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(72) Inventor(s):
Roberto Pricci
Srinivas Rana

(73) Proprietor(s):
Medical Wireless Sensing Ltd
(Incorporated in the United Kingdom)
Suite 7, QMB Innovation Centre, 42 New Road, London, E1 2AX, United Kingdom

(74) Agent and/or Address for Service:
Kilburn & Strode LLP
Lacon London, 84 Theobalds Road, London, Greater London, WC1X 8NL, United Kingdom

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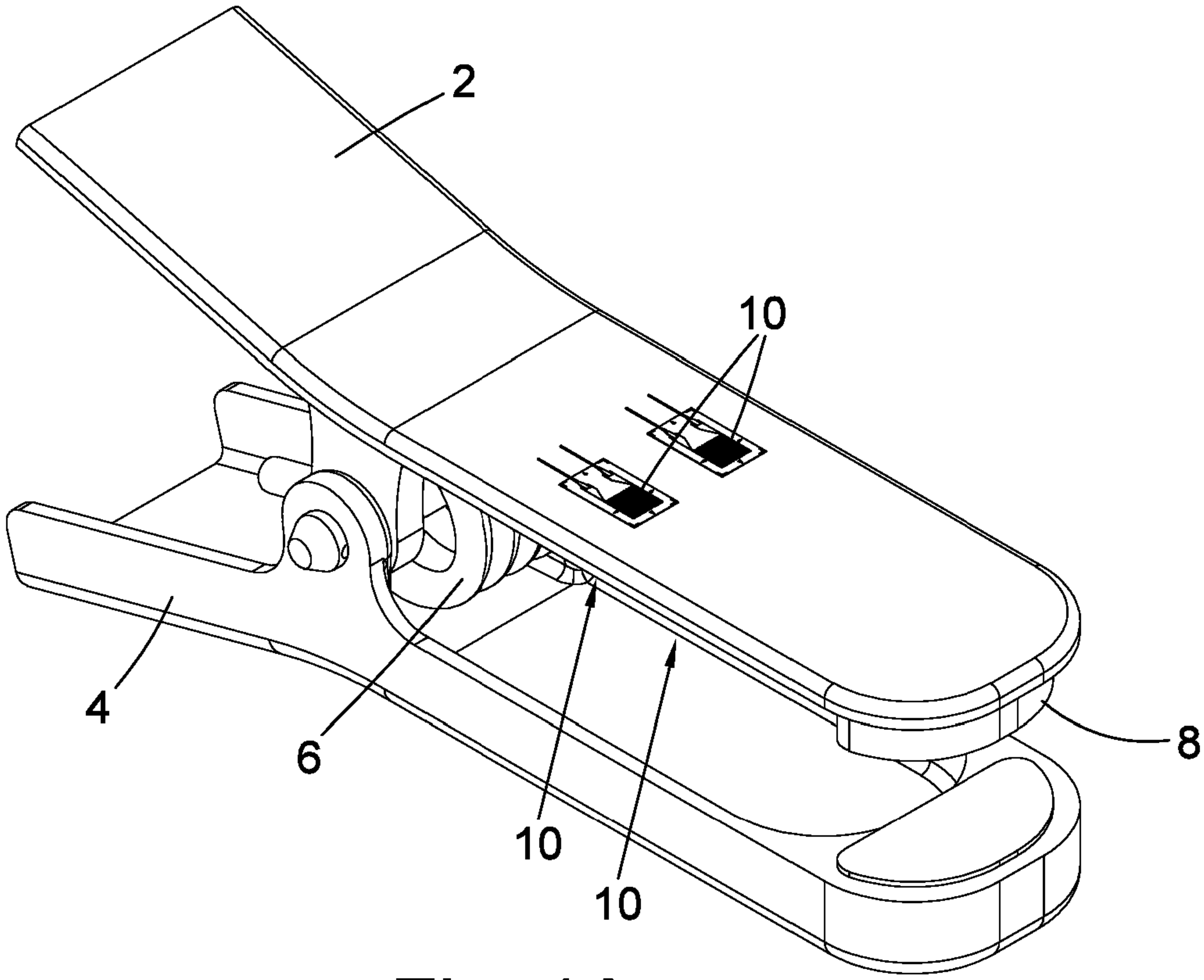

Fig. 1A

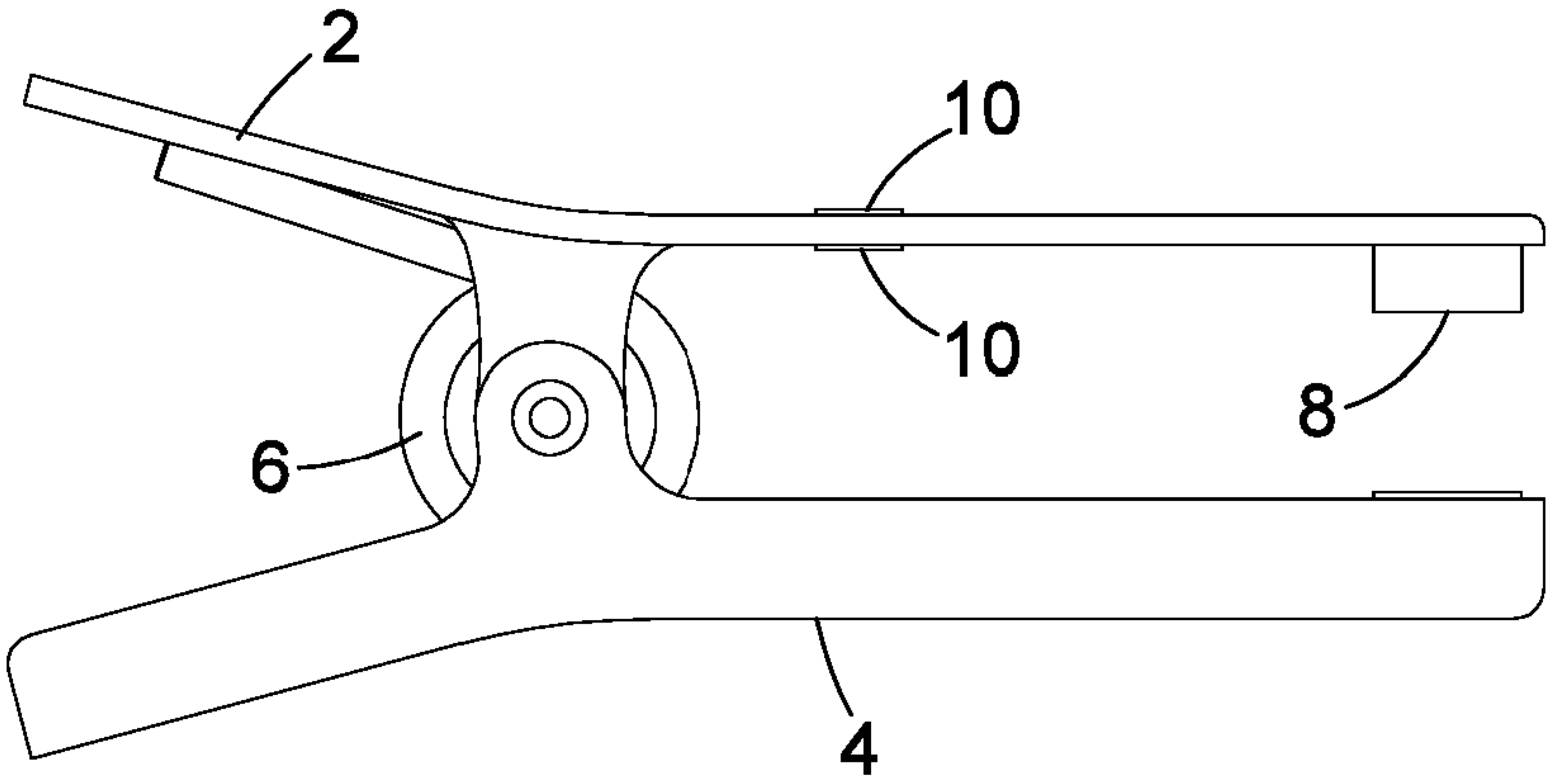

Fig. 1B

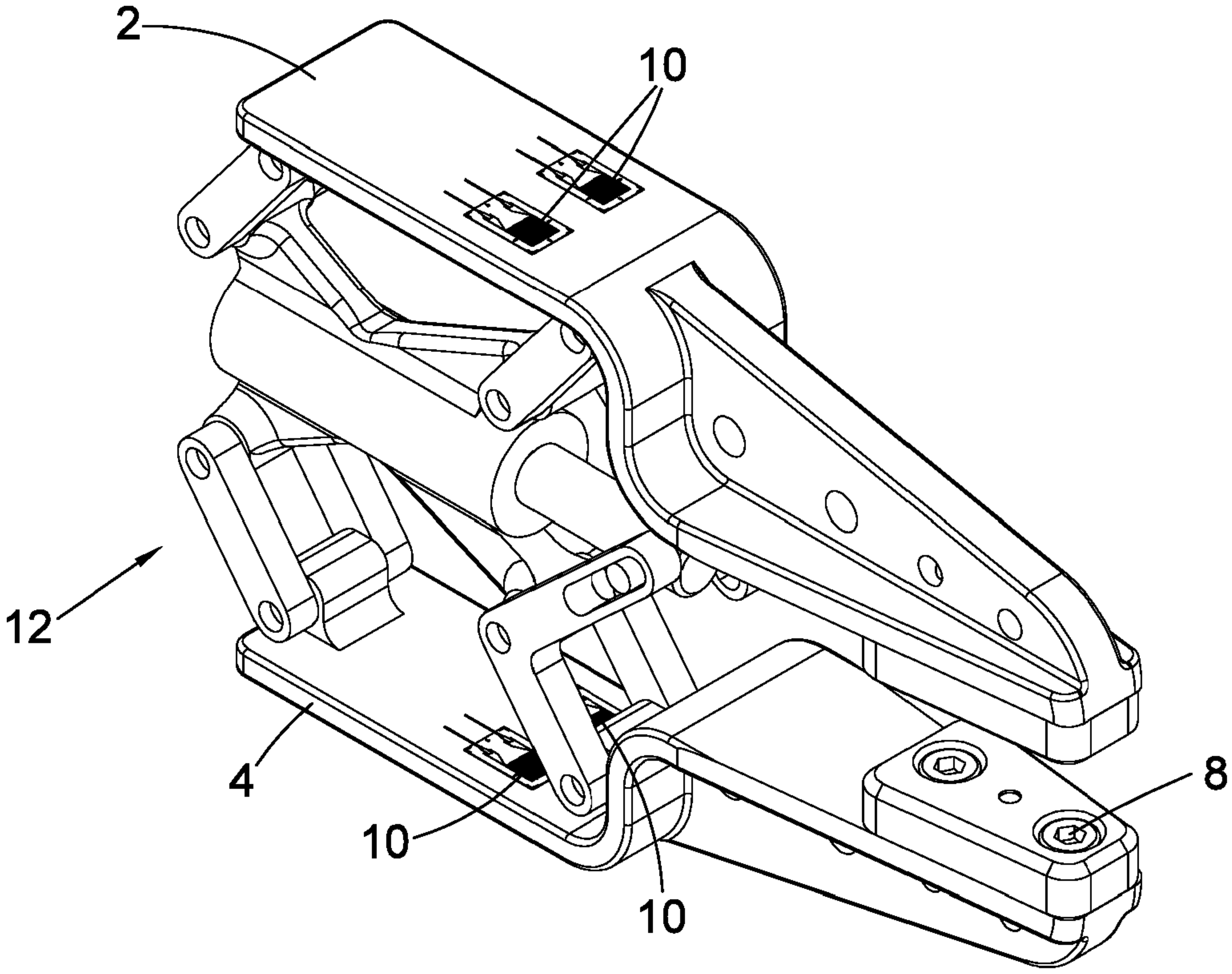

Fig. 2

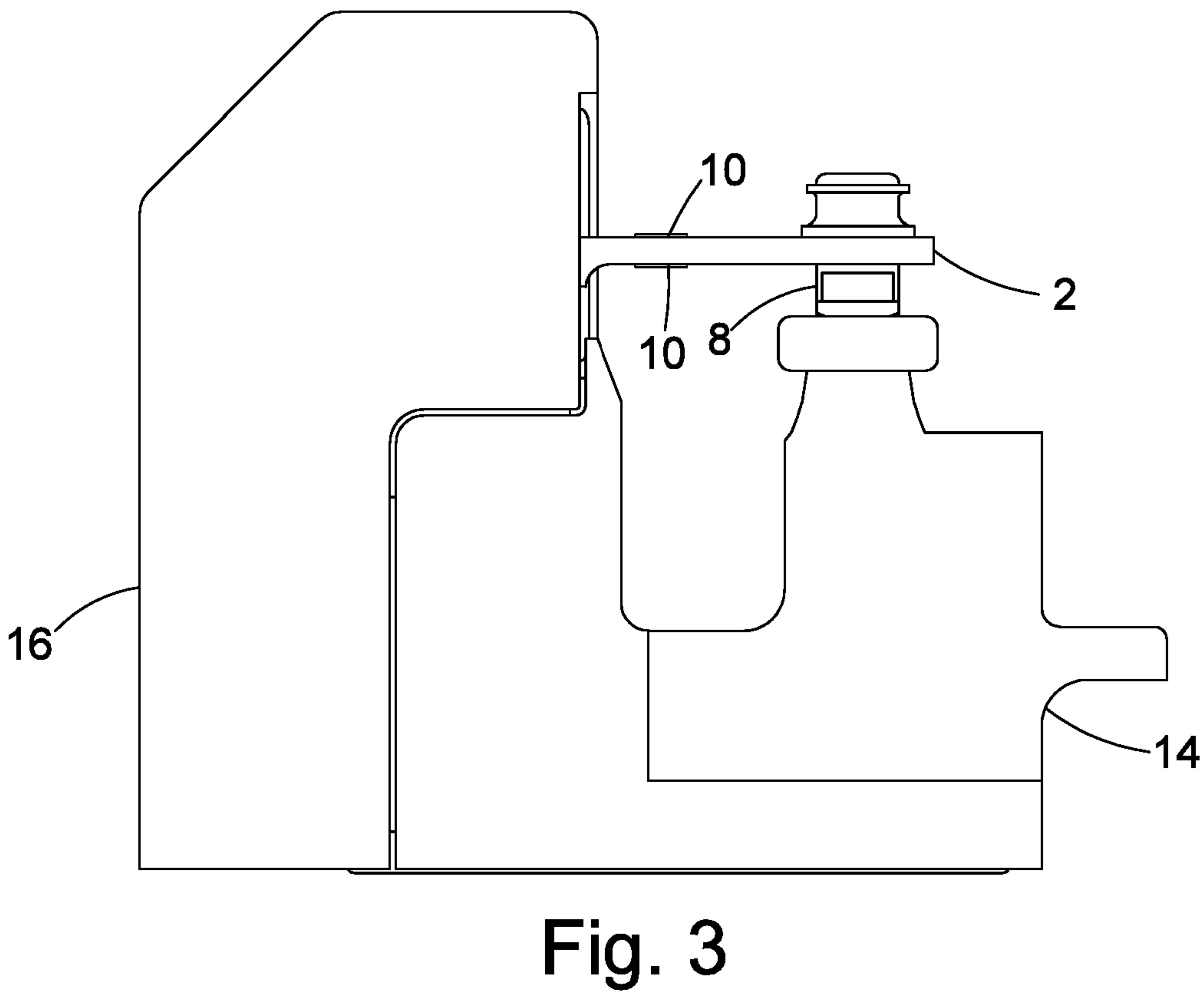

Fig. 3

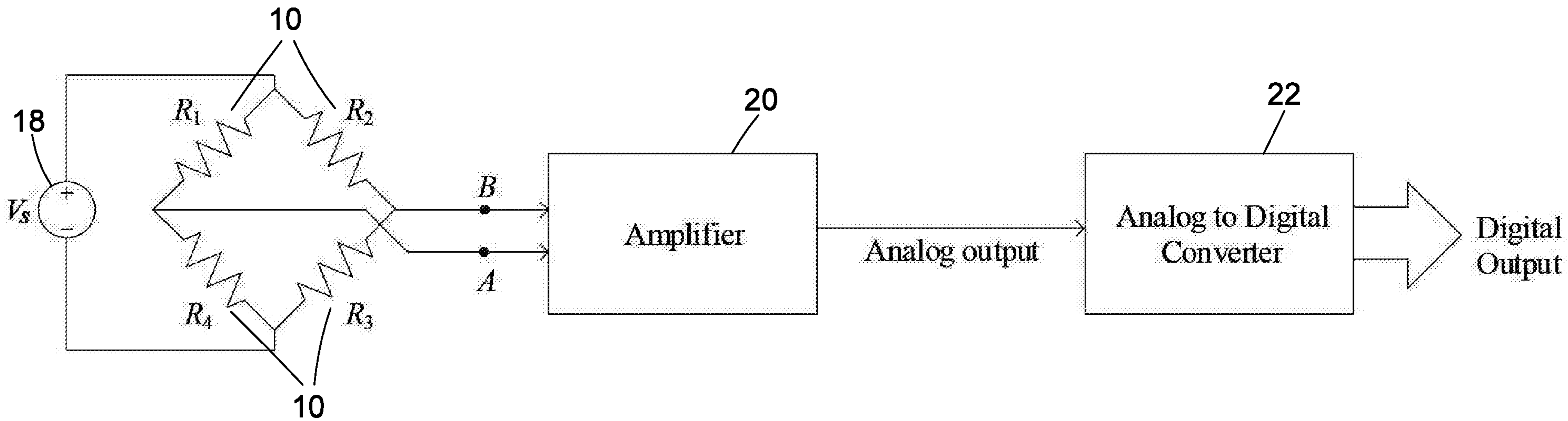
10
18
R_1
R_2
V_s
R_4
R_3
10
B
A
20
Amplifier
Analog output
22
Analog to Digital Converter
Digital Output

Fig. 4

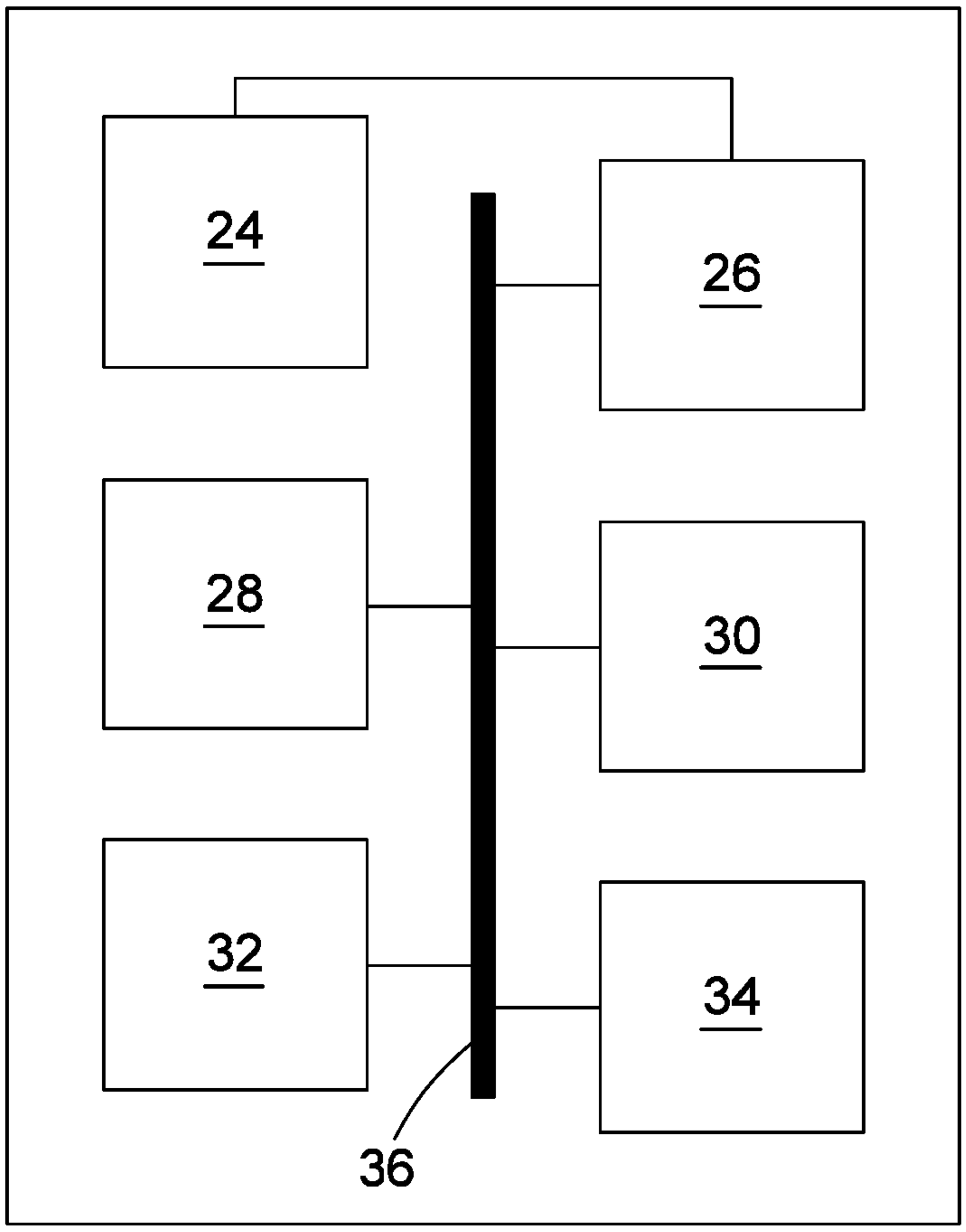

Fig. 5

MOVEMENT SENSING CLAMP

FIELD

The present disclosure relates to a clamp for clamping to an object, such as a body part of a subject from which physiological measurements are obtained, as well as to a measurement system comprising such a clamp.

BACKGROUND

Many measurements, in particular physiological measurements on a human or non-human subject, involve clamping a sensor to an object, for example a body part of the subject. Motion of the object (or the clamp) may result in relative motion of the object and clamp (and hence any sensor attached to the clamp). Such motion may result in motion artefacts that corrupt data collected from the sensor. Motion artefacts affect a variety of instruments and devices, predominantly but not exclusively in the medical device sector such as blood oxygen saturation and photoplethysmography devices, vital sign monitoring and pulse oximeters, to name a few. These artefacts can mimic pathology in surrounding structures and may thereby lead to a misleading or erroneous measurement.

Motion artefacts are difficult to deal with, in particular when the motion is unpredictable. Motion artefacts are usually corrected using a range of methods such as statistical analysis, adaptive filtering and other signal processing techniques. However, it is typically impossible to retrieve the original data once it has been corrupted by artefacts.

A common difficulty encountered with any of these approaches is the sensitivity exhibited by motion artefacts to the relative movement between the measurement site and measurement system and a corresponding requirement for sensitivity in motion artefact detection.

SUMMARY

A clamp is disclosed that comprises first and second clamp portions, one or both of which are moveable relative to the other. For example, the clamp may have two arms that can move relative to each other or one arm moveable relative to a fixed counter portion. The portions may be resiliently biased one or both towards the other or may be provided with any other means of exerting a clamping force, such as a vice mechanism, to apply a clamping force to an object held between the clamp portions. The object may, for example, be a body part of a subject such as a human. Example body portions that may be clamped include a finger, a toe, an ear lobe and the like. The clamp may comprise a measurement sensor for taking a measurement or obtaining a signal from the object, or such a sensor may otherwise be used in conjunction with the clamp, for example the clamp may be used to clamp a measurement sensor that is independent of the clamp.

The clamp comprises one or more strain sensors, such as strain gauges. The strain sensors are secured to the clamp in a sensing region of the clamp that deforms in response to the clamping force. The one or more strain sensors may be secured to the first portion only or to both the first and second portion. More generally, the one or more strain sensors may be fixed to any moving or fixed portion of the clamp that deforms in response to the clamping force (as experienced during normal use of the clamp).

Once an object is clamped by the clamp, any motion of the object relative to the clamp results in a force applied to the clamp and hence a deformation of the clamp (for example the first and/or second clamp portions) in the sensing region. The deformation of the sensing region can be detected as a change of a signal obtained from the strain sensor, for example a change in resistance of a strain gauge. The resulting signal is indicative of motion occurring and can be used to detect motion for any number of purposes, for example to gate signal acquisition from a measurement sensor or reject signal portions potentially corrupted by motion, either online or later when the signal is stored for later use. Equally, the resulting signal could be used for other purposes, for example grip-force detection in a robotic gripper where the clamp is used as a robotically driven gripper. In any case, the signal may be used online or stored for later use.

Advantageously, by detecting relative motion of the clamp and clamped object based on clamp deformation, the use of strain sensors to detect deformation of the clamp may provide a highly sensitive, reliable and low noise signal indicative of motion of a clamped object, in particular as compared to sensors based on detecting overall motion of the clamp and clamped object together, such as accelerometers and gyroscopes. Since the strain sensors can be put in practice with relatively inexpensive components, the disclosed arrangement may provide a cost-effective motion sensing solution.

The clamp may comprise a first strain sensor secured to the clamp in a part of the sensing region lengthening in response to the clamping force and a second strain sensor secured to the clamp in a part of the sensing region shortening in response to the clamping force.

Advantageously, such an arrangement allows a differential signal from the two strain sensors to be obtained.

For example, the first and second strain sensors may be mounted on respective opposing faces of the first clamp portion so that one gets stretched and the other compressed as the first clamp portion deforms in a given direction. Alternatively, one strain sensor may be mounted on the first clamp portion and another one mounted on the second clamp portion so that one gets stretched and the other compressed as the first and second clamp portions deform relative to each other in a given direction, for example bend away from each other.

The first and second strain sensors may be connected to a measurement circuit to detect a difference between a signal from the first strain and a signal from the second strain sensor, for example in a differential arrangement directly between the first and second sensors or as part of a Wheatstone bridge with fixed or variable resistors, a further two strain sensors arranged in a similar manner, or a fixed or variable resistor and a further strain sensor. More generally, the one or more strain sensors may have a variable resistance dependent on strain applied to the strain sensor and may be connected in a Wheatstone bridge circuit to detect changes in the variable resistance. For example, one, two or three strain sensors in a Wheatstone bridge with fixed or variable resistances to make up the four resistors in the bridge, or four strain sensors.

In some specific arrangements, the clamp comprises a third strain sensor secured to the clamp in a portion of the sensing region lengthening in response to the clamping force and a fourth strain sensor secured to the clamp in a portion of the sensing region shortening in response to the clamping force. For example, the third and fourth strain sensors may be mounted on respective opposing faces of the first clamp portion so that one gets stretched and the other compressed as the first clamp portion deforms in a given direction. The third and fourth strain sensors may instead be mounted on respective opposing faces of the second clamp portion so that one gets stretched and the other compressed as the first clamp portion deforms in a given direction. Alternatively, one of the third and fourth strain sensor may be mounted on the first clamp portion and another one mounted on the second clamp portion so that one gets stretched and the other compressed as the first and second clamp portions deform relative to each other in a given direction, for example bend away from each other. Generally, the third strain sensor may be secured to the clamp to respond in the same way as the first clamp sensor and the fourth strain sensor may be secured to the clamp to respond in the same way as the second strain sensor in response to deformation, for example. The first, second, third and fourth strain sensors may have a variable resistance dependent on strain applied to the strain sensor and may be connected in a Wheatstone bridge configuration.

The clamp may further comprise a motion sensor, for example an accelerometer or gyroscope, for sensing motion of the clamp, which may be caused by motion of the object the clamp is clamped to. A signal from such a global or systemic motion sensor complements the deformation-based motion signal described above and may be used to detect unconstrained motion that is too gradual to result in sufficient clamp deformation to be detected to complement or cross-validate motion detection as described above.

As mentioned above, the clamp may comprise a measurement sensor secured to the clamp to be in proximity to or in contact with an object clamped between the first and second counter portions, to measure a primary signal related to the object. For example, the measurement sensor may be configured to sense light transmitted through or reflected by the object, or an impedance, pressure or temperature of the object and/or may be or comprise one or more of a pulse oximeter, a pulse sensor, a glucose sensor, an impedance sensor, a plethysmography sensor, a temperature sensor or a pressure sensor.

Also disclosed is a measurement system comprising a clamp with a measurement sensor as described above. The system comprises a processor configured to receive a movement signal indicative of deformation of the clamp. The processor is configured to store the signal and/or to detect relative motion of the clamp and an object held in the clamp based on the signal. The system may be configured to process the movement signal as it is received and to detect motion “online”, for example by applying a threshold to the motion signal and detecting when the threshold is exceeded. Alternatively, the processing may be done at a later time. In either case, for example, the processor may be configured to receive the measurement signal and to discard portion(s) of the measurement signal corresponding to portion(s) of the movement signal indicating relative motion of the clamp and the object, either online or later on. Of course, the system may be configured to correct the measurement signal in any other suitable way in response to detecting a motion artefact, either instead or in addition to discarding the relevant portion(s).

If the clamp comprises a motion sensor for sensing motion of the clamp, the processor may be configured to receive a motion signal representative of motion of the clamp from the motion sensor and to use the motion sensor to correct for system level artefacts, for example to detect motion of the clamp itself (together with the object) that is not detected by the strain sensors.

In dependence on the specific arrangement, a driver for driving the strain sensors and/or receiving signals therefrom (for example a suitably connected voltage or current source and/or a suitably connected voltage or current measuring device) may be provided on the clamp or on or in another part of system. For example, the clamp may have only passive components driven by other parts of the system or one or more of the movement signal, motion signal and measurement signal may be generated on board on the clamp. In some arrangements, the entire system described above is integrated with the clamp.

BRIEF DESCRIPTION OF THE DRAWINGS

Specific embodiments are now described by way of example with reference to the accompanying Figures, in which:

Figures 1A and B illustrate an embodiment of the disclosed clamp;

Figure 2 illustrates another embodiment of the disclosed clamp;

Figure 3 illustrates yet another embodiment of the described clamp;

Figure 4 illustrates a Wheatstone bridge used to detect deformation of the disclosed clamp; and

Figure 5 illustrates a measurement system comprising the disclosed clamp.

DETAILED DESCRIPTION

With reference to Figures 1A and 1B, a clamp comprises a first clamp arm 2 and a second clamp arm 4 resiliently biased against each other by a spring 6 to enable clamping of an object between the first and second clamp arms 2,4 in the region of a measurement sensor 8 configured to take a measurement from the clamped object, for example a pulse, impedance or glucose measurement, or any other measurement, for example as discussed above. In some arrangements the measurement sensor 8 comprises a light source and a light detector. The measurement sensor 8 may of course be provided on the second clamp arm or may be distributed between the first and second clamp arms.

Four strain gauges 10 are secured to the first clamp arm 2, two on a face of the first clamp arm 2 facing the second clamp arm 4 and two on an opposed face of the clamp arm 2, in a region where the clamp arm experiences a deformation due to a clamping force being applied to an object held between the first and second clamping arms 2,4. It will be appreciated that the strain gauges on the side facing the second clamp arm 4 are stretched by an increased clamping force or a force exerted by the clamped object against the first clamp arm 2, while the other two strain gauges are compressed by the same force. This allows the strain gauges to be connected in a differential arrangement, specifically a Wheatstone bridge, as discussed below.

With reference to Fig 2, in which like elements are given like reference signs, alternative clamp replaces the spring 8 and associated pivot action with a resilient biasing arrangement 12 that comprises a parallel linkage system and pneumatic spring to bias the two clamp arms 2 and 4 towards each other. In some arrangements, the pneumatic spring can be replaced with other biasing means that enable and adjustable amount of clamping force to be applied, for example a pneumatic or hydraulic cylinder with a controllable input pressure. In general, in either type of arrangement, or in general, other means such as worm gear or other geared drive arrangement, or a set screw may be used. Two of the strain gauges 10 are secured on each clamp arm 2,4 on a respective face facing in the same direction as the other. As a result, as for the arrangement described above, two of the strain gauges 10 are compressed by a change in clamping force and two are stretched.

Yet another alternative arrangement is illustrated in Figure 3, equally applying like reference signs for like elements. In this arrangement, the second clamp arm 4 is replaced by a fixed clamp portion 14 secured to a clamp housing 16 and the clamp arm 2 is moveable relative to the clamp housing 16 so as to exert a clamping force against the clamp portion 14, with strain gauges secured to the clamp arm 2 as described above with reference to Figures 1A and 1B.

With reference to Figure 4, a measurement arrangement for a strain gauge arrangement as described above comprises a voltage source 18 connected to the four strain gauges 10 identified as resistances R1, R2, R3 and R4 in Figure 4 and connected in a Wheatstone bridge configuration. An amplifier 20 is connected to the terminals A, B of the bridge to amplify a voltage signal indicative in a difference between the strain gauges, as set out in the table below. Alternatively, the voltage source 18 may be replaced with a current source and the amplifier 20 amplifies a current signal. The analogue amplified output of the amplifier is converted to a digital output by an analogue to digital converter 22, for further use, for example as described above.

It will be appreciated that various changes of the bridge configuration are possible, for example using only one, two or three of the four strain gauges 10, and providing the remaining ones of the resistors R1, R2, R3 and R4 as fixed or variable resistors. These are illustrated in the following table. The resistance of each strain gauge can be represented in a linear regime as R0(1+x) or R0(1-x), x being a fractional change in resistance due to strain, the sign indicating the direction of strain (stretch or compression) for a given direction of relative movement of the clamp arms and R0 being the baseline resistance corresponding either to a no strain condition or the strain corresponding to the object being held in the clamp, for example for measurement.

R_1	R_2	R_3	R_4	**Constant V_s**	**Constant I_s**
R_0	R_0	$R_0(1+x)$	R_0	$V_s\frac{x}{2(2+x)}$	$I_sR_0\frac{x}{4+x}$
$R_0(1+x)$	R_0	$R_0(1+x)$	R_0	$V_s\frac{x}{2+x}$	$I_sR_0\frac{x}{2}$
R_0	R_0	$R_0(1+x)$	$R_0(1-x)$	$V_s\frac{2x}{4-x^2}$	$I_sR_0\frac{x}{2}$
R_0	$R_0(1-x)$	$R_0(1+x)$	R_0	$V_s\frac{x}{2}$	$I_sR_0\frac{x}{2}$
$R_0(1-x)$	R_0	$R_0(1+x)$	R_0	$V_s\frac{-x^2}{4-x^2}$	$I_sR_0\frac{-x^2}{4}$
$R_0(1+x)$	$R_0(1-x)$	$R_0(1+x)$	$R_0(1-x)$	V_sx	I_sR_0x

The last row corresponds to an arrangement with all four strain gauges 10 as described above, while the rows above correspond to two or three of the strain gauges being replaced by a fixed or variable resistor R0 (which can be adjusted to zero the bridge signal in an object clamped but not moving condition to find R0, for example). Alternatively, R0 may be fixed or subject to one time or occasional calibration and the signal may be zeroed online or offline by recording a baseline signal to subtract from or compare to the ouput signal of the bridge. The last two columns represent, respectively, the output voltage and current signals measured between points A and B when the bridge is connected to a constant voltage source providing an input voltage Vs and a constant current source providing an input current Is, respectively.

With reference to Figure 5, a measurement system comprises a clamp 24 as described above, strain sensing circuitry 26, for example a circuit as described above connected to the strain gauges 10 on the clamp 24 and outputting a movement signal that is received by a processor 28, for example a CPU, ASIC or microprocessor, to detect periods in which the movement signal indicates movement exceeding a threshold that could give rise to motion artefacts. The processor may store the movement signal and/or periods in a memory 30 for further processing.

The processor 28 is further configured to receive a measurement signal from measurement circuitry 32 producing a signal from the sensor 8 and to process the signal to mitigate for motion artefacts, for example excising the data corresponding to detected periods from the measurement signal and storing the result in the memory 30, or another memory. The processing may be done online as the signals are received or the signals may be stored and processed later to remove or reduce motion artefacts. In some embodiments, the system further comprises an output interface 34, for example a display or wireless transmitter, to output the measurement signal or a measured value derived from the measurement signal by the processor 28.

The sensing circuitry 26, processor 28, memory 30, measurement circuitry 32 and output interface 34 are in communication over a data bus 36, in some embodiment. Some or all of the components of the system may be integrated in a single component or housing, for example a wearable clamp for measurement of a physiological signal as described above, or the components may be distributed amongst different components or units, for example a wearable clamp on the one hand and a base station or smart phone on the other hand, the wearable clamp and remainder of the system communicating over respective communication interfaces, using an appropriate protocol such, for example, a wireless connection using Bluetooth™, or a wired connection.

While various specific embodiments have been disclosed, it will be appreciated that they have been described by way of example and not limitation and that many modifications, extensions, combinations and juxtapositions of the described features are possible and within the scope of the appended claims including and taking due account of any equivalents.

CLAIMS

1. A clamp for a body part, the clamp comprising first and second clamp portions, one or both of which are moveable relative to the other to exert a clamping force on an object held between the clamp portions, the clamp comprising a first strain sensor and a second strain sensor each secured to the clamp in a sensing region of the clamp that deforms in response to the clamping force, the first strain sensor secured to the clamp in a part of the sensing region lengthening in response to the clamping force and the second strain sensor secured to the clamp in a part of the sensing region shortening in response to the clamping force, either wherein the first and second strain sensors are mounted on respective opposing faces of the first clamp portion or wherein the first strain sensor is mounted on the first clamp portion and the second strain sensor is mounted on the second clamp portion so that one of the first and second strain sensors gets stretched and the other compressed as the first and second clamp portions deform relative to each other.

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2. A clamp according to claim 1, wherein the first and second strain sensors are connected to a measurement circuit to detect a difference between a signal from the first strain sensor and a signal from the second strain sensor.

3. A clamp according to any preceding claim wherein the first and second strain sensors have a variable resistance dependent on strain applied to the strain sensor and are connected in a Wheatstone bridge circuit to detect changes in the variable resistance.

4. A clamp according to claim 1, comprising a third strain sensor secured to the clamp in a portion of the sensing region lengthening in response to the clamping force and a fourth strain sensor secured to the clamp in a portion of the sensing region shortening in response to the clamping force.

5. A clamp according to claim 4, wherein the first, second, third and fourth strain sensors have a variable resistance dependent on strain applied to the strain sensor and are connected in a Wheatstone bridge configuration.

6. A clamp according to any preceding claim, wherein the first clamp portion comprises a moveable clamp arm and the sensing region is on or part of the clamp arm.

7. A clamp according to any one of claims 1 to 5 wherein the first and second clamp portions each comprise a respective moveable clamp arm, the sensing region having a respective portion on each clamp arm.

8. A clamp according to any preceding claim comprising a measuring circuit to generate a signal indicative of deformation of the sensing region once a clamping force has been applied to enable detection of motion of the object relative to the clamp.

9. A clamp according to any preceding claim comprising a motion sensor for sensing motion of the clamp.

10. A clamp according to any preceding claim comprising a measurement sensor secured to the clamp to be in proximity to or in contact with an object clamped between the clamp arm and a counter portion, to measure a measurement signal related to the object.

10 02 21

11. A clamp according to claim 10, wherein the measurement sensor is configured to sense light transmitted through or reflected by the object, or an impedance, pressure or temperature of the object, and/or wherein the clamp sensor comprises one or more of a pulse oximeter, a pulse sensor, a glucose sensor, an impedance sensor, a plethysmography sensor, a temperature sensor or a pressure sensor.

12. A measurement system comprising a clamp according to claim 10 or claim 11, the system comprising a processor configured to receive a movement signal indicative of deformation of the clamp and to store the signal and/or to detect relative movement of the clamp and an object held in the clamp based on the signal.

13. A measurement system according to claim 12, the processor being configured to receive the measurement signal and to discard portions of the measurement signal corresponding to portions of the movement signal indicating relative motion of the clamp and the object.

14. A measurement system according to claim 12 or 13, the processor being configured to receive the measurement signal and, as the measurement and movement signals are received, to process the measurement signal based on the movement signal to eliminate or reduce motion artefacts.

15. A measurement system according to claims 12, 13 or 14 when dependent on claim 9, the processor being configured to receive a motion signal representative of motion of the clamp from the motion sensor and to detect motion not resulting in a signal from the strain sensors.

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