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(54) Title: METHOD FOR DETERMING A POSITION OF A VALVE CLOSURE ELEMENT MOVED BY A ROTATABLE VALVE ACTUATOR SHAFT

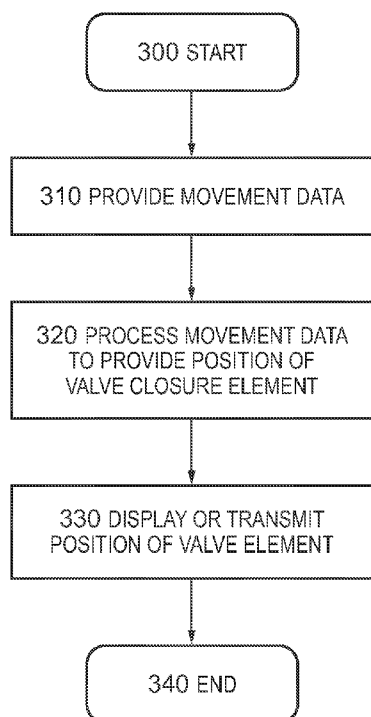


FIG. 3

(57) Abstract: The invention relates to a method, a device and a computer program product for determining a position of a valve closure element moved by a rotatable valve actuator shaft. The valve may be a non-rising stem valve, e.g. included in a oil and/or gas surface wellhead. The actuator shaft may be manually rotatable by a handwheel attached to the shaft. The device comprises an inertial sensor device, e.g., an accelerometer or a gyroscope, attached to the rotatable valve actuator shaft, providing movement data, e.g. acceleration or angular velocity data. The device further comprises a processing device, configured, to process the movement data to obtain the position of the valve closure element moved by the rotatable valve actuator shaft. Data representing the obtained position of the valve closure element may be transmitted to an external monitoring device or displayed to an operator.

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METHOD FOR DETERMINING A POSITION OF A VALVE CLOSURE ELEMENT MOVED BY A ROTATABLE VALVE ACTUATOR SHAFT

TECHNICAL FIELD

5 The invention relates to a method, a device and a computer program product for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

BACKGROUND

10 In the field of manually operated fluid valves, in particular valves with a rotatable valve actuator shaft, e.g. so-called non-rising stem valves, an operator is generally unable to determine, in a reliable way, the position of the valve closure element during operation of the valve. Typically, the operator relies on haptic feedback to identify when the gate is at an end point. This leaves position determination open to interpretation as to whether the gate is in a full open, closed or simply impeded somewhere in between, for instance due
15 to scale, wax or sand build up in the valve. Issues can occur in the field when a valve can be misinterpreted as stuck when it is actually at an end stop. The valve can be over torqued, causing the stem to break. If the gate is interpreted as being in a full open position when it is partially stroked the well can end up producing through a restricted bore, limiting production and leaving the gate more susceptible to erosion.

20 EP 0 872 676 discloses an electronic position indicator apparatus for a valve. A potentiometer converts the rotary movement of a rotatable handwheel to an electrical signal, providing position indication of the valve. A disadvantage of this apparatus is that the rotatable potentiometer shaft must be mechanically connected to the handwheel, while the potentiometer body must be secured to the non-rotatable part of the valve. In
25 particular, this solution is not well-suited for retrofitting to an existing valve.

Hence, there is a need for an improved method and device for determining a rotational state of a rotatable shaft.

SUMMARY OF THE INVENTION

30 The invention provides a method for determining a position of a valve closure element moved by a rotatable valve actuator shaft, comprising providing movement data by an

inertial sensor device attached to the rotatable valve actuator shaft, and processing the movement data to obtain the position of the valve closure element. This leads, i.a., to the advantage that no equipment needs to be attached to the non-rotary part of the valve, improving reliability and ease of manufacturing and installation, and reducing costs.

5 Also, it facilitates retrofitting to an already existing valve.

In an aspect, the inertial sensor device comprises an accelerometer, and the movement data comprises acceleration data. In another aspect, the inertial sensor device comprises a gyroscope, and the movement data comprises angular velocity data. Both alternatives provide for reliable, accurate measurements and a low cost, robust inertial sensitive
10 device.

The processing of movement data may include counting a number of rotations of the inertial sensor device. This enables, i.a., monitoring of multi-turn valves.

The processing of movement data may further include determining a direction of each rotation of the inertial sensor device. This enables, i.a., monitoring of the valve when
15 operated in both rotational directions by an operator.

In an aspect, the method further comprises transmitting, to a monitoring device, data representing the position of the valve closure element. This enables remote monitoring and/or control.

The method may further comprise displaying, on a display device, data representing the position of the valve closure element. This enables direct feedback to the operator.
20

The invention also relates to a device for determining a position of a valve closure element moved by a rotatable valve actuator shaft, comprising:

- an inertial sensor device attached to the rotatable valve actuator shaft, providing movement data, and
- 25 - a processing device, configured to process the movement data to obtain a position of the valve closure element moved by the rotatable valve actuator shaft.

This leads, i.a., to the advantage that no equipment needs to be attached to the non-rotary part of the valve, improving reliability and ease of manufacturing and installation, and reducing costs. Also, it facilitates retrofitting to already existing valves.

The inertial sensor device may comprise an accelerometer, and the movement data may comprise acceleration data. Alternatively, the inertial sensor device may comprise a gyroscope, and the movement data may comprise angular velocity data.

5 In an aspect, the rotatable valve actuator shaft may be an actuator shaft of a non-rising stem valve.

In an aspect, the rotatable valve actuator shaft may be rotatable by a handwheel attached to the shaft, and the inertial sensor device may be attached to the handwheel.

In an aspect, a plurality of turns of the shaft corresponds to a complete movement of the closure element between a fully open valve and a fully closed valve.

10 The valve may be included in a oil and/or gas surface wellhead.

The processing device may be configured to process the movement data by counting a number of rotations of the inertial sensor device. The processing device may be further configured to process the movement data by determining a direction of each rotation of the inertial sensor device.

15 The device may further comprise a data transmitting device, configured to transmit, to a monitoring device, data representing the position of the valve closure element.

Alternatively or in addition, the device may comprise a display device, configured to display data representing the state of the position of the valve closure element.

20 The invention also relates to a computer program product, which comprises processing instructions that, when executed by a processing device, causes the processing device to perform a method as disclosed in the present specification.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram illustrating a valve equipped with a device for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

25 Fig. 2 is a schematic block diagram illustrating a device for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

Fig. 3 is a schematic flow chart illustrating a method for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

Fig. 4 is a schematic example graph illustrating measured acceleration with respect to time.

5 Fig. 5 is a schematic example graph illustrating a rotation angle with respect to time.

Fig. 6 is a schematic block diagram illustrating aspects of position determination using an accelerometer.

Fig. 7 is a schematic block diagram illustrating aspects of angular position and velocity determination using a gyroscope.

10 Fig. 8 is a schematic block diagram illustrating angular position measurements.

DETAILED DESCRIPTION

Fig. 1 is a schematic diagram illustrating a valve equipped with a device for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

15 In a typical application, the valve 100 may be a valve included in a oil and/or gas surface wellhead.

The valve 100 includes a housing 110, a fluid inlet 120, a fluid outlet 130 and a closure element (not shown). The closure element is actuated by a rotatable valve actuator shaft (not shown). A rotatable handwheel 140 is attached to the valve actuator shaft in order to enable a human operator to operate the valve.

20 The valve 100 may be of a type wherein a plurality of turns of the shaft, and hence a plurality of turns of the handwheel 140, represents the closure element's movement from a fully open valve to a fully closed valve and vice versa.

For instance, the valve 100 may be a non-rising stem valve. For such a valve type, the operator will generally be unable to determine the absolute position of the valve during
25 intervention.

In order to provide information about a status of the valve 100, in particular the position of the valve closure element, a device 150 for determining the position of the valve

closure element moved by the rotatable valve actuator shaft is attached to the handwheel 140 and hence to the rotatable shaft of the valve.

Fig. 2 is a schematic block diagram illustrating a device for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

5 The device 150 for determining a position of a valve closure element moved by a rotatable valve actuator shaft comprises an inertial sensor device 220, which is attached to the rotatable valve actuator shaft, in this case via the handwheel 140. The inertial sensor device 220 may be secured within a housing of the device 150, which is in turn attached to the handwheel 140. The inertial sensor device 220 provides movement data, which
10 may include acceleration data and/or angular velocity data. The inertial sensor device 220 may e.g. include a 3-axis accelerometer, or a 2-axis accelerometer. If the inertial sensor device includes an accelerometer, the movement data comprises acceleration data.

Alternatively, the inertial sensor device 220 may include a gyroscope. In this case the movement data comprises angular velocity data.

15 The inertial sensor device 220 may include both an accelerometer and a gyroscope. In this case the movement data may include both acceleration data and angular velocity data.

The device 150 further comprises a processing device 210, which is configured to process the movement data (including acceleration data and/or angular velocity data) to obtain the a position of the valve closure element moved by the rotatable valve actuator shaft. The
20 processing device 210 may e.g. include a microcontroller, i.e. a microprocessor provided with I/O circuits and a memory circuit, at least for holding processing instructions.

Alternatively, the processing device may include a microprocessor and separate I/O circuits and separate memory circuits.

25 A log memory 230 may be provided and interconnected with the processing device 210, e.g. for storing acquired acceleration data and for keeping intermediate and final results of the processing performed by the processing device 210.

The device 150 may be powered by a power supply device 240, e.g. a battery, which may be rechargeable or non-rechargeable. The power supply device 240 may be connected to

a power regulation circuit 250, which supplies all power-consuming elements of the device 150 with necessary electrical power.

The processing device 210 may be connected to a display driver 260 and further to a display device 270, which may be a low power display. The display device may be
5 configured to display data representing the position of the valve closure element, thus conveying information about the status of the valve 100 to the human operator.

A data transmitting interface device 280, such as a wireless interface device, may be communicatively connected to the processing device 210. The data transmitting interface device 280 may be further connected to a communication device 282, such as a wireless
10 communication module, causing the communication device 282 to transmit data representing the position of the valve closure element. This data may be received by a wireless monitoring device or equipment (not shown) which is external to the device 150.

A user input interface 290, e.g. including a push button, may be connected to the processing device 210. The user input interface 290 may e.g. be used for calibration
15 and/or resetting purposes.

The processing device 210 in the device 150 may be configured to process the movement data, provided by the inertial sensor device 220, by counting a number of rotations of the inertial sensor device 220.

The processing device 210 may further be configured to process the movement data,
20 provided by the inertial sensor device 220, by determining a direction of each rotation of the inertial sensor device 220.

The processing device may be configured to execute a computer program product which comprises a set or sequence of processing instructions. The computer program product may be held in a program memory included in or interconnected with the processing
25 device 210. The computer program product may also be held in a separate computer-readable medium, such as a memory device or an optical or magnet medium, or the computer program product be embodied as a propagated signal through a wired or wireless network or on a communication carrier.

When the computer program product is executed by the processing device 210, it causes the processing device 210 to perform a method as disclosed in the present specification, in particular as described by example below with reference to figure 3.

Fig. 3 is a schematic flow chart illustrating a method for determining a position of a valve closure element moved by a rotatable valve actuator shaft.

The method starts at the initiating step 300.

First, in the movement data providing step 310, movement data is provided by an inertial sensor device attached to the rotatable valve actuator shaft. The movement data may be provided by a 3-axis or 2-axis accelerometer, or a gyroscope.

10 In the case wherein the inertial sensor device includes an accelerometer, the movement data includes acceleration data. In this case at least the acceleration components in the directions defined by the accelerometer's X and Y axes are provided in step 310. It may be assumed that the acceleration-sensitive device is arranged to be moved in the XY plane, i.e. the plane defined by the X and Y axes. This is reasonable since the inertial
15 sensor device, in this case the accelerometer, is attached to the shaft of the valve, for instance via the handwheel of the device, and the handwheel is primarily allowed only to make rotational movements in the XY plane as long as the valve is otherwise stationary. In this case the measurement along the third axis (Z axis) of the accelerometer may be ignored, or not measured at all, or used for monitoring/control purposes.

20 In the case wherein the inertial sensor device includes a gyroscope, the gyroscope may measure the angular velocity of the handwheel during operation, i.e., the movement data includes angular velocity data. The gyroscope may e.g. be used to measure rotation in °/sec in both the horizontal and vertical plane. From these angular measurement signals, the number of rotations and rotational direction may readily be derived.

25 Next, in the movement data processing step 320, the movement data is processed to obtain the position of the valve closure element.

The processing step 320 may include counting a number of rotations of the inertial sensor device.

The processing step 320 may also include determining a direction of each rotation of the inertial sensor device.

In order to obtain the number of rotations and the direction of each rotation, the processing step 320 may include applying appropriate trigonometric functions to the movement data values (including acceleration and angular velocity values). Both the
5 angle of rotation, number of turns, and the direction of each turn (clockwise or anti clockwise direction) may thereby be determined.

Next, in the display or transmitting step 330, calculated data representing the position of the valve closure element, resulting from the processing step 320, may either be
10 transmitted to a monitoring device, or displayed on a display device, such as the display device 270 (cf. fig. 2), or both.

The transmitting of data representing the position of the valve closure element to a monitoring device may be facilitated by the communication interface device 280 and its interconnected communication module 282, which may transmit data representing the
15 position of the valve closure element to an external monitoring device or equipment (not illustrated).

The method illustrated in figure 3 may be performed by a processing device, such as the processing device 210 referred to with reference to fig. 2.

The method may be embodied by means of a computer program product which comprises
20 a set or sequence of processing instructions. The computer program product may be held in a program memory included in or interconnected with the processing device 210, as already described above with reference to fig. 2. The method is performed when the set or sequence of instructions in the computer program product is executed by the processing device 210.

25 Further possible details of the processing steps performed by the processing device 210 appear from the remaining figures and description, in particular figures 6, 7 and 8 and their corresponding detailed description. The steps of the disclosed method correspond to the functions that the processing device 210 in the device 150 are configured to perform.

Fig. 4 is a schematic example graph illustrating measured acceleration with respect to time when the handwheel is operated manually. Hence, in this example, the inertial sensor device includes an accelerometer.

Fig. 4 shows output acceleration on X, Y and Z axis versus number of samples, i.e. with respect to time, in an example when the handwheel is turned 2 full rotations clockwise (indicated at 1cw, 2cw), then 2 full rotations anti clockwise (indicated at 1acw, 2acw), followed by a further 2 full rotations clockwise (indicated at 1cw, 2cw).

A first graph 410 indicates acceleration on the X axis. A second graph 420 indicates acceleration on the Y axis. A third graph 430 indicates acceleration on the Z axis.

The output acceleration on the Z axis, indicated at 430, should ideally remain zero as the handwheel rotates. However, in the case of a 3-axis accelerometer, the Z axis values can advantageously be monitored to measure vibration or detect physical impact to the valve structure.

The graphs 410, 420, and 430 of figure 4 clearly show that the output acceleration values for the X and Y axis range between +1 and -1. When the X axis output value is leading the Y axis output value the wheel is being rotated clockwise. When the X axis output value is lagging the Y axis output value the wheel is being rotated anticlockwise.

Fig. 5 is a schematic example graph illustrating a rotation angle with respect to time.

The graph 510 shows an exemplary sequence of determined rotation angles with respect to time (or samples). The direction of rotation can be determined by monitoring the gradient of the slope of the angle of rotation value. If the gradient of the slope is negative, the wheel is determined to rotate clockwise. If the gradient of the slope is positive, the wheel is determined to rotate anti-clockwise.

Fig. 6 is a schematic block diagram illustrating aspects of position determination using an accelerometer.

An angle of the device 150 for determining a position of a valve closure element may be determined by the processing device 210 by calculating an inverse tangent ($\tan^{-1}$) of the ratio of x and y axis. This way the accelerometer 220 remains equally sensitive around 360 degrees. Quadrant position may be determined by the processing device 210 by

looking at the values of both x and y axis. If both values are positive then the actual angle is determined to be equal to the measured angle. If the x axis value is negative and the y axis value is positive, then it is determined that the device 150 is pointing in fourth quadrant, hence 360 will be added to the measured angle (measured angle will be a negative value). Similarly, if both axes' values are negative, then the device 150 is determined to be pointing towards third quadrant, as both values are negative so result will be positive and 180 will be added to get actual angle. And at the last, if the x axis value is positive and the y axis value is negative, then the device 150 is determined to be pointing in second quadrant, the result will be negative so the processing device will add 180 degree to get the actual angle.

Further possible aspects of direction determination and counter calculation of the device 150 for determining a position of a valve closure element are described in the following.

Direction of rotation may be determined, by the processing device 210, by comparing a current angle value with the previous value. There are two special cases which may advantageously be handled to avoid an error.

The first case is when the device 150 is rotating in counter-clockwise direction and crossing 0 degree (previous position fourth quadrant, new position first quadrant), in this case 360 degree is to be added to new angle position. The second case is when the device 150 is rotating in clockwise direction and crossing 0 degree (previous position first quadrant, new position fourth quadrant), in this case 360 degree is to be subtracted from new angle position.

Angle values may be divided by 360 to convert from angle to number of cycles and added to previous counter value to determine final counter rotation value. Finally zero offset rotation counter value is subtracted from raw counter value and multiplied with orientation variable.

All the above-mentioned calculations, including adding, subtracting, division, etc., may be performed by appropriate configuration of the processing device 210 in the device 150.

Fig. 7 is a schematic block diagram illustrating aspects of angular position and velocity determination using a gyroscope.

A gyroscope can be used to reliably sense and measure the angular velocity of a valve wheel during operation. Using a gyroscope as the measurement device enables measuring of rotation in °/sec, i.e., angular velocity, or angular rate, in both the horizontal and vertical plane.

- 5 In figure 7, the angle $\theta(t)$ may be defined as the angular position of the device 150 as a function of time t .

Angular acceleration is given by

$$\alpha = \frac{d^2\theta}{dt^2}$$

Angular velocity is given by

$$\omega(t) = \frac{d\theta}{dt}$$

- 10 By integrating the angular velocity value output from the gyroscope over time we can obtain the angular position of the module:

$$\theta(t) = \int \omega(t) dt$$

These angle measurements are made at times

$$t = k\tau_0 (\tau_0, 2\tau_0, 3\tau_0 \dots)$$

Fig. 8 is a schematic block diagram illustrating angular position measurements.

- 15 Fig. 8 shows angular position measurements, also referred to with reference to fig. 7 above, made at discrete points of time. Number of samples are N , the sample period is τ_0 , and index k varies from 1 to N .

Further possible aspects of an accelerometer used as the inertial sensor device 220 are described in the following.

The use of an accelerometer as the inertial sensor device 220 may involve the need for calibration. A “No-Turn” calibration technique may be used to avoid error caused by

offset along the x and y axes. This calibration may be done by placing the axes of interest (here x and y axes) into a 1g (g =acceleration of gravity) field and measuring the output, which is equal to the offset.

$$A_{OUT}[g] = A_{OFF} + (Gain \times A_{ACTUAL})$$

- 5 To achieve this, the accelerometer may be configured with no threshold values, and then capturing x and y axes data to determine offset.

The use of an accelerometer as the inertial sensor device 220 may involve the need for sensitivity setting of the accelerometer. Once calibrated, the accelerometer may be configured to detect and wakeup for acceleration/vibration lasting more than a certain
10 period, e.g. 50 ms, and of magnitude greater than a certain threshold value, e.g. 100mg (g =acceleration of gravity). The values of the period and the magnitude threshold may need to be changed according to circumstances, and may easily be adjusted after field trial.

- Similarly, if there is no acceleration/vibration greater than e.g. 100mg (or similar threshold value) for another period value, e.g. 10 s, then module may go into sleep mode.
15 These functions may be performed by the processing device 210 in the device 150. Accelerometer data may be captured and stored in an interrupt call to the processing device 210 and then processed.

If both x and y axes data is less than a certain acceleration threshold value, e.g. 600mg, then the device 150 may be determined to be inclined in z axis. (e.g., at least 45 degrees
20 in horizontal direction). This is when x and y axes accelerometer become less sensitive and prone to false reading, hence the processing device may be configured to ignore any data if both x and y axes data is less than 600mg.

Under such conditions the gyroscope would become the preferred measurement device. The latter may be particularly useful in a configuration wherein the inertial sensor device
25 comprises both an accelerometer and a gyroscope.

By example, the invention has been described for use with a manually operated valve, in particular a valve included in a surface oil/gas wellhead. However, the invention has numerous alternative applications, for instance with manually operated valves in any type of pumping systems for fluids, including liquids (e.g. water) and gas. The invention may
30 also be used with valves or similar operating equipment in hydraulic and/or pneumatic

control systems. Other conceivable applications include water supply systems, sprinkler systems and fire fighting arrangements.

CLAIMS

1. Method for determining a position of a valve closure element moved by a rotatable valve actuator shaft, comprising
 - providing movement data by an inertial sensor device attached to the rotatable valve
 - 5 actuator shaft, and
 - processing the movement data to obtain the position of the valve closure element.
2. Method according to claim 1,
wherein the inertial sensor device comprises an accelerometer, and wherein the movement data comprises acceleration data.
- 10 3. Method according to claim 1,
wherein the inertial sensor device comprises a gyroscope, and wherein the movement data comprises angular velocity data.
4. Method according to one of the claims 1-3,
wherein the processing of movement data includes counting a number of rotations of the
- 15 inertial sensor device.
5. Method according to claim 4,
wherein the processing of movement data further includes determining a direction of each rotation of the inertial sensor device.
6. Method according to one of the claims 1-5,
20 further comprising transmitting, to a monitoring device, data representing the position of the valve closure element.
7. Method according to one of the claims 1-6,
further comprising displaying, on a display device, data representing the position of the valve closure element.
- 25 8. Device for determining a position of a valve closure element moved by a rotatable valve actuator shaft, comprising
 - an inertial sensor device attached to the rotatable valve actuator shaft, providing movement data, and

- a processing device, configured to process the movement data to obtain the a position of the valve closure element moved by the rotatable valve actuator shaft.

9. Device according to claim 8,
wherein the inertial sensor device comprises an accelerometer, and wherein the
5 movement data comprises acceleration data.
10. Device according to claim 8,
wherein the inertial sensor device comprises a gyroscope, and wherein the movement data
comprises angular velocity data.
11. Device according to one of the claims 8-10,
10 wherein the rotatable valve actuator shaft is an actuator shaft of a non-rising stem valve.
12. Device according to claim 11,
wherein the rotatable valve actuator shaft is rotatable by a handwheel attached to the
shaft, and the inertial sensor device is attached to the handwheel.
13. Device according to claim 11 or 12,
15 wherein a plurality of turns of the shaft corresponds to a complete movement of the
closure element between a fully open valve and a fully closed valve.
14. Device according to one of the claims 8-13,
wherein the valve is included in a oil and/or gas surface wellhead.
15. Device according to one of the claims 8-14,
20 wherein the processing device is configured to process the movement data by counting a
number of rotations of the inertial sensor device.
16. Device according to claim 15,
wherein the processing device is further configured to process the movement data by
determining a direction of each rotation of the acceleration-sensitive device.
- 25 17. Device according to one of the claims 8-16,
further comprising a data transmitting device, configured to transmit to a monitoring
device data representing the position of the valve closure element.

18. Device according to one of the claims 8-17,
further comprising a display device, configured to display data representing the state of
the position of the valve closure element.

19. Computer program product, comprising processing instructions that, when
5 executed by a processing device, causes the processing device to perform a method as set
forth in one of the claims 1-7.

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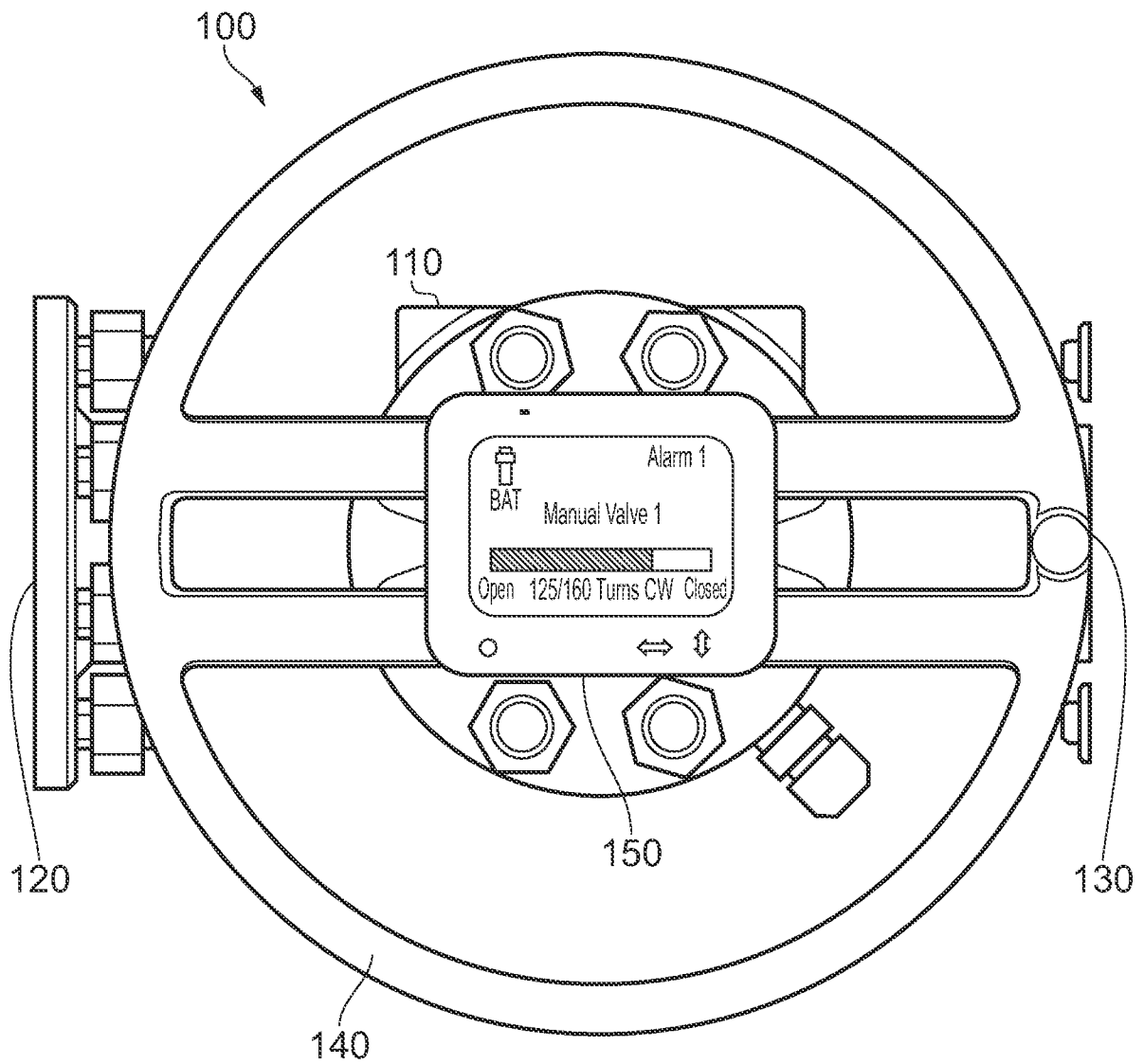


FIG. 1

REPLACEMENT SHEET

SUBSTITUTE SHEET (RULE 26)

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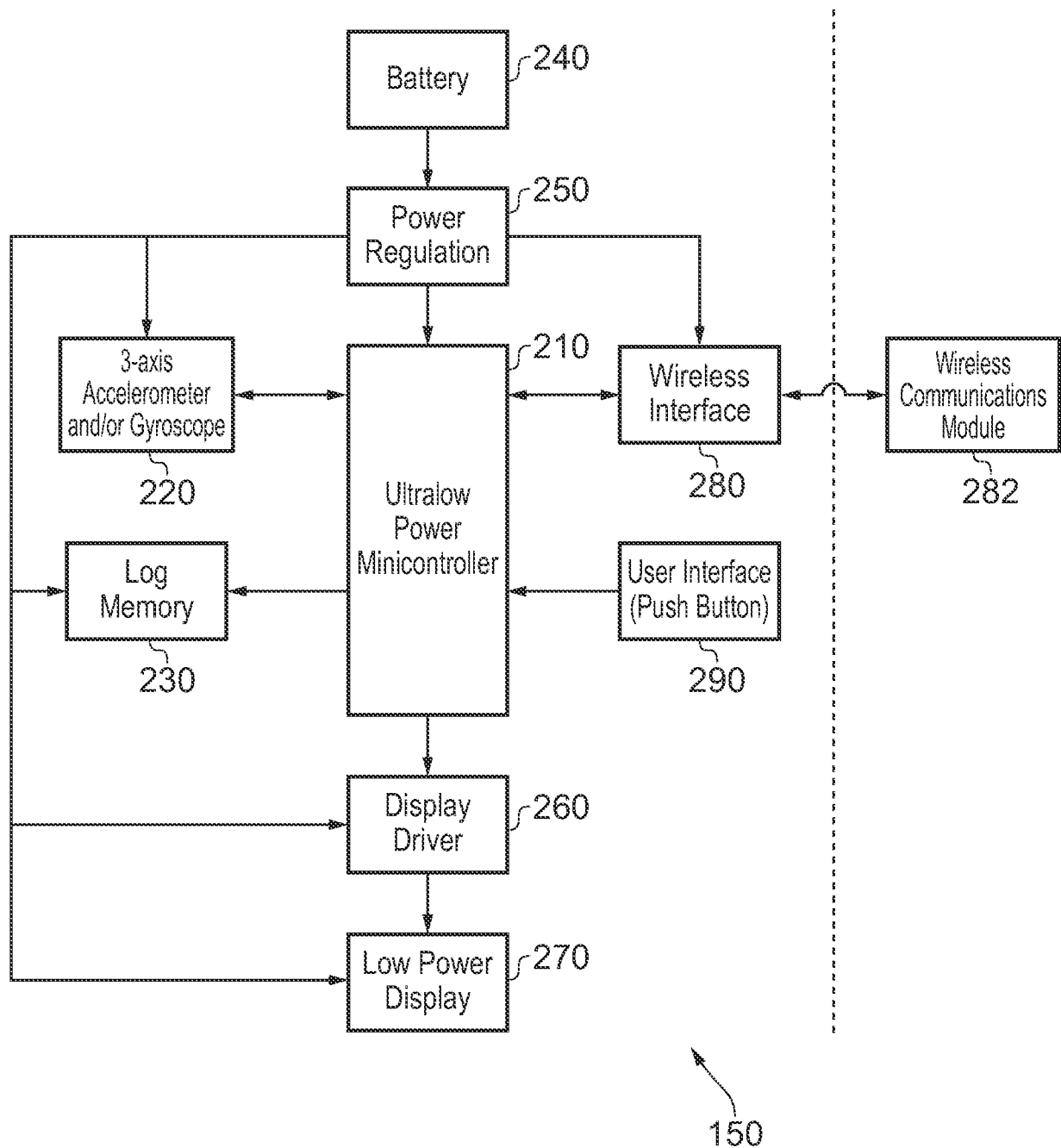


FIG. 2

REPLACEMENT SHEET

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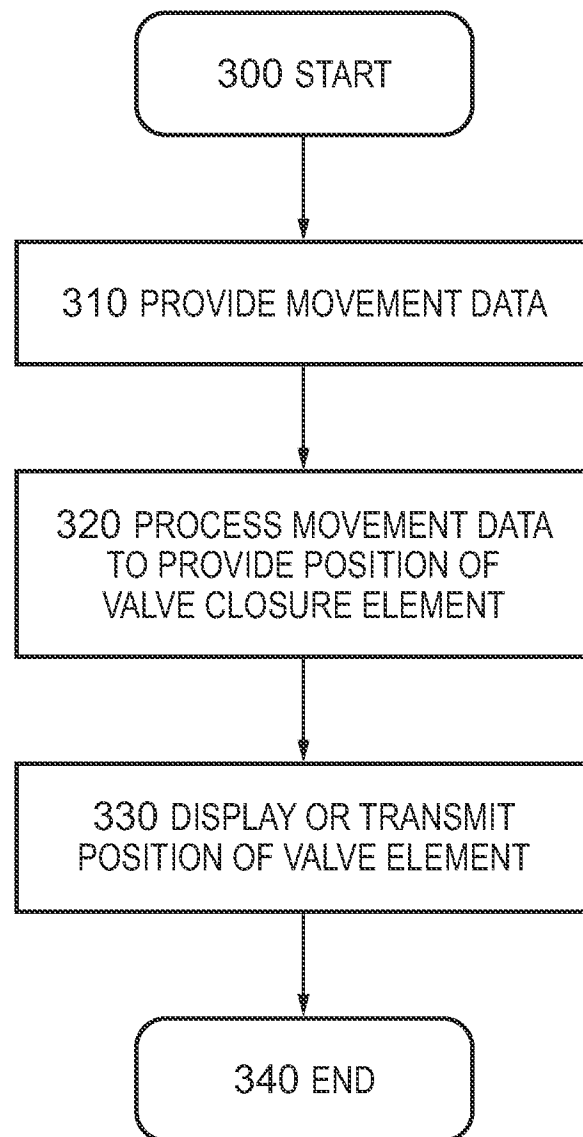
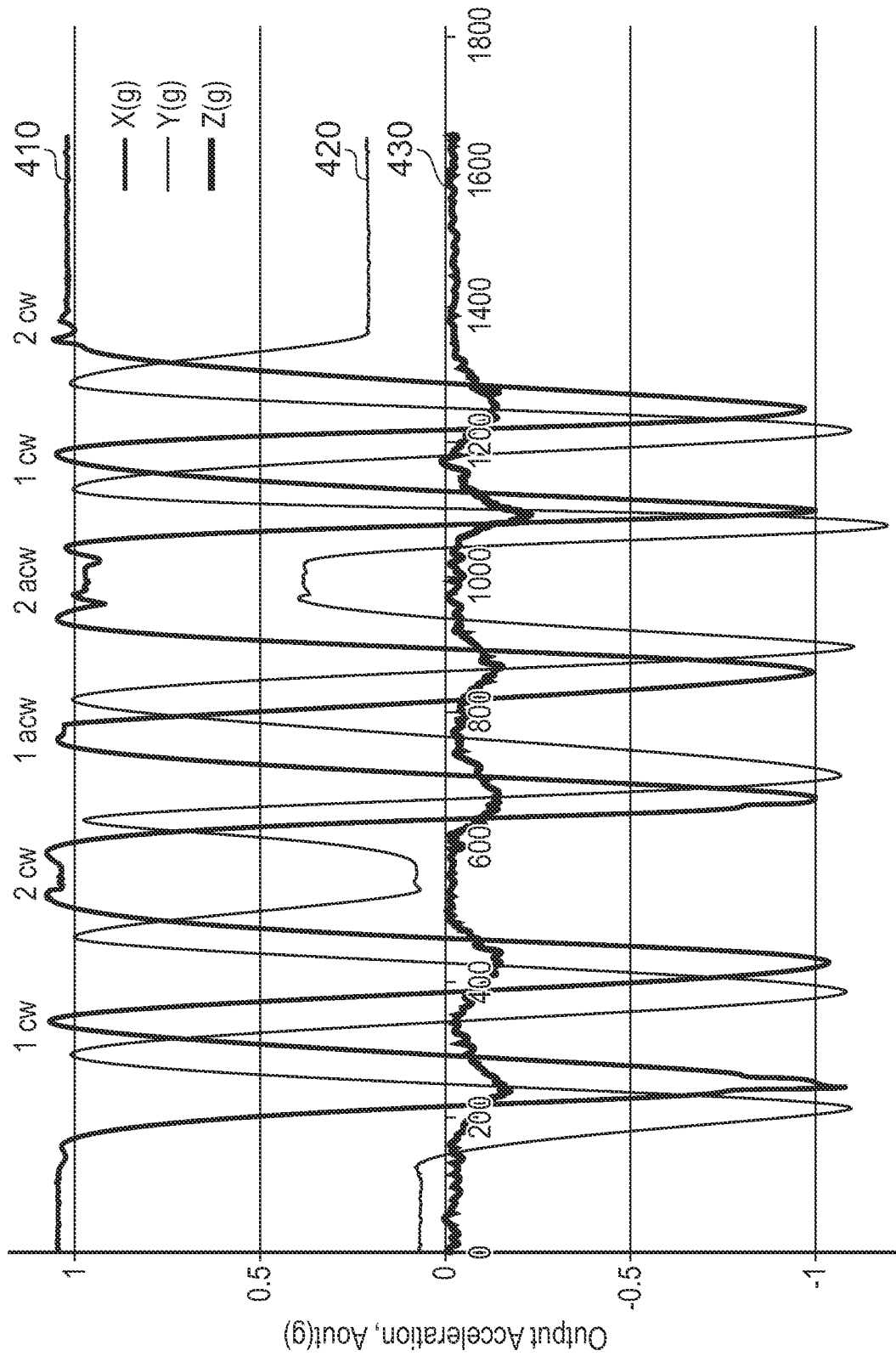


FIG. 3

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REPLACEMENT SHEET

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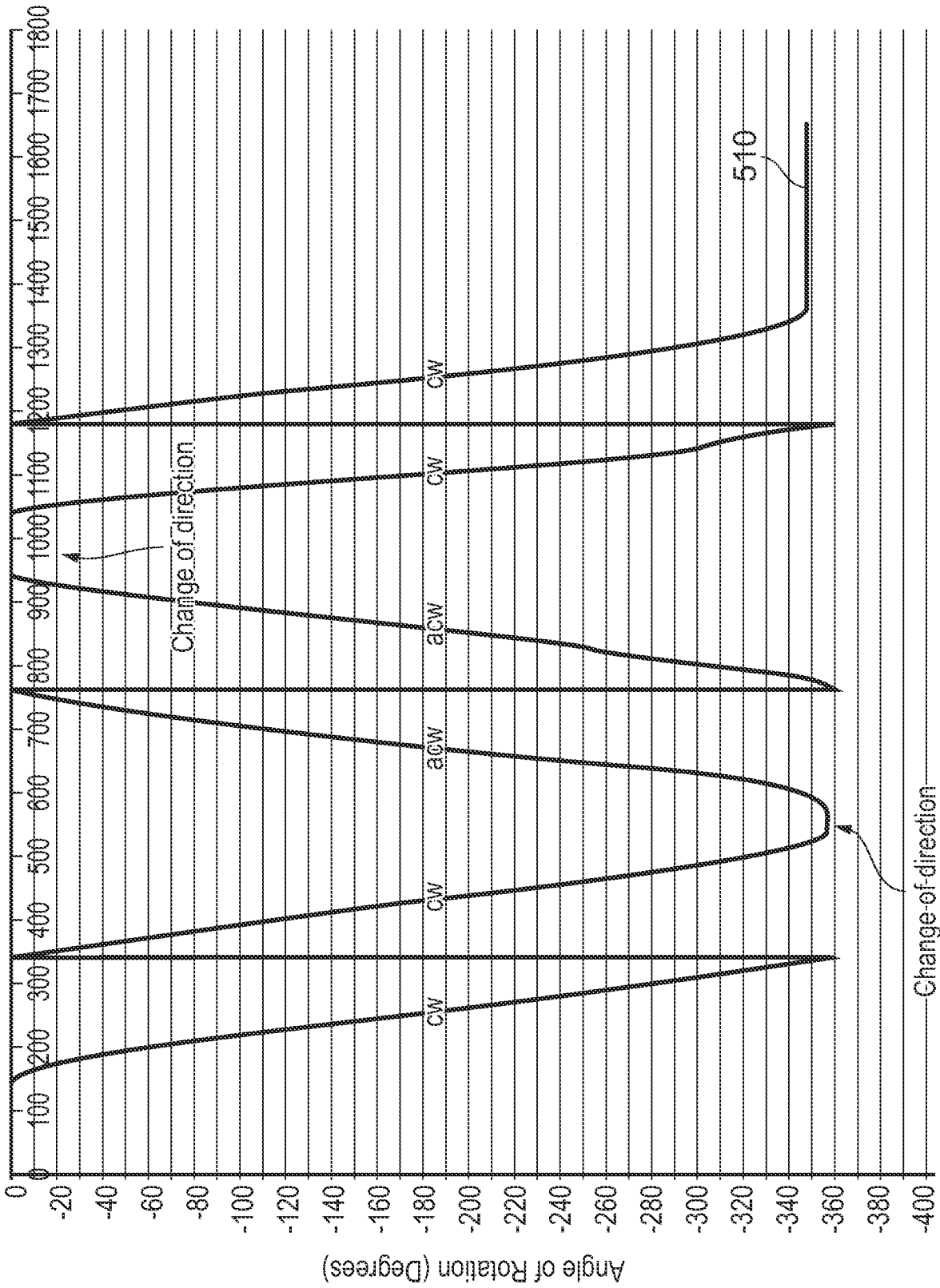


FIG. 5

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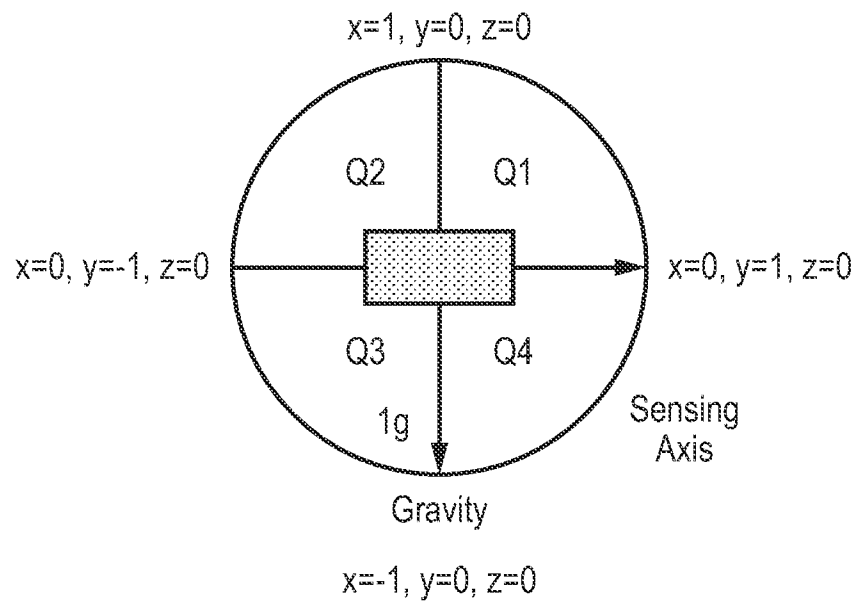


FIG. 6

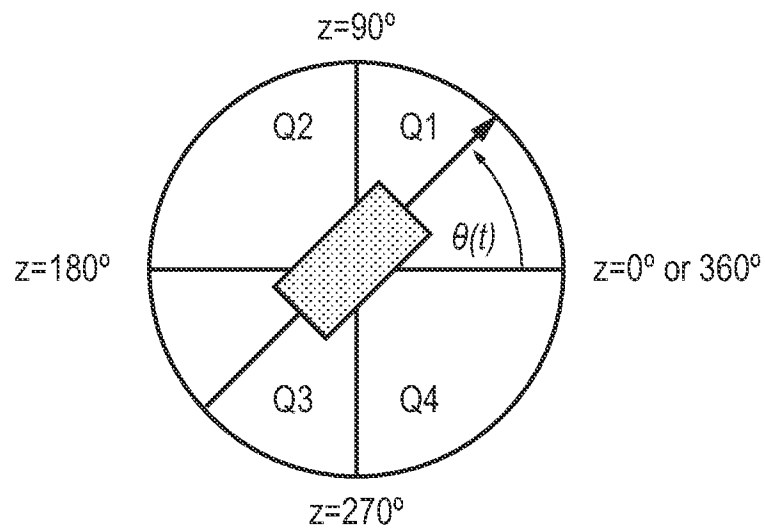


FIG. 7

REPLACEMENT SHEET

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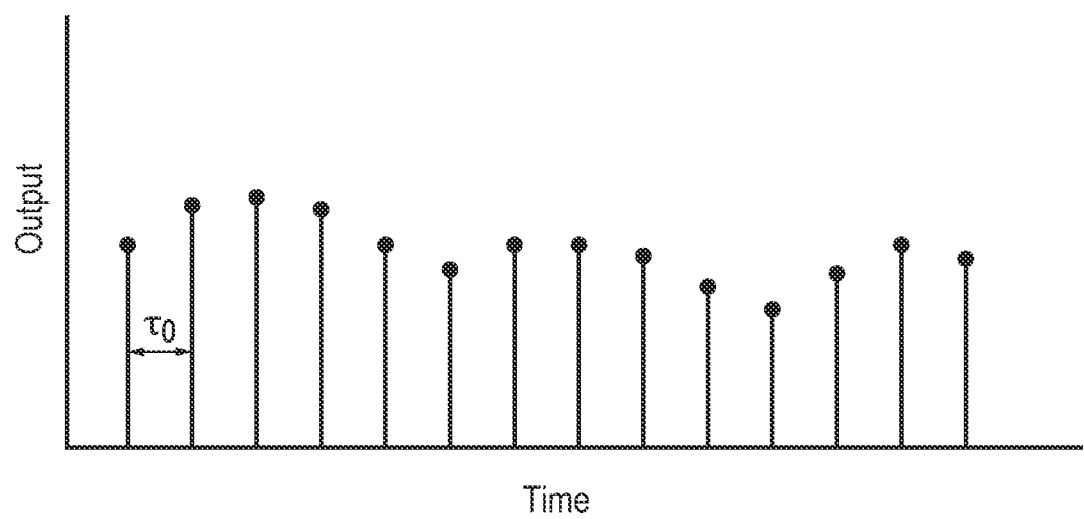


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/028334

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16K37/00 G01C19/42 G01P15/18
ADD.

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)

F16K G01C G01P

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/074938 A1 (CHEN JUI-CHIEN [TW] ET AL) 28 March 2013 (2013-03-28) abstract; figures 1-3 paragraphs [0029], [0036], [0046] - [0047] -----	1-19
A	US 2013/314239 A1 (CLARK KENNETH A [US] ET AL) 28 November 2013 (2013-11-28) abstract; figures 1-13 paragraphs [0059] - [0060] -----	1-19
A	DE 20 2009 015142 U1 (ABB TECHNOLOGY AG [CH]) 7 January 2010 (2010-01-07) the whole document -----	1-19
A	EP 0 410 317 A2 (LIBERTY TECH CENTER [US]) 30 January 1991 (1991-01-30) abstract; figures 1-3 column 7, line 31 - column 10, line 53 -----	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/028334

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