How an earbud chooses where to measure

The original drawing, with the controller, carrier and electrode groups explained where they appear.

THE ORIGINAL. EXPLAINED.

FIG. 6 / Original PDF page 7 / Geometry and labels preserved

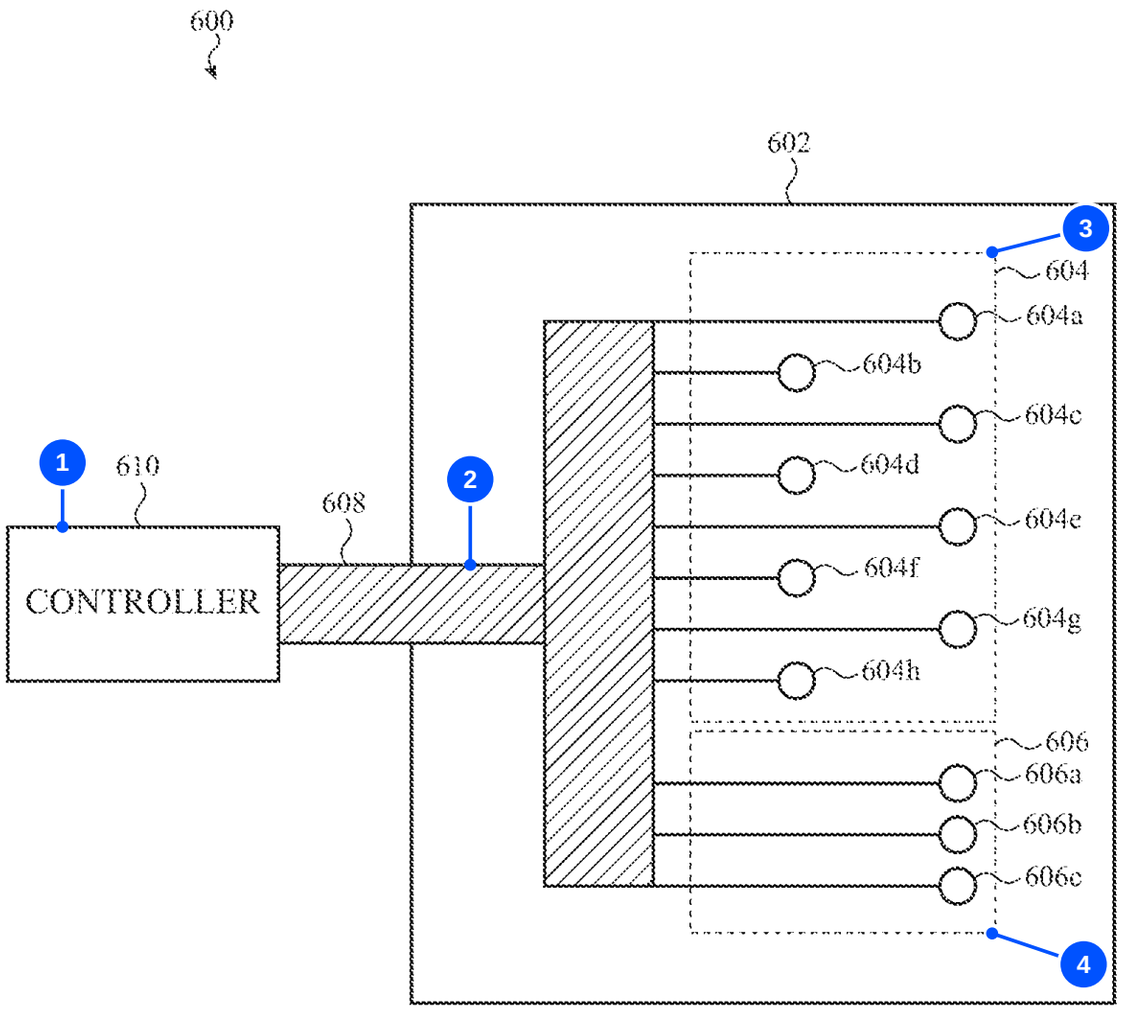

FIG. 6

FOLLOW THE NUMBERED CALLOUTS

1

610 / Controller

The controller chooses.

It may choose an active subset and a reference subset, then perform a measurement test using both. EEG is one example.

2

608 / Electrode carrier

The carrier connects.

The hatched carrier holds the electrodes and may electrically couple them to the controller. The description names a flex or microaxial cables.

3

604a-604h / Active electrodes

Eight active electrodes.

These eight contacts form the active group shown here. The controller may select one or more; the drawing does not identify a chosen subset.

4

606a-606c / Reference electrodes

Three reference electrodes.

A reference subset is also selected. The measurement uses the selected active and reference subsets together.

Inspect original page 7 >

Read description [0068]-[0069] on original page 21 >

THE QUESTION, ANSWERED

What makes this more than a fixed set of earbud electrodes?

Selection is part of the design. The controller can choose which active and reference electrodes participate in a measurement, using the criteria set out in the description. The callouts identify those parts; paragraph [0069] explains the choice before measurement.

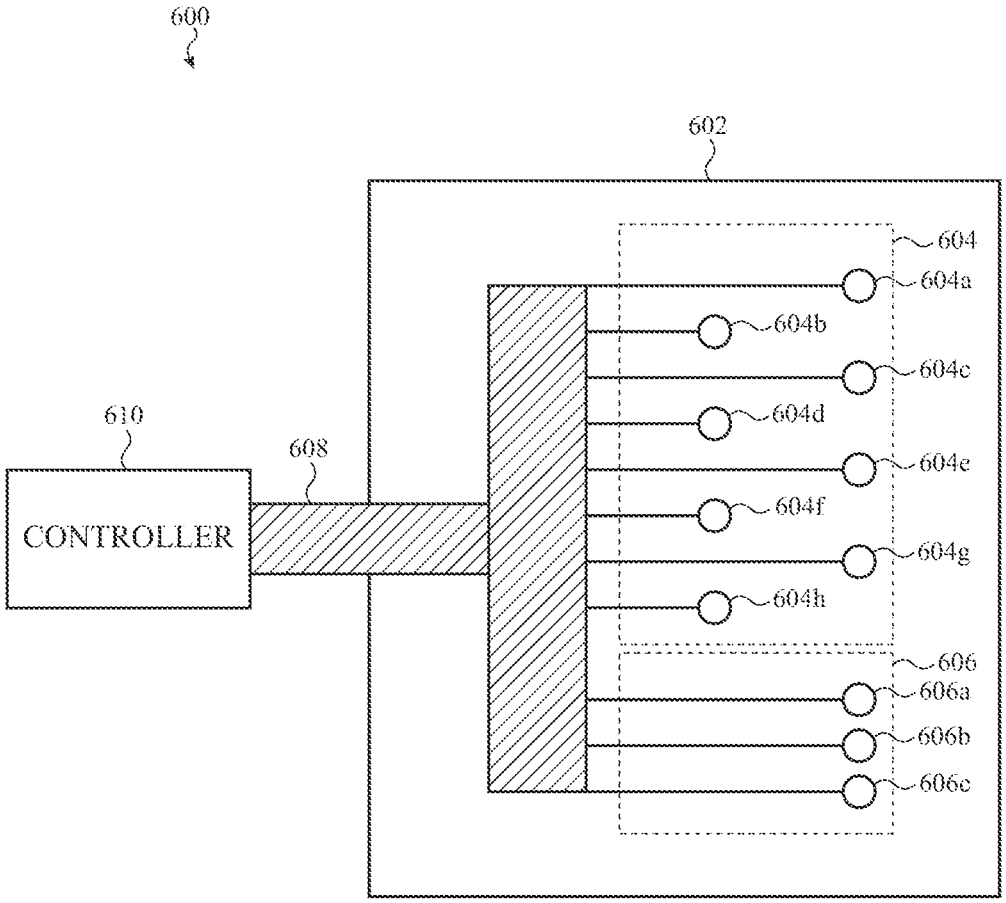
600
602
604
604a
604b
604c
604d
604e
604f
604g
604h
606
606a
606b
606c
610
608
CONTROLLER

FIG. 6

may be sent a notification in accordance with the analyzed electrical activity from the measurement. The notification may be sent as an auditory signal, a visual signal, haptic feedback, an email and/or a text, etc.

[0063] FIG. **3** depicts one view of a portion of an example wearable electronic device, such as an earbud, as described herein, in accordance with some embodiments. The portion of the earbud **300** shown in FIG. **3** is the tip **302** of the earbud, which has active electrodes **304***a*-**304***c*. Each active electrode of the active electrodes **304***a*-**304***c* on the tip **302** may be ring-shaped or shaped the same as (or differently from) the shape of an active electrode shown in FIG. **2**. One or more active electrodes **304***a*-**304***c* may be selected for measuring a biosignal, as described herein, in accordance with some embodiments.

[0064] FIG. **4** depicts one view of a portion of an example wearable electronic device, such as an earbud, as described herein, in accordance with some embodiments. A portion of the earbud **400** shown in FIG. **4** illustrates a tip **402** of the earbud, which has active electrodes **404***a*-**404***f*. Each active electrode of the active electrodes **404***a*-**404***f* on the tip **402** may be of an oval shape, for example. Each active electrode of the active electrodes **404***a*-**404***f* may be of the same size of a different size. One or more active electrodes **404***a*-**404***f* may be selected for measuring a biosignal, as described herein, in accordance with some embodiments. In alternative embodiments, the electrodes **404***a*-**404***f* may be rectangular-shaped or have other shapes. The electrodes **404***a*-**404***f* may each have the same shape and size or may have different shapes or sizes.

[0065] FIG. **5** depicts an example wearable electronic device, such as an earbud, and turning on or off a feature to measure a biosignal, as described herein, in accordance with some embodiments. The earbud **500** shown in FIG. **5** includes an earpiece **502** and a stem **504**. One or more reference electrodes **506***a*-**506***c* may be disposed on the earpiece **504**. Each reference electrode of the one or more reference electrodes **506***a*-**506***c* may be of an oval shape, for example. The reference electrodes may, however, be of any shape or size.

[0066] In some embodiments, a reference electrode may also be used to start or stop measurement of a biosignal. The reference electrode may also include or be coupled with a force sensor and/or accelerometer to receive an input from a user. The input from the user may be a tap, a touch, and/or a squeeze, etc., as shown in FIG. **5** as **508**.

[0067] In some embodiments, the input from the user may be an audio input, which may be received at a microphone of the earbud. In some embodiments, an optical sensor in the earbud may also be configured to receive an input from the user to start and/or stop measurement of the biosignal.

[0068] FIG. **6** depicts an electrical block diagram of a wearable electronic device **600**, as described herein, in accordance with some embodiments. The electrical block diagram **600** includes a set of electrodes **602** including a number of active electrodes **604** and a number of reference electrodes **606**. The number of active electrodes **604** may include active electrodes **604***a*-**604***h*. The number of reference electrodes **606** may include reference electrodes **606***a*-**606***c*. The active electrodes **604***a*-**604***h* and the reference electrodes **606***a*-**606***c* may be carried by an electrode carrier **608**, which may be a flex and/or a set of microaxial cables and may be electrically coupled to a controller **610**.

[0069] In some embodiments, the controller **610** may include a processor, a microcontroller, a DSP, an FPGA, and/or an ASIC, etc. The controller **610** may select one or more active electrodes **604***a*-**604***h* to form a subset of active electrodes of a number of subsets of active electrodes. The one or more active electrodes **604***a*-**604***h* may be selected based on criteria described herein, such as, including, but not limited to, an impedance level, noise (e.g., ambient noise, and/or electrode-skin interface noise, etc.), physical distance between an active electrode and a reference electrode, half-cell potentials, etc. Similarly, the controller **610** may select one or more reference electrodes **606***a*-**606***c* to form a subset of reference electrodes of a number of subsets of reference electrodes. The controller **610** may then perform a measurement test using the selected subsets of active and reference electrodes. In one example, the measurement may be for measuring an EEG.

[0070] FIGS. **7**A-**7**C depict a number of patterns of electrodes on a housing of a wearable electronic device, as described herein, in accordance with some embodiments. As shown in FIGS. **7**A-**7**C, a block diagram **700** in each figure may represent a view of electrodes, such as a number of active electrodes arranged in a particular pattern. For example, in FIG. **7**A, a view **702** is shown in which active electrodes **704***a*-**704***f* are arranged in a spine form using an electrode carrier (e.g., a flexible circuit substrate). In FIG. **7**B, a view **706** is shown in which active electrodes **708***a*-**708***d* are arranged in an octopus shape using an electrode carrier (e.g., a flexible circuit substrate). In FIG. **7**C, a view **710** is shown in which active electrodes **712***a*-**712***i* are arranged in a mesh network using an electrode carrier (e.g., a flexible circuit substrate). A particular form or shape in which the active electrodes may be arranged is not limited to the ones described herein. The form or shape may be selected based on the size of an earbud and available space for routing of a flex substrate, flexible circuit substrate, and/or a set of one or more micro axial cables.

[0071] FIG. **8** depicts an electrical block diagram of a sensing circuit of a wearable electronic device **800**, as described herein, in accordance with some embodiments. The sensing circuit **802** may include a switching circuit **804** including one or more switches **806***a*-**806***d*. Each of the one or more switches **806***a*-**806***d* may be connected to an active electrode and/or a reference electrode of a number of active and/or reference electrodes **808***a*-**808***d*. A processor **814**, which may be similar to the controller **610**, may include and/or execute an algorithm **812** to select one or more active electrodes to form a subset of active electrodes of a number of subsets of active electrodes, and to select one or more reference electrodes to form a subset of reference electrodes of one or more subsets of reference electrodes. The processor **814** may evaluate the criteria for selection of one or more active electrodes using an analyzer **810**. The analyzer may evaluate criteria including, but not limited to, an impedance level, noise (e.g., ambient noise, and/or electrode-skin interface noise, etc.), physical distance between an active electrode and a reference electrode, half-cell potentials, etc. The processor **814**, using the algorithm **812**, may initiate measurement of a biosignal using the selected subset of active electrodes and the selected subset of reference electrodes. In some cases, the electrodes of a subset of electrodes may be temporarily ganged, and a measurement of the biosignal may be obtained as a voltage between a subset of active electrodes and a subset of reference electrodes. In some