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Other: **WPI, EPODOC, INTERNET, XPESP, XSPRNG**

(54) Title of the Invention: **Biosensing textile and garment**
Abstract Title: **Biosensing textile used in clothing**

(57) The textile includes a distributed sensing system. The sensing system comprises a controller in communication with and controlling sensor electrodes on the textile. The sensor electrodes are formed of two-dimensional (2D) electrically conductive material, preferably graphene. Graphene forming the electrodes and electrical conductors is preferably printed or transferred onto the cloth. Alternatively, the conductor comprises conductive fibres or yarns forming the fabric. The preferred system includes a rechargeable battery, energy harvesting device, communicator operable over a 4G or 5G wireless cellular network. The textile is formed into a garment, especially shirt, t-shirt, blouse, dress, brassiere, shorts, trousers, vest, jacket, coat, glove, armband, underwear, headband, hat, cap, collar, waistband, stocking, sock, show, swimwear, wetsuit, drysuit or athletic clothing.

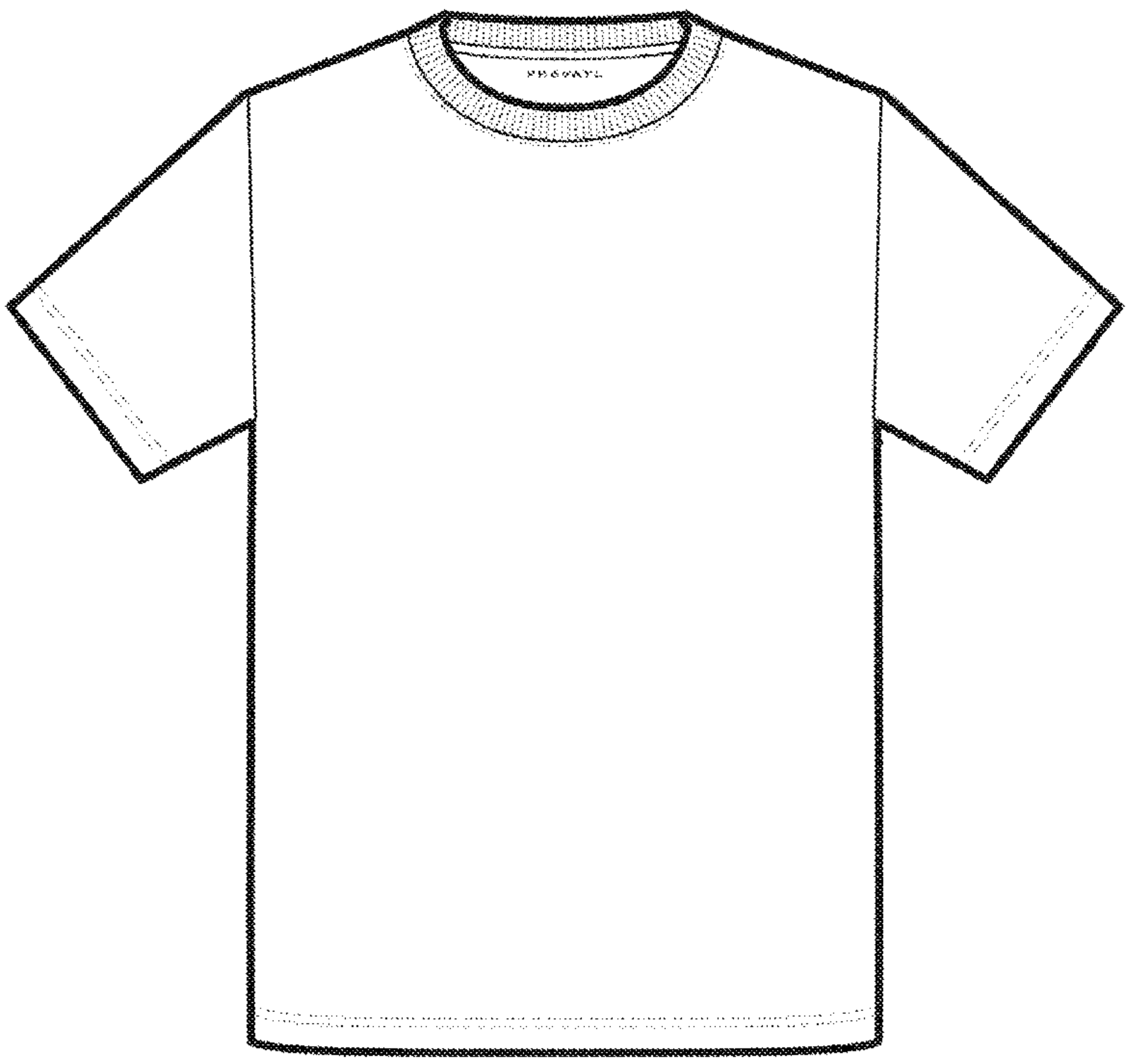

Fig. 9 20

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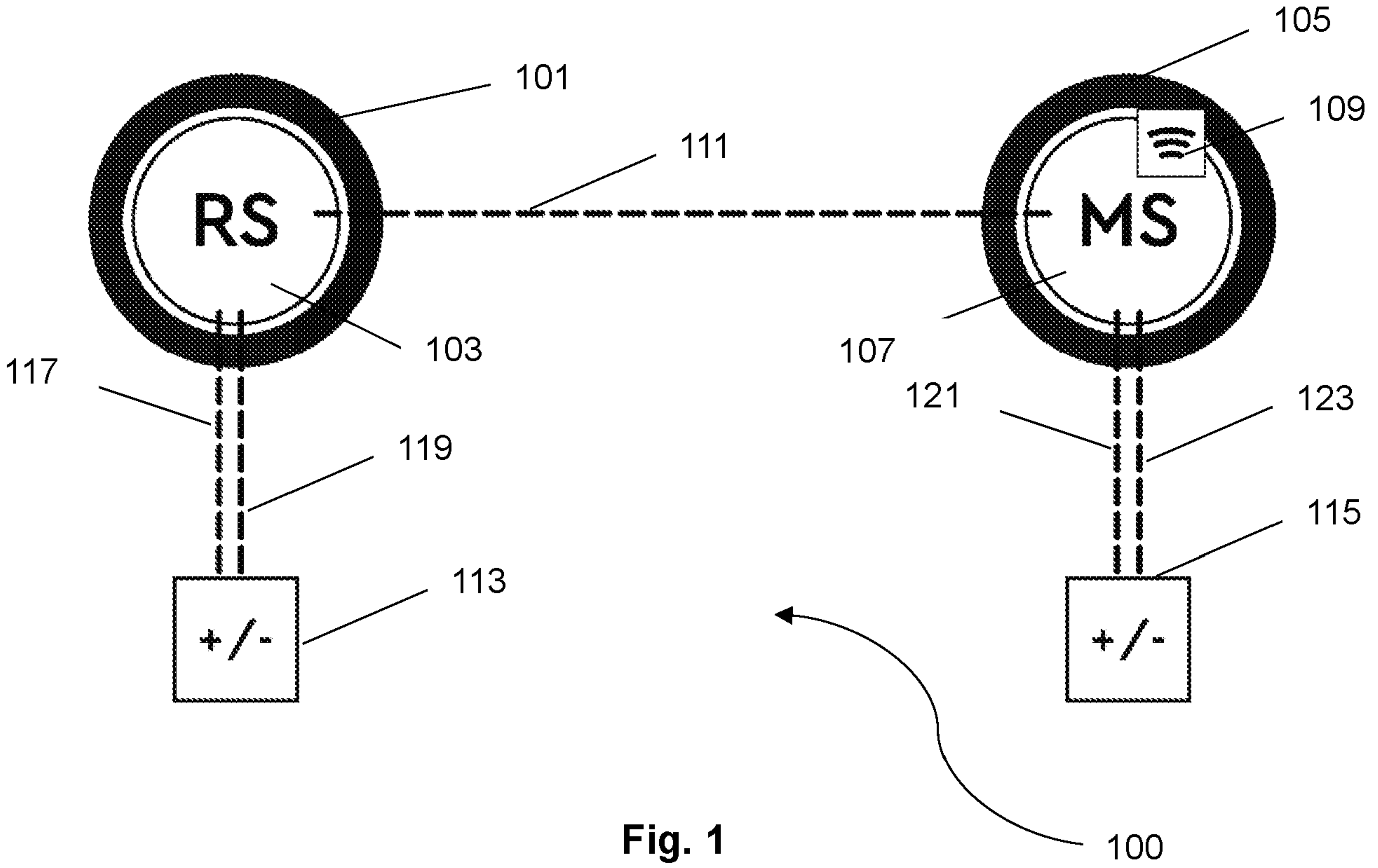
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Fig. 1

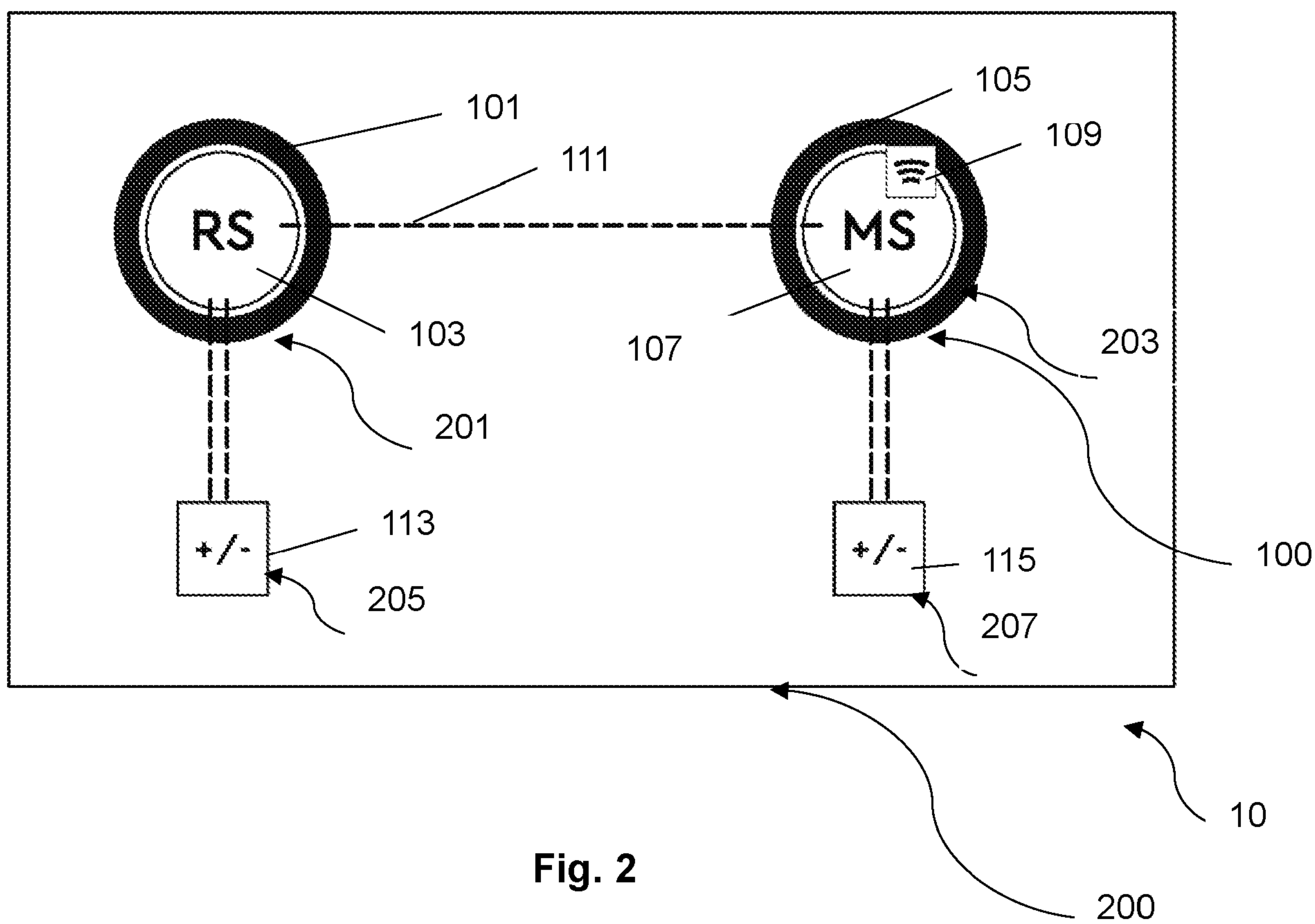
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Fig. 2

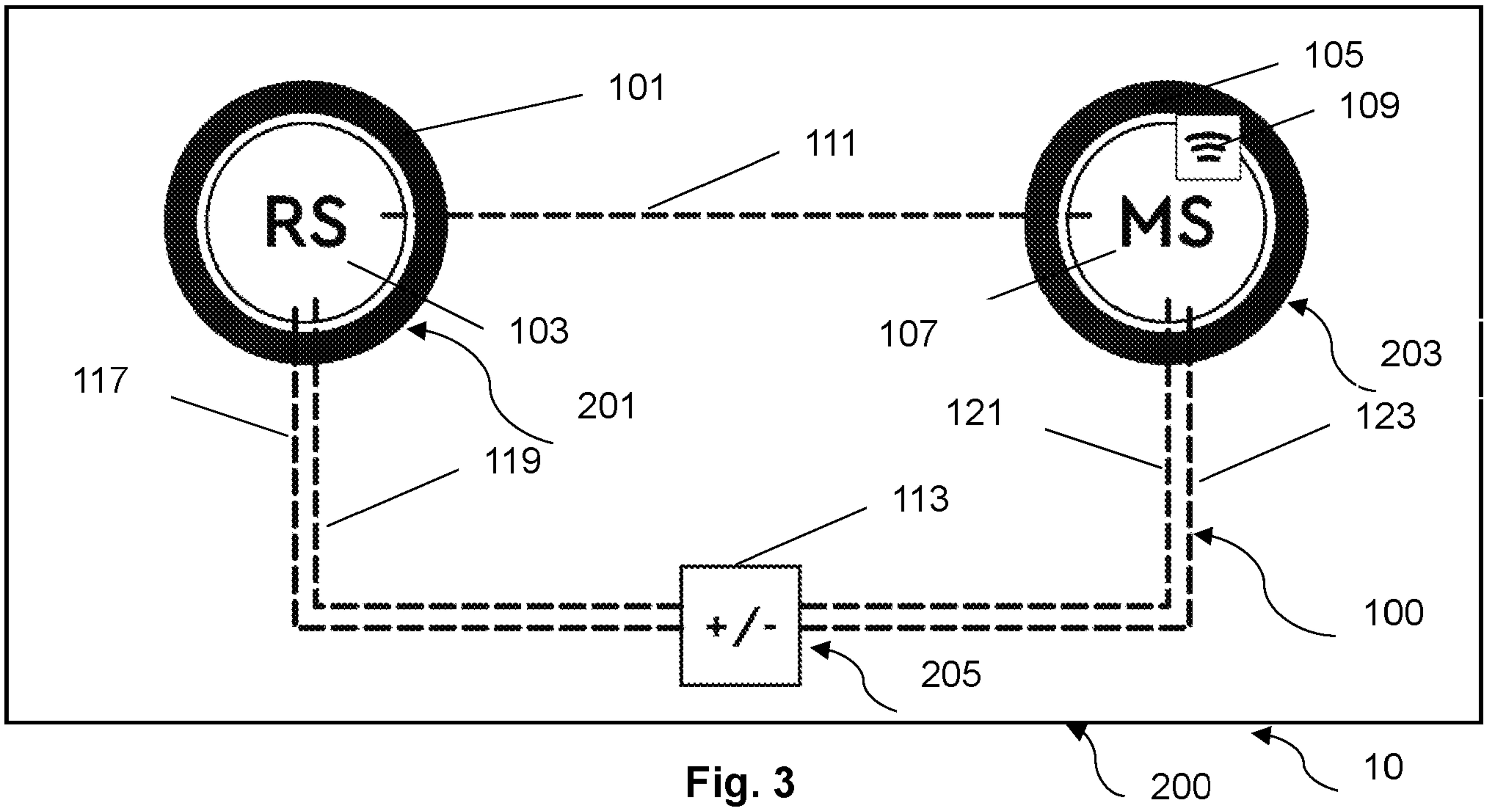

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Fig. 3

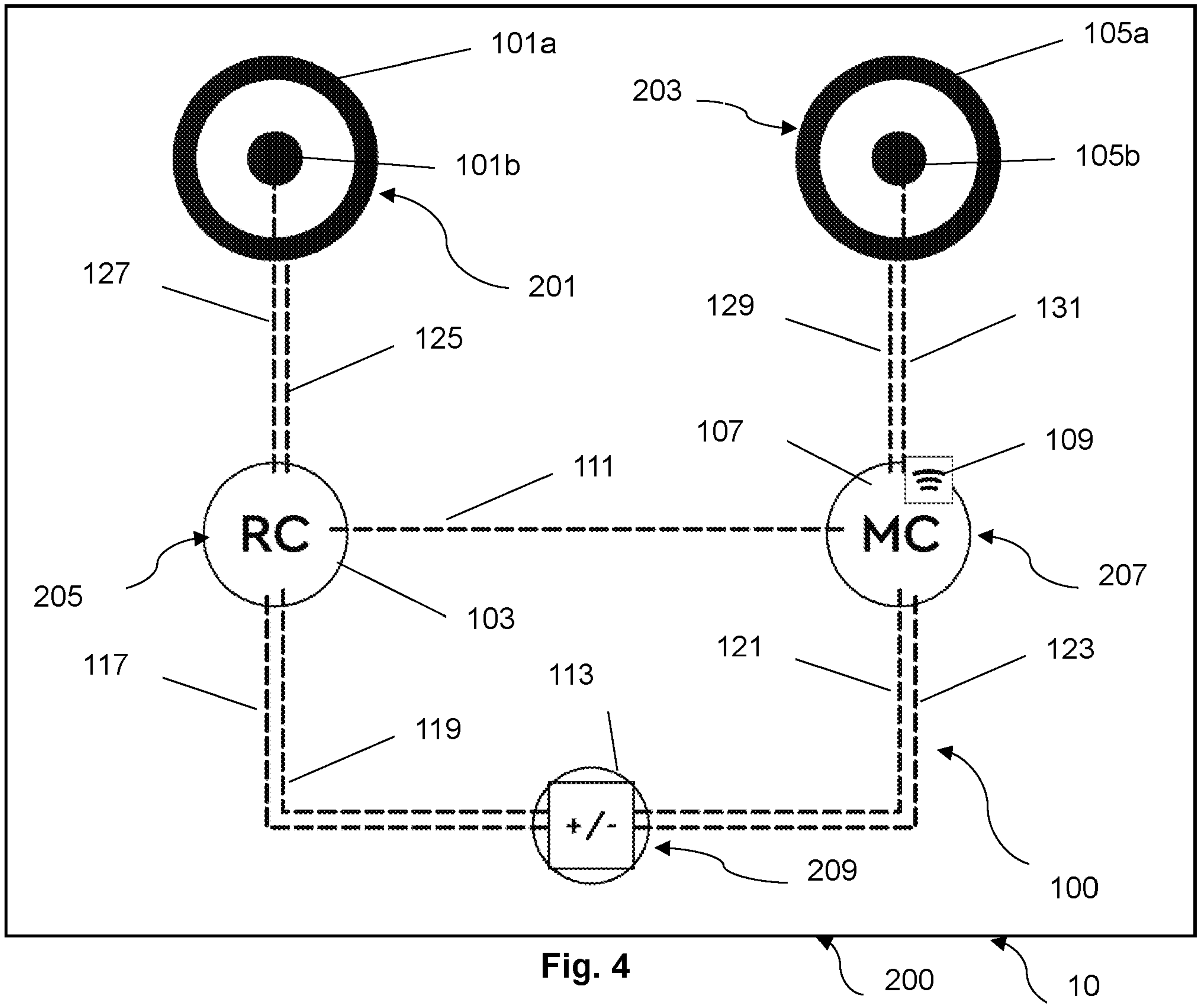

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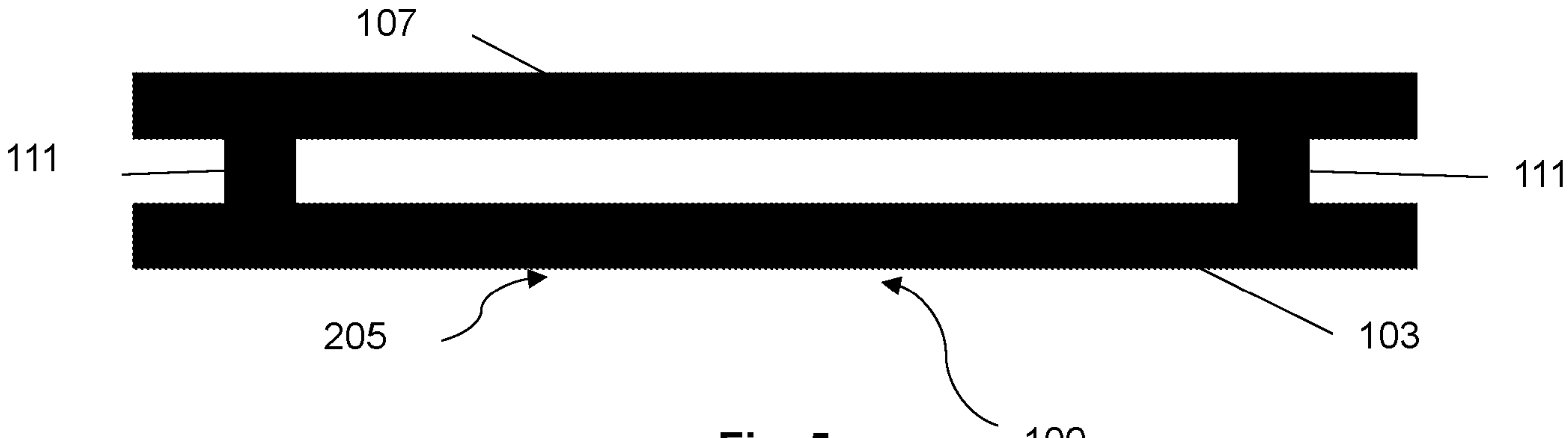
Fig. 4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111
111
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103

Fig. 5

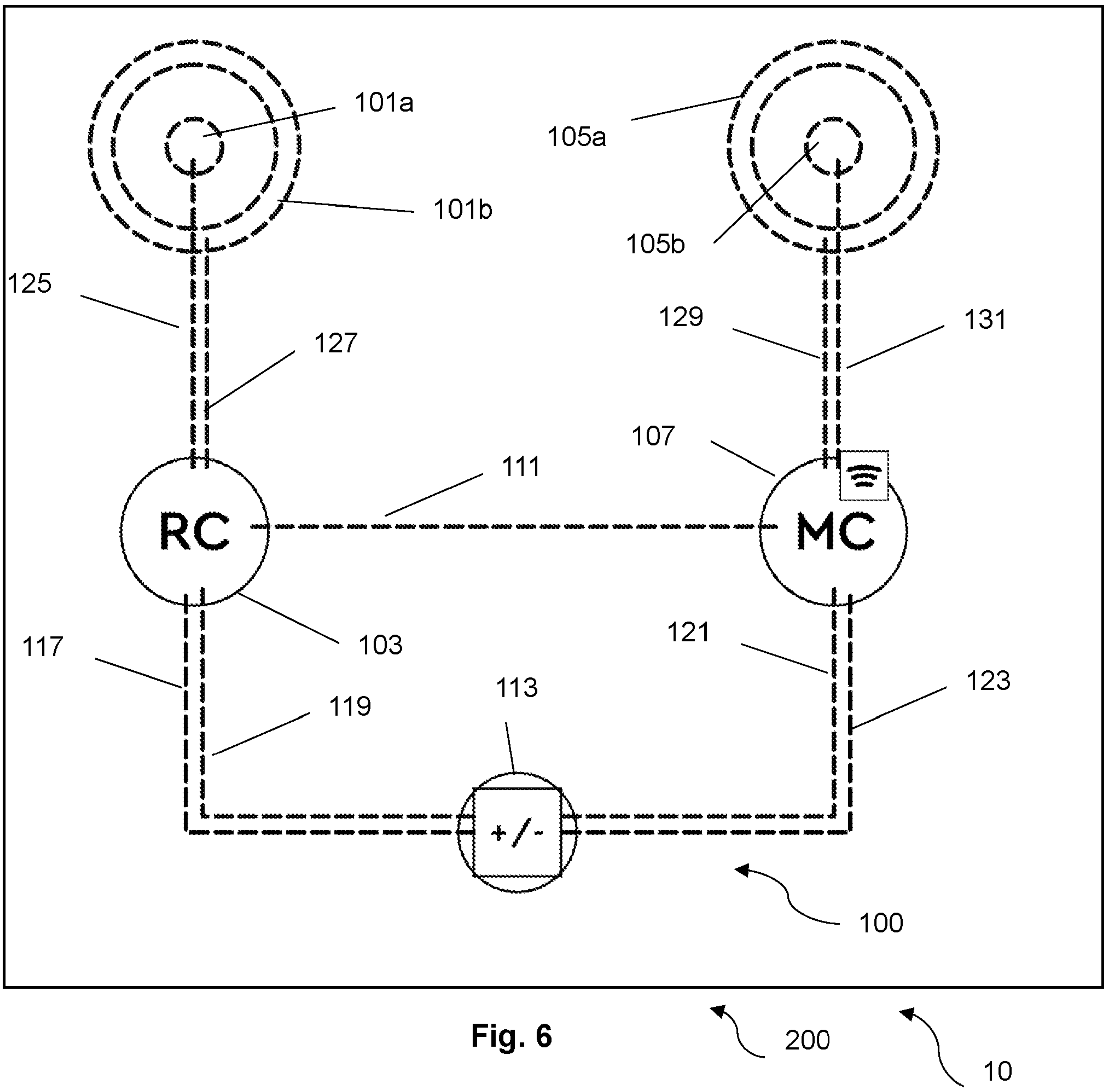
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Fig. 6

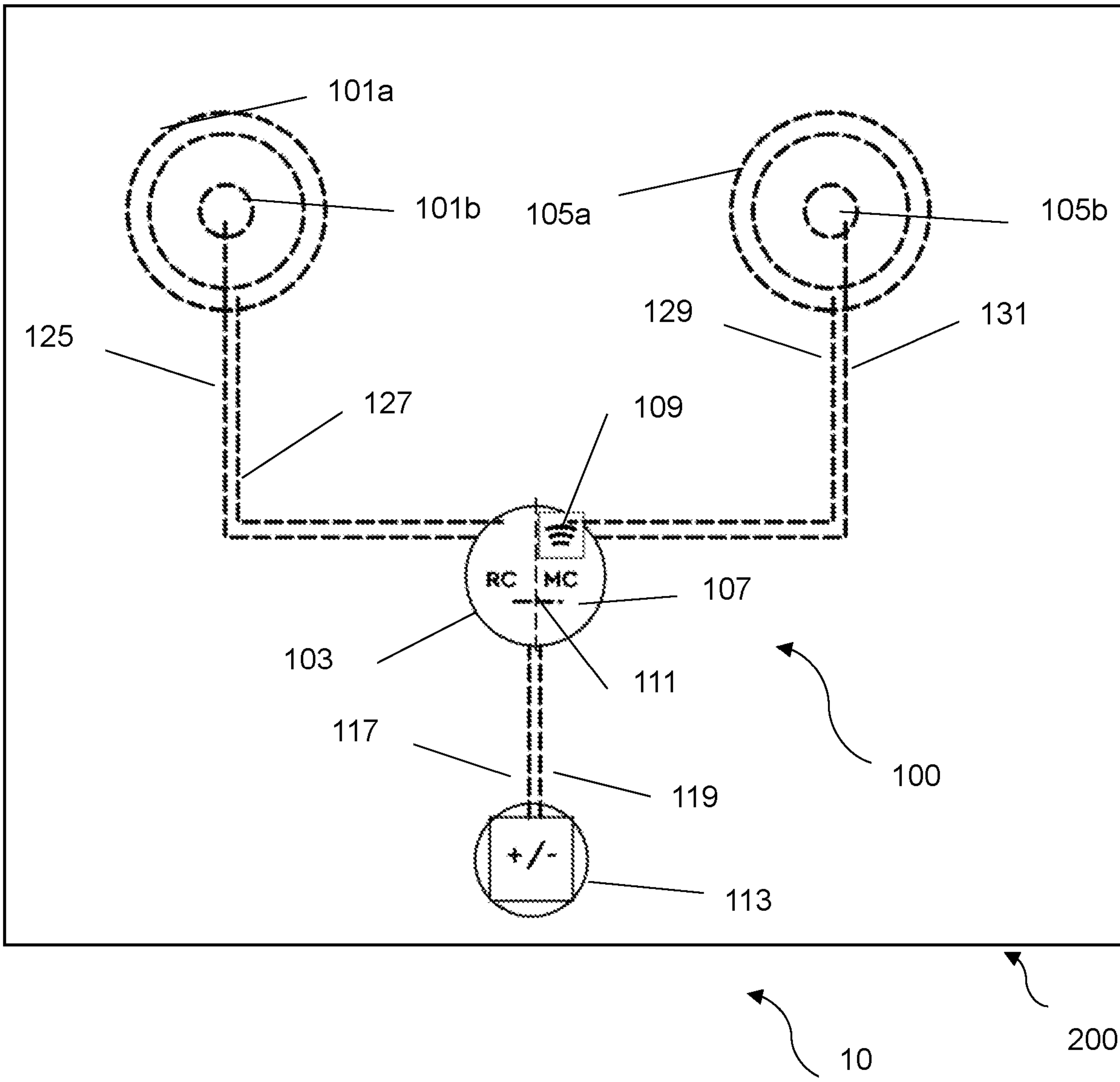
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Fig. 7

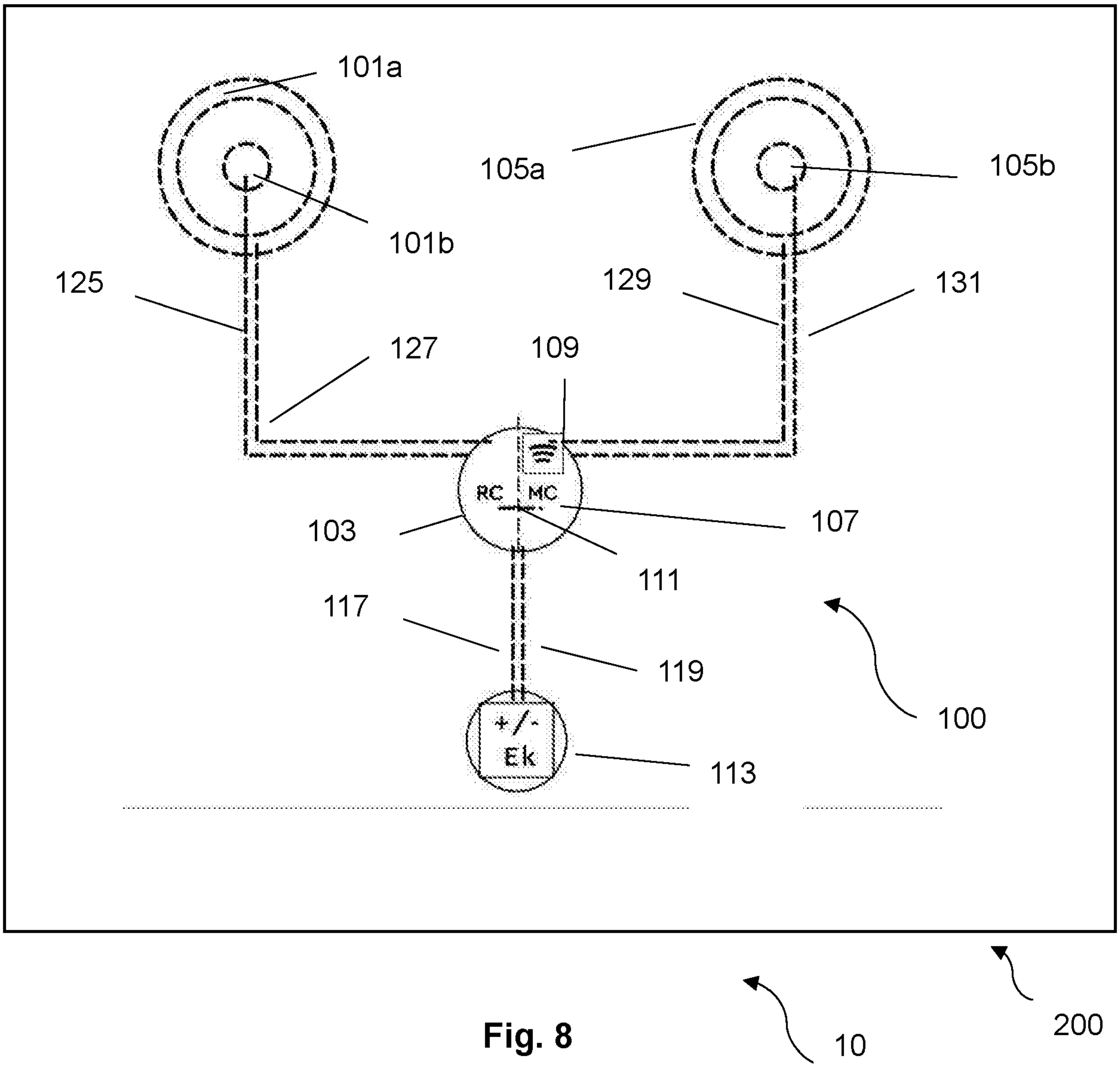
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Fig. 8

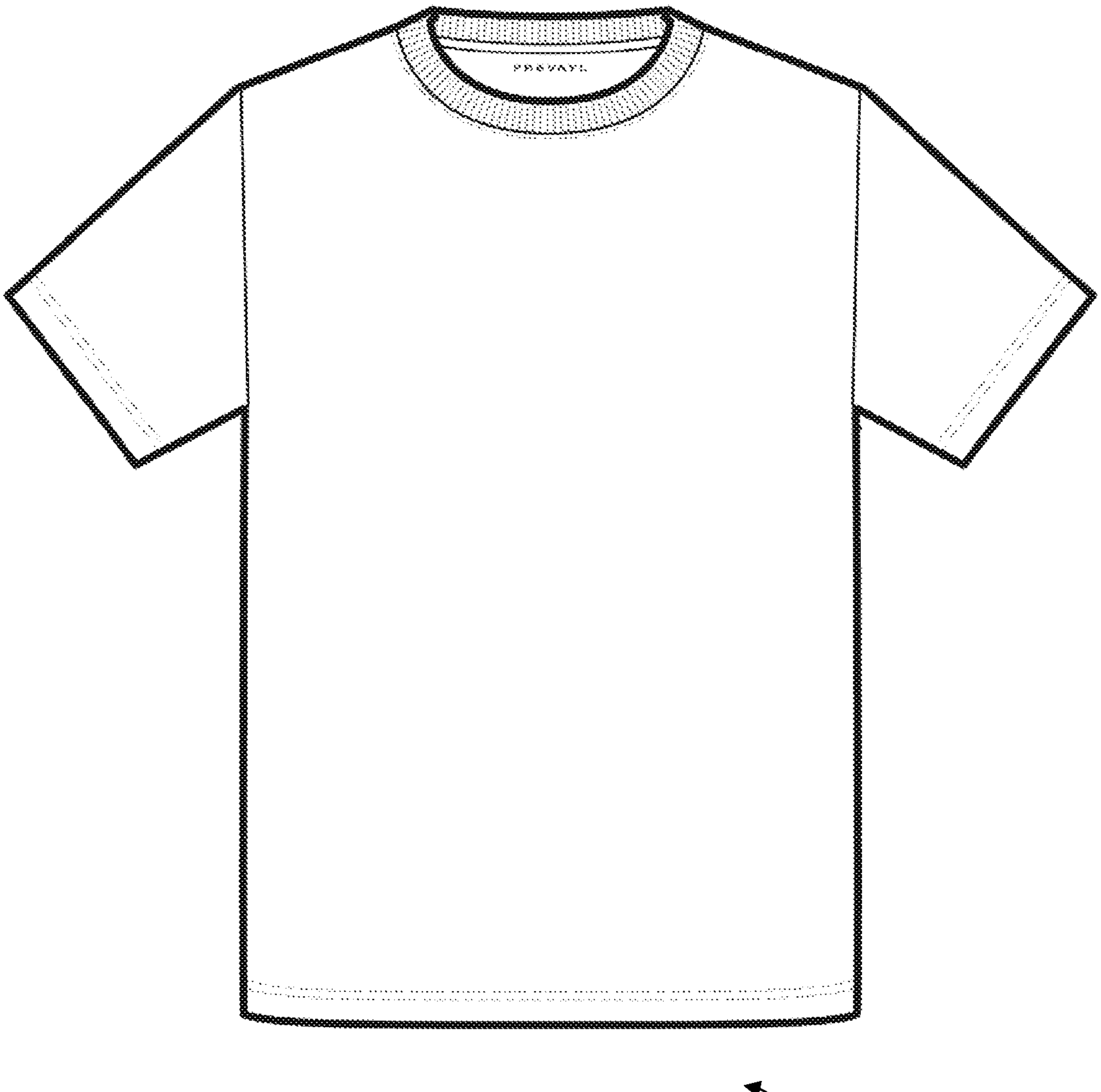

Fig. 9

BIOSENSING TEXTILE AND GARMENT

The present invention is directed towards a biosensing textile and garment. The present invention is directed in particular towards providing a biosensing textile with a distributed sensing system and a garment formed from the biosensing textile.

Background

Garments incorporating sensors are wearable electronics designed to interface with a wearer of the garment, and to determine information such as the wearer's heart rate, rate of respiration, activity level, and body positioning. Such properties can be measured with a sensor assembly that includes a sensor for signal transduction and/or microprocessors for analysis. Such garments are commonly referred to as ‘biosensing garments’ or ‘smart clothing’. A drawback of many biosensing garments is that they contain bulky electronic hardware, wires, and other components that can make them uncomfortable to the wearer. As such, there is a general need for biosensing garments that are more comfortable to wear.

Accordingly, it is desirable to provide a biosensing textile and garment formed from or incorporating the biosensing textile that is more comfortable to wear.

Summary

According to the present disclosure there is provided a biosensing textile and garment as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

According to a first aspect of the disclosure, there is provided a biosensing textile. The biosensing textile comprises a textile. The biosensing textile comprises a distributed sensing system. The distributed sensing system comprises a plurality of electrodes incorporated on the textile. The plurality of electrodes are formed of a 2D electrically conductive material. The distributed sensing system comprises a controller in communication with the plurality of electrodes and operable to control the plurality of electrodes. The plurality of electrodes are spaced apart from one another and the controller on the textile.

Beneficially, the biosensing textile comprises a distributed sensing system in which electrodes are formed of a 2D electrically conductive material that is incorporated into the textile. The electrodes are therefore flush with or substantially flush with the textile and do not add additional height to the textile. In addition, the electrodes are spaced apart from one another and the controller on the textile. This arrangement does not require bulky sensor housings in which controllers and electrodes are combined to form a single unit. This makes the biosensing textile more comfortable when worn such as when the biosensing textile is incorporated into or forms a garment.

The 2D material may be a carbon-based material. The carbon-based material may comprise graphene, e.g. pristine graphene, and/or reduced graphene oxide. The carbon-based material may be graphene and/or reduced graphene oxide in combination with one or more additional conductive agents. The carbon-based material may be a graphene derivative. The graphene, reduced graphene oxide or graphene derivative may comprise nanoparticles, nanosheets, and microparticles.

The 2D material may be printed onto the textile. The 2D material may be screen printed, digitally (e.g. inkjet) printed, transfer printed, sublimation printed, pad printed, coated, transfer coated, sprayed, or extruded onto a surface of the textile. The 2D material may be formed of conductive inks, conductive pastes and/or conductive coatings, or any combination thereof.

One or more of the electrodes may be adapted to be placed on or near the surface of a human or animal body.

One or more of the electrodes may be formed by printing an electrically conductive formulation comprising graphene and/or graphene oxide onto the hydrophobic substrate to form the electrode. An additional step of reducing any graphene oxide present to form an electrode comprising reduced graphene oxide may be performed. The reduced graphene oxide has superior electrical conductivity. The printing may be screen printing. The printing may be digital printing such as inkjet printing.

One or more of the electrodes may comprise single layers of graphene or thin stacks of two to ten graphene layers. The thin stacks of graphene are distinguished from graphite by their thinness and a difference in physical properties. In this regard, it is generally acknowledged that crystals of graphene which have more than 10 molecular layers (i.e. 10 atomic layers which equates to a thickness of approximately 3.5 nm) generally exhibit properties more similar to graphite than to graphene. Thus, throughout this specification, the term graphene is intended to mean a carbon nanostructure with up to ten graphene layers. Similarly, the reduced graphene oxide may be present as single layers of reduced graphene oxide or thin stacks of two to ten reduced graphene oxide layers.

One or more of the electrodes may be formed from flakes of graphene or reduced graphene oxide that comprise 1 to 10 layers. Each layer of graphene or reduced graphene oxide present within a flake has a length and a width dimension to define the size of the plane of the layer. Typically, the length and width of the layers are within the range of 10 nm to 2 microns. The flakes may be deposited by printing an electrically conductive ink formulation that comprises flakes of graphene or graphene oxide. The printing may be performed using screen printing or digital (e.g. inkjet) printing. Digital printing, and in particular inkjet printing provides a simple and efficient way of producing the electrically conductive materials.

In some examples. there may be additional electrically conductive agents present in one or more of the electrodes, such as metallic components (e.g. silver precursor, silver nanoparticles, carbon nanotubes, or poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT/PSS)).

One or more of the electrodes may be a textile-based electrode which incorporates a 2D electrically conductive material such as graphene into the fibre/yarn. The 2D material may be incorporated by a dyeing process in which a liquid composition containing the 2D material is contacted with the fibre/yarn. The yarn may be based on synthetic materials such as polyester, nylon, and viscose or may be based on natural materials such as cotton and wool. The yarn may be based on a combination of natural and synthetic materials. Therefore, a 2D material such as reduced graphene oxide or a graphene derivative or another 2D material may be incorporated into a yarn in order to produce a yarn which is capable of conducting electricity and forming an electrode.

In some examples, the yarn forming the electrode may be a graphene yarn. That is, a yarn constructed entirely, essentially or substantially of graphene, e.g. graphene fibres.

The controller may comprise a first controller communicatively coupled to a first of the plurality of electrodes. The controller may comprise a second controller communicatively coupled to a second of the plurality of electrodes. The first controller and the second controller may be spaced apart from one another and the plurality of electrodes. Alternatively, the first controller and the second controller may be arranged in a stacked configuration whereby one of the controllers is stacked on top of the other of the controllers.

The controller may be wirelessly connected to one or more of the electrodes. That is, one or more of the electrodes may comprises a communicator for wireless communication with the controller.

The controller may be conductively connected to one or more of the electrodes. The controller may be conductively connected to the electrodes by a conductor. The conductor may be incorporated into the textile. The conductor may be an electrically conductive track or film.

The conductor may be formed of a 2D material. The 2D material may be a carbon-based material. The carbon-based material may comprise graphene, e.g. pristine graphene, and/or reduced graphene oxide. The conductor may be formed of the same material or in the same manner as the electrodes of the textile.

The conductor may be a conductive transfer. The conductive transfer may comprise a first non-conductive ink layer and a second non-conductive ink layer. An electrically conductive layer may be positioned between the first non-conductive ink layer and the second non-conductive ink layer. The conductive transfer may be adhered to the textile via use of an adhesive layer so as to form the conductor on the textile. An example conductive transfer is described in UK Patent Application Publication No. GB 2555592 (A) the disclosures of which are hereby incorporated by reference. The electrically conductive layer may comprise graphene.

The conductor may be formed from a fibre or yarn of the textile. This may mean that an electrically conductive materials such as graphene is incorporated into the fibre/yarn. In some examples, the yarn forming the conductor may be a graphene yarn. That is, a yarn constructed entirely, essentially or substantially of graphene.

The distributed sensing system may further comprise a power source for powering the controller.

When the controller comprises a plurality of controllers for controlling the plurality of electrodes (e.g. so that each controller controllers a different one or a different subset of the electrodes), each of the controllers may be powered by a different power source. That is, the distributed sensing system may comprise a plurality of power sources for powering the plurality of controllers. Alternatively, the power source may comprise a single power source for powering the controller or the plurality of controllers.

The plurality of controllers may be conductively connected together via a conductor. The conductor may be formed of a 2D material. The 2D material may be a carbon-based material. The carbon-based material may comprise graphene, e.g. pristine graphene, and/or reduced graphene oxide. The conductor may be formed of the same material or in the same manner as the electrodes of the textile. The conductor may be a conductive transfer. The conductor may be formed from a fibre or yarn of the textile. This may mean that an electrically conductive materials such as graphene is incorporated into the fibre/yarn. In some examples, the yarn forming the conductor may be a graphene yarn. That is, a yarn constructed entirely, essentially or substantially of graphene.

The power source may be conductively connected to the controller by a conductor. The conductor may be formed of a 2D material. The 2D material may be a carbon-based material. The carbon-based material may comprise graphene, e.g. pristine graphene, and/or reduced graphene oxide, and/or a graphene derivative. The conductor may be formed of the same material or in the same manner as the electrodes of the textile. The conductor may be a conductive transfer. The conductor may be formed from a fibre or yarn of the textile. This may mean that an electrically conductive materials such as graphene is incorporated into the fibre/yarn. In some examples, the yarn forming the conductor may be a graphene yarn. That is, a yarn constructed entirely, essentially or substantially of graphene, e.g. graphene fibres.

The power source may be a battery. The battery may be a rechargeable battery. The battery may be a rechargeable battery adapted to be charged wirelessly such as by inductive charging. The power source may comprise an energy harvesting device. The energy harvesting device may be configured to generate electric power signals in response to kinetic events such as kinetic events performed by a wearer of a garment that the biosensing textile forms or is incorporated into. The kinetic event could include walking, running, exercising or respiration of the wearer. The energy harvesting material may comprise a piezoelectric material which generates electricity in response to mechanical deformation of the converter. The energy harvesting device may harvest energy from body heat of a wearer of a garment that the biosensing textile forms or is incorporated into. The energy harvesting device may be a thermoelectric energy harvesting device.

The distributed sensing system may further comprise a communicator arranged to communicate with an external device over a wireless network. The communicator may be arranged to communicative over a cellular network. That is, the wireless network may be a cellular network. The cellular network may be a fourth generation (4G) or fifth generation (5G) cellular network or sixth generation (6) cellular network or any other future cellular communication network. The communicator may be incorporated into the controller.

The plurality of electrodes may be conductively connected together via a conductor. The conductor may be formed of a 2D material. The 2D material may be a carbon-based material. The carbon-based material may comprise graphene, e.g. pristine graphene, and/or reduced graphene oxide. The conductor may be formed of the same material or in the same manner as the electrodes of the textile. The conductor may be a conductive transfer. The conductor may be formed from a fibre or yarn of the textile. This may mean that an electrically conductive materials such as graphene is incorporated into the fibre/yarn. In some examples, the yarn forming the conductor may be a graphene yarn. That is, a yarn constructed entirely, essentially or substantially of graphene.

The textile may be a fabric. The textile may be formed from yarn. The yarn may be a natural fibre or a natural fibre blended with one or more other materials which can be natural or synthetic. The yarn may be cotton. The cotton may be blended with polyester and/or viscose and/or polyamide according to the particular application. Silk may also be used as the natural fibre. Cellulose, wool, hemp and jute are also natural fibres that may be used in the textile. Polyester, polycotton, nylon and viscose are synthetic fibres that may be used in the textile

The biosensing textile may be incorporated into or may form a garment.

The plurality of electrodes may be used for measuring the biopotential and/or bioimpedance of the wearer of the biosensing textile. The plurality of electrodes may be controlled for use in biopotential measurements such as ECG or EKG (electrocardiogram), EEG (electroencephalogram), and EMG (electromyogram), sensor. The plurality of electrodes may be controlled for use in bioimpedance measurement such as plethysmography (e.g., for respiration), body composition (e.g., hydration, fat, etc.), or EIT (electroimpedance tomography) sensor. The plurality of electrodes may be controlled for use in temperature measurements.

According to a second aspect of the disclosure, there is provided a garment. The garment comprises the biosensing textile of the first aspect of the disclosure. The garment may be one of a shirt, t-shirt, blouse, dress, brassiere, shorts, pants, arm or leg sleeve, vest, jacket/coat, glove, armband, underwear, headband, hat/cap, collar, wristband, stocking, sock, or shoe, athletic clothing, swimwear, wetsuit or drysuit.

According to a third aspect of the disclosure, there is provided a sensing system for measuring biopotential and/or bioimpedance of a human or animal body. The sensing system comprises a reference electrode adapted to be placed on or near the body surface. The sensing system comprises a measuring electrode adapted to be placed on or near the body surface. The sensing system comprises a reference sensor controller conductively connected to the reference electrode. The sensing system comprises a measuring sensor controller conductively connected to the measuring electrode. The sensing system comprises a conductor comprising an electrically conductive 2D material connecting the reference sensor controller to the measuring sensor controller.

According to a fourth aspect of the disclosure, there is provided a sensing system for measuring biopotential and/or bioimpedance of a human or animal body. The sensing system comprises a reference electrode adapted to be placed on or near the body surface. The sensing system comprises a measuring electrode adapted to be placed on or near the body surface. The sensing system comprises a reference sensor controller conductively connected to the reference electrode. The sensing system comprises a measuring sensor controller conductively connected to the measuring electrode. The sensing system comprises a communication unit arranged to communicate with an external device over a wireless network, wherein the wireless network is a cellular network.

According to a fifth aspect of the disclosure, there is provided a sensing system for measuring biopotential and/or bioimpedance of a human or animal body. The sensing system comprises a reference electrode adapted to be placed on or near the body surface. The sensing system comprises a measuring electrode adapted to be placed on or near the body surface. The sensing system comprises a reference sensor controller conductively connected to the reference electrode. The sensing system comprises a measuring sensor controller conductively connected to the measuring electrode. The reference sensor controller and the measuring sensor controller are stacked relative to one another in a sandwich configuration.

According to a sixth aspect of the disclosure, there is provided a system for measuring biopotential and/or bioimpedance of a human or animal body. The system comprises a reference electrode adapted to be placed on or near the body surface. The system comprises a measuring electrode adapted to be placed on or near the body surface. The system comprises a reference sensor controller conductively connected to the reference electrode. The system comprises a measuring sensor controller conductively connected to the measuring electrode. The reference sensor controller and the measuring sensor controller are formed on a single circuit board.

According to a seventh aspect of the disclosure, there is provided a system for measuring biopotential and/or bioimpedance of a human or animal body. The system comprises a reference electrode adapted to be placed on or near the body surface. The system comprises a measuring electrode adapted to be placed on or near the body surface. The system comprises a reference sensor controller conductively connected to the reference electrode. The system comprises a measuring sensor controller conductively connected to the measuring electrode. The reference electrode and measuring electrode are physically spaced apart from the reference sensor controller and the measuring sensor controller.

According to an eighth aspect of the disclosure, there is provided a system for measuring biopotential and/or bioimpedance of a human or animal body. The system comprises a reference electrode adapted to be placed on or near the body surface. The system comprises a measuring electrode adapted to be placed on or near the body surface. The system comprises a reference sensor controller conductively connected to the reference electrode. The system comprises a measuring sensor controller conductively connected to the measuring electrode. The system comprises at least one power source conductively connected to the reference sensor controller and the measuring sensor controller for powering the reference sensor controller and the measuring sensor controller. The power source comprises an energy harvesting device.

According to a ninth aspect of the disclosure, there is provided a system for measuring biopotential and/or bioimpedance of a human or animal body. The system comprises a reference electrode adapted to be placed on or near the body surface. The system comprises a measuring electrode adapted to be placed on or near the body surface. The system comprises a reference sensor controller conductively connected to the reference electrode. The system comprises a measuring sensor controller conductively connected to the measuring electrode. The system comprises a single power source conductively connected to the reference sensor controller and the measuring sensor controller for powering the reference sensor controller and the measuring sensor controller.

Brief Description of the Drawings

Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a simplified schematic diagram of an example sensing system according to aspects of the present disclosure;

Figure 2 shows a simplified schematic diagram of an example biosensing textile comprising the sensing system of Figure 1;

Figure 3 shows a simplified schematic diagram of an example biosensing textile according to aspects of the present disclosure;

Figures 4 shows a simplified schematic diagram of another example biosensing textile according to aspects of the present disclosure;

Figure 5 shows a side view part of an example sensing system according to aspects of the present disclosure;

Figure 6 shows a simplified schematic diagram of an example biosensing textile according to aspects of the present disclosure;

Figure 7 shows a simplified schematic diagram of another example biosensing textile according to aspects of the present disclosure;

Figure 8 shows a simplified schematic diagram of yet another example biosensing textile according to aspects of the present disclosure; and

Figure 9 shows an example garment incorporating a biosensing textile according to aspects of the present disclosure.

Detailed Description

The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of various embodiments of the disclosure as defined by the claims and their equivalents. It includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the various embodiments described herein can be made without departing from the scope and spirit of the disclosure. In addition, descriptions of well-known functions and constructions may be omitted for clarity and conciseness.

The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used by the inventor to enable a clear and consistent understanding of the disclosure. Accordingly, it should be apparent to those skilled in the art that the following description of various embodiments of the disclosure is provided for illustration purpose only and not for the purpose of limiting the disclosure as defined by the appended claims and their equivalents.

It is to be understood that the singular forms `a,_ `an,_ and `the_ include plural referents unless the context clearly dictates otherwise.

The term `graphene_ refers to a particular crystalline allotrope of carbon in which each carbon atom is bound to three adjacent carbon atoms (in a sp<2 >hybridised manner) so as to define a one atom thick planar sheet of carbon. The carbon atoms in graphene are arranged in the planar sheet in a honeycomb-like network of tessellated hexagons. Graphene is often referred to as a 2-dimensional crystal because it represents a single nanosheet or layer of carbon of nominal (one atom) thickness. Graphene is a single sheet of graphite.

Unless defined otherwise, in the specification the term `graphene_ not only refers to `pristine graphene_ but also to `graphene oxide_ or another `graphene derivative_.

The term pristine graphene refers to ultrapure graphene, whereby little or no impurities or oxides are present. Pristine graphene displays little or very limited solubility in most organic solvents.

Graphene oxide is an analogue form of graphene whereby oxygenated functionalities are introduced into the graphene structure. One advantage of graphene oxide over pristine graphene is its increased solubility, particularly in water. The reduction of the oxygenated functionality in graphene oxide consequently can lead to the generation of reduced graphene oxide, which is a form of graphene that still retains some residual oxygen content.

The term "graphene derivative" includes graphene oxide, reduced graphene oxide, partially oxidised graphene, hydrogenated graphene (graphane), fluorinated graphene and any other functionalised graphene material, including graphene functionalised with oxygen or nitrogen containing groups. The graphene derivative may be oxygenated graphene. Oxygenated graphene may refer to graphene oxide, reduced graphene oxide, partially oxidised graphene etc. Where the oxygenated graphene is reduced graphene oxide or partially oxidised graphene, the oxygen level may be lower than in graphene oxide.

The present disclosure is not limited to graphene or reduced graphene oxide 2D materials and other conductive or semiconductor 2D materials may be used. Molybdenum disulphide (M0S2) and tungsten disulphide (WS2) are two such materials. The 2D material may thus be any conductive or semi-conducting material. Reduced graphene oxide is a preferred 2D material because it contains a number of hydroxyl and epoxy oxide functional groups and this facilitates binding to the yarn. This is especially true when the yarn is a material such as cellulose which has its own polar functional groups such as hydroxyl.

The yarn may be a natural fibre or a natural fibre blended with one or more other materials which can be natural or synthetic. Cotton is particularly preferred as a substrate for the two-dimensional material when forming the two-dimensional material containing yarn. However, cotton may be blended with polyester and/or viscose and/or polyamide according to the particular application. Silk may also be used as the natural fibre. Cellulose, wool, hemp and jute are also natural fibres that may be used in the production of the yarn of the invention. Polyester, polycotton, nylon and viscose are synthetic fibres that may be used in the production of the yarn of the invention.

Referring to Figure 1, there is shown a simplified schematic circuit diagram of a sensing system 100 according to aspects of the present disclosure. The sensing system 100 comprises a first electrode 101 and a first controller 103 that is conductively connected to the first electrode 101. The sensing system 100 further comprises a second electrode 105 and a second controller 107. The first electrode 101 may act as a reference electrode 101. The first controller 103 may act as a reference controller 103. The second electrode 105 may act as a measuring electrode 101. The second controller 107 may act as a measuring controller 107. That is, one of the first and second electrodes 101, 103 may be controlled to act as a reference during biopotential and/or bioimpedance measurements. The first electrode 101 and second electrode 105 may be conventional metallic electrodes such as silver/silver chloride (Ag/AgCl) electrodes.

The first controller 103 and the second controller 107 are able to stimulate the body, such as by injecting a current into the body via the electrode(s) 101, 105 for performing an impedance measurement. The first controller 103 and the second controller 107 are also able to measure a physiological signal of the body, such as an ECG, by measuring a potential via the electrode(s) 101, 105. The first electrode 101 and the second electrode 105 may both comprise a first electrical contact 101a, 105a and a second electrical contact 101b, 105b (Figure 4). The potential may be measured between the electrical contacts of the first electrode 101 and/or the second electrode 105. A detailed example of how the sensing system 100 may be used to measure the biopotential and/or bioimpedance of the body is described in European Patent Application Publication No. 2 886 049 A1, European Patent Application Publication No. 2 567 657 A1 and European Patent Application Publication No. 2 101 408 A1. The disclosures of these patent documents are hereby incorporated by reference.

The system 100 further comprises a communicator 109. The communicator 109 transmits biometric data recorded by the electrodes 101, 105 and optionally processed by the first/second controller 103, 107 wirelessly to an external device. In some examples of the present disclosure,, the communicator 109 is a cellular communicator 109 operable to communicate the biometric data wirelessly with an external server via one or more base stations. The cellular communicator 109 may be a fourth generation (4G) enabled radio communicator 109 or a fifth generation (5G) enabled cellular communicator 109. This means that the communicator 109 is able to communicate the biometric data to an external server over a cellular network. This contrasts with existing systems which are typically only able to communicate with a local device such as a mobile phone over a short range communication network such as Bluetooth ÷. This existing approach is disadvantageous as it requires the user to additionally be in possession of a mobile device in order to record biometric data. The present invention does not require the user to be in possession of any additional electronic devices for biometric data to be recorded.

The communicator 109 in this example is shown incorporated with the second controller 107. This is just one example. The communicator 109 may be incorporated with the first controller 103 or may be separate from the first controller 103 and the second controller 107.

The first electrode 101 and/or first controller 103 are conductively connected to the second electrode 105 and/or second controller 107 via a conductor 111.

In this example, the conductor 111 is formed of graphene or a graphene-derivative and is printed onto the textile 200 (Figure 2) using a screen-printing process. Other printing processes may be used. In some examples, the conductor 111 may be a conductive transfer. The conductive transfer may comprise graphene.

The device 100 further comprises a first power source 113 for powering the first controller 103 and a second power source 115 for powering the second controller 107. The first power source 113 and the second power source 115 may be batteries 113, 115. A positive terminal of the first power source 113 is conductively connected to the first controller 103 by a conductor 117. A negative terminal of the first power source 113 is conductively connected to the first controller 103 by a conductor 119. A positive terminal of the second power source 115 is conductively connected to the second controller 107 by a conductor 121. A negative terminal of the second power source 115 is conductively connected to the second controller 107 by a conductor 123.

The conductors 117, 119, 121, 123 are also formed of a graphene or a graphene-derivative and are printed onto the textile 200 (Figure 2) using a screen-printing process. Other printing processes may be used. In some examples, the conductor 111 may be a conductive transfer. The conductive transfer may comprise graphene.

It will be appreciated that the present disclosure is not limited to screen printing conductors onto a textile or the use of conductive transfers. In other examples, the conductors may be incorporated into one or more fibres of the textile.

Referring to Figure 2, there is shown an example implementation of a biosensing textile 10 according to aspects of the present disclosure.

The biosensing textile 10 comprises the textile 200 and the sensing system 100 as shown in Figure 1.

The first electrode 101 and first controller 103 are incorporated on the textile 200 at a first position 201. The second electrode 105, second controller 107 and communicator 109 are incorporated on the textile at a second position 203 on the textile 200 spaced apart from the first position 201.

The first power source 113 is located at a third position 205 spaced apart from the first position 201 and the second position 203. The second power source 115 is located at a fourth position 207 spaced apart from the first position 201, second position 203 and third position 205. Beneficially, distributing the components on the textile such as by separating the first and second power sources 113, 115 from the electrodes 101, 105 and controllers 103, 107 can reduce the apparent footprint of the components on the textile 200. Existing solutions provide the electrodes, controllers, and power sources as integrated units within a housing that this then attached to the textile. This integrated units are bulky and protrude outward from the textile. This makes the resultant garments uncomfortable to wear and unattractive. In some examples of the present disclosure, however, the first power source 113 is incorporated with the first controller 103 at the first position 201 and the second power source 115 is incorporated with the second controller 107 at the second position 203. This may be, for example, when a bulky construction is not particularly disadvantageous such as in a medical setting.

Referring to Figure 3, there is shown a simplified schematic circuit diagram of a biosensing textile 10 according to aspects of the present disclosure. The biosensing textile 10 comprises the textile 200 and a sensing system 100. The sensing system 100 comprises a first electrode 101, first controller 103, second electrode 105, second controller 107, a communicator 109, and a conductor 111. These components are the same as the corresponding components of the device 100 as described above in relation to Figure 1.

Importantly, the device 100 comprises a single power source 113 rather than the first power source 113 and second power source 115 described above in relation to Figure 1. Providing a single power source 113 can simplify the construction of the device 100 as fewer components are required. In addition, the reduction in the number of power sources can improve the integration of the device 100 onto a textile. The positive terminal of the power source 113 is conductively connected to the first controller 103 by a first conductor 117. The negative terminal of the power source 113 is conductively connected to the first controller 103 by a second conductor 119. The positive terminal of the power source 113 is conductively connected to the second controller 107 by a first conductor 121. The negative terminal of the power source 113 is conductively connected to the second controller 107 by a second conductor 123.

The first electrode 101 and first controller 103 are located at a first position 201 on the textile 200. The second electrode 105, second controller 107, and communicator 109 are located at a second position 203 on the textile 200 spaced apart from the first position.

Referring to Figure 4, there is shown an example of a biosensing textile 10 according to aspects of the present disclosure. The biosensing textile 10 comprises a textile 200 and a distributed sensing system 100. The distributed sensing system 100 comprises a first electrode 101a, 101b, second electrode 105a, 105b, first controller 103, second controller 107, communicator 109, conductor 111, and single power source 113. These components are the same as the corresponding components of the device 100 as described above in relation to Figure 3.

In Figure 4, it is visible that the first electrode 101a, 101b comprises a first electrical contact 101a and a second electrical contact 101b. The first electrical contact 101a is conductively connected to the first controller 103 by a first conductor 125. The second electrical contact 101b is conductively connected to the second controller 103 by a second conductor 127. Further, it is visible that the second electrode 105a, 105b comprises a first electrical contact 105a and a second electrical contact 105b. The first electrical contact 105a is conductively connected to the second controller 107 by a first conductor 129. The second electrical contact 105b is conductively connected to the second controller 107 by a second conductor 131.

Importantly, in the example shown in Figure 4, the first electrode 101a, 101b is located at a first position 201 on the textile 200. The second electrode 105a, 105b is located at a second position 203 on the textile 200. The first position 201 is spaced apart from the second position 203. Moreover, the first controller 105 is located at a third position 205 on the textile 200. The second controller 107 is located at a third position 207 on the textile 200. The third position 205 is spaced apart from the first position 201, second position 203, and fourth position 207. The fourth position 207 is spaced apart from the first position 201, second position 203, and third position 205. In this way, the electrodes 101a, 101b, 105a, 105b are spaced apart from one another and from the controllers 103, 107. Beneficially, distributing the components on the textile 200 such as by separating the first and second power sources 113, 115 from the electrodes 101, 105 and controllers 103, 107 and separating the electrodes 101, 105 from the controllers 103, 107 can reduce the apparent footprint of the components on the textile 200. Existing solutions provide the electrodes, controllers, and power sources as integrated units within a housing that this then attached to the textile. This integrated units are bulky and protrude outward from the textile. This makes the resultant garments uncomfortable to wear and unattractive.

Referring to Figure 5, there is shown another arrangement of the distributed sensing system 100. In this example, the first controller 103 and the second controller 107 are located at the same position 205 on the textile. In this example, the second controller 107 is stacked on top of the first controller 103. The first controller 103 and second controller 107 are conductively connected by conductors 111. This arrangement may be beneficial when space on the textile is limited. However, this arrangement may also increase the thickness of the distributed sensing system 100 on the textile 200 which may be undesirable in some instances.

Referring to Figure 6, there is shown another arrangement of a biosensing textile 10 according to aspects of the present disclosure. The biosensing textile 20 comprises a textile 200 and a distributed sensing system 100.

The distributed sensing system 100 comprises a first electrode 101a, 101b and a second electrode 105a, 105b. Importantly, the first and second electrodes 101a, 101b, 105a, 105b are incorporated onto the textile 200. Being `incorporated_ onto the textile 200 may mean that the electrodes 101a, 101b, 105a, 105b are printed onto the textile 200 or are formed from one or more fibres or yarns of the textile 200 such as by coating the fibres or yarns of the textile 200 with an electrically conductive material. Importantly still, the first and second electrodes 101a, 101b, 105a, 105b are formed of a 2D electrically conductive material. In the particular example of Figure 6, this material is a graphene or graphene-derivative which is screen printed onto the textile 200. The combination of the electrodes 101a, 101b, 105a, 105b being integrated into the textile 200 and formed of a 2D electrically conductive material means that the electrodes 101a, 101b, 105a, 105b have a minimal footprint on the textile 200. This means that the impact of the sensing system 100 on the textile 200 is minimised. The textile 200 is more comfortable when worn as there are no or only minimal bulky electronics components.

The other components of the distributed sensing system 100 are the same as the distributed sensing system 100 of Figure 4.

Referring to Figure 7, there is shown another arrangement of a biosensing textile 10 according to aspects of the present disclosure. In this example, the first controller 103, the second controller 107, and the communicator 109 are provided on a single circuit board. In this way, a single controller 103, 107 is provided for controlling the first electrode 101a and the second electrode 101b. The other components of the distributed sensing system 100 are the same as the distributed sensing system 100 of Figure 5.

Referring to Figure 8, there is shown another arrangement of a biosensing textile 20 according to aspects of the present disclosure. In this example, the single power source 113 comprises an energy harvesting device and, in particular, is in the form of a kinetic battery.

Referring to Figure 9, there is shown an example garment 20 incorporating a biosensing textile according to aspects of the present disclosure. The biosensing textile is not visible.

While the above examples show each textile with two electrodes, the present invention is not limited to textiles having two electrodes. More than two electrodes may be provided on the textile. For example, more than 5 electrodes, more than 10 electrodes, or more than 20 electrodes may be provided on the textile.

At least some of the example embodiments described herein may be constructed, partially or wholly, using dedicated special-purpose hardware. Terms such as :component˘, :module˘or :unit˘ used herein may include, but are not limited to, a hardware device, such as circuitry in the form of discrete or integrated components, a Field Programmable Gate Array (FPGA) or Application Specific Integrated Circuit (ASIC), which performs certain tasks or provides the associated functionality. In some embodiments, the described elements may be configured to reside on a tangible, persistent, addressable storage medium and may be configured to execute on one or more processors. These functional elements may in some embodiments include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables. Although the example embodiments have been described with reference to the components, modules and units discussed herein, such functional elements may be combined into fewer elements or separated into additional elements. Various combinations of optional features have been described herein, and it will be appreciated that described features may be combined in any suitable combination. In particular, the features of any one example embodiment may be combined with features of any other embodiment, as appropriate, except where such combinations are mutually exclusive. Throughout this specification, the term `comprising_ or `comprises_ means including the component(s) specified but not to the exclusion of the presence of others.

Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A biosensing textile, comprising:
a textile; and
a distributed sensing system comprising:
a plurality of electrodes incorporated on the textile, wherein the plurality of electrodes are formed of a 2D electrically conductive material; and
a controller in communication with the plurality of electrodes and operable to control the plurality of electrodes,
wherein the plurality of electrodes are spaced apart from one another and the controller on the textile.

2. A biosensing textile as claimed in claim 1, wherein the 2D material is a carbon-based material.

3. A biosensing textile as claimed in claim 2, wherein the carbon-based material comprises graphene.

4. A biosensing textile as claimed in any preceding claim, wherein the 2D material is printed onto the textile.

5. A biosensing textile as claimed in any preceding claim, wherein the plurality of electrodes incorporate a 2D electrically conductive material into a fibre or yarn of the textile.

6. A biosensing textile as claimed in any of claims 1 to 4, wherein the plurality of electrodes are formed from yarns constructed from graphene fibres.

7. A biosensing textile as claimed in any preceding claim, wherein the controller comprises:

a first controller communicatively coupled to a first of the plurality of electrodes; and

a second controller communicatively coupled to a second of the plurality of electrodes.

8. A biosensing textile as claimed in claim 7, wherein the first controller and the second controller are spaced apart from one another and the plurality of electrodes.

9. A biosensing textile as claimed in claim 7, wherein the first controller and the second controller are arranged in a stacked configuration whereby one of the controllers is stacked on top of the other of the controllers.

10. A biosensing textile as claimed in any preceding claim, wherein the controller is conductively connected to the electrodes by a plurality of conductors.

11. A biosensing textile as claimed in claim 10, wherein the conductors are formed of a 2D material.

12. A biosensing textile as claimed in claim 11, wherein the 2D material comprises graphene.

13. A biosensing textile as claimed in any of claims 10 to 12, wherein the conductor is a conductive transfer.

14. A biosensing textile as claimed in any of claims 10 to 12, wherein the conductor is formed from a fibre or yarn of the textile.

15. A biosensing textile as claimed in any preceding claim, wherein the distributed sensing system comprises a power source for powering the controller.

16. A biosensing textile as claimed in claim 15, wherein the power source is a rechargeable battery.

17. A biosensing textile as claimed in claim 15 or 16, wherein the power source comprises an energy harvesting device.

18. A biosensing textile as claimed in any preceding claim, wherein the distributed sensing system further comprises a communicator arranged to communicate with an external device over a wireless network.

19. A biosensing textile as claimed in claim 18, wherein the communicator is arranged to communicative over a cellular network, optionally a fourth generation (4G) or fifth generation (5G) cellular network.

20. A biosensing textile as claimed in any preceding claim, wherein the plurality of electrodes are conductively connected together via a conductor.

21. A biosensing textile as claimed in any preceding claim, wherein the conductor is formed of a 2D material, optionally a carbon-based material, and optionally comprising graphene

22. A garment comprising a biosensing textile as claimed in any preceding claim.

23. A garment as claimed in claim 22, wherein the garment is one of a shirt, t-shirt, blouse, dress, brassiere, shorts, pants, arm or leg sleeve, vest, jacket/coat, glove, armband,

underwear, headband, hat/cap, collar, wristband, stocking, sock, or shoe, athletic clothing, swimwear, wetsuit or drysuit.

Amendments to the Claims have been filed as follows:-

CLAIMS

1. A biosensing textile, comprising:
a textile; and
a distributed sensing system comprising:
a plurality of electrodes incorporated on the textile, wherein the plurality of electrodes are formed of a 2D electrically conductive material; and
a controller in communication with the plurality of electrodes and operable to control the plurality of electrodes,
wherein the plurality of electrodes are spaced apart from one another and the controller on the textile,
wherein the controller comprises:
a first controller communicatively coupled to a first of the plurality of electrodes; and
a second controller communicatively coupled to a second of the plurality of electrodes, and
wherein the first controller and the second controller are arranged in a stacked configuration whereby one of the controllers is stacked on top of the other of the controllers.

2. A biosensing textile as claimed in claim 1, wherein the 2D material is a carbon-based material.

3. A biosensing textile as claimed in claim 2, wherein the carbon-based material comprises graphene.

4. A biosensing textile as claimed in any preceding claim, wherein the 2D material is printed onto the textile.

5. A biosensing textile as claimed in any preceding claim, wherein the plurality of electrodes incorporate a 2D electrically conductive material into a fibre or yarn of the textile.

6. A biosensing textile as claimed in any of claims 1 to 4, wherein the plurality of electrodes are formed from yarns constructed from graphene fibres.

7. A biosensing textile as claimed in any preceding claim, wherein the controller is conductively connected to the electrodes by a plurality of conductors.

8. A biosensing textile as claimed in claim 7, wherein the conductors are formed of a 2D material.

9. A biosensing textile as claimed in claim 8, wherein the 2D material comprises graphene.

10. A biosensing textile as claimed in any of claims 7 to 9, wherein the conductor is a conductive transfer.

11. A biosensing textile as claimed in any of claims 7 to 10, wherein the conductor is formed from a fibre or yarn of the textile.

12. A biosensing textile as claimed in any preceding claim, wherein the distributed sensing system comprises a power source for powering the controller.

13. A biosensing textile as claimed in claim 12, wherein the power source is a rechargeable battery.

14. A biosensing textile as claimed in claim 12 or 13, wherein the power source comprises an energy harvesting device.

15. A biosensing textile as claimed in any preceding claim, wherein the distributed sensing system further comprises a communicator arranged to communicate with an external device over a wireless network.

16. A biosensing textile as claimed in claim 15, wherein the communicator is arranged to communicative over a cellular network, optionally a fourth generation (4G) or fifth generation (5G) cellular network.

17. A biosensing textile as claimed in any preceding claim, wherein the plurality of electrodes are conductively connected together via a conductor.

18. A biosensing textile as claimed in any preceding claim, wherein the conductor is formed of a 2D material, optionally a carbon-based material, and optionally comprising graphene

19. A garment comprising a biosensing textile as claimed in any preceding claim.

20. A garment as claimed in claim 19, wherein the garment is one of a shirt, t-shirt, blouse, dress, brassiere, shorts, pants, arm or leg sleeve, vest, jacket/coat, glove, armband, underwear, headband, hat/cap, collar, wristband, stocking, sock, or shoe, athletic clothing, swimwear, wetsuit or drysuit.

Intellectual Property Office

Application No:	GB1909336.8	**Examiner:**	Mr Robert Black
Claims searched:	1-23	**Date of search:**	6 December 2019

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	X = 1-4, 8, 8, 10-13 and 15-23; Y = 5, 6 and 14	US 2019/0132948 A1 (LONGINOTTI-BUITONI) See especially figures 1A, 1B, 6B, 6E and 25A-25C, and paragraph 0015, 0026, 0027, 0040, 0068, 0086, 0246, 0247, 0253, 0258, 0331, 0332, 0411, 0439, 0449-0451, 0454 and 0455
X,Y	X = 1-4, 7, 8, 10-12 and 15-23; Y = 5, 6 and 14	WO 2017/009879 A1 (XEOS) See especially figure 1, page 3 line 20 to page 4 line 9, page 5 lines 7-21 and page 12 line 4 to page 17 line 2
X	1-4, 7, 8, 15, 16, 18, 19, 22 and 23	CN 107951473 A (CHINESE) See especially WPI abstract 2018-33098Y, the EPODOC abstract, and claims 1, 3 and 7
X	1-3, 15, 16, 18, 22 and 23	CN 108403097 A (SHANGHAI) See especially figure 1, the EPODOC abstract, WPI abstract 2018-66070X, and claims 1, 3 and 7
Y	5, 6 and 14	Xu, Z. and Gao, C. "Graphene fiber: a new trend in carbon fibers", Materials today, November 2015, volume 18, number 9, pages 480-492, Elsevier See especially paragraph starting on page 486, last paragraph on page 489, first three full paragraphs on page 491 and full paragraph on page 492
Y	5, 6 and 14	Guan-Hang Y. et.al. "Graphene fibers: advancing applications in sensor, energy storage and conversion", Chinese journal of polymer science, 2019, volume 37, pages 535-547 See especially the abstract and paragraph starting on page 538

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date

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earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

A61B; D06M

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, INTERNET, XPESP, XSPRNG

International Classification:

Subclass	Subgroup	Valid From
D06M	0011/74	01/01/2006
A41D	0001/00	01/01/2018
A61B	0005/00	01/01/2006