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(54) **BIOIMPEDANCE MEASUREMENT CONFIGURATION**

(57) The present document discloses a garment made of flexible material, comprising: a first measurement electrode integrated into the garment at a first location; a second measurement electrode integrated into the garment at a second location different from the first location; and a measurement circuitry configured to measure bioimpedance by using the first measurement electrode and the second electrode and to transmit the

measured bioimpedance, and to measure electrocardiogram by using at least one of the first measurement electrode and the second electrode or another electrode, wherein the garment is an upper body garment, wherein the first measurement electrode is disposed above a heart level and the second measurement electrode is disposed below the heart level.

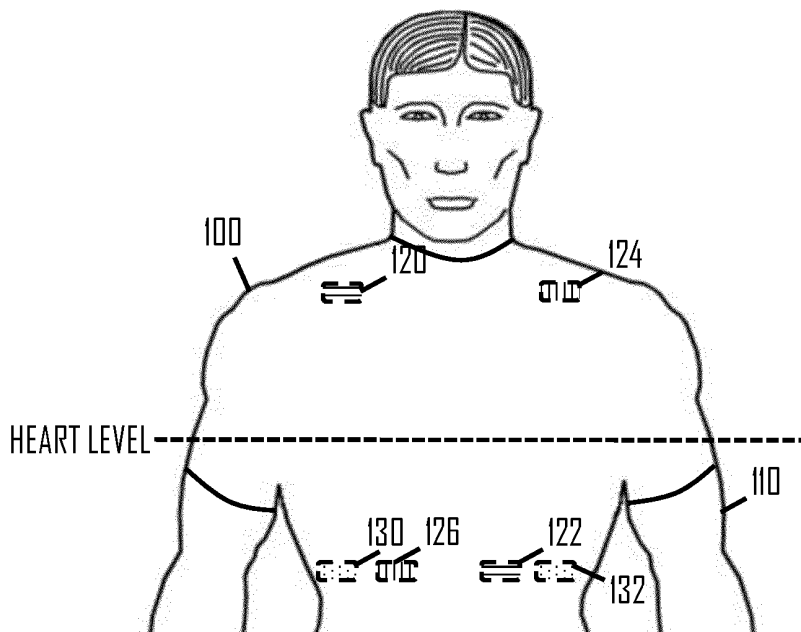


Fig 3

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a field of physiological or biometric measurements and, in particular, a measurement configuration for measuring bioimpedance from a human body.

TECHNICAL BACKGROUND

10 **[0002]** A typical configuration for measuring bioimpedance includes a set of measurement electrodes disposable to contact with skin, a measurement circuitry for measuring bioimpedance from one or more of the electrodes, and a processing circuitry for processing measurement data. There may also be provided a communication circuitry for communicating the processed measurement data in a wired or wireless manner.

15 BRIEF DESCRIPTION

[0003] The present invention is defined by the subject matter of the independent claim.

[0004] Embodiments are defined in the dependent claims.

20 BRIEF DESCRIPTION OF THE DRAWINGS

[0005] In the following the invention will be described in greater detail by means of preferred embodiments with reference to the accompanying drawings, in which

25 Figure 1 illustrates a garment comprising a measurement circuitry according to an embodiment;
Figure 2 an embodiment of the measurement circuitry;
Figures 3 and 4 illustrate further embodiments of placement of the electrodes in the garment;
Figure 5 illustrates an embodiment of an arrangement for switching a mode of one or more electrodes of the garment;
Figure 6 illustrates a flow diagram of a process for configuring the operation of the electrodes of the garment according
30 to an embodiment of the invention;
Figures 7 and 8 illustrate an embodiment for synchronising bioimpedance measurements with a cardiac cycle;
Figure 9 illustrates a flow diagram of a process for performing motion compensation for a bioimpedance measurement signal according to an embodiment of the invention;
Figure 10 illustrates stages and intermediate products of a manufacturing process for producing electrodes according
35 to an embodiment of the invention;
Figures 11 and 12 illustrate embodiments of a layered structure of an electrode in the garment;
Figure 13 and 14 illustrate embodiments of a detachable electronics module for the garment;
Figure 15 illustrates a process for providing training guidance according to an embodiment of the invention;
Figure 16 illustrates a process for adapting duration of a rest period of an interval exercise according to an embodiment
40 of the invention;
Figure 17 illustrates a process for adapting duration of a work period of an interval exercise according to an embodiment of the invention;
Figure 18 illustrates an example of guidance during a physical exercise when employing the processes of Figures 16 and 17;
45 Figure 19 illustrates a process for monitoring users fatigue level during the exercise according to an embodiment of the invention;
Figure 20 illustrates a block diagram of an apparatus according to an embodiment of the invention; and
Figure 21 illustrates an embodiment reducing undesired electric coupling between measurement electrodes.

50 DETAILED DESCRIPTION OF THE INVENTION

[0006] The following embodiments are exemplifying. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

55 **[0007]** Figure 1 illustrates an embodiment of a garment 100 made of flexible material. The garment comprises: a first measurement electrode 120 integrated into the garment at a first location, a second measurement electrode 122 integrated into the garment at a second location different from the first location, and a measurement circuitry 114 configured

to measure bioimpedance by using the first measurement electrode and the second electrode and to transmit the measured bioimpedance, and to measure electrocardiogram (ECG) by using at least one of the first measurement electrode and the second electrode or another electrode, wherein the garment is an upper body garment, wherein the first measurement electrode is disposed above a heart level and the second measurement electrode is disposed below the heart level.

[0008] In an embodiment, the garment is a shirt, a vest, or a harness. The garment may equally be a bra or any other garment designed as an under layer to contact the skin of a human 110 (a user). The garment may be made of one or more of the following materials: nylon, polyamide, elastane, polyester, cotton, and wool.

[0009] In the embodiment of Figure 1, the first measurement electrode 120 is disposed above the heart level, when the garment is worn by the user 110, while the second measurement electrode 122 is disposed below the heart level. The measurement circuitry 114 may be provided in a casing at an arbitrary location in the garment, and signal lines 116, 118 may connect the measurement electrodes 120, 122 to the measurement circuitry 114. The signal lines may be integrated into the garment.

[0010] Let us now describe the structure of the measurement circuitry 114 in greater detail with reference to Figure 2 illustrating an embodiment of an apparatus. The apparatus may comprise at least one processor 204 and at least one memory 220 storing a computer program 228 comprising a program instructions that configure the at least one processor to execute the embodiments described herein. The apparatus may further comprise a user interface 214 comprising at least a display device and a user input device.

[0011] The bioimpedance measurement may be carried out by arranging signal feed electrodes 210 in the garment and, further arranging measurement the electrodes 212 in the garment. The measurement electrodes 212 may comprise the electrodes 120, 122. The measurement circuitry 114 may be configured to control the signal feed and the measurement, e.g. the following manner. One or more processors 204 may control a current generator 202 to output electric current to the feed electrodes 210. The current generator 202 may be signal synthesizer capable of outputting alternating current one various frequencies. The bioimpedance measurements may be used for estimating body composition, and multiple frequencies may be output for that purpose.

[0012] While the current generator is outputting current to the body, the processor 204 may configure a voltage measurement circuitry 206 to measure voltage between the measurement electrodes 212 and to acquire voltage measurement data from the measurement electrodes. The knowledge of the measured voltage U and the applied current I may then be used to compute the bioimpedance Z according to the well known formula: $Z = U/I$.

[0013] The measurement circuitry 114 may further comprise or have access to at least one memory 220. The memory 220 may store a computer program code comprising instructions readable and executable by the processor(s) 204 and configuring the above-described operation of the processor(s). The memory 220 may further store a configuration database 224 defining parameters for the processor(s), e.g. parameters for the current feed control.

[0014] The apparatus may further comprise a communication circuitry configured to transmit measurement data acquired by the measurement circuitry to an external device such as a smart phone or a wrist computer. The external device may be a training computer configured to monitor a physical exercise performed by the user. The communication circuitry may be a wireless communication circuitry supporting a wireless communication protocol such as ANT, ANT+, or Bluetooth®, e.g. Bluetooth Smart ®.

[0015] As used in this application, the term 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware.

[0016] The techniques and methods described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more modules), or combinations thereof. For a hardware implementation, the apparatus(es) of embodiments may be implemented within one or more application-specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), graphics processing units (GPUs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, the implementation can be carried out through modules of at least one chipset (e.g. procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case, it can be communicatively coupled to the processor via various means, as is known in the art. Additionally, the components of

the systems described herein may be rearranged and/or complemented by additional components in order to facilitate the achievements of the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be appreciated by one skilled in the art.

5 [0017] From the measured bioimpedance, other physiological characteristics such as a heart stroke volume may be computed. Patent publication US 2002/0193689 discloses one method of computing the stroke volume by using the bioimpedance and the ECG, and the processor 204 may employ such a method in some embodiments.

10 [0018] In the embodiment of Figure 1, the electrodes 120, 122 may be used as both feed electrodes through which the electric current is applied and as voltage measurement electrodes. A switching mechanism may be applied which switches the function of the electrodes 120, 122 between the current feed and the voltage measurement. The switching mechanism may perform time-multiplexing and connect the electrodes either to the current generator 202 or the voltage measurement circuitry, under the control of the processor 204 and depending on the desired function of the electrodes 120, 122.

15 [0019] In a further embodiment, one or more of the electrodes 120 and 122 are further configured to measure the ECG. In such a case, the switching mechanism may further control switching of the electrodes to a differential amplifier used as a front-end in the ECG measurements.

20 [0020] Figures 3 and 4 illustrate further measurement configurations according to other embodiments. In the embodiment of Figure 3, there are further electrodes 124, 126, 130, 132. In the configuration, electrodes 120 and 122 may be used as the current feed electrodes and the electrodes 124 and 126 may be the measurement electrodes. As illustrated in Figure 3, each electrodes is provided at a different location. The locations of the electrodes 120 to 126 may be selected such that a line drawn from the measurement electrode 124 to the measurement electrode 126 intersects with a line drawn from the feed electrode 120 to the feed electrode 122. This provides symmetry between the current feed and the voltage measurement. The electrodes 130 and 132 may be configured as ECG measurement electrodes and disposed at an arbitrary location in the garment.

25 [0021] Figure 4 illustrates an embodiment where the electrodes 124, 126, 130, 132 are replaced by electrodes 134 and 136 that are configured to function as both the voltage measurement electrodes for the bioimpedance measurements and as the ECG measurement electrodes by using the switching mechanism. In this embodiment as well, the feed electrodes and the measurement electrodes are disposed such that the above-mentioned lines will intersect.

30 [0022] In the embodiments of Figures 3 and 4, one of the feed electrodes is above the heart level while the other one of the feed electrodes is below the heart level. In a similar manner, one of the measurement electrodes is above the heart level while the other one of the measurement electrodes is below the heart level.

35 [0023] The garment may have a backside arranged to face a backside of the user and further have a front side arranged to face a front side of the user. In any one of the embodiments of Figures 1, 3, and 4, the electrode(s) 120, 124, 134 disposed above the heart level may be disposed at a neck or shoulder area of the garment on at least the backside of the garment. This improves the skin contact during a physical exercise such as running. In an embodiment, the electrode(s) above the heart level is/are elongated and extend(s) from the backside of the garment to the front side of the garment over a shoulder of the user. During the exercise, the shoulder area of the garment typically has the best skin contact, and this embodiment further improves the skin contact.

40 [0024] The electrode(s) 122, 126, 136 disposed below the heart level may be disposed in a chest area of the garment, wherein the garment is arranged to be form-fitting at the location of the second electrode. The form-fitting may be realized by the elastic material of the garment or by a strap in the garment.

45 [0025] In embodiments modified from those described above in connection with Figures 3 and 4, at least some of the electrodes may be disposed on an opposite side of the human body. For example, one or more or even all the electrodes 122, 126, 130, 132, 136 may be disposed on the back side of the body. Those electrodes disposed below the heart level may be disposed on the back side of the garment or on either side. In an embodiment, the garment comprises one or more electrodes disposed below the heart level on the back side and further electrode(s) disposed below the heart level on the front side.

50 [0026] In an embodiment, the feed electrodes may have a different shape than the measurement electrodes. For example, the measurement electrodes may be elongated while the feed electrodes may have a round or point shape. The point shape enables more accurate determination of the current path between the feed electrodes and, thus, simplifies the system configuration. Elongated measurement electrodes provide a better skin contact for the measurements and, thus, improved measurement accuracy.

55 [0027] Figure 5 illustrates a block diagram of the measurement circuitry comprising the switching mechanism 520. The switching mechanism 520 may be realized by one or more switches that perform(s) switching a function of at least one of the measurement electrodes between the ECG measurement and bioimpedance measurement. The switching mechanism 520 may comprise one or more electronic switches.

[0028] In an embodiment the switching mechanism 520 switches the function of the measurement electrodes between at least two of the following measurement modes: full ECG mode where all measurement electrodes are used to measure ECG, a full bioimpedance measurement mode where all measurement electrodes are used to measure bioimpedance,

and a hybrid measurement mode where a first subset of the measurement electrodes are used to measure ECG and a second subset of the measurement electrodes are used to measure bioimpedance. The switching mechanism may be controlled by the processor 204. The processor 204 may comprise a mode selector circuitry 504 configured to perform a process for selecting a measurement arrangement according to the flow diagram of Figure 6.

5 **[0029]** Referring to Figure 6, the mode selector circuitry 504 selects the measurement mode in block 600. The selection may be made based on a measurement profile acquired on the basis of a user input, for example. Upon selecting the full ECG mode in block 600, the process may proceed to block 604 where the mode selector configures the switching mechanism 520 to couple all the electrodes 120 to 132 to inputs of an ECG measurement circuitry 502. The ECG measurement circuitry 502 may comprise a plurality of differential amplifiers, and each pair of electrodes 120 to 132
10 may be connected to inputs of one of the differential amplifier. For example, the switching mechanism 520 may couple the electrodes 120 and 122 to different inputs of one of the differential amplifiers, the electrodes 124 and 126 to different inputs of another one of the differential amplifiers, and the electrodes 130 and 132 to different inputs of yet another one of the differential amplifiers. In this manner, the switching mechanism may realize a multi-channel ECG measurement arrangement where two or more pairs of electrodes are connected to the ECG measurement circuitry 502. The mode selector 504 may further activate the ECG measurement circuitry 502 to start the multi-channel ECG measurements. The ECG measurement circuitry 502 may combine the ECG measurement signals received through the different measurement channels. Full ECG mode may be used when only the heart rate or heart activity is monitored, e.g. during a physical exercise.

20 **[0030]** Upon selecting the full bioimpedance mode in block 600, the process may proceed to block 602 where the mode selector 504 configures the switching mechanism 520 to couple all the electrodes 120 to 132 for bioimpedance measurements. In the full bioimpedance mode, the switching mechanism 520 may couple at least one pair of the electrodes for current feed and at least one pair of electrodes for voltage measurement. In an embodiment, the current feed electrodes may be coupled to a current generator 202 configured to feed constant current. In an embodiment, the voltage measurement electrodes are coupled to a voltmeter 500 configured to measure voltage between the voltage measurement
25 electrodes while the current generator feeds the current.

[0031] In the embodiment using four electrodes, e.g. electrodes 120 to 126, electrodes 120 and 122 may be coupled to the current generator 202 for current feed and electrodes 124, 126 to the voltmeter 500, as described above in connection with Figure 3. In the embodiment using six electrodes, e.g. electrodes 120 to 132, a measurement channels may be realized by coupling one or more of the electrodes 130, 132 also to the voltmeter 500. For example, a further
30 voltage measurement may be realized between electrodes 124 and 132 and/or 124 and 130.

[0032] In the embodiment using only two electrodes, the switching mechanism may be configured to alternately switch the electrodes to the current generator 202 and to the voltmeter 500 with a determined frequency. In this manner, only two electrodes may be used when measuring the bioimpedance. The voltmeter may be configured to measure a voltage sample while the electrodes are coupled to the voltmeter and not take samples while the electrodes are coupled to the
35 current generator.

[0033] The full bioimpedance mode may be used when measuring body composition, for example. In the full bioimpedance mode, the current generator may be configured to output current one at least two frequencies, either simultaneously or in a time-multiplexed manner.

40 **[0034]** Upon selecting the hybrid mode in block 600, the process may proceed to block 606 where the mode selector 504 configures the switching mechanism 520 to couple a subset of the electrodes for the bioimpedance measurements and another subset of electrodes for the ECG measurements. This mode may be employed when measuring the stroke volume and heart rate during a physical exercise or when measuring the body composition and the heart rate simultaneously, for example.

45 **[0035]** In the hybrid mode, the switching mechanism may couple at least two electrodes to the ECG measurement circuitry 502, at least two electrodes to the current generator 202, and at least two electrodes to the voltmeter 500. In the embodiment of Figure 3 using six electrodes, each electrode may be configured to a specific function in a fixed manner in the hybrid mode. For example, the electrodes 120, 122 may be coupled to the current generator 202, electrodes 124, 126 to the voltmeter 500, and electrodes 130, 132 to the ECG measurement circuitry 502.

50 **[0036]** In the embodiment using a reduced set of electrodes, e.g. four electrodes as in Figure 4, the switching mechanism 520 may be configured to alternately switch the electrodes to the ECG measurement circuitry 502 and to the voltmeter 500 with a determined frequency. The voltmeter may be configured to measure a voltage sample while the electrodes are coupled to the voltmeter and not take samples while the electrodes are coupled to the ECG measurement circuitry. The ECG measurement circuitry 502 may be configured to measure an ECG sample while the electrodes are coupled to the ECG measurement circuitry and not take samples while the electrodes are coupled to the voltmeter.

55 **[0037]** In the embodiments using the alternating switching, the switching frequency may be higher than 60 Hertz (Hz).

[0038] When computing the stroke volume from the bioimpedance, the ECG measurement signal may be used for acquiring a time reference for the stroke volume measurement. Figure 7 illustrates an embodiment for acquiring a bioimpedance sample set for the stroke volume estimation by the processor(s) 204. Referring to Figure 7, the process

comprises measuring the ECG signal and the bioimpedance in a synchronous manner (block 700). The processor may maintain a time reference common to both measurements. When performing the switching between the ECG and voltage measurements, the switching frequency may be sufficiently high such that satisfactory synchronization accuracy is maintained.

5 **[0039]** The processor may monitor for a signature in the ECG signal. R peak is a typical strong signature point which may be monitored. Figure 8 illustrates a bioimpedance signal and, below that, an ECG signal. The R peaks are circled in the ECG signal. Upon detecting the signature in the ECG signal in block 702, the processor may trigger a start of a new bioimpedance sample set in block 704 (circles in the bioimpedance signal in Figure 8). In this manner, the process of Figure 7 may generate multiple sets of bioimpedance samples, e.g. for the stroke volume measurement. The process of Figure 7 also synchronizes the stroke volume estimation with the cardiac cycle of the user.

10 **[0040]** In an embodiment, the processor performs averaging over the bioimpedance sample sets. The averaging may be smoothing where the samples having the same index in the respective sample set are averaged. Referring to Figure 8 illustrating multiple sample sets of the bioimpedance samples, the averaging will result in an average bioimpedance sample set computed from the multiple sample sets of the bioimpedance samples. As Figure 8 illustrates, the bioimpedance may be volatile, and the smoothing may improve the accuracy of the stroke volume estimation.

15 **[0041]** In an embodiment, the processor may further estimate respiratory rate from the signature. The respiratory rate may be computed from a phase of the ECG signal, for example. In another embodiment, the respiratory rate is computed by measuring R-R intervals of the ECG signal. The respiratory rate may be detected from the R-R intervals by using the knowledge that the R-R interval is shorter when the user inhales than when the user exhales. By monitoring this periodicity in the R-R intervals, the respiratory rate may be computed. The processor may compute the respiratory rate by using the measured bioimpedance instead of, or in addition to, the ECG. In an embodiment, the processor(s) 204 may perform motion compensation for the bioimpedance measurements. The garment may comprise one or more motion sensors integrated therein. In an embodiment, the motion sensors are integrated at a locations of the measurement electrodes, e.g. electrodes configured to measure the voltage, for example. In another embodiment, the motion sensor(s) is/are

25 comprised in the same casing as the measurement circuitry. **[0042]** The motion sensor(s) may be configured to measure motion of the garment at the location(s) of the measurement electrodes, and the measurement circuitry may be configured to perform motion compensation for the measured bioimpedance on the basis of the measured motion. Figure 9 illustrates an embodiment for performing the motion compensation by the measurement circuitry 114.

30 **[0043]** Referring to Figure 9, the processor(s) may acquire motion measurement data from the motion sensor(s) in block 900. The processor may be configured to attempt detection of a cadence in the motion measurement data. Upon detecting the cadence in block 902, the processor may trigger a motion compensation algorithm to start motion compensation.

35 **[0044]** In an embodiment, the cadence is detected by computing a Fourier transform of the motion measurement data and performing peak detection for the transformed data. If a frequency component above a determine threshold has been detected, the processor may determine that cadence has been detected in block 902.

40 **[0045]** In an embodiment, the motion compensation in block 904 comprises adjustment of averaging window used in the above-described smoothing (block 906). The length of the averaging window, i.e. the number of sample sets to be included in the smoothing, may be determined on the basis of the cadence, for example. For a higher cadence, a larger window may be selected. Instead of cadence, another criterion may be used, e.g. training intensity acquired from a measured heart rate. For a higher intensity, a larger window may be selected. In another embodiment, the size of the window is also or alternatively dependent on an estimate of a signal-to-noise ratio of the bioimpedance measurement signal.

45 **[0046]** In an embodiment, the motion compensation in block 904 comprises an interference rejection algorithm (block 908). The interference rejection may attempt to detect a signal component having a frequency of the determined cadence and to remove the signal component from the bioimpedance measurement signal.

50 **[0047]** In yet another embodiment, the motion compensation may include using auxiliary data. For example, when performing stroke volume measurements and detecting cadence, poor signal-to-noise ratio, or another indicator for a need of motion compensation, the processor may use auxiliary data in the stroke volume estimation. For example, the processor may store a mapping table mapping a training intensities or heart rates to stroke volumes. Upon detecting the need for motion compensation, the processor may compute the stroke volume at least partially on the basis of the mapping table. In an embodiment, upon detecting cadence above a determined threshold or a signal quality below another determined threshold, the processor may use only the mapping table for the stroke volume estimation.

55 **[0048]** Let us now describe some embodiments regarding implementation of the electrodes and electronics in the garment.

[0049] In an embodiment, the material of the electrodes is thermoplastic polyurethane (TPU). Properties of TPU include elasticity, transparency, and resistance to oil, grease and abrasion which make them suitable for use in garments. Another option for the electrode material is silver.

[0050] In an embodiment, the electrodes are manufactured into the garment through a laminating or a printing process. Through printing, the electrodes may be arranged to form an arbitrary pattern in the garment. Figure 10 illustrates the process in terms of intermediate products of the electrode during the process. First, a textile layer 1000 is provided wherein the textile layer is the garment or a part of the garment. A heat transfer substrate 1002 is then formed on the textile at an intended location of the electrode and the signal line connecting the electrode to the measurement circuitry. Thereafter, an EMI shield 1004 may be disposed on the substrate. The EMI shield may be realized by a conductive ink printed on the substrate. The EMI shield 1004 may cover the intended locations of the electrode and the signal line, thus protecting them both. Then, a further substrate layer 1006 may be formed on the EMI shield to isolate the EMI shield from the electrode and the signal line. On the further substrate layer 1006, conductive ink 1008 may be disposed to form the signal lines and the electric connection between the signal line and the electrode. Thereafter, a heat transfer coverlay 1010 may be disposed on edges of the electrode location and, further, on the signal line to cover the signal line. This layer isolates the signal line and the conductive ink from the user's skin. Thereafter, the heat transfer coverlay may be covered with a heat transfer film comprising one or more through holes to enable electric coupling to the conductive ink 1008. On top of the heat transfer film, the electrode layer 1012 is formed from conductive thermoplastic, for example. The hole(s) in the heat transfer film at the location of the electrode enable the electric coupling between the electrode layer and the conductive ink 1008.

[0051] In an embodiment, the electrodes are arranged to have a layered structure. Figure 11 illustrates such an embodiment. In the embodiment of Figure 11, a first layer 1100 arranged to contact the skin is a conductive layer made of the TPU, for example. This may form the electrode layer. The next layer may comprise the heat transfer film with the hole(s) and the coverlay 1102 isolating the first layer 1100 from the exterior, e.g. the garment's textile, and yet providing the electric coupling for the electrode layer. The layer 1102 may comprise the one or more holes for the electric coupling between the electrode and the signal line. The signal line is illustrated by numeral 1114 in Figure 11. The first layer 1100 may contact a contact point 1104 such as a contact plate through the hole(s) in the layer 1102, and the signal line (e.g. 116 or 118) may be brought to the contact point 1104. Another TPU layer 1108 may be disposed on the heat transfer overlay layer. The TPU layer 1108 may be isolated from the contact point by an isolation member 1106. Then, a heat transfer film 1110 or the substrate layer 1002 may be provided as a coupling member to the garment 1112. The heat transfer film may act as glue and penetrate the textile material of the garment, thus fixing the other layers to the garment.

[0052] In another embodiment illustrated in Figure 12, an electromagnetic interference (EMI) shield layer 1200 (1004 in Figure 10) may be provided inside the TPU layer 1108 or between the TPU layer 1108 and the heat transfer coverlay 1102, for example. The EMI shield layer may be isolated from the contact point 1104, as in the embodiment of Figure 10.

[0053] The signal line 116 or 118 may be sewn in the textile or provided on top of the textile. The signal lines may be formed of a conductive yarn. In an embodiment, EMI shielding is provided for the signal lines 116, 118 of the apparatus. The EMI shielding according to these embodiments may be suitable for any signal lines that conduct electric signals and are susceptible to the EMI. The signal line may comprise an electric conductor that may be formed by an electrically conductive thread or threading in an article of clothing, an apparel or a garment. The electric conductor may be isolated by an isolation layer protecting the electric conductor and isolating the electric conductor. On top of the electric conductor, the EMI shielding may be provided by arranging a conductive threading to cover the electric conductor. The conductive threading may be arranged on top of the electric conductor by stitching or sewing the conductive threading with a sewing machine. The conductive threading may be formed by using zigzag stitching such that the zigzag pattern covers the signal line without penetrating the isolation layer. The conductive threading may be sewn through a substrate in which the signal line is provided, e.g. a textile or a garment. When used in an application where the substrate is in contact with the user's skin, the conductive threading thus engages the user's skin and operates as a skin electrode for grounding the EMI.

[0054] In another embodiment, the shielding may be realized by using a coaxial yarn which is basically a yarn having a structure of a coaxial cable. An inner signal line may be surrounded by an isolation layer and a grounding protective layer. The coaxial signal line may be so thin that it can be sewn. The coaxial signal line may comprise two signal lines: one connected to the contact point 1104 and the other to the ground, e.g. the EMI shield 1200. In this manner, shielding for the signal line may be realized.

[0055] In yet another embodiment where two or more signal lines are drawn from one location to another, e.g. in the embodiment where the motion sensor is employed at the location of the electrode where the signal lines are drawn from the electrode to the location of the measurement circuitry, the signal lines may be twisted with respect to each other. Accordingly, a twisted pair signal line is formed which provides protection against EMI.

[0056] In an embodiment, the signal lines may be covered by a silicone or another protective material.

[0057] In an embodiment, the EMI shielding of the signal lines may be provided a conductive paste coating the signal lines.

[0058] In an embodiment, a casing housing the electronics including the measurement circuitry 114 is detachable from the garment. The casing may be waterproof and attached mechanically to the garment by using snap fastening, for example. The snap fastening may also align the casing with respect to the garment such that the signal lines in the

garment will couple with the corresponding interfaces in the casing. Figure 13 illustrates an example of such an embodiment.

[0059] Referring to Figure 13, the measurement circuitry may comprise a housing 1322 integrated or attached to the garment 1112, e.g. in a fixed or permanent manner. The housing may function as a positioning member for the casing 1320 housing the measurement circuitry. The housing 1322 may comprise a first set of signal connectors 1300, 1302 that connect to the electrodes in the garment, e.g. the ECG electrodes and bioimpedance electrodes. The housing 1322 may comprise a second set of signal connectors 1304, 1306 configured to provide connection with respect connectors in the casing 1320. The connectors 1304, 1306 may be exposed when the module 1320 is detached from the housing 1322. The connectors 1300, 1302 maybe covered, e.g. in the housing, and connecting in the housing to the respective signal lines 1114 leading to the respective electrodes. Internal wiring may be disposed in the housing 1322 to connect the connectors of the first set 1300, 1302 to the appropriate connectors of the second set 1304, 1306, as illustrated in the bottom of Figure 13.

[0060] The casing 1320 may comprise the set of connectors 1310, 1312 that are disposed such that the connectors connect to the appropriate connectors of the second set 1304, 1306 when the casing 1320 is attached to the housing. Internal wiring may be provided in the module to connect the connectors to respective components of the measurement circuitry, e.g. to the differential amplifier 502, voltmeter 500, and/or the current generator 202.

[0061] In an embodiment, the housing comprises a hole at the location where the casing is to be attached. Figure 14 illustrates such an embodiment. The hole 1400 is illustrated in the housing, and, in the corresponding location in the casing 1402, a sensor head 1410 is disposed. A sensor may be provided on a surface of the casing in the sensor head 1410 designed to enter the hole 1400 and contact the skin. The sensor head 1410 may comprise a photo sensor, a photoplethysmogram (PPG) sensor, ECG sensor and/or a temperature sensor. In such embodiment, the sensor head 1410 in the casing may replace one or more of the above-described electrodes, depending on the location of the casing 1402 in the garment. For example, if the location is above the heart level, the sensor head may replace one or more of the sensors 120, 124 and 134. If the location is below the heart level, the sensor head may replace one or more of the sensors 122, 126, 136. The sensor head may replace the ECG sensors 130, 132. The switching mechanism 520 may nevertheless work in the above-described manner.

[0062] Any one of the above-described measurement configurations may be used in the following embodiments for monitoring a physical exercise performed by the user 100. Figure 15 illustrates a process for providing training guidance in connection with the physical exercise. The process may be executed by a training computer. Referring to Figure 15, the process comprising: measuring (block 300), by using a heart activity sensor, heart activity of a user during the physical exercise; measuring (block 300), by using a bioimpedance measurement sensor, bioimpedance of the user during the physical exercise; computing (block 302), by a processing circuitry, a stroke volume from the bioimpedance synchronized to a cardiac cycle of the user by using the measured heart activity; computing (block 304), by the processing circuitry, training intensity for the physical exercise or a part of the physical exercise by using at least the computed the stroke volume; and comparing (block 306 and 308), by the processing circuitry, the training intensity with at least one threshold and outputting (block 310) at least one training guidance instruction on the basis of the comparison.

[0063] Computation of the training intensity by using the stroke volume provides several advantages over conventional techniques that determine the training intensity from the heart rate. The heart rate does not yield the whole picture of cardiac output and user's effort level. This may lead for example to inaccurate training load or energy expenditure estimation. A typical example where the heart rate is a sub-optimal measure is high intensity interval training (HIIT) or strength training. After finishing a high-intensity work period, the heart rate drops relatively fast. This results in estimation of a mild training effect for the exercise although the user's muscles become exhausted. Stroke volume behaves differently and provides better correlation with tissue saturation index than the heart rate. The tissue saturation index is a measure of oxygenated haemoglobin in the blood and may be considered to represent true training intensity. The stroke volume may also increase after the heart rate has reached its maximum. It means that the estimation of the training intensity by using the stroke volume enables quantification of the training intensity when the heart rate has saturated. Accordingly, computation of the training intensity by using the stroke volume provides better accuracy in the estimation of the training intensity during and/or after the exercise.

[0064] In an embodiment, the training intensity is computed from the stroke volume.

[0065] In an embodiment, the processing circuitry computes heart rate from the measured heart activity, and computes the training intensity from cardiac output (CO) defined by a product of the computed stroke volume (SV) and the heart rate (HR) as:

$$CO(n) = SV(n) \times HR(n)$$

where n represents a time/sample index. As described above, the bioimpedance and the heart activity may be computed

synchronously. The CO may thus be computed from samples or sample sets having the same time index or indices.

[0066] In an embodiment, the processing circuitry computes the heart rate from the measured heart activity, and further computes the training intensity from oxygen intake (VO₂) defined by a product of the computed stroke volume, the heart rate, and a constant factor as:

$$VO_2(n) = SV(n) \times HR(n) \times avdiff$$

where *avdiff* represents arteriovenous oxygen difference. *avdiff* is an indication of how much oxygen is removed from the blood in capillaries as the blood circulates in the body. In another words, it can be defined as a net difference of oxygen content between aorta and vein in terms of litres of oxygen per litre of blood. For the processing circuitry, this factor may be considered as a constant. It may be a predefined user-specific parameter.

[0067] In an embodiment, the processing circuitry computes the heart rate from the measured heart activity, and further computes the training intensity from energy expenditure (EE) defined by a product of the computed stroke volume, the heart rate, the factor *avdiff*, and a predetermined user-related parameter as:

$$EE(n) = SV(n) \times HR(n) \times avdiff \times oec$$

where *oec* is an oxygen-to-energy coefficient that represents the user's ability to convert oxygen into energy, e.g. 5 kilocalories per litre of oxygen. EE may be a momentary energy expenditure at timing *n*.

[0068] Any one or a combination of the above-described training intensity measures may be used in block 304. All of them are training intensity metrics based on the stroke volume.

[0069] In an embodiment, the processing circuitry may utilize training intensity zones that are mapped to different training intensity ranges by using the stroke volume as a factor for the training intensity. In this embodiment, the processing circuitry may determine a plurality of training intensity zones on the basis of the stroke volume, wherein ranges of each training intensity zone is mapped to a unique range of stroke volume values. Thereafter, the processing circuitry may perform said comparison in blocks 306 and 308 by comparing the training intensity with at least one training intensity zone. In this embodiment, the at least one threshold may comprise at least one limit of the at least one training intensity zone.

[0070] The training intensity zones may be created for any one of the above-described training intensity measures, e.g. the SV, CO, VO₂ or EE. All of them are based on the stroke volume and, thus represent the training intensity and training effect better than heart rate zones, for example. Another feature that distinguishes the stroke-volume-based training intensity zones from the heart rate zones, for example, is that the processing circuitry may indicate the zones to the user by using a different factor than that on which the zones are based, e.g. the stroke volume. The zone ranges may be mapped to the values of SV, CO, VO₂, or EE but the training intensity zones may be indicated to the user by using verbal definitions or by percentages from the maximum value, as illustrated in the middle column of Figure 4. Stroke volume or cardiac output values as such may not be illustrative to an average user and, therefore, use of more illustrative zone definitions serves the purpose of improved training guidance.

[0071] The heart rate may be a sub-optimal metric for measuring the training intensity and training load of a strength training or HIIT exercise. In a typical HIIT exercise which is an example of interval training, the user performs with high training intensity during work periods and rests or performs with mild training intensity during the rest periods. A general tendency with the TSI is that the TSI drops dramatically shortly after the start of the high-intensity work period and slowly recovers during the rest period. This indicates that the user works out in an anaerobic zone during the work period, which is typical for the HIIT exercise. The heart rate increases during the work period but falls quite quickly during the rest period, depending on the user's heart rate recovery capability. However, the stroke volume rises during the work periods and remains high during the work period. Eventually, the SV starts to drop but at a much slower pace than the heart rate, for example.

[0072] HIIT is an efficient exercise to maximize time at maximal SV. The SV has been shown to remain high during rest periods or even surpass SV values measured during the work periods, while VO₂ as well as HR decrease quite rapidly during the rest periods. Reducing the training intensity of the rest periods or even resting during the rest periods of the HIIT exercise may therefore prolong the time to exhaustion. It may also allow the accumulation of more time on high-intensity zones, prolong accumulated time spent at maximal SV, maximal CO, maximal VO₂, and/or maximal EE and lead to improved training benefit.

[0073] In an embodiment, the processing circuitry determines the training guidance such that the SV values are maximized. The processing circuitry may instruct the user to perform to maintain the SV above a determined threshold level. In an embodiment, upon detecting that the SV drops below a determined level, the processing circuitry may instruct

the user to increase the training intensity. Figure illustrates an embodiment where the processing circuitry adapts the work periods of the interval exercise to the observations of the measured stroke volume. In this embodiment, the at least one threshold comprises a threshold for triggering the next work interval after a rest period of the physical exercise.

[0074] Referring to Figure 16, the processing circuitry may trigger the start of the rest period in block 950. The trigger may be the end of the previous work period, and the end may be detected on the basis of measured time of the work period or measured training intensity accumulation during the work period. During the rest period, the processing circuitry may execute block 302 and compute the SV. In block 952, the processing circuitry compares the computed stroke volume with the threshold for triggering the next work interval. Upon detecting in block 954 that the comparison indicates that the stroke volume has dropped below a determined level defined by the threshold (YES in block 954), the processing circuitry outputs the training guidance instruction that instructs the user to start the next work interval (block 956). Otherwise, the process may return to block 302 to compute the next SV value. This embodiment enables maintenance of the SV above the threshold level, thus optimizing the training effect of the interval training.

[0075] In an embodiment, the determined level defined by the threshold is a selected drop of the stroke volume from a reference stroke volume measured at the start of the recovery interval, e.g. a value between 5 and 15 percent. In other words, when the SV has dropped for an amount determined by the value from the start of the rest period, the processing circuitry may trigger the next work period in block 956.

[0076] In an embodiment, a similar approach for adapting the length of the work period is utilized by the processing circuitry and, in particular, the end of the work period. In this embodiment, the at least one threshold comprises a threshold indicating a minimum training intensity for a work period of the interval exercise. The processing circuitry accumulates time the stroke volume remains above the threshold during the work period, and outputs the training guidance instruction as an instruction to end the work period. The instruction is triggered by the processing circuitry upon detecting that the stroke volume has remained above the threshold for a determined target time interval T. Figure 17 illustrates a process according to this embodiment.

[0077] Referring to Figure 17, the processing circuitry triggers the start of the work period in the interval exercise in block 1050. The start may be triggered according to the process of Figure 16 or by using a preset timing for the duration and end of the previous rest period (block 1050). During the work period, the processing circuitry may compute the stroke volume in the above-described manner in block 302. The computed stroke volume may be compared with the threshold indicating the minimum training intensity for the work period in block 1052. If the stroke volume indicates training intensity above the threshold level, the processing circuitry may accumulate the time the training intensity is above the threshold level (not shown). In block 1054, the processing circuitry compares the accumulated time with the target time interval T. If it is determined in block 1054 that the training intensity indicated by the stroke volume has remained above the threshold level for the target time interval or above the target time interval, the process may proceed to block 1058 where the processing circuitry triggers the end of the work period, start of the subsequent rest period, and outputs an instruction for the user to end the work period. Thereafter, the processing circuitry may start monitoring for the trigger of starting the next work period in block 1060, e.g. according to the embodiment of Figure 9. Upon determining in block 1054 that the training intensity has not yet been above the threshold level long enough, the process may determine to maintain the instruction to continue the work period (block 1056) and then return to block 302.

[0078] Figure 18 illustrates an example of guidance during the exercise in the form of a curve illustrating a stroke-volume-based training intensity during the exercise. Y-axis of the graph of Figure 18 represents the stroke-volume-based training intensity such as the SV, CO, VO₂, or EE. Two thresholds are mapped to the Y-axis, TH_{work} for the accumulation of the training intensity during the work period according to the embodiment of Figure 17 and TH_{rest} for triggering the end of the rest period according to the embodiment of Figure 16. Referring to Figure 18, the start of the interval exercise may be triggered in an arbitrary manner, e.g. the user starting the exercise and providing a start input to the training computer executing processes of Figures 16 and 17. Accordingly, the first work period starts. A warm-up phase may precede the first work period but that is omitted in this description for the sake of conciseness. During the first work period, the processing circuitry executes the process of Figure 17, computes the stroke volume and compares the SV-based training intensity with the threshold TH_{work}. Whenever the training intensity is above the threshold, a time value is accumulated. When the time value reaches the target time interval T_{target}, the processing circuitry triggers the start of the rest period and starts comparing the stroke volume with the threshold TH_{rest}. When the stroke volume drops below the threshold TH_{rest}, the processing circuitry may trigger the start of the next work period. In this manner, the procedure may continue until the end of the interval exercise.

[0079] In an embodiment, the SV-based training intensity monitored in the embodiment of Figure 16 may be different from the SV-based training intensity monitored in the embodiment of Figure 17. For example, any one of the SV-based training intensities (SV, CO, VO₂, EE) may be suitable for embodiment of Figure 17 but it may be advantageous to measure only the SV in the embodiment of Figure 16. Let us remind that the HR may be sub-optimal for the adaptation of the rest period because of the characteristic of dropping quickly. Accordingly, metrics involving the HR may also be less optimal than a metric not having the HR but having the SV.

[0080] In an embodiment, the processing circuitry is configured to detect fatigue of the user from the computed stroke

volume during the work interval and to output a training guidance instruction for the user to end the interval exercise. Figure 19 illustrates an embodiment for cancelling the exercise upon detecting that the user is fatigued. The fatigue can be detected by evaluating the SV and the heart rate during the work period. Referring to Figure 19, the processing circuitry may execute blocks 1050, 302, 1052, 1054, 1056, 1058, and 1060 in the above-described manner. Upon determining in block 1054 that the work period continues, the processing circuitry may next check the user's fatigue level. The checking may comprise evaluating the development of the SV. If the processing circuitry detects that the SV has dropped for at least a determined amount during the work period, e.g. by using threshold comparison, the processing circuitry may consider this as an indicator of fatigue and, next, check the development of the user's performance (block 1250). If one or more other indicators indicate that the user is still performing with high intensity, the processing circuitry may in block 1250 determine that the user is fatigued and proceed to block 1252 where the processing circuitry ends the exercise. Block 1252 may comprise outputting an indication to the user to end the exercise. Block 1252 may comprise outputting an indication to the user that the user is possibly fatigued and should rest.

[0081] The one or more other indicators indicate that the user is still performing with high intensity may comprise heart rate or motion intensity. The motion intensity may be measured by using a motion sensor, a force sensor, a cadence sensor, or a combination of these sensors. One or more thresholds may be employed in block 1250, e.g. one for determining the sufficient drop in the SV and another for determining that the training intensity remains sufficiently high for triggering the end of the exercise.

[0082] In an embodiment, the fatigue check of block 1250 may be carried out at another instance of the process or in a process parallel with respect to the process of Figure 10 and/or Figure 9.

[0083] Figure 20 illustrates an embodiment of the training computer comprising the processing circuitry for carrying out the process of Figure 15 or any one of its embodiments in a computer-implemented process. The training computer may be a smart phone, a tablet computer, a wrist computer, or even a server computer. The training computer may comprise a measurement circuitry 10 configured to perform computation and interfacing when monitoring the physical exercise performed by the user, e.g. during or after the exercise. The measurement circuitry 10 comprises the above-described processing circuitry 14. The measurement circuitry may further comprise a sensor interface 12 configured to provide a communication connection with one or more sensors 25 internal to the training computer. For example, a wrist computer may comprise an ECG sensor or a PPG sensor for measuring the heart activity. In some embodiments, the sensor interface and the internal sensors are omitted. The measurement circuitry may further comprise a communication interface 16 providing wireless communication connection with the external sensors 28, e.g. with the measurement circuitry 114 comprised in the garment. The communication interface 16 may support Bluetooth® protocol, for example Bluetooth Low Energy or Bluetooth Smart.

[0084] The training computer may further comprise a user interface 26 comprising a display screen and input means such as buttons or a touch-sensitive display. The processing circuitry 14 may output the instructions regarding the exercise to the user interface 26.

[0085] The training computer may further comprise or have access to at least one memory 20. The memory 20 may store a computer program code 24 comprising instructions readable and executable by the processing circuitry 14 and configuring the above-described operation of the processing circuitry 14. The memory 20 may further store a configuration database 22 defining parameters for the processing circuitry, e.g. the thresholds and/or the mapping table of the embodiment of Figure 16.

[0086] Some embodiments as described herein may be carried out in the form of a computer process defined by a computer program or portions thereof. Embodiments of the methods described in connection with Figures 6, 7, 9, 15 to 17, and 19 may be carried out by executing at least one portion of a computer program 10 comprising corresponding instructions. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example, the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. The computer program medium may be a non-transitory medium. Coding of software for carrying out the embodiments as shown and described is well within the scope of a person of ordinary skill in the art.

[0087] Figure 21 illustrates yet another embodiment for implementing the electrodes and, particularly, improving electric coupling between the skin and the electrodes. The electrodes are illustrated in Figure 21 by reference numbers 124 and 127. When the garment comprising the multiple electrodes gets wet during the exercise, for example, electric coupling between the electrodes through the garment may be formed. Such a coupling may degrade the performance of the measurements. In order to isolate this form of electric coupling, the electric path between the electrodes through the garment may be isolated. Figure 21 illustrates an embodiment where the isolation is realized by isolating the electrodes from the garment by an isolation element 125, 129. The isolation element may be made of TPU, for example, or another electrically isolating material. The isolation element may be provided between the respective electrode and the garment, e.g. surrounding the respective electrode. In this manner, the electric coupling between the electrodes 124, 127 through

the garment is isolated, thus improving the measurement accuracy.

[0088] It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

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Claims

- 10 1. A garment made of flexible material, comprising:
- a first measurement electrode integrated into the garment at a first location;
 a second measurement electrode integrated into the garment at a second location different from the first location;
 and
 a measurement circuitry configured to measure bioimpedance by using the first measurement electrode and
 15 the second electrode and to transmit the measured bioimpedance, and to measure electrocardiogram by using
 at least one of the first measurement electrode and the second electrode or another electrode,
 wherein the garment is an upper body garment, wherein the first measurement electrode is disposed above a
 heart level and the second measurement electrode is disposed below the heart level.
- 20 2. The garment of claim 1, wherein the measurement circuitry is configured to trigger, upon detecting a determined
 signature in the measured electrocardiogram, a start of a new bioimpedance sample set, and to compute heart
 stroke volume from one or more bioimpedance sample sets.
- 25 3. The garment of claim 1 or 2, wherein the measurement circuitry comprises at least one switch switching a function
 of at least one of the measurement electrodes between electrocardiogram measurement and bioimpedance meas-
 urement.
- 30 4. The garment of claim 3, wherein the at least one switch switches the function of the measurement electrodes between
 at least two of the following measurement modes: full electrocardiogram mode where all measurement electrodes
 are used to measure electrocardiogram, a full bioimpedance measurement mode where all measurement electrodes
 are used to measure bioimpedance, and a hybrid measurement mode where a first subset of the measurement
 electrodes are used to measure electrocardiogram and a second subset of the measurement electrodes are used
 to measure bioimpedance.
- 35 5. The garment of any preceding claim, wherein the garment has a backside arranged to face a backside of a user
 wearing the garment and further has a front side arranged to face a front side of the user, wherein the first meas-
 urement electrode is disposed in a neck or shoulder area of the garment on at least the backside of the garment.
- 40 6. The garment of claim 5, wherein the second electrode is disposed in a chest area of the garment, wherein the
 garment is arranged to be form-fitting at the location of the second electrode.
7. The garment of claim 5 or 6, wherein the first measurement electrode is elongated and extends from the backside
 of the garment to the front side of the garment over a shoulder of the user.
- 45 8. The garment of any preceding claim, further comprising:
- a third electrode integrated into the garment at a third location;
 a fourth electrode integrated into the garment at a fourth location, wherein a line drawn from the first measurement
 electrode to the second measurement electrode intersects with a line drawn from the third electrode to the fourth
 50 electrode, and
 wherein the measurement circuitry is configured to form a current feed circuitry by using the third electrode and
 the fourth electrode, to form a voltage measurement circuitry by using the first measurement electrode and the
 second measurement electrode.
- 55 9. The garment of any preceding claim, further comprising at least one motion sensor configured to measure motion
 of the garment at the first location and/or the second location, wherein the measurement circuitry is configured to
 perform motion compensation for the measured bioimpedance on the basis of the measured motion.

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10. The garment of claim 9, wherein the measurement circuitry is configured to detect cadence from the measured motion and, upon detecting the cadence, to perform the motion compensation by adapting an averaging window of the bioimpedance measurement on the basis of the measured motion.

5 **11.** The garment of any preceding claim, wherein the measurement circuitry is comprised in a casing detachable from the garment, and wherein the garment further comprises a housing configured to receive and position the casing and to connect the measurement circuitry to the first and second measurement electrode.

10 **12.** The garment of claim 11, wherein the casing comprises a sensor head coupled to the measurement circuitry, wherein the housing comprises a hole to receive the sensor head, and wherein the sensor head arranged to contact user's skin when the casing is connected to the housing and when the garment is worn by the user.

13. The garment of claim 12, wherein the sensor head comprises at least one of the first measurement electrode and the second measurement electrode.

15 **14.** The garment of claim 12, wherein the sensor head comprises at least one of a photoplethysmogram sensor head and a temperature sensor head.

20 **15.** The garment of any preceding claim, wherein the garment is a shirt, a vest, or a harness.

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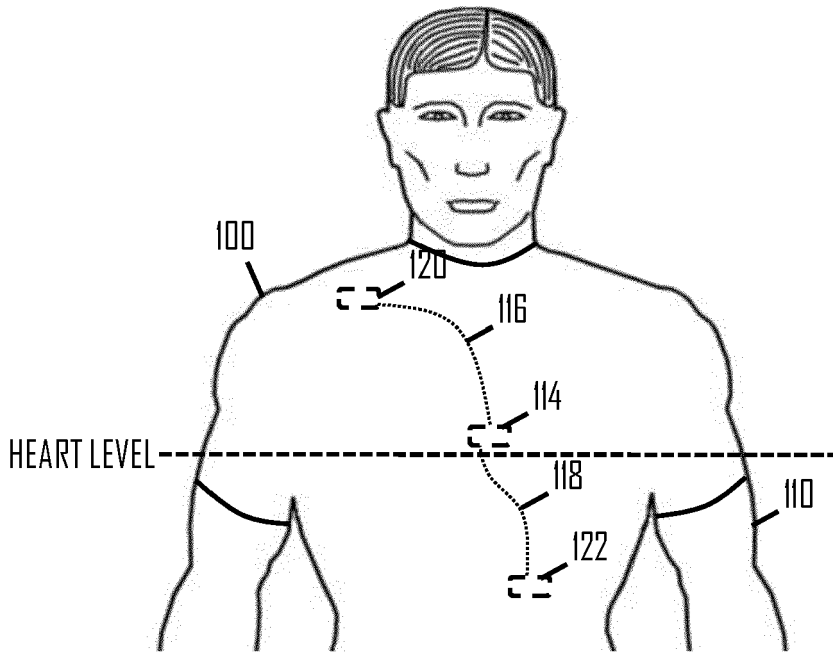


Fig 1

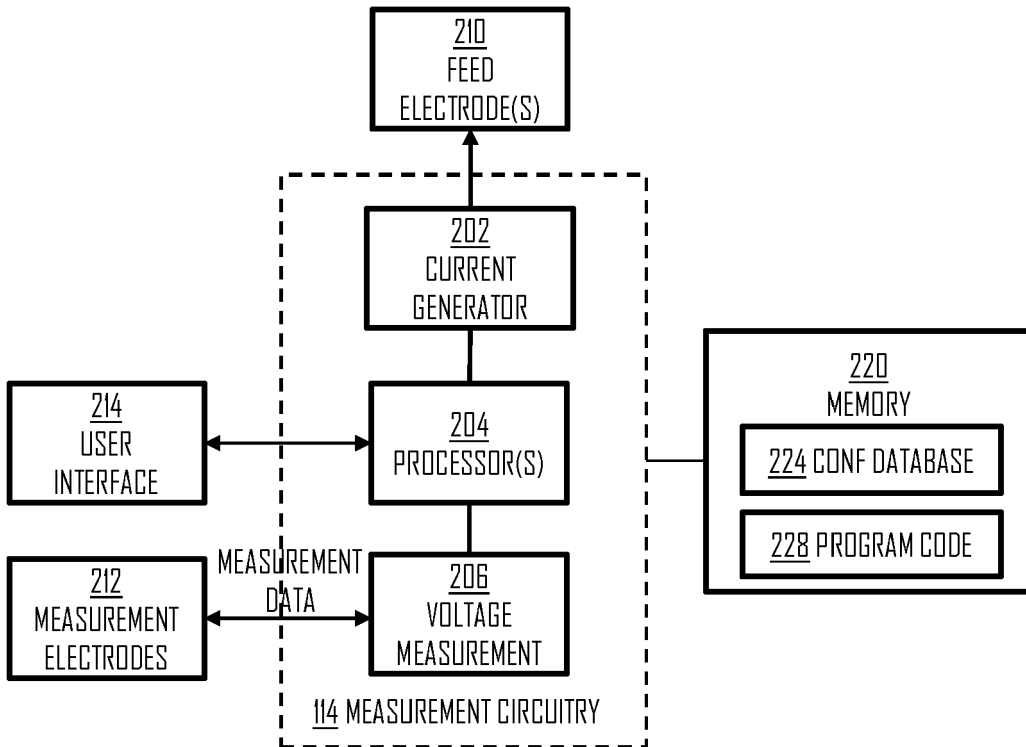


Fig 2

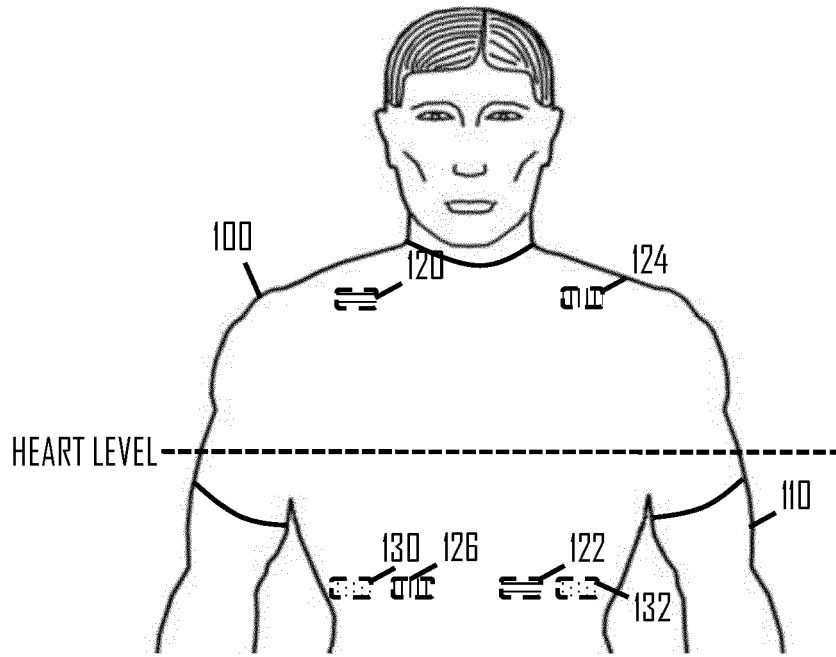


Fig 3

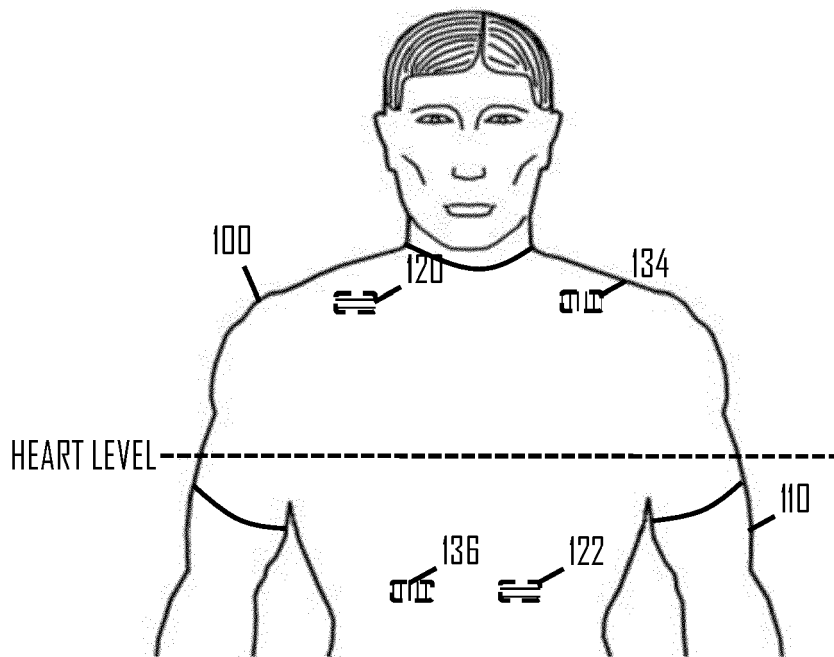
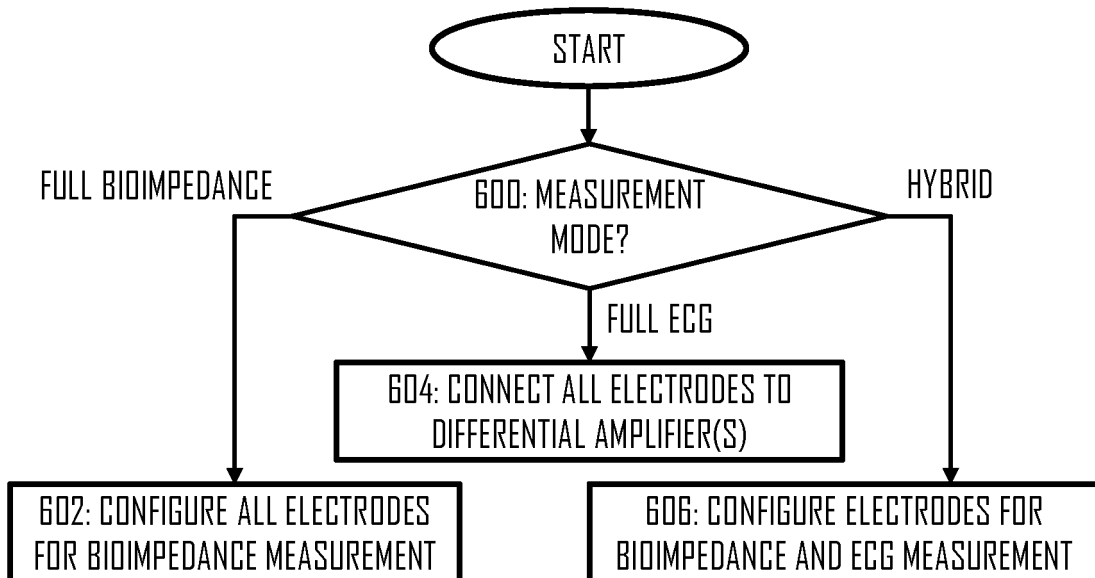
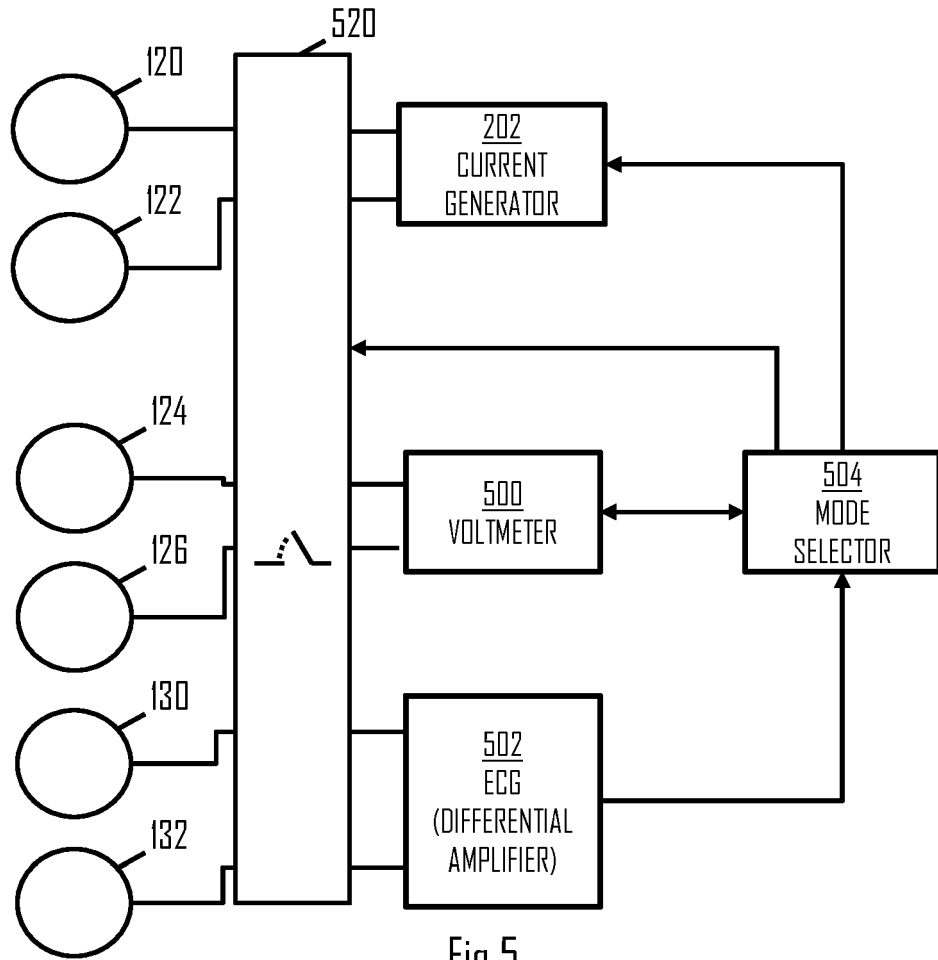


Fig 4



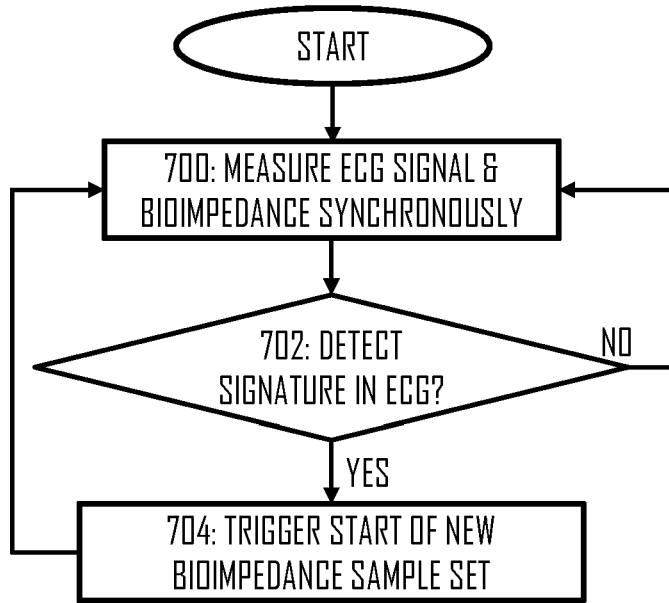


Fig 7

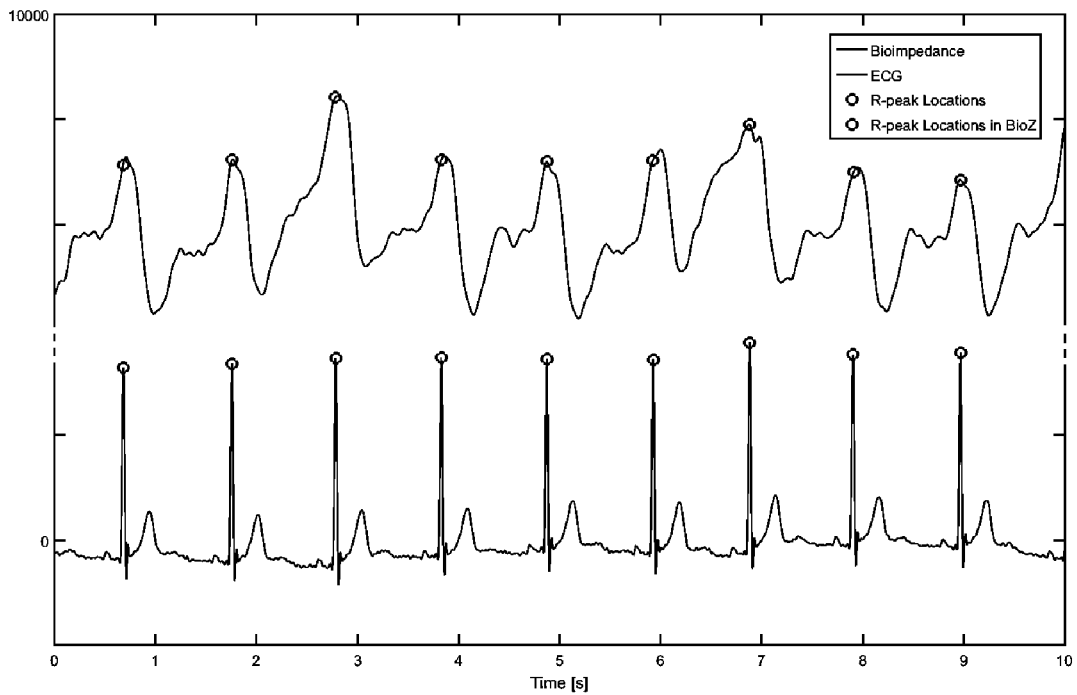


Fig 8

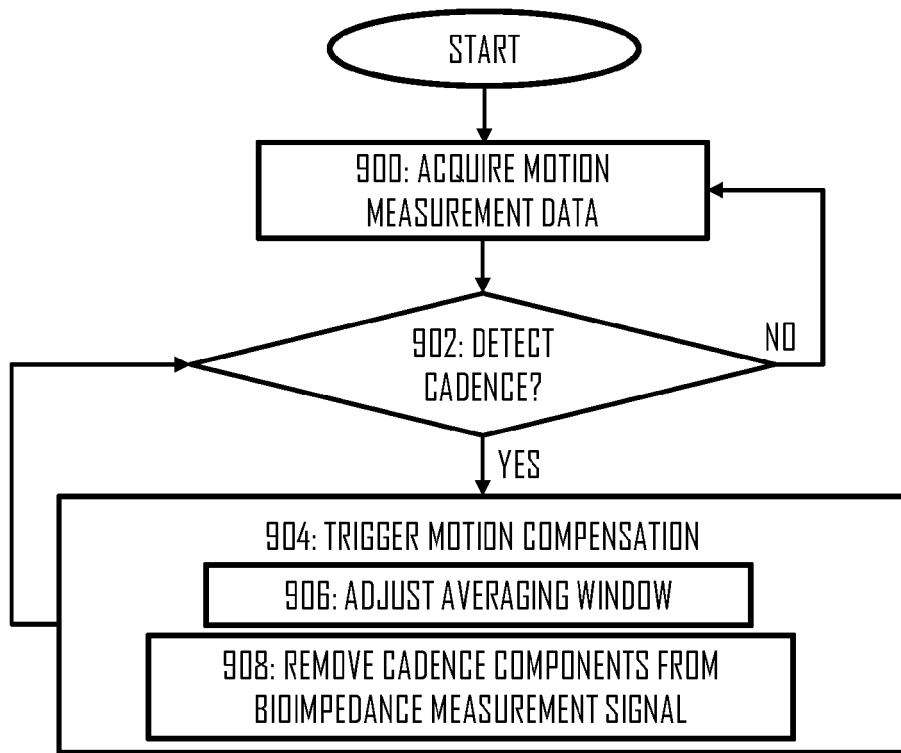


Fig 9

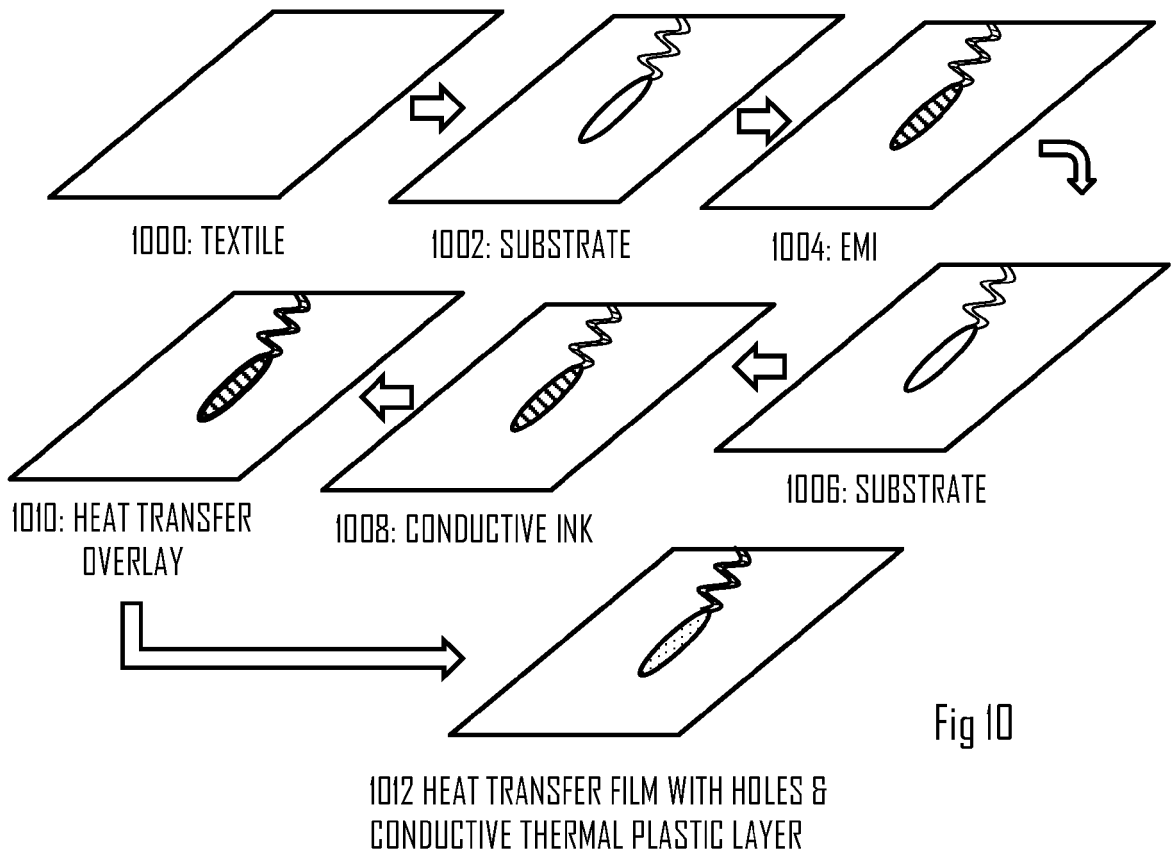


Fig 10

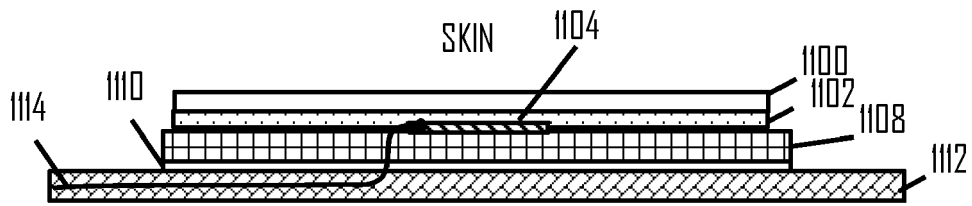


Fig 11

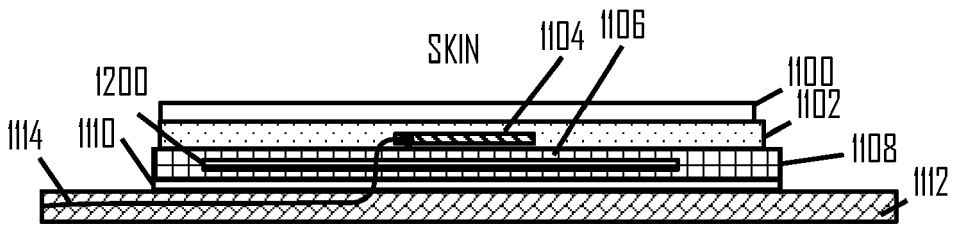


Fig 12

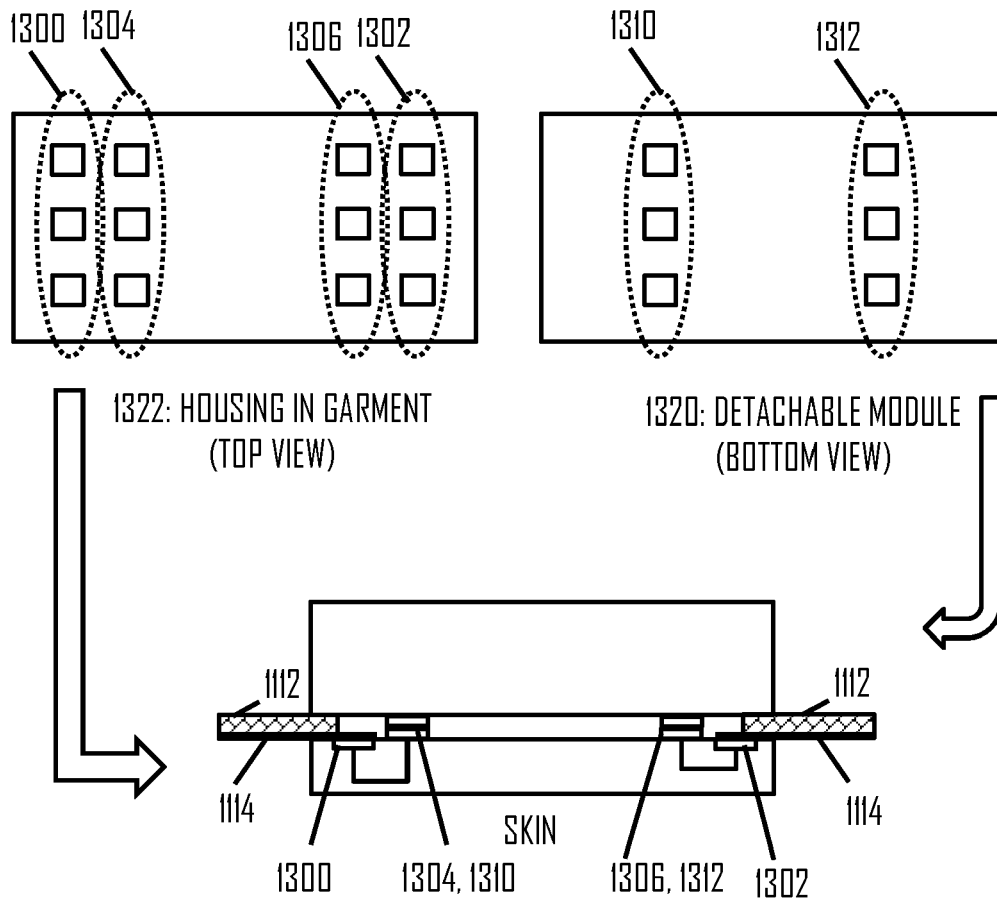


Fig 13

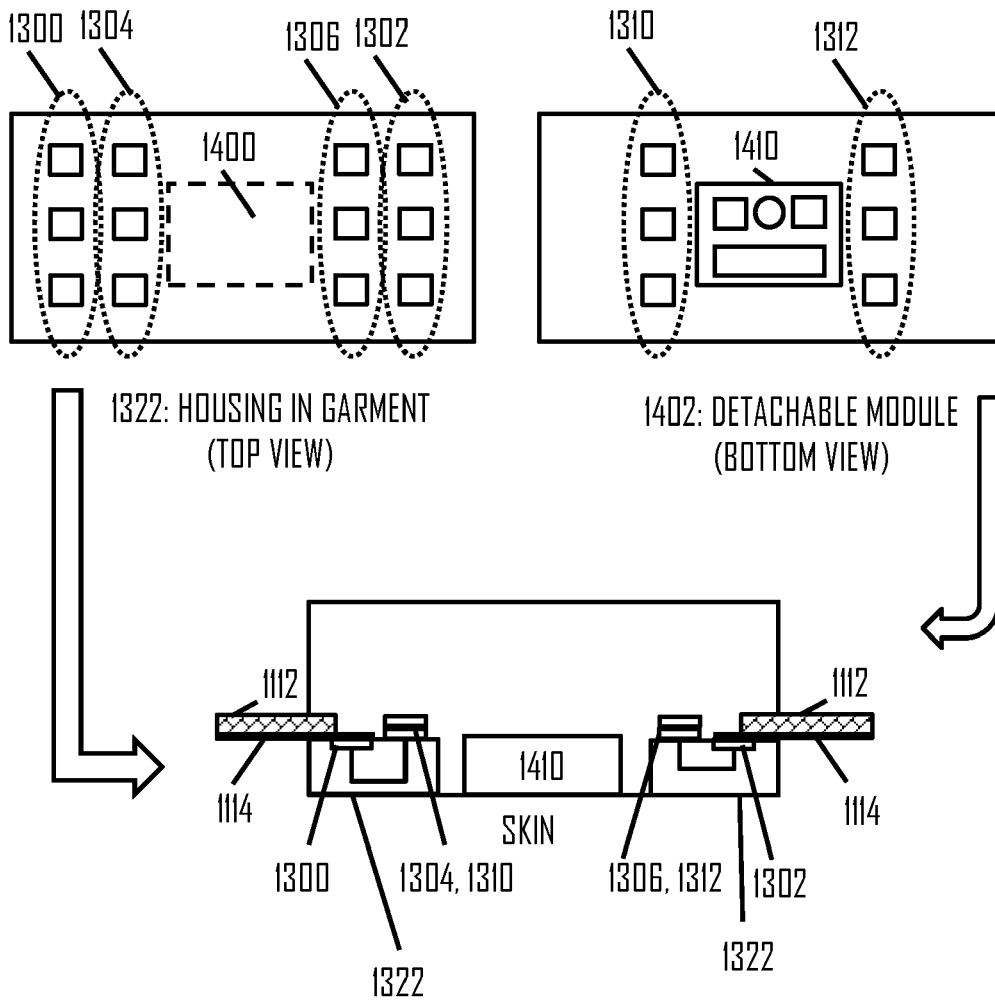


Fig 14

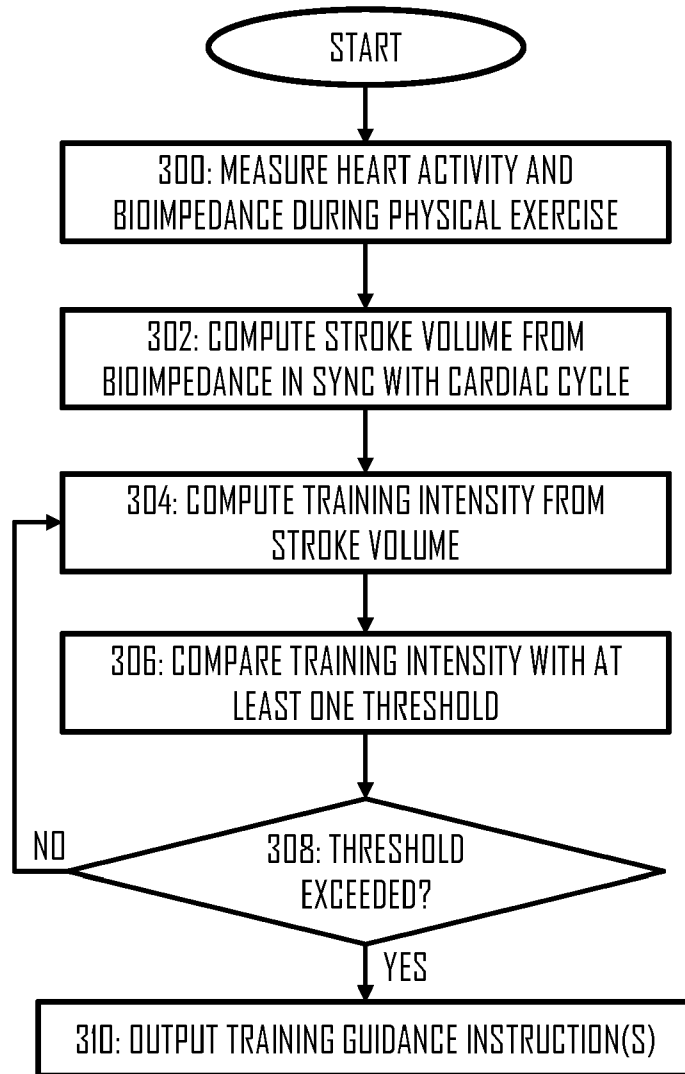


Fig 15

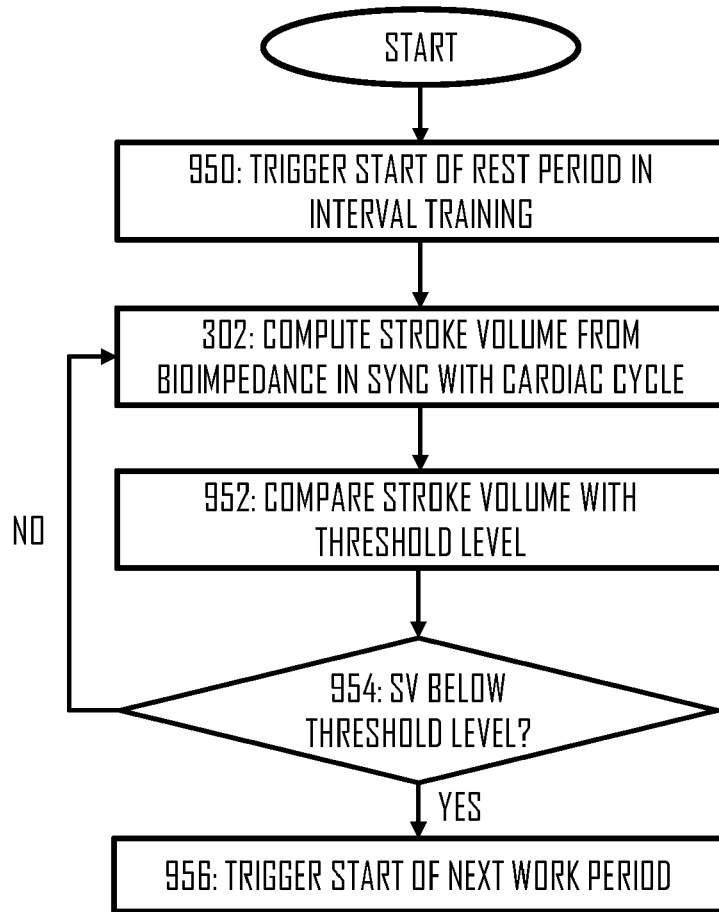


Fig 16

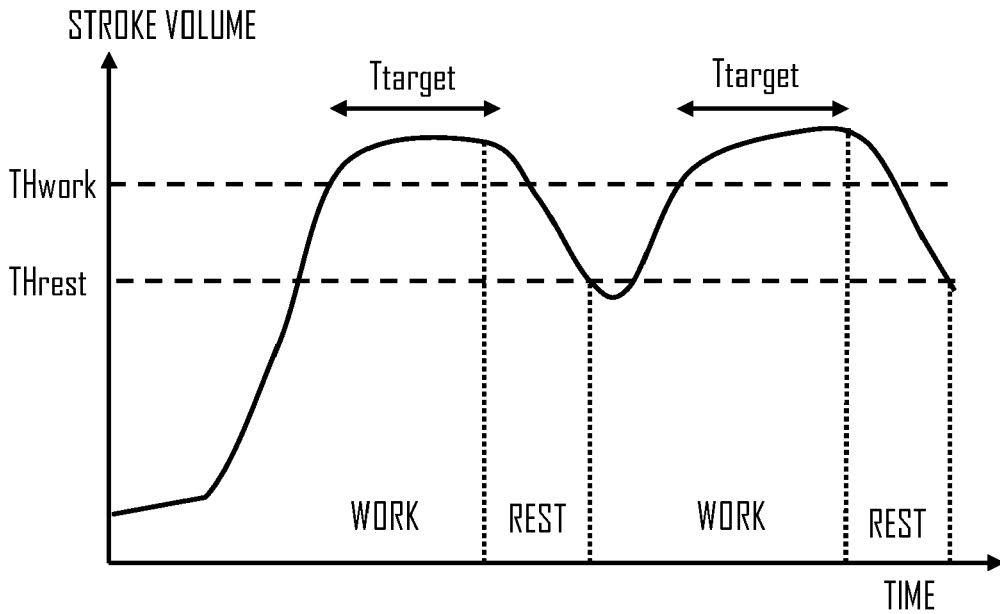


Fig 18

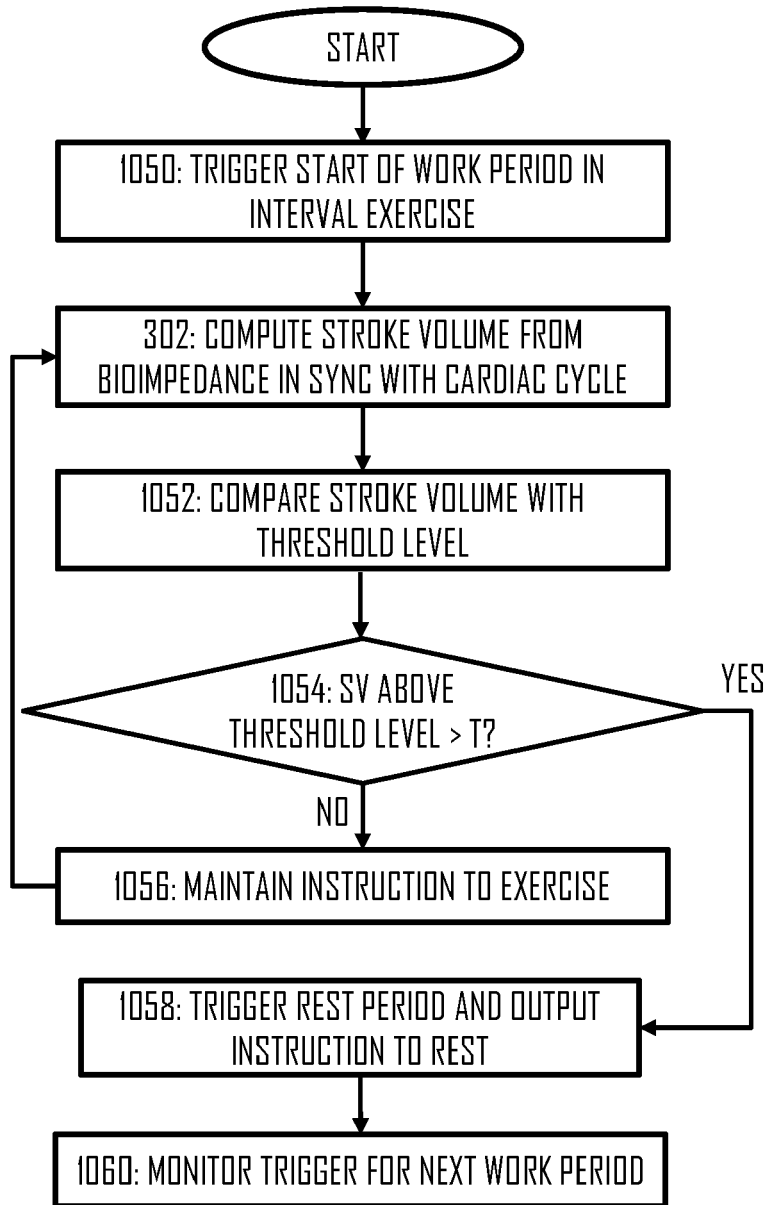


Fig 17

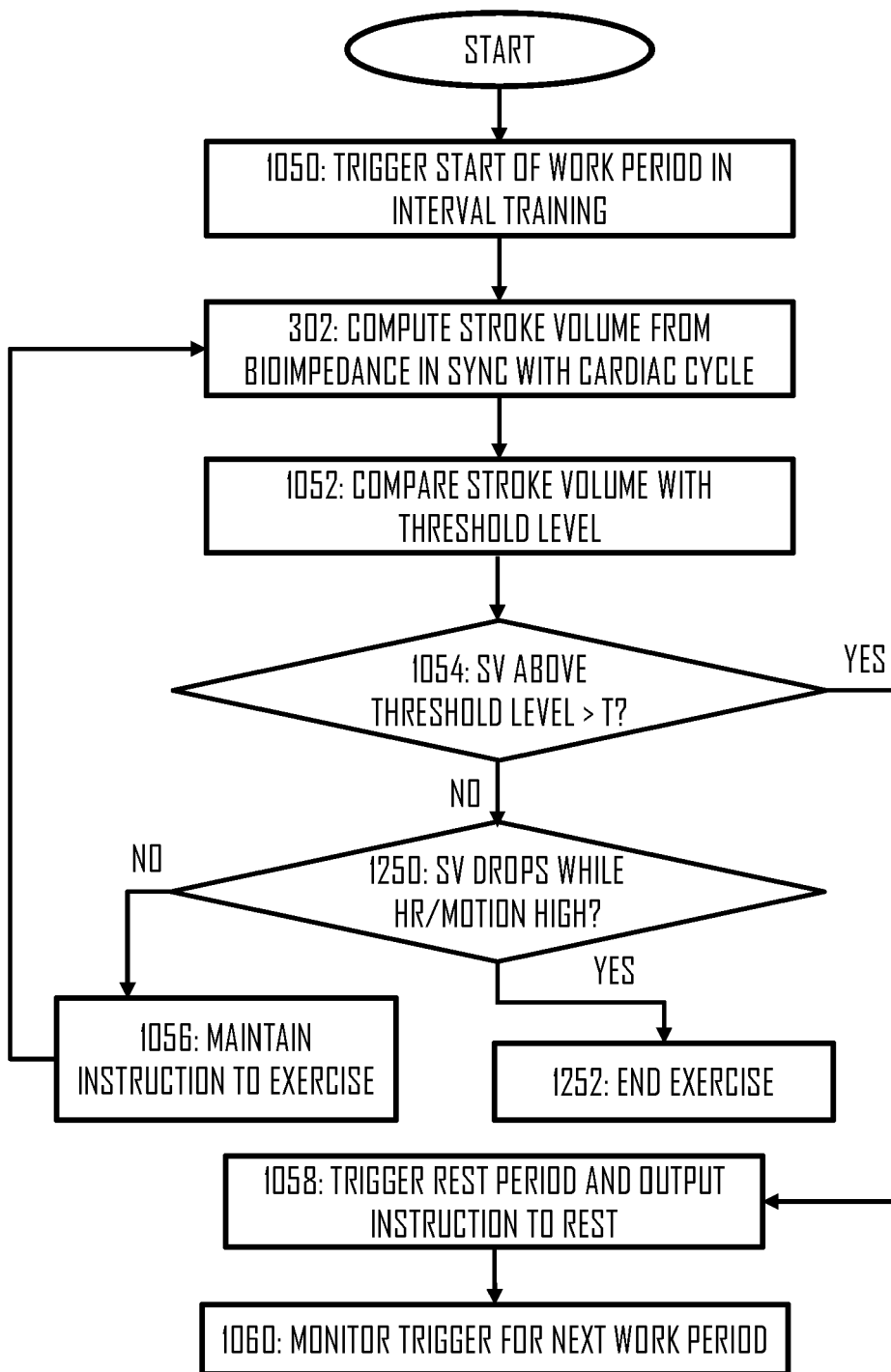


Fig 19

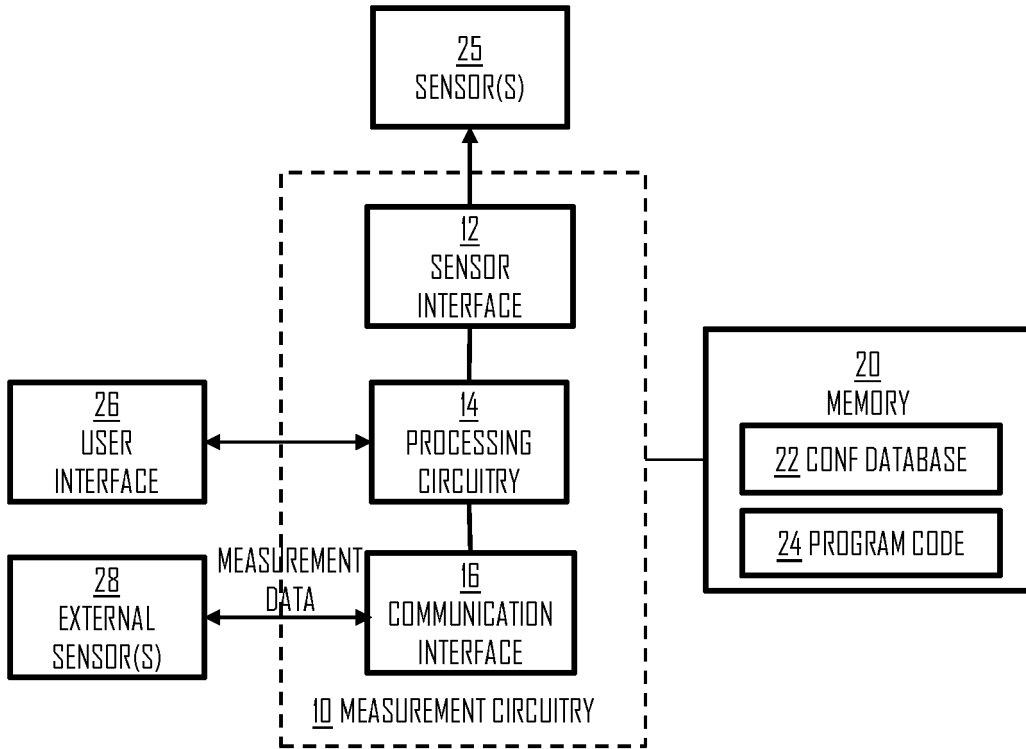


Fig 20

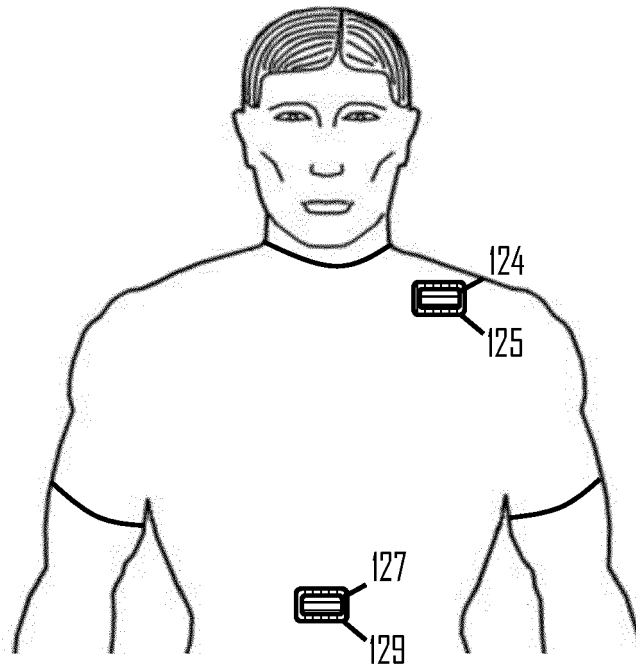


Fig 21



EUROPEAN SEARCH REPORT

Application Number
EP 18 17 6972

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	MARK ULBRICH ET AL: "The IMPACT shirt: textile integrated and portable impedance cardiography", PHYSIOLOGICAL MEASUREMENT, INSTITUTE OF PHYSICS PUBLISHING, BRISTOL, GB, vol. 35, no. 6, 20 May 2014 (2014-05-20), pages 1181-1196, XP020264705, ISSN: 0967-3334, DOI: 10.1088/0967-3334/35/6/1181 [retrieved on 2014-05-20]	1-4, 8-11,15	INV. A61B5/0205 A61B5/024 A61B5/0245 A61B5/029 A61B5/053 A61B5/11 A61B5/22 A61B5/00
Y	* section 2.1 * * section 3.2.1 * * section 3.2.2 * * equation (1) * * figures 2, 5 *	5-7, 12-14	
Y	----- US 2008/287770 A1 (KURZWEIL RAYMOND C [US] ET AL) 20 November 2008 (2008-11-20)	5-7	
A	* paragraph [0015] * * paragraph [0051] * * paragraph [0067] * * paragraph [0074] * * figures 1, 2 *	8-11,14, 15	TECHNICAL FIELDS SEARCHED (IPC) A61B A63B
Y	----- US 2015/366504 A1 (CONNOR ROBERT A [US]) 24 December 2015 (2015-12-24) * paragraph [0183] * * paragraph [0231] * * paragraph [0498] *	12-14	
X	----- WO 2006/009627 A2 (BERNSTEIN DONALD P M D [US]) 26 January 2006 (2006-01-26) * paragraph [0015] * * paragraph [0020] * * figure 1 *	1-4,8	
	----- -/--		
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 3 October 2018	Examiner Gooding Arango, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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EUROPEAN SEARCH REPORT

Application Number
EP 18 17 6972

5

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15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2018/055228 A1 (NOKIA TECHNOLOGIES OY [FI]) 29 March 2018 (2018-03-29) * abstract *	2	
A	US 2014/288436 A1 (VENKATRAMAN SUBRAMANIAM [US] ET AL) 25 September 2014 (2014-09-25) * paragraph [0131] * * paragraph [0154] * * paragraph [0164] *	9,10	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
Place of search The Hague		Date of completion of the search 3 October 2018	Examiner Gooding Arango, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

1
EPO FORM 1503 03.02 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 18 17 6972

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

03-10-2018

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008287770 A1	20-11-2008	US 2008287770 A1 US 2014031705 A1	20-11-2008 30-01-2014
US 2015366504 A1	24-12-2015	NONE	
WO 2006009627 A2	26-01-2006	US 2005283088 A1 WO 2006009627 A2	22-12-2005 26-01-2006
WO 2018055228 A1	29-03-2018	NONE	
US 2014288436 A1	25-09-2014	US 2014275854 A1 US 2014276119 A1 US 2014288436 A1 US 2014288438 A1 US 2015196256 A1 US 2017027523 A1	18-09-2014 18-09-2014 25-09-2014 25-09-2014 16-07-2015 02-02-2017

15

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45

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20020193689 A [0017]

专利名称(译)	bioimpedanzmesskonfiguration		
公开(公告)号	EP3581100A1	公开(公告)日	2019-12-18
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申请(专利权)人(译)	Polar Electro Oy公司		
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CPC分类号	A61B5/0205 A61B5/02438 A61B5/0245 A61B5/029 A61B5/053 A61B5/0535 A61B5/0537 A61B5/1112 A61B5/1118 A61B5/1123 A61B5/222 A61B5/486 A61B5/4875 A61B5/6805 A61B5/681 A61B5/6822 A61B5/6823 A61B5/7285 A61B5/746 A61B2503/10 A61B2505/09 A61B5/0408 A61B5/6804 A61B5 /6831 A61B5/742 A61B2562/0219		
代理机构(译)	KOLSTER OY AB		
外部链接	Espacenet		

摘要(译)

本文件公开了一种由柔性材料制成的服装，包括：第一测量电极，该第一测量电极在第一位置处集成到服装中；以及第二测量电极。第二测量电极在不同于第一位置的第二个位置处集成到衣服中；以及测量电路，其被配置为通过使用第一测量电极和第二电极来测量生物阻抗并传输所测量的生物阻抗，并且通过使用第一测量电极和第二电极中的至少一个或另一个电极来测量心电图，其中，服装是一种上衣，其中第一测量电极设置在心脏水平上方，第二测量电极设置在心脏水平下方。

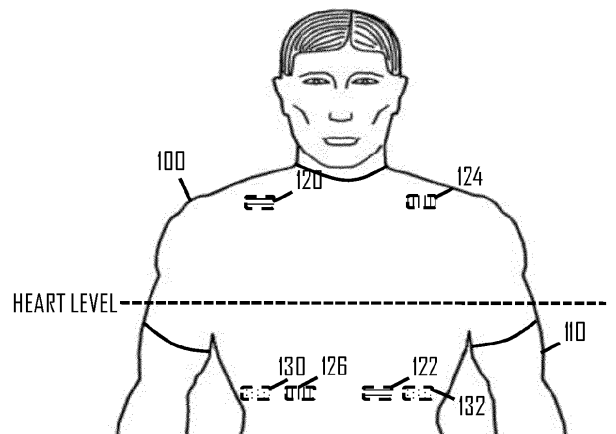


Fig 3