode. The gaps between the individual electrodes can vary in size. The meaning of substantially circular is that each electrode surrounds the centrally positioned excitation electrode in a specific angular range and each electrode covers a different angular range. Without being limited thereto according to the invention, the basic shape of one or all of the remaining electrodes can be a segment of a circle. To ensure the maximum signal amplitude is obtained, in accordance with the invention it can also be provided that in total the spaces between the electrodes enclose an angle of less than 90° around the excitation electrode. Preferably, the angular range of all the spaces combined is between 50° and 80°. The remaining angular range is then available for use as an electrode surface, which allows a relatively large voltage signal to be generated by the capacitor arrangements of the different electrodes with the coupling surface, a signal that is less susceptible to external effects.

In accordance with the invention it can also be advantageous if the distance between the two sensor electrodes is greater than the distance between a sensor electrode and the reference electrode, preferably by a factor of 3 to 6. This favours a significantly larger phase shift between the two differences in the voltage signals between the one or the other sensor electrode and the reference electrode that are formed according to the invention. According to the invention, the desired phase shift can also be suitably adjusted, in particular using the size of the intermediate spaces.

In a preferred design of the arrangement according to the invention, the reference electrode can be dimensioned in such a way that at a special rotational position of the rotary element the coupling electrode exactly covers the surface area of the reference electrode, possibly including the adjacent intermediate spaces. In this position, the voltage signal at the reference electrode is a maximum and the voltage signal at both sensor electrodes on each side adjacent to the reference electrode is comparatively small. Such an arrangement is one that also favours a suitable phase shift between the voltage signals of the one and the other sensor electrode in the order of 90°. The sensor electrodes and the reference electrode can also be dimensioned and arranged in such a way that in each rotational position of the rotary element, the coupling surface covers a maximum of two of the three remaining electrodes, or can be dimensioned and arranged in such a way that, in the event of three remaining electrodes being covered in a rotational position, at least one of the three electrodes has an angular coverage of <50°, preferably <30°. This leads to a particularly good decoupling of the different signals and thus to a particularly suitable phase shift between the voltage signals of the sensor electrodes.

A particularly preferred specific arrangement can be designed in accordance with the invention such that the excitation electrode is circular, the coupling surface is circular in an inner section and semi-circular in an outer section partially surrounding the inner section, and that the common reference electrode covers an angular range of approximately 140° to 150° and each sensor electrode an angular range of approximately 50 to 70°. In this case the inner section of the coupling surface can have an extension substantially corresponding to the extension of the excitation electrode, i.e. subject to a small deviation. This means that in each rotational position of the rotary element a good capacitive coupling of the excitation electrode to the coupling area is obtained. In addition, in this specific arrangement the angular range of the space between the two sensor electrodes is preferably between 40° to 50°. In such an arrangement, in one rotational position the coupling surface only covers the reference electrode, possibly also including the adjacent spaces.

In accordance with one practical design of the arrangement according to the invention, the evaluation circuit can comprise two comparators, each of which forms a difference between the voltage signal of the one or the other sensor electrode and the voltage signal of the reference electrode, wherein one or each comparator produces an output signal only if a difference value is above a threshold value, which is adjustable either for both together or separately. This enables four independent states to be defined for the two differential signals according to the invention, each state corresponding to a rotational position of the coupling surface relative to the electrodes. In the optimized design and positioning of the electrodes as previously described, the rotational position of the coupling surface can therefore be divided into four quadrants, each of 90°, thus implementing a reliable detection of the direction of rotation by virtue of the sequence of the successively identified quadrants being evaluated.

Preferably, the threshold can be adjusted in such a way that the threshold value lies approximately in the middle of the range between the maximum and the minimum difference value. This can be effected by means of a suitable operating point offset, e.g. by connecting suitable voltage dividers, for the voltage signals from the sensor electrode and the reference electrode. The evaluation circuit overall can be implemented, for example, by a microprocessor, in which the analogue voltage signals, possibly after the offset of the operating point, are detected at the inputs and further processed. The two comparators in particular can also be integrated as part of the microprocessor.

According to the invention, to generate voltage pulses with a higher voltage than is provided as a whole by a supply battery of the arrangement, the excitation circuit can comprise an electric circuit which is connected to the supply voltage of the battery and having an inductance, a switch and a device for measuring current (current meter), wherein the excitation circuit is configured for closing the switch of the circuit for charging the inductance with a charging current and for opening the switch again when a charging current threshold value is reached to form the voltage pulse. This process is repeated at the desired frequency for sensing the rotational position of the rotary element, for example controlled by a suitable frequency generator. Preferably, for the purpose of monitoring for manipulation, the excitation circuit is at the same time configured for measuring the charging time between the closing of the switch and the attainment of the charging current threshold value.

Since the time constant of the charging current, i.e. the slope in a current-time diagram according to Fig. 6, depends on the inductance and the inductance is affected by an externally acting permanent magnetic field, such that after the closing of the circuit with the switch the charging current threshold value is reached more quickly, then such an external magnetic field applied for the purpose of manipulation is easy to detect, in particular if the arrangement is used in a meter according to the invention, such as a water meter. With the above described arrangement such an external magnetic field can thus be discovered by measuring the charging time and comparing this with a previously recorded reference value.

In the case of manipulation by the application of an external magnetic field, the reading of a standard meter, in particular a water meter, can be influenced in such a way that it can no longer detect the consumption, or at least does not fully detect the consumption. The background to this is that meters often comprise a magnetic coupling for connecting the rotary element with the coupling surface to a component that detects the consumption. The magnetic field can be made to influence this connection, which may result in a lower reading. It also reduces the amplitude of the voltage pulse generated by the coil, among other reasons because the total charging current flowing is lower over time. A possible consequence of this is that the threshold values defined in the comparator can no longer be reached and no reading takes place at all. Any such manipulation can be reliably detected by the measurement of the charging time of the inductance according to the invention, without any additional sensors or electronics having to be used. The arrangement according to the invention therefore also solves the problem, in a reliable and technically simple way, of detecting manipulation by an external magnetic field. The time measurement can be simply implemented in the arrangement, e.g. in the already existing microprocessor.

In addition to the arrangement, the invention also relates to a corresponding method for capacitive sensing of the rotational motion of a rotary element having an arrangement of a central excitation electrode together with a reference electrode and two sensor electrodes, which surround the central excitation electrode, wherein the excitation electrode, the reference electrode and the sensor electrodes are arranged in a plane and opposite a coupling surface provided on the rotary element. The coupling surface covers the excitation electrode to at least a very large extent, and depending on the rotational position, also portions of the remaining the electrodes, for providing the rotational position-dependent capacitive coupling of the excitation electrode to the reference electrode and the two sensor electrodes. Therefore, according to the invention, this is in particular a method for capacitive sensing of the above described arrangement.

In the method, voltage or excitation pulses are applied to the excitation electrode at a specified frequency, wherein the resulting voltages of the reference electrode, the first sensor electrode and the second sensor electrode are measured. To enable the detection of a direction of rotation with a small number of electrodes, with low space requirements and without a high level of circuit complexity, it is proposed according to the invention that the differences between the voltage of one or the other sensor electrode and the reference electrode which is common to the two sensor electrodes are each formed and evaluated, in order to determine the movement and the rotational position of the rotary element. The mechanism for this has already been explained in the description of the arrangement, so that reference can be made thereto. The designs for the arrangement also apply mutatis mutandis to the method according to the invention.

In accordance with a preferred extension of the method according to the invention, if a voltage difference between one sensor electrode and the reference electrode is above a threshold value and a difference between the voltage of the other sensor electrode and the reference electrode is above a threshold value, preferably the same one, then in a comparator of an evaluation circuit an output signal can be generated, which can be simply evaluated in a downstream logic.

Since the voltage signals of the sensor electrodes are phase shifted due to the arrangement of the sensor electrodes described, this phase shift is also transferred to the differences formed, so that the output signals delivered by the comparators can be used to deduce the rotational position of the rotary element having the coupling surface. With two comparators a total of four different conditions can be distinguished, so that - in the case of a suitable configuration and design of the sensor electrodes and the reference electrode - in each case a position determination is possible which accurately identifies the quadrant. By monitoring the successive quadrants, the direction of rotation can then be determined.

In accordance with the invention it can be provided by the proposed method that an excitation or voltage pulse, which is output to the excitation electrode, is generated, by a switch being closed in a circuit connected to a battery and containing an inductance and the charging current being monitored, wherein the switch is opened when the charging current reaches a charge current threshold value.

After opening the switch, as a result of the inductance, current first continues to flow in the circuit and so generates a voltage which is greater than the voltage provided by the battery of the arrangement. The amplitude of the voltage is determined by the duration of the charging current and the charging current threshold value, and can be adjusted in accordance with the invention so that it reaches 10 to 15 times the battery voltage. In the case of a battery voltage of 3 V the preferred voltage of the voltage pulse is approximately 30 to 35 V, which produces a sufficient amplitude for the evaluation circuit. The temporal waveform of the pulse is substantially sinusoidal and its frequency is selected such that the evaluation comparator can detect this pulse. The frequency can also be configurable by the frequency generator. This allows the exact position of the rotary element to be determined.

In addition, the charging time from the closing of the switch until the attainment of the charging current threshold value can be monitored. This enables the manipulation monitoring already described in connection with the arrangement to be obtained, which determines the presence of an external magnetic field on the arrangement that affects the charging time. If necessary, the method according to the invention can provide that, in the event of manipulation, the arrangement outputs a message to a data collector recording the consumption data, preferably by means of radio communication. This can be implemented, for example, by an error signal being generated if a charging time, which is or can be specified as a limit value, is undershot or overshot before the charging current threshold value (L) is reached.

Finally, the present invention also relates to a use of an arrangement according to any one of Claims 1 to 7 in a consumption meter, in particular a water, gas or electricity meter, which comprises a rotary consumption sensor having a coupling, in particular a magnetic coupling, to which the rotary element of the arrangement in accordance with any of Claims 1 to 7 can be coupled, said consumption meter comprising an arithmetic unit for evaluating the rotational position of the rotary element delivered by the arrangement and for converting it into consumption values. According to the invention, this arithmetic unit can also be integrated into the arithmetic unit of the previously described arrangement as well. The consumption counter can also comprise a communication module for radio transmission of the consumption values and/or error messages to a data collector, e.g. if any manipulation is detected. The communication module can be integrated into a module comprising the arrangement according to the invention.

With the arrangement and the proposed method according to the invention for capacitive sensing of the rotary motion of a rotating element, due to the voltage pulses having a voltage on the order of magnitude between 30 and 35 V, which can be generated in a technically simple manner, an increase in the signal-to-noise ratio and thus a lower sensitivity of the arrangement to electromagnetic interference is achieved, such as is produced, using lamp transformers, for example.

In addition, the optimized geometry of the arrangement results in a very good level control of the signals, so that a robust and reliable evaluation of the sensed voltage signals can be realized by means of the microprocessor system.

In addition, a facility for detecting manipulation by an externally generated magnetic field is possible without any additional electronic components. This tampering detection is particularly effective against frequently used manipulation techniques. For manipulation detection, the charging current waveform of the inductance is evaluated. This also prevents an impermissibly high current being drawn from the battery, which would occur in the case of such manipulation, since the charging current of the coil in the manipulated operating state is limited by means of the charging current threshold value, which is specified in any case. This allows the battery-power dependent service life of the module to be ensured, even in the event of tampering.

It is advantageous if the microprocessor system or the evaluation device of the arrangement documents the times of onset and, if appropriate, removal of the disrupted operating condition due to the manipulation with a stationary magnetic field. This can be achieved by the date and time of day of the onset of the disruption being stored in a non-volatile memory. This is effected in the same manner once the disrupted operating condition no longer exists. This means that the duration of the manipulation is documented and can be read out using a service unit or transmitted via a wireless telegram. This can then be taken into account when calculating the consumption charges.

Further features, advantages and application possibilities of the present invention can also be obtained from the following description of exemplary embodiments and from the drawings. All features described and/or depicted form the subject matter of the invention either alone or in any combination, regardless of how they are concentrated in the claims or by their reference.

Shown are in:

Fig. 1 a schematic diagram of the arrangement according to the invention showing the sensor electrodes, the reference electrode and the counter electrode;

Fig. 2 the coupling surface associated with the rotary element in accordance with the invention;

Fig. 3a a common arrangement of the electrodes and the coupling surface in a first rotational position of the coupling surface;

Fig. 3b a common arrangement of the electrodes and the coupling surface in a second rotational position of the coupling surface, rotated by 90° relative to Fig. 3a;

Fig. 3c a common arrangement of the electrodes and the coupling surface in a third rotational position of the coupling surface, rotated by 90° relative to Fig. 3b;

Fig. 3d a common arrangement of the electrodes and the coupling surface in a fourth rotational position of the coupling surface, rotated by 90° relative to Fig. 3c;

Fig. 4 a diagram showing the voltage signals tapped off at the sensor electrodes and the common reference electrode, and with the resulting differential signals formed as a function of the rotational position of the coupling surface.

Fig. 5 a voltage-time graph showing the waveform of the battery voltage in the excitation circuit and the pulse current on different scales and in arbitrary units;

Fig. 6 a variation of the voltage signals of the sensor electrode with small, medium and high capacitive sensing, depending on the position of the coupling surface in arbitrary units;

Fig. 7 a voltage-time graph showing the voltage signals of the first sensor electrode and the reference electrode, the difference signal formed from the two signals and the output signal of the comparator generated as a function of the value of the difference signal, in different scaling and arbitrary units;

Fig. 8 a voltage-time graph showing the voltage signals of the second sensor electrode and the reference electrode, the difference signal formed from the two signals and the output signal of the comparator generated as a function of the value of the difference signal, in different scaling and arbitrary units;

Fig. 9 a schematic circuit diagram of the excitation circuit and the evaluation circuit in accordance with the arrangement according to the invention and

Fig. 10 a current-time graph of the charging current of the inductance used for pulse generation.

Figure 1 is a schematic representation of the arrangement of the electrodes of the arrangement according to the invention for capacitive sensing of the rotary motion of a rotary element. This arrangement consists of a first sensor electrode 1, a reference electrode 2, a second sensor electrode 3 and an excitation electrode 4. On the opposite side of this electrode arrangement shown in Figure 1, a coupling surface 5, which is made of electrically conductive material, shown in Fig. 2 is arranged on a rotary element, said coupling surface 5 being moved over the electrode arrangement as shown in Fig. 1 during a rotation of the rotary element.

In a particularly preferred arrangement, but one to which the present invention is not limited, the excitation electrode 4 is designed circular in shape, and around which the remaining electrodes, i.e. the first and the second sensor electrode 1, 3 and the reference electrode 2 are arranged. The first and second sensor electrode 1, 3 are designed identically and have the form of a segment of a circle, wherein the centre of the circle is at the centre of the excitation electrode 4. The sensor electrodes 1 and 3 in this arrangement cover an angular segment of approximately 60° with respect to a complete circle. The reference electrode 2 is also designed as a circle segment, wherein the centre of this circle is also located at the centre of the excitation electrode 4. The angular range covered by the reference electrode 2 is approximately 145° in relation to the full circle.

The depth of the reference electrode in the radial direction is smaller than the depth of the sensor electrodes 1, 3 in the radial direction, wherein the sizes of the electrodes 1, 2, 3 are preferably adapted in such a way that the voltage signals of the first sensor electrode 1, the second sensor electrode 3 and the reference electrode 2 in operation are of the same order of magnitude.

Between the first sensor electrode 1 and the second sensor electrode 3, an intermediate space 6 is formed in which no electrode surface is located. The space 6 approximately comprises an angular range of 50°. The remaining angular range around the excitation electrode 4, which is not covered by electrodes 1, 2, 3, is evenly divided over two more spaces 7, 8 between the first sensor electrode 1 and the reference electrode 2, or the second sensor electrode 3 and the reference electrode 2 respectively, which are equal in size. The first sensor electrode 1, the second sensor electrode 3 and the reference electrode 2 surround the excitation electrode 4 in a substantially circular manner, wherein in the radial direction a distance also exists between the excitation electrode 4 and the remaining electrodes 1, 2, 3 to provide insulation.

Overall, the arrangement of the electrodes 1, 2, 3, 4 is symmetric about an axis of symmetry A, which passes through the centre of the circular excitation electrode 4 and bisects the space 6 between the first sensor electrode 1 and the second sensor electrode 3. On the opposite side to the intermediate space 6 relative to the excitation electrode 4, the axis of symmetry A bisects the reference electrode 2 symmetrically. The entire arrangement is therefore mirror symmetrical in relation to the axis of symmetry A.

The coupling surface 5 shown in Fig. 2, which is mounted on or attached to a rotary element not shown and arranged opposite the electrodes 1, 2, 3, 4, comprises an inner circular section 9 and an outer semi-circular section 10, partially surrounding the inner section 9. The circularly shaped inner section 9 merges into the outer section 10, so that in contour only a semi-circle can be seen of the circular inner section 9. The coupling surface 5 is formed of a conductive material, in particular a metallic material.

Figs. 3a to 3d show an assembly condition of the arrangement according to the invention with the electrodes 1, 2, 3, 4 and the coupling surface 5, wherein in the interests of clarity the coupling surface 5 is shown as transparent. In the view shown in Fig. 3a, the inner section 9 of the coupling surface 5 substantially covers the excitation electrode 4, the radius of the inner section 9 of the coupling surface 5 being designed slightly smaller than the radius of the excitation electrode 4. This overlap applies, as Figs. 3b to 3d show, in each rotational position of the coupling surface 5 relative to the electrodes 1, 2, 3, 4. To this end, the axis of rotation of the coupling surface 5 is located at the centre of the circle of the inner section of the coupling surface 5 and at the centre of the circular excitation electrode 4.

In the rotary position as shown in Fig. 3a, the outer section 10 of the coupling surface 5 covers the second sensor electrode 3, the one half of the reference electrode 2 adjoining the sensor electrode 2 and the space 8 formed between the second sensor electrode 3 and the reference electrode 2, and also the one half of the space 6, which adjoins the first sensor electrode 3, between the first sensor electrode 1 and the second sensor electrode 3. In this rotational position, a capacitive coupling takes place between the excitation electrode 4 and the second sensor electrode 3 and the reference electrode 2, due to the coupling surface 5.

In Fig. 3b, the coupling surface 5 has been turned 90° to the left compared to the rotational position shown in Fig. 3a, i.e. counter-clockwise, so that the coupling surface 5 with the outer section 10 covers the reference electrode 2 and the adjacent spaces 7, 8.

In the rotary position as shown in Fig. 3c, the outer section 10 of the coupling surface 5 covers the first sensor electrode 1, the one half of the reference electrode 1 adjoining the first sensor electrode 1, the space 7 formed between the first sensor electrode 1 and the reference electrode 2, and also the one half of the space 6, which adjoins the first sensor electrode 1, between the first sensor electrode 1 and the second sensor electrode 2. In this position, the excitation electrode 4 is capacitively coupled to the first sensor electrode 1 and the reference electrode 2 by the coupling surface 5.

Finally, Fig. 3d shows a further rotation of the coupling surface 5 by 90°, so that with its outer section 10 the coupling surface 5 now covers the first sensor electrode 1 and the second sensor electrode 3 and the space 6 which is formed between the first sensor electrode 1 and the second sensor electrode 3. The first sensor electrode 1 and the second sensor electrode 3 are therefore capacitively coupled.

This motion, shown quadrant-by-quadrant in Figs. 3a to 3d, is executed during a complete rotation of the coupling surface 5 with the rotary element over the arrangement consisting of the electrodes 1, 2, 3, 4, wherein the rotation positions are shown as snapshots after 90° in each case.

The term "cover" means that with its outer section 10 the coupling surface 5 covers at least a portion of the surfaces of the first sensor electrode 1, the second sensor electrode 3 or the reference electrode 2, so that a strong capacitive coupling takes place between the covered electrodes 1, 2, 3 and the excitation electrode 4, wherein the latter excitation electrode 4 is always covered. For coverage to exist in the terminology of this application, a complete coverage of the region of the electrodes 1, 2, 3, 4 by the coupling surface 5 is not absolutely necessary.

If a voltage is applied to the excitation electrode 4, then due to the capacitive coupling a charge is induced on the coupling surface 5, which results in the particular electrodes 1, 2, 3 that are currently covered by the coupling surface 5, depending on the rotational position of the coupling surface 5, being capacitively coupled together and at the different electrodes 1, 2, 3, a voltage signal can then be detected, the amplitude of which varies depending on the rotational position of the coupling surface 5. Fig. 4 shows the curve of the voltage U as a function of the rotational position of the coupling surface 5, wherein the rotation position is given in degrees and the voltage is given in arbitrary units. The angle indicated is defined by the peak 11 for the angular measurement of the coupling surface 5 in accordance with the angular positions marked in Fig. 1 and Fig. 3a to 3d.

For the sake of simplicity the voltage curves are labelled with the particular numbers of the electrodes 1, 2, 3, at which the voltage is tapped off. In the diagram the positions according to Fig. 3a to Fig. 3d are marked by vertical lines, which extend beyond the edges of the diagram and are provided with labels corresponding to Fig. 3a to Fig. 3d. In the position as shown in Fig. 3a, the second sensor electrode 3 is coupled to half of the reference electrode 2. The voltage applied at the second sensor electrode 3 therefore approaches the maximum value. Accordingly, the first sensor electrode 1, which is not covered, is close to its minimum value. The half-covered reference electrode 2 is located approximately in the middle between the maximum and the minimum voltage value.

In the position shown in Fig. 3b, in a symmetrical manner the first sensor electrode 1 and the second sensor electrode 3 are not covered, so that their voltage values are equal and comparatively low. The fully covered reference electrode 2 has its maximum value in this position.

Fig. 3c corresponds to the position as shown in Fig. 3a, wherein the values between the first sensor electrode 1 and the second sensor electrode 3 are exactly reversed, since in this rotational position the first sensor electrode 1 is covered by the coupling surface 5.

In the rotary position as shown in Fig. 3d, the first sensor electrode 1 and the second sensor electrode 3 are capacitively coupled by the coupling surface 5. Their values are close to the maximum values and are equal. The reference electrode 2, which is not covered at all, has its minimum value in this position.

The additional curves shown are the difference values formed according to the invention between the first sensor electrode 1 and the reference electrode (designated DIFF 1) and the second difference between the second sensor electrode 3 and the reference electrode (designated DIFF 2).

It is clearly shown that the phase difference between the voltage waveform of the first sensor electrode 1 and the voltage waveform of the second sensor electrode 3 is exactly 90° (relative to the rotational position of the coupling element). The voltage signal of the reference electrode 2 is a maximum when the voltage signals of the first sensor electrode 1 and the second sensor electrode 3 are equal and close to their minimum voltage value. Correspondingly the voltage signal of the reference electrode 2 is a minimum when the voltage values of the first sensor electrode 1 and the second sensor electrode 3 are equal and close to their maximum.

Due to the difference formation according to the invention of the voltage waveform of the first sensor electrode 1, or second sensor electrode 3, in each case with the reference electrode 2, by performing a comparison of each of the differences DIFF 1 and DIFF 2 with a threshold value, information about the rotational position of the coupling element 5 is obtained. A suitable threshold is drawn in Figure 4 as a horizontal line S. This line is located approximately half-way between the maximum value and the minimum value of the two difference curves DIFF 1 and DIFF 2. In the rotational position as shown in Fig. 3a, the value DIFF 1 is $< S$ and the value DIFF 2 is $> S$. In the position shown in Fig. 3b both difference values

DIFF 1, DIFF 2 are < S. In the rotational position as shown in Fig. 3c, the difference value DIFF 1 is > S and the difference value DIFF 2 is < S. In the rotational position shown in Fig. 3d by contrast, both difference values DIFF 1 and DIFF 2 are > S. In Fig. 4 the respective function values at the intersection lines with the vertical lines which indicate the rotary position are shown by means of dots. The comparison with the threshold values S is given under the diagrams of Fig. 3a to Fig. 3d.

As can be clearly seen there, the four possible constellations of the difference values DIFF 1 and DIFF 2 in comparison to the threshold value S can each be assigned to a rotational position of the coupling surface 5 rotated by 90°, so that due to this evaluation the respective quadrant in which the coupling surface 5 is located can be accurately determined.

To be able to check the position of the rotating element at a frequency matched to the normal counting rate of the meter, it is proposed according to the invention to apply voltage pulses to the excitation electrode 4 at a sufficiently high frequency that at a maximum expected rotational frequency of the meter at least one sampling of the rotary element takes place in each quadrant.

Since the meters are frequently battery-operated devices and the nominal supply voltage available from a battery is too low to obtain a sufficiently accurate pulse response with a simple electronic evaluation, according to the invention it is proposed to generate voltage pulses in a circuit operated by the battery 21 by means of an inductance 22. To achieve this, the battery circuit is completed by a pulse generator or frequency generator 24 at the required pulse frequency, so that the battery voltage is applied to the inductance 22. This leads to a charge current in the inductance 22, wherein after opening the circuit, due to the behaviour of the inductance 22 current initially continues to flow and a high voltage pulse 13 is thereby generated for a brief time. This is shown in figure 5, where the battery voltage applied in the charging circuit when the switch 23 is closed is preferably applied until a particular charge current is reached. The circuit is then opened, leading to a drop in the battery voltage across the inductance 22. At the same time, as a result of the inductance 22 a voltage pulse 13 is produced having a voltage approximately 10 to 15 times higher than the battery voltage 12. This is shown in Fig. 5 by the two different voltage scales.

The resulting voltage pulse 13 is passed to the excitation electrode 4, and via the coupling element 5 is transferred onto the particular electrodes 1, 2, 3 that are currently covered by the coupling element 5.

Fig. 6 shows a voltage signal that can be tapped off at these electrodes 1, 2, 3, depending on whether a strong, a medium or weak capacitive coupling is achieved by the coupling surface 5. The highest sensor voltage pulse 14 is tapped off at a sensor or reference electrode 1, 2, 3 when a maximum capacitive coupling exists. In the event of a medium level of capacitive coupling, the medium sensor voltage pulse 15 is detected at the electrode 1, 2, 3 and under a weak capacitive coupling the low sensor voltage pulse 16 is detected there.

Figs. 7 and 8 then show the sensor signals between the first sensor electrode 1 (Fig. 7) and the second sensor electrode 3 (Fig. 8) respectively and the reference electrode 2, wherein for the sake of simplicity these are labelled with the reference numerals assigned to electrodes 1, 2, 3. On a different scale, the difference signal of the two voltage signals of the sensor electrode 1, 3 and the reference electrode 2 is also shown, which is designated as DIFF 1 or DIFF 2 as appropriate.

In Fig. 7 this signal is negative in the voltage pulse because the voltage value of the reference electrode 2 is greater than the voltage value of the first sensor electrode 1. A comparator 26, which forms the difference between the two signals, therefore only provides the output signal 17 with the value 0. In Fig. 7 the difference signal DIFF 1 and the voltage signals from the first sensor electrode 1, the reference electrode 2 and the output signal 17, each use a different scaling.

The same applies to the diagram in Fig. 8, which shows the voltage signal of the second sensor electrode 3 and the voltage signal of the reference electrode 2. The difference DIFF 2 of these two signals is greater than 0 in the voltage pulse because the voltage value of the sensor electrode 3 is greater than the voltage value of the reference electrode 2. This positive difference signal DIFF 2 causes a comparator 27, which forms the difference DIFF 2 of the two voltage signals, to emit an output signal 18 which is not equal to 0.

In the case of the Figs. 7 and 8, the value DIFF 1 < S and the value DIFF 2 > S. Accordingly, the coupling surface 5 is located in a rotational position as shown in Fig. 3a.

Fig. 9 shows a schematic view of a logical circuit diagram of the evaluation device 18 of the arrangement according to the invention. The evaluation device 18 comprises an excitation circuit 19 for generating excitation pulses in the form of voltage pulses 13 and an evaluation circuit 20 for recording the voltage signals applied at the electrodes 1, 2, 3, for the purpose of comparing these voltage signals. In the excitation circuit 19 a battery 21 provides the supply voltage, in order to charge an inductance 22 by means of a charging current when a switch 23 is closed by a frequency generator 24, which specifies the frequency of the voltage pulses 13. With the switch 23 closed a current meter 25 measures the charging current of the inductance 22 until this reaches a charging current threshold value L. This causes the switch 23 to break the power circuit. Directly following this, as a result of the inductance 22 current continues to flow, causing a voltage pulse 13 to be generated which is output to the excitation electrode 4.

The excitation electrode 4 is capacitively coupled with the coupling surface 5 via the inner section 9 of the coupling surface 5, which in turn is capacitively coupled with the first sensor electrode 1, the second sensor electrode 3 or the reference electrode 2, depending on the rotational position. This enables a voltage value to be tapped off at each of the first sensor electrode 1, the second sensor electrode 3 and the reference electrode 2, which voltages are fed to a first comparator 26, which forms the differential signal DIFF 1 and to a second comparator 27, which forms the differential signal DIFF 2. The threshold value S is set in the input conductors to the first or second comparator 26, 27 by an operating point adjustment 28, which comprises, for example, suitable voltage dividers in order to shift the voltage levels supplied to the comparators 26, 27 accordingly.

The first comparator 26 and the second comparator 27, depending on the result of the difference formation, emit the output signal 17 in the manner described above, which is either 0, or different from 0. This output signal 17 is then used for rotation detection, position detection and for detecting the rotation direction of the rotary element.

Fig. 10 shows the behaviour of the charging current in the excitation circuit 19 with the switch 23 closed. As can be discerned from the current curve of Fig. 10, the charging current increases during the charging process until the charging current threshold L is measured in the current meter 25, whereupon the switch 23 is opened. The amplitude of the excitation pulse 13 then depends in particular on the quantity of charge accumulated below the curve.

Specifying a charging current threshold value L as the limit value for opening the switch 23 has the advantage that no overloading of the inductance 22 can occur.

In accordance with one design according to the invention, this charging mechanism can be used for detecting manipulation of the meter with an external magnetic field. In the case of a magnetic coupling of the rotary element of the arrangement according to the invention to a metering element which determines consumption, this could, for example, lead to the slippage of the magnetic coupling, thus affecting the advancement of the meter. This is therefore a common type of manipulation found in practice.

This manipulation can then be detected according to the invention by the fact that the inductance 22 is modified by the external magnetic field. This leads to a faster increase in the charging current, as shown in Fig. 10 by the dashed line. In this case, the charging current threshold value L is reached within a shorter period of time than in a normal charging process, such as takes place in accordance with the solid line. By measuring the charging time until the charging current threshold value L is reached it can therefore be determined whether the entire sensor arrangement is being influenced by an external magnetic field.

This tampering detection is particularly simple to carry out, because no separate electronic components must be provided. The time from the closure of the switch until the attainment of the charging current threshold value can be detected, for example, with a microprocessor that is already provided in the arrangement.

List of reference numerals:

1	first sensor electrode
2	reference electrode
3	second sensor electrode
4	excitation electrode
5	coupling surface
6	intermediate space
7	intermediate space
8	intermediate space
9	inner section
10	outer section
11	peak for angular measurement
12	battery voltage
13	voltage pulse, excitation pulse
14	large sensor voltage pulse
15	medium sensor voltage pulse
16	small sensor voltage plus
17	output signal
18	evaluation device

19 excitation circuit
20 evaluation circuit
21 battery
22 inductance
23 switch
24 frequency generator
25 device for current measurement, current meter
26 first comparator
27 second comparator
28 operating point adjustment

A axis of symmetry
S threshold value
L charging current threshold value
DIFF1 difference between the voltage signal of the first sensor electrode and the reference electrode
DIFF2 difference between the voltage signal of the second sensor electrode and the reference electrode

Elrendezés és eljárás egy forgó elem forgómozgásának kapacitív mintavételezésére

Szabadalmi igénypontok

1. Elrendezés egy forgó elem forgómozgásának kapacitív mintavételezésére, ahol az elrendezés négy, egy síkban elrendezett elektródát (1, 2, 3, 4), egy az elektródákhoz (1, 2, 3, 4) csatlakoztatott kiértékelő egységet (18) és egy villamosan vezető csatolófelületet (5) tartalmaz, amely a forgó elemen az elektródákkal (1, 2, 3, 4) szemben van elrendezve,

ahol az elektródák (1, 2, 3, 4) egy központi gerjesztő elektródát (4) tartalmaznak, és a többi elektróda (1, 2, 3) központi gerjesztő elektróda (4) körül van elrendezve,

ahol a csatolófelület (5) a felület minden forgási helyzetében a gerjesztő elektródával (4) szemben helyezkedik el és lefedi a többi elektróda (1, 2, 3) által képzett felület egy részét, valamint a forgó elem forgása során végigsimítja a többi elektróda (1, 2, 3) által képzett felület különböző tartományait, és

ahol a forgóelem forgási helyzetének időbeli azonosítására a kiértékelő egység (18) egy a gerjesztő elektródához (4) csatlakoztatott gerjesztő áramkört (19) tartalmaz gerjesztő impulzusok (13) egy előre meghatározott frekvenciával való létrehozására, és egy a többi elektródához (1, 2, 3) csatlakoztatott kiértékelő áramkört (20) tartalmaz a többi elektródára (1, 2, 3) rákapcsolt feszültségjelek érzékelésére és ezeknek a feszültségjeleknek az összehasonlítására,

azzal jellemezve, hogy a többi elektródát (1, 2, 3) két érzékelő elektróda (1, 3) és egy közös referencia elektróda (2) alkotja, ahol legalább a közös referencia elektróda (2) az érzékelő elektródáktól (1, 3) különbözően van kiképezve, és hogy a kiértékelő áramkör (20) úgy van kiképezve, hogy a forgó elem mozgásának és forgási helyzetének meghatározására rendre az egyik érzékelő elektróda (1, 3) és a közös referencia elektróda (2) közötti feszültségjel különbségét (DIFF1, DIFF2) képzi.

2. Az 1. igénypont szerinti elrendezés, **azzal jellemezve,** hogy a gerjesztő elektródra (4), az érzékelő elektródákra (1,3) és a referencia elektródra (2) vonatkozóan egy szimmetriatengelye van, amelyhez képest az elektródák (1, 2 ,3, 4) alakja és pozíciója az elrendezésben tükörszimmetrikus.

3. Az 1. vagy a 2. igénypont szerinti elrendezés, **azzal jellemezve,** hogy a többi elektróda (1, 2, 3) a gerjesztő elektródát (4) lényegében kör alakúan veszik körül, ahol a két érzékelő elektróda (1, 3) között és mindegyik érzékelő elektróda (1, 3) és a referencia elektróda (2) között rendre egy térköz (6, 7, 8) van.

4. Az előző igénypontok bármelyike szerinti elrendezés, **azzal jellemezve,** hogy a referencia elektróda (2) úgy van méretezve, hogy a csatolófelület (5) a forgó elem forgási helyzetében pontosan a referencia elektróda (2) felületét fedje le, adott esetben a szomszédos közbenső terekkel (7, 8) együtt.

5. Az előző igénypontok bármelyike szerinti elrendezés, **azzal jellemezve,** hogy a gerjesztő elektróda (4) kör alakúan van kiképezve és a csatolófelület (5) egy belső szakaszon (9) kör alakúan és egy a belső szakaszt (9) részben körülvevő külső szakaszon (10) félkör alakúan van kiképezve, valamint hogy a közös referencia elektróda (2) körülbelül 140° és 150° közötti szögtartományt fed le, és minden érzékelő elektróda (1, 3) körülbelül 50° és 70° közötti szögtartományt fed le.

6. Az előző igénypontok bármelyike szerinti elrendezés, **azzal jellemezve,** hogy a kiértékelő áramkörnek (20) két komparátora (26, 27) van, amelyek rendre az egyik, illetve a másik érzékelő elektróda (1, 3) feszültségjele és a referencia elektróda (2) feszültségjele közötti különbségeket (DIFF1, DIFF2) képezik, ahol egy komparátor (26, 27) csak egy beállítható küszöbértéket meghaladó különbségértéknél ad kimenőjelet (17).

7. Az előző igénypontok bármelyike szerinti elrendezés, **azzal jellemezve,** hogy a gerjesztő áramkör (19) egy akkumulátor (21) tápfeszültségére kapcsolt, induktivitást (22) tartalmazó áramkört, egy kapcsolót (23) és egy árammeréshez (25) való készüléket tartalmaz, ahol a gerjesztő áramkör (19) úgy van kiképezve, hogy az áramkör kapcsolóját (23) az induktivitás (22) töltőárammal való feltöltéséhez zárja és a kapcsolót (23) a töltőáram-küszöbérték (L) elérésekor az aktiválóimpulzus (13) létrehozásához ismét nyitja, ahol a gerjesztő áramkör (19) úgy van továbbá kiképezve, hogy manipulálás felismeréséhez mérje a kapcsoló (23) zárása és a töltőáram-küszöbérték (L) elérése közötti töltőidőt.

8. Eljárás egy forgó elem forgómozgásának kapacitív letapogatására egy központi gerjesztő elektródából (4), referencia elektródából (2) és a központi gerjesztő elektródát (4) körülvevő két érzékelő elektródából (1, 3) álló elrendezés útján, ahol legalább a referencia elektródát (2) az érzékelő elektródáktól (1, 3) különbözően képezzük ki és a gerjesztő elektródát (4), a referencia elektródát (2) és az érzékelő elektródákat (1, 3) egy síkban és a forgó elemen lévő csatolófelülettel (5) szemben rendezzük el, mely csatolófelület a gerjesztő elektródát (4) és a forgási helyzet szerint a többi elektróda (1, 2, 3) egyes részeit elfedi a gerjesztő elektróda (4) forgási helyzettől függő kapacitív csatolására a referencia elektróddal (2) és a két érzékelő elektróddal (1,3), mely eljárás során a gerjesztő elektródára (4) előre meghatározott frekvenciával gerjesztő impulzusokat (13) juttatunk, ahol mérjük a referencia elektróda (2), az első érzékelő elektróda (1) és a második érzékelő elektróda (3) feszültségét, **azzal jellemezve,** hogy az egyik és a másik érzékelő elektróda (1, 3) feszültségének a különbségeit (DIFF 1, DIFF2) rendre a referencia elektróda (2) feszültségével képezzük és számítjuk ki a forgó elem mozgásának és forgási helyzetének meghatározására.

9. A 8. igénypont szerinti eljárás, **azzal jellemezve,** hogy rendre egy kiértékelő áramkör (20) egy komparatorában (26, 27) egy kimenőjelet (17) hozunk létre, ha az egyik érzékelő elektróda (1) és a referencia elektróda (2) feszültsége közötti különbség (DIFF1) meghalad egy küszöbértéket (S) és a referencia elektróda (2) és a másik érzékelő elektróda (3) feszültsége közötti különbség (DIFF2) egy, előnyösen ugyanakkora küszöbérték (S) feletti.

10. A 8. vagy a 9. igénypont szerinti eljárás, **azzal jellemezve,** hogy létrehozunk egy a gerjesztő elektródra (4) leadott gerjesztő impulzust (13), ahol egy, egy akkumulátorhoz (21) csatlakoztatott és egy induktivitást (22) tartalmazó áramkörben lévő kapcsolót (23) zárunk, figyeljük a töltőáramot, és ahol a kapcsolót (23) nyitjuk, amikor a töltőáram elér egy töltőáram-küszöbértéket (L).

11. A 10. igénypont szerinti eljárás, **azzal jellemezve,** hogy figyeljük a kapcsoló (23) zárásától a töltőáram-küszöbérték (L) eléréséig terjedő töltési időt.

12. A 10. igénypont szerinti eljárás, **azzal jellemezve,** hogy egy a töltőáram-küszöbérték (L) eléréséig terjedő, határértékként előre meghatározható töltési idő túllépése és/vagy el nem érése esetén hibajelet állítunk elő.

13. Az 1-7. igénypontok bármelyike szerinti elrendezés alkalmazása fogyasztásmérőben, különösen víz-, gáz- vagy villamos fogyasztásmérőben, amely egy forgatható fogyasztásérzékelőt tartalmaz egy olyan tengelykapcsolóval, amelyhez az 1-7. igénypontok bármelyike szerinti elrendezés forgó eleme kapcsolható, ahol a fogyasztásmérőnek egy, a forgó elem elrendezés által közölt forgási helyzetének kiértékelésére és fogyasztási értékekre történő átalakítására való számolóegysége van.

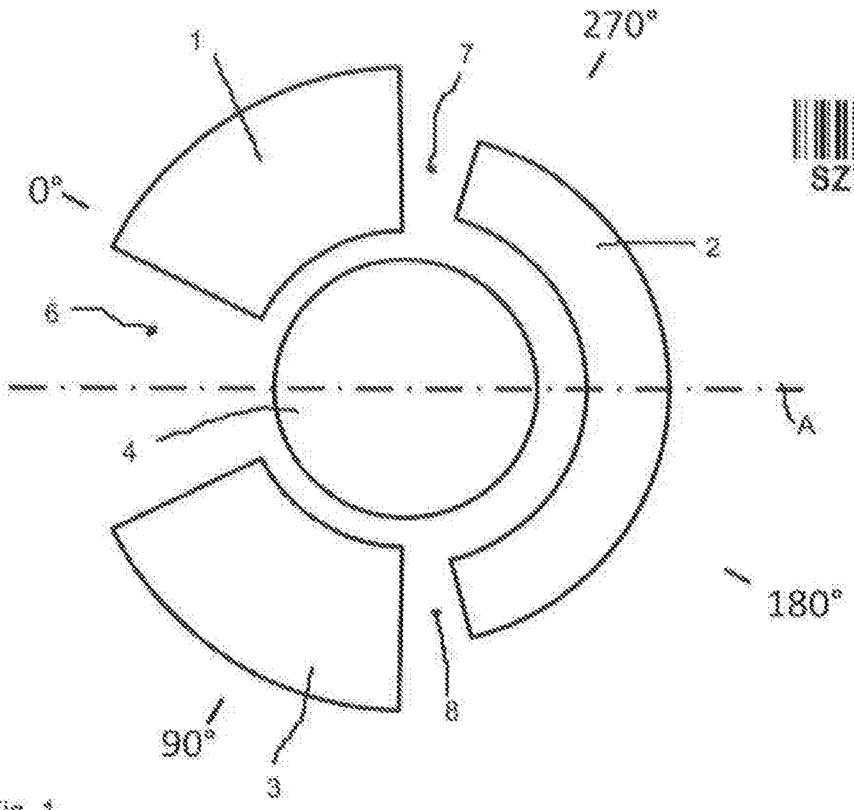

Fig. 1

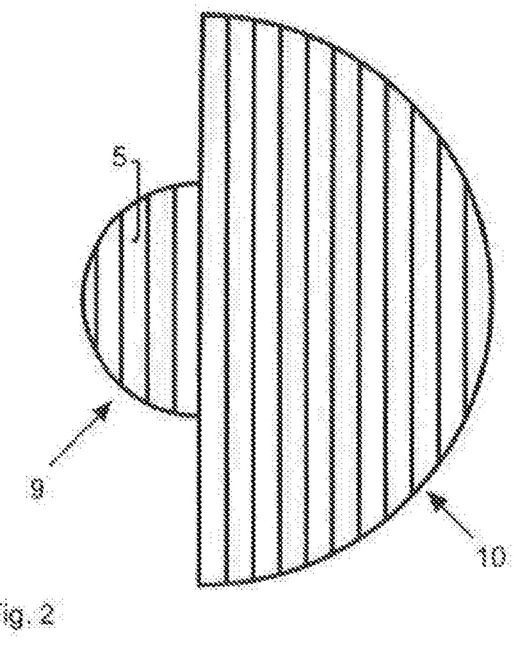

Fig. 2

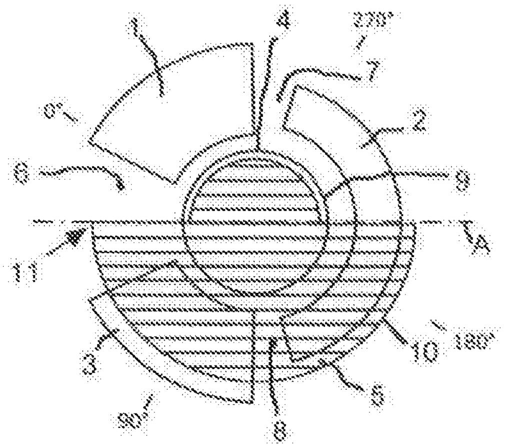

Fig. 3a

DIFF 1 < S
DIFF 2 > S

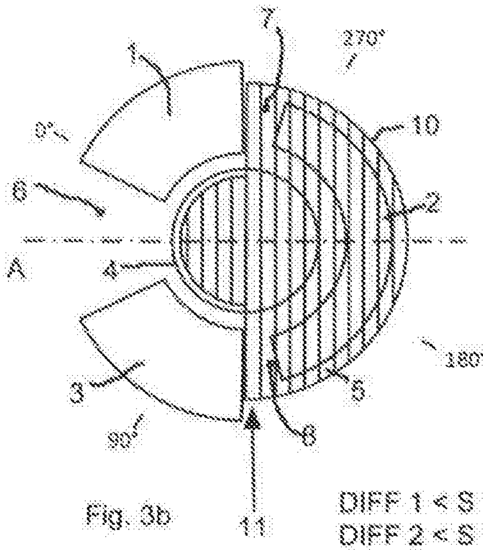

Fig. 3b

DIFF 1 < S
DIFF 2 < S

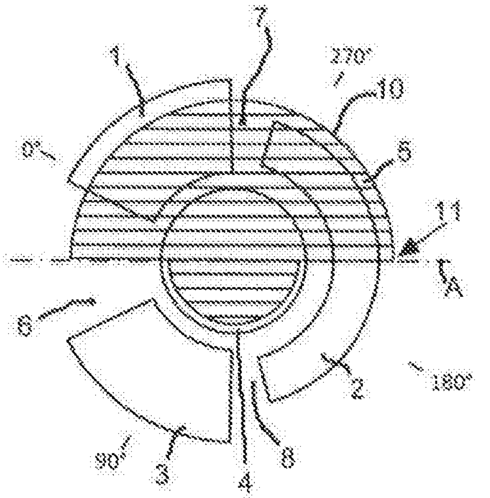

Fig. 3c

DIFF 1 > S
DIFF 2 < S

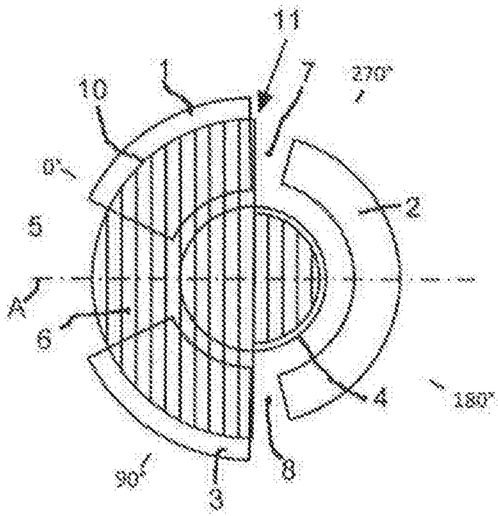

Fig. 3d

DIFF 1 > S
DIFF 2 > S

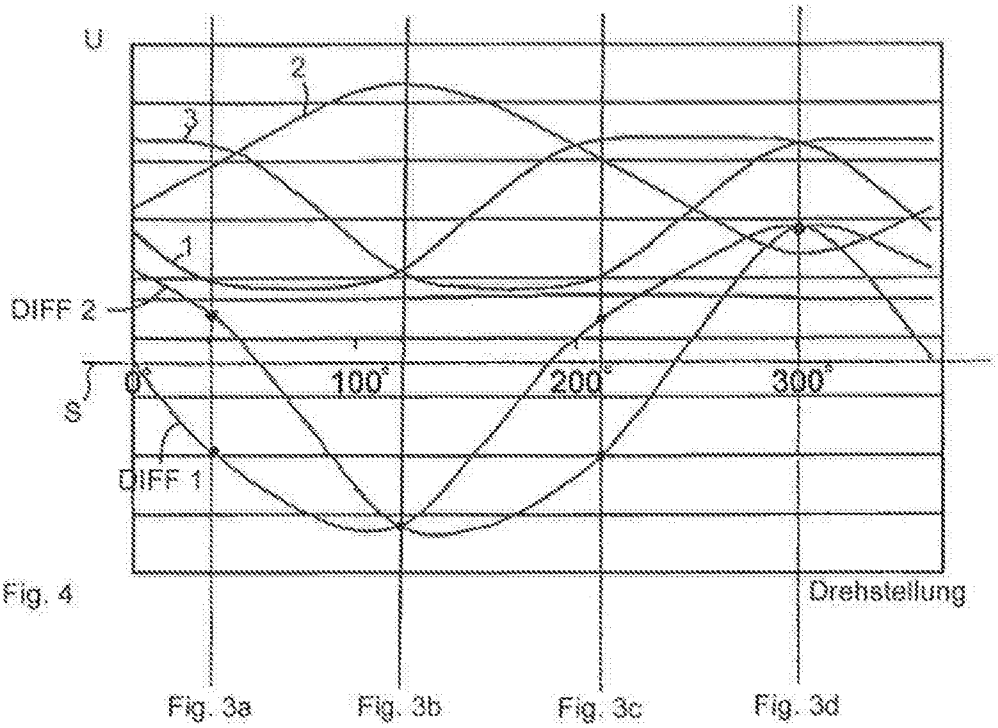
U
2
3
1
DIFF 2
S
0°
100°
200°
300°
DIFF 1
Drehstellung
Fig. 3a
Fig. 3b
Fig. 3c
Fig. 3d

Fig. 4

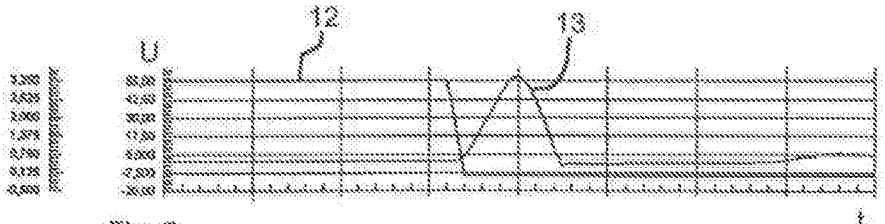

Fig. 5

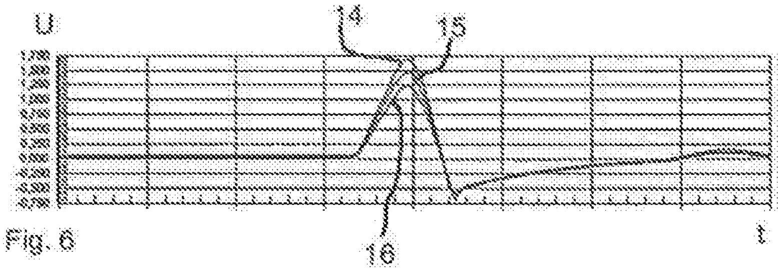

Fig. 6

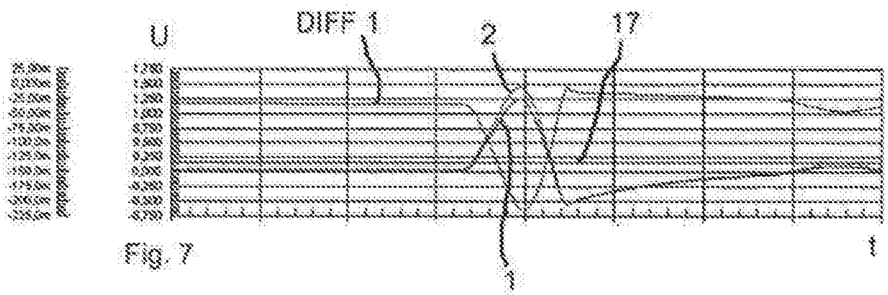

Fig. 7

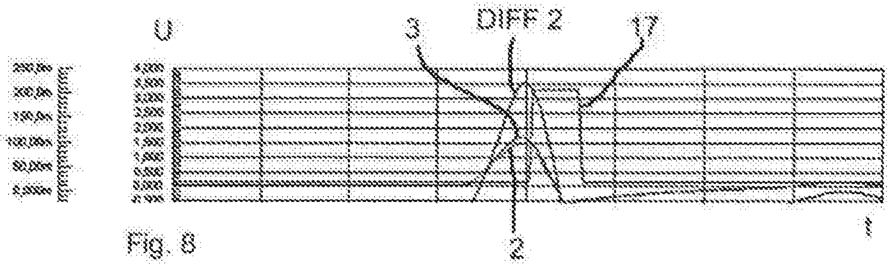

Fig. 8

Fig. 8

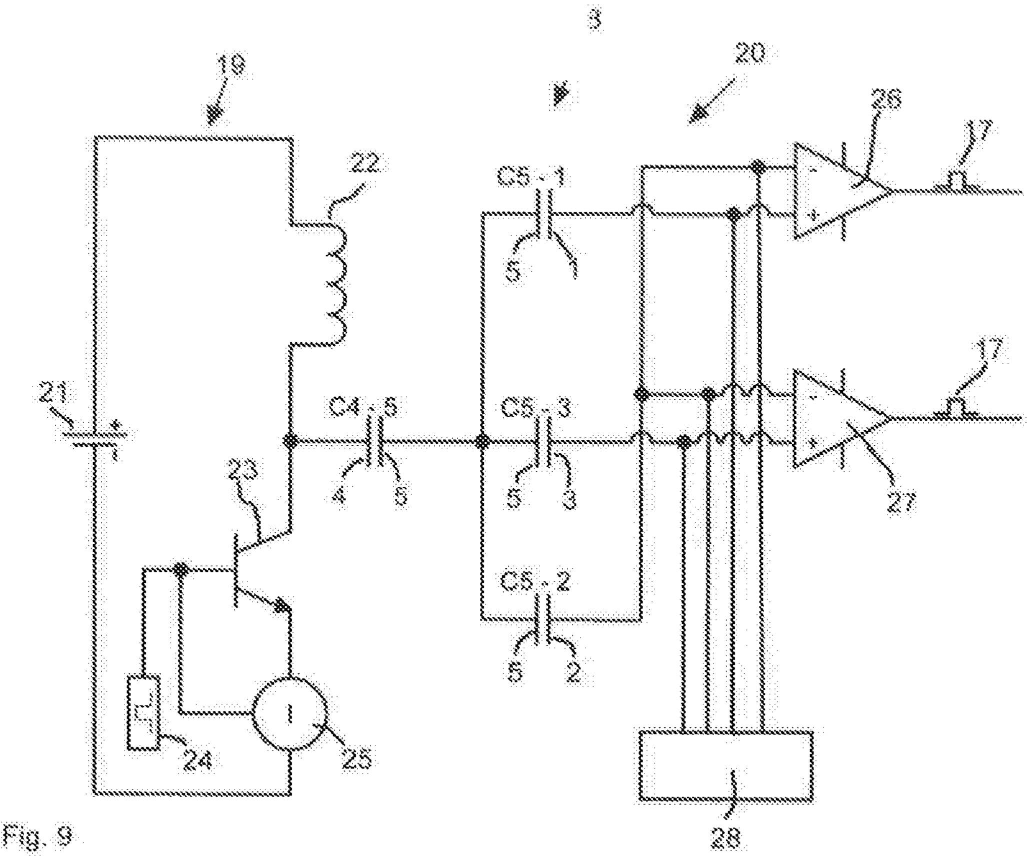

Fig. 9

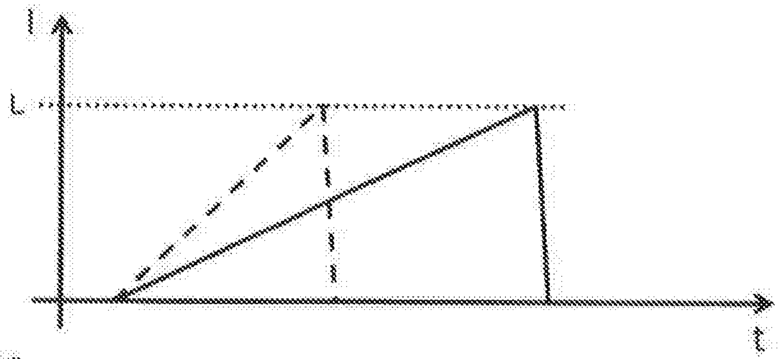

Fig. 10