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(72) Inventor; and
(71) Applicant : **DRAKE, Stefan** [US/US]; 10390 Wilshire Blvd., #809, Los Angeles, CA 90024 (US).

(74) Agents: **MILLER, Kevin, L.** et al.; Saliwanchik, Lloyd & Eisenschenk, PO Box 142950, Gainesvile, FL 32614-2950 (US).

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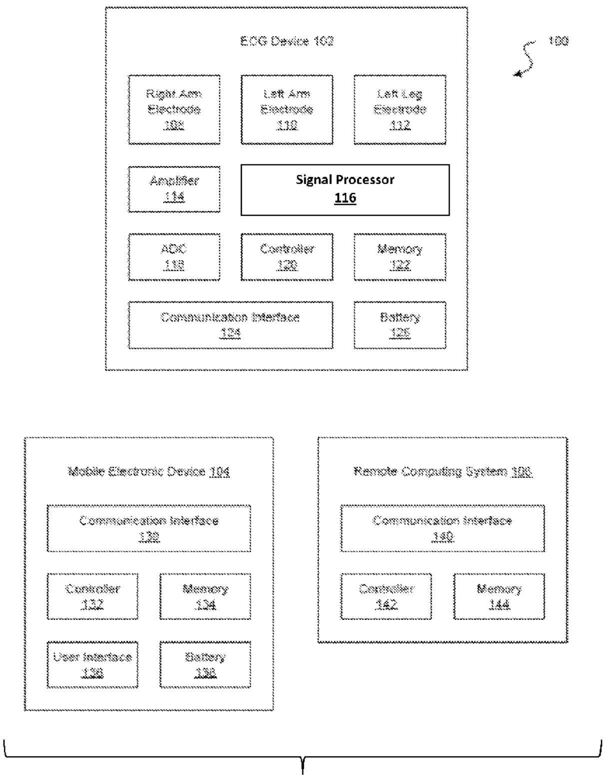

FIG. 1

(57) Abstract: A system for performing an electrocardiogram (ECG) can include a handheld electrocardiograph device having a right arm electrode, a left arm electrode, and a left leg electrode, and can be configured to receive signals from the electrodes and to send data based on the electrode signals to a mobile electronic device. The mobile electronic device can be configured to process and analyze the receive information to provide ECG data, such as 6-lead ECG data. The mobile electronic device can analyze the ECG data to provide diagnostic information. The mobile electronic device can transfer the ECG data to a remote computing system, which can analyze the ECG data to provide diagnostic information.

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SYSTEMS AND METHODS FOR PERFORMING ELECTROCARDIOGRAMS

CROSS-REFERENCE TO A RELATED APPLICATION

This application claims the priority benefit of U.S. Provisional Application Serial No. 62/080,203, filed November 14, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The electrocardiogram (ECG or EKG) is recognized as one of the most successful and important tools for rapid, noninvasive assessments of cardiac conditions. The resting 12-lead ECG (standard 12-lead ECG) recordings have been used to determine cardiac conditions in the presence of conflicting or ambiguous clinical symptoms. A 12-lead ECG can be obtained by attaching 10 electrodes to a patient: 4 limb lead electrodes are attached to limbs (left and right wrist, left and right ankle) and 6 precordial lead electrodes are attached to the torso. This configuration allows for recording leads I, II, Vi leads (where i = 1 to 6), and calculating leads III, aVR, aVL and aVF. Electrocardiographs can be used to display/print ECG waveforms and for generating clinical statements based on diagnostic criteria derived from ECG measurements. Interpretation of an ECG is performed by electrocardiogram waveform analysis and can sometimes be performed by a serial comparison of a current ECG to a previously recorded ECG.

However, the resting 12-lead ECG obtained in the hospital or doctor's office can have limitations imposed by the recording environment. Everyday life, exercise, stress and a number of physiological conditions can elicit cardiac problems that can be masked or are not present during recordings on the human body at rest. Therefore, a stress test and ambulatory recordings can be used as additional sources of information on cardiac status. During a stress test, limb electrodes can be moved to the torso to reduce noise and artifacts caused by movement of long wires, muscle activity, and unstable electrode-skin interface.

Moreover, the acquisition of cardiac signals from a patient while in a non-hospital setting can be hampered by a variety of circumstances. To obtain high-quality ECG recordings, the electrode-skin interface needs to be stable, otherwise noise and artifacts can distort the recording of signals. Furthermore, in some situations, it is impractical to attach electrodes and wires to the body of a patient in motion. In ambulatory settings, it can be impractical to record with a large number of wires, so a small recorder can be used to record only a few ECG channels.

BRIEF SUMMARY OF THE INVENTION

Systems and techniques are disclosed for obtaining electrocardiogram recordings with a portable handheld device that enables obtaining 6-lead electrocardiogram data. Obtaining 6-lead electrocardiogram data requires a device capable of recording leads I and II simultaneously in standard ECG mode. Such recordings require connection of the device with a patient's left arm, right arm, and left leg, therefore various embodiments disclosed herein relate to electrocardiograph devices that can have three electrodes (e.g., three dry electrodes). To obtain recordings, left and right hand device electrodes can be held by left and right hands and the third electrode can be pressed against the left leg. The device's third electrode can be pressed against the skin, for example, just above the knee or above the ankle.

In some embodiments, 3-electrode electrocardiograph devices can be coupled with mobile electronic devices that can provide 6-lead electrocardiogram data. In some cases, a mobile electronic device can display user interface elements configured to output information based on the 6-lead electrocardiogram data. In certain embodiments, a remote computing system may receive the 6-lead electrocardiogram data and provide diagnostic information.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an example embodiment of a system for performing electrocardiogram (ECG or EKG) recordings.

Figure 2 shows an example embodiment of a handheld electrocardiograph device.

Figure 3 shows an example embodiment of a handheld electrocardiograph device that is removably attached to a mobile electronic device.

Figure 4 shows a flow chart of an example method for performing electrocardiogram recordings.

Figure 5 shows a flow chart of an example method of operating an electrocardiogram system.

Figure 6 shows an example embodiment of a user interface for an electrocardiogram system.

Figure 7 shows a block diagram illustrating components of a computing device or system used in some implementations of systems and techniques for performing an electrocardiogram.

DETAILED DESCRIPTION OF THE INVENTION

Various embodiments disclosed herein relate to a portable handheld electrocardiograph device with three dry electrodes allowing for recordings of left arm (LA), right arm (RA) and left leg (LL) signals, which can be used to obtain 6 ECG leads (I, II, III, aVR, aVF, and aVL), as discussed herein. Various embodiments relate to medical instrumentation and information systems. A handheld electrocardiographic device, as disclosed herein, can provide the ability to record limb leads and auxiliary limb leads (e.g., 6 leads total) from subjects in ambulatory settings, which can be comparable the 12 leads recorded using a standard 12-lead electrocardiograph in hospital settings.

Use of a presently available single-lead handheld ECG device in ambulatory settings has limited diagnostic value compared to 12-lead ECG recorders. It can provide basic heart monitoring and it can be useful for characterizing various arrhythmias. When a recording is made between the left and right hand, it represents lead I (I=LA-RA) and it is equivalent to only lead I of a standard 12-lead ECG.

A device capable of recording leads I and II simultaneously in standard ECG mode would increase diagnostic yield compared to using a single-lead device. As recordings of lead II (II=LL−RA) requires connection of the device to the left leg, various embodiments disclosed herein relate to ECG devices that can have three electrodes (e.g., three dry electrodes). To obtain recordings, device left and right hand electrodes can be held by the subject's left and right hands and the third electrode can be pressed against the left leg. The device's third electrode can be pressed against the skin, for example, just above the knee or above the ankle.

ECG signals I and II obtained from electrodes can be amplified and digitized (e.g., by a microcontroller with an internal analog-to-digital converter. Data can then be transferred (e.g., via serial interface and Bluetooth module) to a mobile electronic device (e.g., a cellular phone) for initial display and storage. The mobile electronic device (e.g., a cellular phone) can perform initial processing and transmit data to a remote computing system (e.g., an ECG server or ECG cloud service) for interpretation, serial comparison, and analysis.

Various embodiments disclosed herein can relate to a handheld electrocardiographic device for simultaneous acquisition of six leads (limb leads and auxiliary limb leads). The device can include three dry electrodes for obtaining ECG signals I and II from a subject. Signals I and II can be obtained in the same manner as on a traditional 12-lead electrocardiograph. Leads III and auxiliary leads aVR, aVL and aVF can be calculated (e.g., based on Leads I and II). To emphasize ambulatory use, the conventional wet electrodes (usually silver-silver chloride Ag/AgCl) and skin preparation that hospitals use are replaced with dry electrodes requiring no skin preparation.

Lead I is defined as LA − RA, and can be obtained by holding the device's left and right electrodes with both the left and right hands while the device is faced down. Lead II is defined as LL − RA. Lead II can be obtained by holding the device with both the left and right hands while simultaneously pressing the third electrode against the skin just above the subject's knee or ankle.

The electrodes can be connected to amplifiers. The input of the amplifiers can be designed to accept signals from the dry electrodes. The output of the amplifiers can be connected to an analog-to-digital converter (ADC). Digital data from the ADC can be connected to a microcontroller. Data from the microcontroller can be sent to a communication interface (e.g., a Bluetooth interface) for transmission to a mobile electronic device (e.g., a cellular phone). The mobile electronic device can be used for initial data evaluation and/or to transfer data to a remote computing system (e.g., an ECG server). The data on the remote computing system (e.g., ECG server) can be evaluated (e.g., by automatic algorithms) and the diagnosis/results can be sent to the end user or to a doctor or other medical professional.

Figure 1 shows an example of a system **100** for performing electrocardiogram (ECG or EKG) recordings according to some embodiments. The system **100** can be configured to perform a 6-lead ECG. The system **100** can include an electrocardiograph (ECG) device **102** and a mobile electronic device **104**, and in some embodiments the system **100** can include a remote computing system **106**. The ECG device **102** can include three electrodes, such as a right arm electrode **108**, a left arm electrode **110**, and a left leg electrode **112**. In some embodiments, the system **100** can use fewer electrodes than a traditional 12-lead ECG, which would use ten electrodes, which can facilitate performance of the ECG procedure, especially for ECG procedures performed by a patient himself or herself. The system **100** can be configured to perform an ECG procedure (e.g., a 6-lead ECG) without using a right leg electrode, a V1 electrode, a V2 electrode, a V3 electrode, a V4 electrode, a V5 electrode, or a V6 electrode, which would ordinarily be used for a traditional 12-lead ECG. The system **100** can be configured to perform the ECG procedure using only the three electrodes **108**, **110**, and **112**.

In some embodiments, the electrodes **108**, **110**, and **112** can be dry electrodes, which can be configured to be used by a patient without applying a gel between the electrodes and the skin and/or with little or no skin preparation (e.g., shaving, cleaning, sanding, etc.). In some embodiments, the use of dry electrodes can result in higher impedance, and the system **100** (e.g., with amplifier **114**) can be configured to compensate for the higher impedance that can result from the use of dry electrodes instead of wet electrodes, which would generally be used for a traditional 12-lead ECG. In some embodiments, the electrodes **108**, **110**, and **112** can be made of stainless steel (e.g., low-carbon stainless steel such as 316L grade stainless steel). Various other conductive materials can be used for the electrodes **108**, **110**, and **112**, such as gold, silver, copper, aluminum, metal alloys, and various other suitably conductive materials.

In some embodiments, one or more wet electrodes can be used, but the use of dry electrodes can facilitate the performance of quick ECG recording procedures, especially those performed by the patient using a mobile device without direct involvement of a medical professional.

The ECG device **102** can include one or more amplifiers **114** configured to amplify signals (e.g., analog signals) from the electrodes **108**, **110**, and **112**. In some embodiments, each electrode **108**, **110**, and **112** has a corresponding amplifier **114** that is configured to amplify the signals from that electrode. In some embodiments, a single amplifier **114** can amplify the signals from two or all three of the electrodes **108**, **110**, and **112**. The one or more amplifiers **114** can be configured to amplify the signals to compensate for impedance, which may be produced, e.g., by the use of dry electrodes.

The ECG device **102** can include a signal processor **116**, which can be configured to perform one or more signal processing operations on the signals received from the right arm electrode **108**, from the left arm electrode **110**, and from the left leg electrode **112** (e.g., on the amplified analog signals output by the one or more amplifiers **114**). In some cases, the signal processor **116** can be configured to perform analog signal processing operations. In some embodiments, the signal processor **116** can be configured to compare and calculate signals from the different electrodes **108**, **110**, and **112**. For example, a first lead (Lead I) can be based at least in part on a voltage difference measured (e.g., by the signal processor **116**) between the left arm electrode **110** and the right arm electrode **108**, and a second lead (Lead II) can be based at least in part on a voltage difference measured (e.g., by the signal processor **116**) between the left leg electrode **112** and the right arm electrode **108**.

In some embodiments, the signal processor **116** can be configured to perform one or more signal processing operations to improve the signal-to-noise ratio for the signals. In some embodiments, the signal processor **116** can be configured to perform one or more signal processing operations to remove or reduce baseline wander. In some embodiments, the signal processor **116** can be configured to perform one or more signal processing operations to compensate for impedance (e.g., produced by the use of dry electrodes).

The ECG device **102** can include an analog-to-digital converter (ADC) **118**, which can be configured to convert analog signals (e.g., received from the signal processor **116**, from the one or more amplifiers **114**, or directly from the electrodes **108**, **110**, and **112**) to digital signals.

The ECG device **102** can include a controller **120**. The controller **120** can be a processor or processing system as described herein. In some embodiments, the ECG device **102** can include memory **122**, which can store executable program instructions that can be executed by the controller **120** to implement various methods, operations, and features described herein. Memory **122** can be a type of computer readable storage media as described herein. In some embodiments, the controller **120** can store data to the memory **122**. For example, data corresponding to the digital signals received over time can be stored on the memory **122** for use in signal processing operations that depend on previous signals. Results of signal processing and/or data analysis can be stored in the memory **122**, and can accessed by the controller **120** be used for later calculations. In some embodiments, data received and/or generated (e.g., by the controller **120**) can be stored on the memory **122** so that it can be periodically transmitted by the communication interface **124** (e.g., as packets of data).

In some embodiments, the controller **120** can be a digital controller and can be configured to receive digital signals (e.g., digital signals output by the ADC). The controller **120** can receive, for example, digital representations of the signals from the right arm electrode **108**, the left arm electrode **110**, and the left leg electrode **112**, or of the amplified (from **114**) and/or signal-processed (from **116**) versions of the original analog signals from the electrodes **108**, **110**, and **112**.

The controller **120** can receive separate signals corresponding to the three electrodes **108**, **110**, and **112**, or the controller **120** can receive signals that represent information from different combinations of the electrodes **108**, **110**, and **112** (e.g., signals associated with the voltage differences between electrodes). For example, in some embodiments, the controller **120** can receive a digital signal representing a voltage difference between the left arm electrode **110** and the right arm electrode **108** and a digital signal representing a voltage difference between the left leg electrode **112** and the right arm electrode **108**.

The controller **120** can perform one or more signal processing operations (e.g., digital signal processing on the digital signals received). The controller **120** can perform one or more digital signal processing operations to remove or reduce baseline wander, to improve the signal-to-noise ratio, to compensate for impedance (e.g., produced by the use of dry electrodes), etc. In some embodiments, the controller **120** can perform one or more linear phase filtering operations (e.g., recursive or non-recursive linear phase filtering).

The controller **120** can analyze the signals received by the controller **120**. For example, the controller **120** can compare and analyze signals corresponding to the different electrodes **108**, **110**, and **112**, for example, to determine a voltage difference between the left arm electrode **110** and the right arm electrode **108** (Lead I) and/or to determine a voltage difference between the left leg electrode **112** and the right arm electrode **108** (Lead II). In some embodiments, the controller **120** can determine the 6 leads for a 6-lead ECG, as discussed herein.

The ECG device **102** can include a communication interface **124**, which can be configured to enable the ECG device **102** to communicate with other communication interfaces to coupled interpretive devices, e.g., the communication interface **130** on the mobile electronic device **104**, the communication interface **140** on the remote computing system **106**, and/or other external systems for reporting results (e.g., a hospital information system, and a doctor email system). The controller **120** can send data to the communication interface **124** for transmission to coupled interpretative devices and/or external devices and systems. The communication interfaces **124**, **130**, and **140** described herein can be wireless communication interfaces as described with respect to device **1000** (Fig. 7). Communication interfaces **124**, **130**, and **140** can include, for example, Wi-Fi, Bluetooth, Bluetooth Low Energy (BLE), near field communication (NFC), 3G, and 4G. In some embodiments, the communication interface **124**, **130**, **140** can use a wire or cable or physical communication port to communicate data. For example, the ECG device **102** can include an electrical connector (e.g., a micro-USB connector or lightning connector) that is configured to engage a corresponding port on the mobile electronic device **104** (e.g., a micro-USB port or lightning port), or on another external device or system, to communicate information between the devices and/or systems. Other communication methods can be used as well. For example, the communication interfaces **124**, **130**, and **140** can be configured to transfer data via an audio input port or microphone.

The ECG device **102** can be a portable device, such as an accessory for use with the mobile electronic device **104**. The ECG device **102** can include a battery **126**, which can facilitate the portable nature of the ECG device **102**. Other power sources can be used. For example, the ECG device **102** can receive electrical power from an external power source (e.g., a wall outlet), or a battery **138** of the mobile electronic device **104** can supply electrical power to the ECG device **102**, for instance, when the ECG device **102** and the mobile electronic device **104** are coupled via a wire or cable (e.g., via a micro-USB or lightning connection) or passive charging system.

The mobile electronic device **104** can be a mobile phone (e.g., a smart phone), a tablet computer, a laptop computer, or other computing device. The mobile electronic device **104** can include a communication interface **130** as discussed. The communication interface **130** can be configured to send and/or receive information to and/or from the ECG device **102** (e.g., via a first communication protocol, which can have a relatively short range, such as Bluetooth, BLE, or NFC). The communication interface **130** can be configured to send and/or receive information to and/or from a remote computing system **106** (e.g., using a second communication protocol, which can have a relatively long range, such as Wi-Fi, 3G, 4G, TCP/IP over Ethernet, the Internet, etc.). In some embodiments, the mobile electronic device **104** can operate as a middleman to relay information between the ECG device **102** and the remote computing system **106** (or another external device or system).

The mobile electronic device **104** can include a controller **132**. The controller **132** can be a processor or processing system as described herein. In some embodiments, the mobile electronic device **104** can include memory **134**, which can store executable instructions that can be executed by the controller **132** to implement various methods, operations, and features described herein. In some embodiments, the controller **132** can store data to the memory **134**. For example, data corresponding to the digital signals received over time can be stored on the memory **134** for use in signal processing operations that depend on previous signals. Results of signal processing and/or data analysis can be stored in the memory **134**, and can accessed by the controller **132** to be used for later calculations. In some embodiments, data received and/or generated (e.g., by the controller **132**) can be stored on the memory **134**, such as for archiving, for later reference, or to be periodically transmitted by the communication interface **130** (e.g., as packets of data). Memory **134** can be a type of computer readable storage media as described herein.

In some embodiments, the controller **132** can run an application or program (which can be stored on memory **134**), which can perform the ECG processing, as described herein. In some embodiments, an application or program can run remotely (e.g., on the remote computing system **106**, using cloud computing, or as Software as a Service (SaaS)) to perform the ECG procedure.

The controller **132** can be configured to perform one or more signal processing operations (e.g., digital signal processing) on the data received from the ECG device **102**. The controller **132** can perform one or more digital signal processing operations to remove or reduce baseline wander, to improve the signal-to-noise ratio, to compensate for impedance (e.g., produced by the use of dry electrodes), etc. In some embodiments, the controller **132** can perform one or more linear phase filtering operations (e.g., recursive or non-recursive linear phase filtering).

The controller **132** can analyze data (e.g., received from the ECG device **102**). For example, the controller **132** can compare signals corresponding to the different electrodes **108**, **110**, and **112**, for example, to determine a voltage difference between the left arm electrode **110** and the right arm electrode **108** (Lead I) and/or to determine a voltage difference between the left leg electrode **112** and the right arm electrode **108** (Lead II).

In some embodiments, the controller **132** can determine the 6 leads for a 6-lead ECG, as discussed herein. The controller **132** can provide a 6-lead ECG having three limb leads: Lead I, Lead II, and Lead III, and three augmented limb leads: augmented vector right (aVR), augmented vector left (aVL), and augmented vector foot (aVF). The 6 leads can be represented by the following equations:

- Lead I = LA − RA;
- Lead II = LL − RA;
- Lead III = LL − LA;
- Augmented vector right (aVR) = RA − ½(LA + LL);
- Augmented vector left (aVL) = LA − ½(RA + LL); and
- Augmented vector foot (aVF) = LL − ½(RA + LA).

In the equations above, LA can correspond to a voltage of the left arm electrode **110**, RA can correspond to a voltage of the right arm electrode **108**, and LL can correspond to a voltage of the left leg electrode **112**. In some embodiments, the system **100** does not produce the precordial leads, which would normally be produced by a 12-lead ECG.

In some embodiments, Lead III, a VR, a VL, and a VF can be calculated based on Lead I and Lead II, as set forth in the following equations (wherein "I" corresponds to Lead I and "II" corresponds to Lead II):

• Lead III = II – I;

• aVR = – (I + II) / 2;

• aVL = I – II / 2; and

• aVF = II – I/2.

In some embodiments, the controller **132** can perform analysis on the ECG data (e.g., the 6-lead ECG data) to determine a heart rate, to make a determination of normal heart rhythm, and/or to diagnose one or more disorders. In some embodiments, data, algorithms, and methods that are established for analysis of 12-lead ECG data can be used to analyze the 6-lead ECG data (which can include 6 of the same leads as a traditional 12-lead ECG).

The mobile electronic device **104** can include a user interface **136**, which can be configured to receive input from a user and/or to output information to a user. In some embodiments, the user interface **136** can include one or more user input elements (e.g., buttons, switches, etc.), a microphone (e.g., for receiving dictated instructions), a display, a touchscreen display, a speaker, etc. The user interface **136** can receive an instruction (e.g., via input from a user) to initiate an ECG recording procedure. The communication interface **130** of the mobile electronic device **104** can send an instruction to the ECG device **102** to initiate the ECG procedure. The user interface **136** can provide instructions to a user for performing the ECG or related activities (e.g., to hold or touch the electrodes **108**, **110**, and **112**, to wait during a delay period or while signals are collected, to contact a doctor or emergency services, etc.). The user interface **136** can report information to a user (e.g., a heart rate, an ECG tracing, an indication of normal rhythm, a diagnosis, etc.).

The mobile electronic device can include a battery **138**, which can facilitate the portable nature of the mobile electronic device **104**. Other power sources can be used. For example, the mobile electronic device **104** can receive electrical power from an external power source (e.g., a wall outlet).

The communication interface **130** of the mobile electronic device **104** can be configured to send ECG data (e.g., 6-lead ECG data) to the remote computing system **106** (using the communication interface **140**), as discussed herein. The remote computing system **106** can be a server, a computer, or other computing system.

The remote computing system **106** can include a controller **142**. The controller **142** can be a processor or processing system as described herein. In some embodiments, the remote computing system **106** can include memory **144**, which can store executable program instructions that can be executed by the controller **142** to implement various methods, operations, and features described herein. Memory **144** can be a type of computer readable storage media as described herein. In some embodiments, the controller **142** can store data to the memory **144**. For example, data corresponding to the digital signals received over time can be stored on the memory **144** for use in signal processing operations that depend on previous signals. Results of signal processing and/or data analysis can be stored in the memory **144**, and can accessed by the controller **142** be used for later calculations. In some embodiments, data received and/or generated (e.g., by the controller **142**) can be stored on the memory **144**, such as for archiving, for later reference, etc. In some embodiments, the controller **142** can run an application or program (which can be stored on memory **144**), which can perform the ECG procedure (e.g., using cloud computing, or as Software as a Service (SaaS)).

The controller **142** of the remote computing system **106** can execute program instructions for performing an analysis on the ECG data (e.g., the 6-lead ECG data), which can be received from the mobile electronic device **104**, for example, to determine a heart rate, to make a determination of normal heart rhythm, and/or to diagnose one or more disorders.

In some embodiments, data, algorithms, and methods that are established for analysis of 12-lead ECG data can be used to analyze the 6-lead ECG data (which can include 6 of the same leads as a traditional 12-lead ECG). In some embodiments, the remote computing system **106** may have access to data and program instructions (e.g., stored in memory **144**) that are not directly accessible to the mobile electronic device **104** and/or more resources such as more powerful processor(s), so that the remote computing system **106** can perform more thorough analysis on the ECG data than would be performed on the mobile electronic device **104**. In some embodiments, the mobile electronic device **104** can perform an initial analysis (which can be performed relatively quickly on the local device) on the ECG data to make one or more initial determinations (e.g., regarding diagnosis and rhythm analysis), and the remote computing system **106** can perform a more detailed analysis (which may take longer time due to transmission of data, backlog of analysis requests, complexity of algorithms for data analysis, and/or the volume of calculations needed for the detailed analysis).

In some implementations, the controller **142** of the remote computing system **106** can be used to perform various signal processing and data analysis tasks described herein (e.g., digital signal processing, improvement of signal-to-noise ratio, removal or reduction of baseline wander, compensation for impedance, linear phase filtering, providing a 6-lead ECG), especially for embodiments where an application or program that performs the ECG procedure runs on the remote computing system **106** (e.g., using cloud computing or SaaS).

In some embodiments, the ECG device **102** can have a relatively low power processor (e.g., controller **120**) as compared to the processor(s) of the mobile electronic device **104** and/or the remote computing system **106** (e.g., controllers **132** and **142**), and the ECG device **102** can have more limited resources (e.g., less battery power, less memory storage, etc.) than the mobile electronic device **104** and/or the remote computing system **106**. Accordingly, in some implementations, the system **100** is configured to minimize or reduce the operations performed by the ECG device **102** and may preferentially perform operations on the mobile electronic device **104** and/or the remote computing system **106**.

In some embodiments, the ECG device **102** can be configured to perform the digital signal processing and analysis, as discussed herein, because the signals are converted to digital data before being transmitted from the ECG device **102**. In some embodiments, the ECG device **102** is configured to perform operations to reduce the amount of data to be transferred by the communication interface **124**, which can save power and time during the transfer of data from the ECG device **102**. For example, in some embodiments, the ECG device **102** is configured to send data corresponding to two voltage differences (leads I and II) instead of sending data corresponding to three signals from the three electrodes **108**, **110**, and **112**. Any or all of these variations of raw, transformed, or interpreted signal data may be referred to as "signal-related data."

The system **100** shown and described in connection with Figure 1 can be modified in various ways. For example, in some embodiments, the ECG device **102** and the mobile electronic device **104** can be combined into a single device (which can be a dedicated ECG and mobile device). In some embodiments, an ECG system can include a single device that performs the functions of the ECG device **102**, the mobile electronic device **104**, and the remote computing system **106** (e.g., a 6-lead ECG machine such as for use in a hospital or doctor's office). Embodiments of a combined ECG system may include fewer components than three separate devices to eliminate redundancy (e.g., controller **120**, **132**, and **142** may be combined into a single controller, communication interface **124**, **130**, and **140** into a single communication interface, etc.).

Figure 2 shows an example embodiment of an ECG device **102**. The ECG device **102** can include a housing **150**, which can house or enclose various components of the ECG device **102** (e.g., the one or more amplifiers **114**, the signal processor **116**, the analog-to-digital converter **118**, the controller **120**, the memory **122**, the communication interface **124**, and the battery **126**). The ECG device **102** can include the right arm electrode **108**, the left arm electrode **110**, and the left leg electrode **112**, which can be exposed to facilitate contact to the patient's skin. The electrodes **108**, **110** and **112** can be positioned on the bottom of the housing **150**. The right arm electrode **108** can be positioned on a right side to facilitate contact to the patient's right arm or hand. The left arm electrode **110** can be positioned on a left side to facilitate contact to the patient's left arm or hand. The left leg electrode **112** can be positioned in a central portion, to facilitate contact to the patient's left leg (e.g., to the left knee, left ankle, or left foot). The left leg electrode **112** can be positioned closer to the patient than the right arm electrode **108** and/or the left arm electrode **110**, when the electrodes face downward with the right arm electrode **108** on the right and the left arm electrode **110** on the left, which can reduce undesired contact between the electrodes **108**, **110**, and **112** with undesired parts of the patient's body and/or can reduce undesired contact between the parts of the patient's body being monitored, which could interfere with the readings for the ECG procedure.

In some embodiments, the right arm electrode **108** and the left arm electrode **110** may be positioned differently, e.g., in reverse of the configuration shown in Fig. 2. This positioning may vary in accordance with the chosen placement of the left leg electrode **112** of the device on the left leg, for example, on the dorsal or ventral sides of the left leg. In some embodiments, the designation of the pads as right arm electrode **108** and left arm electrode **110** may be selectable or configurable by the user, for instance via a user interface provided on the ECG device **102** or the mobile electronic device **104**.

In some embodiments, mobile electronic device **104** can include a user interface that can receive input from the user to assign or reassign one of the three electrodes to a particular limb. The designation can then be transmitted, in some cases, to the ECG device **102** via a communication interface (e.g., **124**, **130**) to associate a particular electrode to a limb reading. Advantageously, a user may be able to reassign the function of a physical electrode to a limb designation that is more comfortable to the user for gathering a particular signal. For example, if the user is more comfortable reading the left leg signal from the dorsal (rear) side of the leg, then the right and left arm electrodes may be assigned to the right and left electrodes, respectively, when the ECG device **102** is facing up. On the other hand, if the user is more comfortable reading the left leg signal from the ventral (front) side of the leg, then the right and left arm electrodes may be assigned to the left and right electrodes (i.e., opposite), respectively, when the ECG device **102** is facing up.

In some embodiments, the electrodes **108**, **110**, and **112** can be positioned immovably on the housing and immovably with respect to each other. In some embodiments, the ECG device **102** does not include wires or cables outside of the housing **150** that couple to the electrodes **108**, **110**, and **112**. The electrodes **108**, **110**, and **112** can be positioned close to each other to facilitate the portable and compact nature of the ECG device **102**, and the electrodes **108**, **110**, and **112** can be spaced apart sufficiently to reduce the likelihood of unintended contact between the electrodes **108**, **110**, and **112** (e.g., such as a body part contacting two or more of the electrodes simultaneously). The electrodes **108**, **110**, and **112** can be spaced apart by a distance that is at least about 3 mm, at least about 5 mm, at least about 10 mm, at least about 25 mm, at least about 50 mm or more, less than or equal to about 100 mm, less than or equal to about 75 mm, less than or equal to about 50 mm, less than or equal to about 25 mm, less than or equal to about 10 mm or less, although values outside these ranges can be used in some instances.

Figure 3 shows an example embodiment of an ECG device **102** that is removably attachable to a mobile electronic device **104** (e.g., a smart phone). The mobile electronic device **104** can include an attachment mechanism **152**, which can be configured to interface with an attachment mechanism **154** on the ECG device **102** to removably attach the ECG device **102** to the mobile electronic device **104** (e.g., onto the back side of the mobile electronic device **104** such as on a side opposite the display on a smart phone). The attachment mechanisms **152** and **154** can use sliding engagement, a snap fit, a clamp, etc. to removably couple the ECG device **102** to the mobile electronic device **104**. In some embodiments, only one or the other of the ECG device **102** and the mobile electronic device **104** may include an attachment mechanism. In the embodiment illustrated in Figure 3, the attachment mechanism **152** can include rails or guides **156a** and **156b** (e.g., formed at the sides of a raised platform) that are configured to slidably engage rails or guides **158a** and **158b** (e.g., formed at the sides of a recessed slot in the housing **150**). Various alternatives are possible for the attachment mechanisms. For example, in some embodiments, the ECG device **102** can be incorporated into a protective case that is configured to enclose at least a portion of the mobile electronic device **104**.

Figure 4 is a flowchart of an example method **200** of operation for performing an ECG procedure in accordance with some embodiments herein. At block **202**, the system can receive a command (e.g., from a user, which can be the patient) to start an ECG procedure. The command from the user can be received by the user interface **136** on the mobile electronic device, although in some embodiments, the ECG device can include a user input element configured to receive a user command to start an ECG procedure. In some embodiments, the ECG device **102** can receive an instruction to start an ECG procedure from the mobile electronic device **104** (e.g., via the communication interfaces **124** and **130**). At block **204**, the method **200** can include a delay, which can give the user time to position the electrodes **108**, **110**, and **112** into contact with the proper body portions (e.g., since the patient can be the user that issued the start command such as by pressing a button on the mobile electronic device **104**). The delay can be between about 1 and about 10, between about 2 seconds and about 5 second, or about 3 seconds, although other amounts of delay outside these ranges can be used in some instances. In some cases the delay may terminate when the user issues a continue command, e.g., by interacting with an element of the user interface on the touchscreen of the mobile electronic device **104** or by pressing a button on the housing of **104** or ECG device **102**.

At block **206**, signals from the electrodes **108**, **110**, and **112** can be received, as discussed herein. At block **208**, the signals from the electrodes **108**, **110**, and **112** can be amplified, as discussed herein. The amplification can compensate for impedance (such as produced by the use of dry electrodes). The amplification can be performed on analog signals received from the electrodes **108**, **110**, and **112**.

At block **210**, analog signal processing can be performed, such as described in connection with the signal processing module **116**. At block **212**, the analog signals can be converted to digital signals, such as by the analog-to-digital converter **118**, as discussed herein. At block **214**, digital signal processing can be performed, such as by the controller **120**, as discussed herein.

At block **216**, the ECG device **102** can communicate data (e.g., raw or interpreted data, depending on embodiment) to the mobile electronic device **104** (e.g., via the communication interfaces **124** and **130**). At block **218**, the mobile electronic device **104** can perform signal processing on the received data, as discussed herein. At block **220**, the mobile electronic device **104** can perform data analysis, such as to produce ECG data (e.g., 6-lead ECG data), to analyze the data to provide a heart rate, to provide a determination of normal or abnormal heart rhythm, and/or to provide a diagnosis of a heart disorder. At block **222**, information can be reported (e.g., to the user/patient, to a doctor, or other entity such as a hospital information system). The memory **134** can include information to facilitate reporting to external devices and systems, such as a doctor email address, hospital information system access information, etc.) In some information, information can be reported to a user via the user interface **136** on the mobile electronic device **104**.

At block **224**, data can be communicated to a remote computing system **106** (e.g., via the communication interfaces **130** and **140**). In some embodiments, the ECG data (e.g., 6-lead ECG data) can be transmitted to the remote computing system **106**, for example, for further processing and/or analysis (blocks **226** and **228**). In some embodiments, the mobile electronic device **104** can send information to the remote computing system **106** regarding initial determinations made by the analysis performed by the mobile electronic device **104**, and the remote computing system **106** can perform additional analysis to confirm or refute the initial determinations made by the mobile electronic device **104**. At block **230**, information, including concerning an additional analysis, can be reported (e.g., to the user/patient, to a doctor, or to another entity such as a hospital information system). The memory **144** at the remote computing system **106** can include information to facilitate reporting to external devices and systems, such as a doctor email address, hospital information system access information, etc. Reporting information can be transferred from the remote computing system **106** to the mobile electronic device **104** (via the communication interfaces **130** and **140**) for reporting to the user (e.g., via the user interface **136**). Many variations are possible. For example, various operations shown and described in connection with Figure 4 can be omitted, combined with other operations, or separated into sub-operations, and additional operations can be added.

Figure 5 is a flowchart showing an example embodiment of a method of use **300** for an ECG system. At block **302**, the user can provide an instruction to start an ECG procedure (e.g., via the user interface **136** on the mobile electronic device **104**). At block **304**, the user can contact the right arm electrode **108** to a portion of the user's right arm, such as by holding the ECG device **102** with a right thumb or finger on the right arm electrode **108**. At block **306**, the user can contact the left arm electrode **110** to a portion of the user's left arm, such as by holding the ECG device **102** with a left thumb or finger on the left arm electrode **110**. At block **308**, the user can contact the left leg electrode **112** to a portion of the user's left leg, such as by holding the ECG device **102** such that the left leg electrode **112** contacts the user's left leg (e.g., at the left knee or left ankle). At block **310**, the user can hold the contact with the electrodes **108**, **110**, and **112** for the duration of the ECG procedure, for example, until instructed via the user interface **136** that the procedure is completed such as with a visual, auditory, or tactile signal from the mobile electronic device **104** or ECG device **102**.

Figure 6 shows an example embodiment of a user interface **400** for an ECG system, which can be used, for example, for the user interface **136**, described herein. The user interface can be implemented on a display, such as a touch screen display, of a mobile electronic device **104**. The user interface **400** can include a user input element (e.g., a digital button on a touch screen display) for initiating an ECG procedure, such as a start button **404**. The user interface **400** can include a notification element **406** to notify the user of a delay period after receipt of a command to start an ECG procedure, such as a displayed count down from 3 to 2 to 1. The user interface **400** can include an ECG tracing portion **408**, which can be configured to show ECG tracing information during the ECG procedure, which can alert the user that the ECG procedure is being performed. In some embodiments, the ECG tracing portion **408** can display information that is unprocessed or only partially processed, which can result in the ECG tracing portion displaying a graphical representation that does not necessarily look like a normal ECG waveform, but which can inform the user that the system is successfully gathering information from the electrodes **108**, **110**, **112**. The user interface **400** can include an ECG waveform portion **410**, which can display a processed ECG tracing (e.g., for a single beat). The processed ECG tracing shown by portion **410** can be an average or weighted average based on some or all of the ECG data that was collected and processed. The user interface **400** can display heart rate information **412**. The user interface **400** can include a reporting portion for displaying commands or reports for the user. For example, as shown in element **414**, the reporting portion can report to the user that the ECG process was completed, that a determination of normal heart rhythm was determined, and that the user's doctor was notified. The user interface **410** can have an options section **416**, which can enable the user to change various options and parameters of the system. For example, the user can set an email address or other contact information for a doctor to be notified of ECG results, the user can change the delay time, etc.

Figure 7 shows a block diagram illustrating components of a computing device or system used in some implementations of techniques and systems for performing an electrocardiogram as described herein. For example, components of the system, including an electrocardiograph device, mobile electronic device, and/or remote computing system may be implemented as described with respect to device **1000.** Device **1000** can itself include one or more computing devices. The hardware can be configured according to any suitable computer architectures such as Symmetric Multi-Processing (SMP) architecture or Non-Uniform Memory Access (NUMA) architecture.

The device **1000** can include a processing system **1001**, which may include a processing device such as a central processing unit (CPU) or microprocessor and other circuitry that retrieves and executes software **1002** from storage system **1003**. Processing system **1001** may be implemented within a single processing device but may also be distributed across multiple processing devices or sub-systems that cooperate in executing program instructions. A controller, such as might be found on one or more system devices, can be a processing system or processor as described herein.

Examples of processing system **1001** include general purpose central processing units, application specific processors, and logic devices, as well as any other type of processing device, combinations, or variations thereof. The one or more processing devices may include multiprocessors or multi-core processors and may operate according to one or more suitable instruction sets including, but not limited to, a Reduced Instruction Set Computing (RISC) instruction set, a Complex Instruction Set Computing (CISC) instruction set, or a combination thereof. In certain embodiments, one or more digital signal processors (DSPs) may be included as part of the computer hardware of the system in place of or in addition to a general purpose CPU.

Storage system **1003** may comprise any computer readable storage media readable by processing system **1001** and capable of storing software **1002** including, e.g., processing instructions performing an electrocardiogram as described herein. Storage system **1003** may include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data.

Examples of storage media include random access memory (RAM), read only memory (ROM), magnetic disks, optical disks, CDs, DVDs, flash memory, solid state memory, phase change memory, 3D-XPoint memory, or any other suitable storage media. Certain implementations may involve either or both virtual memory and non-virtual memory. In no case do storage media consist of a propagated signal. In addition to storage media, in some implementations, storage system **1003** may also include communication media over which software **1002** may be communicated internally or externally.

Storage system **1003** may be implemented as a single storage device but may also be implemented across multiple storage devices or sub-systems co-located or distributed relative to each other. Storage system **1003** may include additional elements capable of communicating with processing system **1001**.

Software **1002** may be implemented in program instructions and, among other functions, may, when executed by device **1000** in general or processing system **1001** in particular, direct device **1000** or processing system **1001** to operate as described herein for performing an electrocardiogram. Software **1002** may provide program instructions **1004** that implement components for performing an electrocardiogram. Software **1002** may implement on device **1000** components, programs, agents, or layers that implement in machine-readable processing instructions **1004** the methods and techniques described herein.

In general, software **1002** may, when loaded into processing system **1001** and executed, transform device **1000** overall from a general-purpose computing system into a special-purpose computing system customized to perform an electrocardiogram in accordance with the techniques herein. Indeed, encoding software **1002** on storage system **1003** may transform the physical structure of storage system **1003**. The specific transformation of the physical structure may depend on various factors in different implementations of this description. Examples of such factors may include, but are not limited to, the technology used to implement the storage media of storage system **1003** and whether the computer-storage media are characterized as primary or secondary storage. Software **1002** may also include firmware or some other form of machine-readable processing instructions executable by processing system **1001**. Software **1002** may also include additional processes, programs, or components, such as operating system software and other application software.

Device **1000** may represent any computing system on which software **1002** may be staged and from where software **1002** may be distributed, transported, downloaded, or otherwise provided to yet another computing system for deployment and execution, or yet additional distribution. Device **1000** may also represent other computing systems that may form a necessary or optional part of an operating environment for the disclosed techniques and systems, e.g., remote computing system or mobile electronic device.

A communication interface **1005** may be included, providing communication connections and devices that allow for communication between device **1000** and other computing systems (not shown) over a communication network or collection of networks (not shown) or the air. Examples of connections and devices that together allow for inter-system communication may include network interface cards, antennas, power amplifiers, RF circuitry, transceivers, and other communication circuitry. The connections and devices may communicate over communication media to exchange communications with other computing systems or networks of systems, such as metal, glass, air, or any other suitable communication media. The aforementioned communication media, network, connections, and devices are well known and need not be discussed at length here.

It should be noted that many elements of device **1000** may be included in a system-on-a-chip (SoC) device. These elements may include, but are not limited to, the processing system **1001**, a communications interface **1005**, and even elements of the storage system **1003** and software **1002**.

Alternatively, or in addition, the functionality, methods and processes described herein can be implemented, at least in part, by one or more hardware modules (or logic components). For example, the hardware modules can include, but are not limited to, application-specific integrated circuit (ASIC) chips, field programmable gate arrays (FPGAs), system-on-a-chip (SoC) systems, complex programmable logic devices (CPLDs) and other programmable logic devices now known or later developed. When the hardware modules are activated, the hardware modules perform the functionality, methods and processes included within the hardware modules. In some cases, one or more capabilities, e.g., the processing system, storage system, and communication interface may be included on a single device such as a microcontroller.

Furthermore, while certain types of user interfaces and controls are described herein for illustrative purposes, other types of user interfaces and controls may be used. A user interface may be generated on a local computer or on a mobile device, or it may be generated from a service or cloud server and sent to a client for rendering, e.g., in a browser or "app."

Certain aspects of the invention provide the following non-limiting embodiments:

Example 1. A system for performing an electrocardiogram comprising: an electrocardiograph device, comprising: a housing comprising three electrodes, wherein the three electrodes are not coupled to the device with wires exterior to the housing; a communication interface; one or more computer readable storage media; program instructions stored on the one or more computer readable storage media that, when executed by a controller, direct the controller to: receive signals from the three electrodes; analyze the signals to determine signal-related data; transmit the signal-related data, via the communication interface, to a coupled interpretive device.

Example 2. The system of example 1, wherein the electrocardiograph device is a portable handheld device.

Example 3. The system of any of examples 1-2, wherein the electrocardiograph device further comprises: one or more amplifiers configured to amplify analog signals received from the three electrodes; and program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to receive and analyze amplified analog signals from the one or more amplifiers.

Example 4. The system of any of examples 1-3, wherein the electrocardiograph device further comprises: an analog signal processor configured to perform analog signal processing on analog signals received from the three electrodes; and program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to receive and analyze processed analog signals from the analog signal processor.

Example 5. The system of any of examples 1-4, wherein the electrocardiograph device further comprises: an analog-to-digital converter configured to convert analog signals from the three electrodes to digital signals; and program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to receive and analyze the digital signals from the analog-to-digital converter.

Example 6. The system of any of examples 1-5, wherein the electrocardiograph device further comprises program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to perform digital signal processing on the signals received from the three electrodes.

Example 7. The system of any of examples 1-6, further comprising: a mobile electronic device comprising: a second communication interface; second program instructions stored on second computer readable storage media that, when executed by second controller, direct the second controller to: receive the signal-related data transmitted by the communication interface of the electrocardiograph device; and provide 6-lead electrocardiogram data based at least in part on the data received by the second communication interface.

Example 8. The system of example 7, wherein the 6-lead electrocardiogram data includes Lead I, Lead II, Lead III, aVR, aVL, and aVF.

Example 9. The system of any of examples 7-8, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to: display user interface elements configured to receive input from a user to initiate an electrocardiogram procedure; and in response to receiving the input from the user, sending an instruction to the electrocardiograph device to initiate the electrocardiogram procedure.

Example 10. The system of example 9, wherein the system delays sending the instruction to initiate the electrocardiogram procedure by a delay time after receiving the input from the user.

Example 11. The system of any of examples 7-10, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to: display user interface elements configured to output information based on the 6-lead electrocardiogram data.

Example 12. The system of any of examples 7-11, further comprising a remote computing system comprising: third program instructions stored on third computer readable storage media that, when executed by third controller, direct the third controller to: receive the 6-lead electrocardiogram data provided from the mobile electronic device; and analyze the 6-lead electrocardiogram data; and provide diagnostic information.

Example 13. The system of example 12, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to: receive the diagnostic information provided from the remote computing system; and display user interface elements configured to output the diagnostic information provided from the remote computing system.

Example 14. The system of any of examples 7-13, wherein the electrocardiograph device is removably attached to the mobile electronic device.

Example 15. The system of any of examples 1-14, wherein the signal-related data includes 6-lead electrocardiogram data comprising Lead I, Lead II, Lead III, aVR, aVL, and aVF.

Example 16. The system of any of examples 1-15, wherein the three electrodes are fixed immovably to the outside of the housing of the electrocardiograph device.

Example 17. The system of any of examples 1-16, wherein the three electrodes comprise dry electrodes.

Example 18. The system of any of examples 17, wherein the electrocardiograph device further comprises program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to compensate for higher impedance of the dry electrodes.

Example 19. The system of any of examples claim 1-18, wherein the three electrodes comprise a right arm electrode, a left arm electrode, and a left leg electrode.

Example 20. The system of any of examples 7-18, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to: display user interface elements configured to receive input from a user to assign each of the three electrodes to a particular limb; and in response to receiving the input from the user, sending an instruction to the electrocardiograph device to associate readings from each of the three electrodes to the particular limb.

The embodiments discussed herein are provided by way of example, and various modifications can be made to the embodiments described herein. Certain features that are described in this disclosure in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can be implemented in multiple embodiments separately or in various suitable subcombinations. Also, features described in connection with one combination can be excised from that combination and can be combined with other features in various combinations and subcombinations. Various features can be added to the example embodiments disclosed herein. Also, various features can be omitted from the example embodiments disclosed herein.

Similarly, while operations are depicted in the drawings or described in a particular order, the operations can be performed in a different order than shown or described. Other operations not depicted can be incorporated before, after, or simultaneously with the operations shown or described. In certain circumstances, parallel processing or multitasking can be used. Also, in some cases, the operations shown or discussed can be omitted or recombined to form various combinations and subcombinations.

CLAIMS

1. A system for performing an electrocardiogram comprising:

an electrocardiograph device, comprising:

a housing comprising three electrodes, wherein the three electrodes are not coupled to the device with wires exterior to the housing;

a communication interface;

one or more computer readable storage media;

program instructions stored on the one or more computer readable storage media that, when executed by a controller, direct the controller to:

receive signals from the three electrodes;

analyze the signals to determine signal-related data; and

transmit the signal-related data, via the communication interface, to a coupled interpretive device.

2. The system of claim 1, wherein the electrocardiograph device is a portable handheld device.

3. The system of claim 1, wherein the three electrodes comprise a right arm electrode, a left arm electrode, and a left leg electrode.

4. The system of claim 1, wherein the electrocardiograph device further comprises:

one or more amplifiers configured to amplify analog signals received from the three electrodes; and

program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to receive and analyze amplified analog signals from the one or more amplifiers.

5. The system of claim 1, wherein the electrocardiograph device further comprises:

an analog signal processor configured to perform analog signal processing on analog signals received from the three electrodes; and

program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to receive and analyze processed analog signals from the analog signal processor.

6. The system of claim 1, wherein the electrocardiograph device further comprises:

an analog-to-digital converter configured to convert analog signals from the three electrodes to digital signals; and

program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to receive and analyze the digital signals from the analog-to-digital converter.

7. The system of claim 1, wherein the electrocardiograph device further comprises program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to perform digital signal processing on the signals received from the three electrodes.

8. The system of claim 1, further comprising:

a mobile electronic device comprising:

a second communication interface;

second program instructions stored on second computer readable storage media that, when executed by second controller, direct the second controller to:

receive the signal-related data transmitted by the communication interface of the electrocardiograph device; and

provide 6-lead electrocardiogram data based at least in part on the data received by the second communication interface.

9. The system of claim 8, wherein the 6-lead electrocardiogram data includes Lead I, Lead II, Lead III, aVR, aVL, and aVF.

10. The system of claim 8, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to:

display user interface elements configured to receive input from a user to initiate an electrocardiogram procedure; and

in response to receiving the input from the user, sending an instruction to the electrocardiograph device to initiate the electrocardiogram procedure.

11. The system of claim 10, wherein the system delays sending the instruction to initiate the electrocardiogram procedure by a delay time after receiving the input from the user.

12. The system of claim 8, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to:

display user interface elements configured to output information based on the 6-lead electrocardiogram data.

13. The system of claim 8, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to:

display user interface elements configured to receive input from a user to assign each of the three electrodes to a particular limb; and

in response to receiving the input from the user, sending an instruction to the electrocardiograph device to associate readings from each of the three electrodes to the particular limb.

14. The system of claim 8, further comprising a remote computing system comprising:

third program instructions stored on third computer readable storage media that, when executed by third controller, direct the third controller to:

receive the 6-lead electrocardiogram data provided from the mobile electronic device; and

analyze the 6-lead electrocardiogram data; and

provide diagnostic information.

15. The system of claim 14, wherein the mobile electronic device further comprises program instructions stored on the second computer readable storage media that, when executed by the second controller, direct the second controller to:

receive the diagnostic information provided from the remote computing system; and

display user interface elements configured to output the diagnostic information provided from the remote computing system.

16. The system of claim 8, wherein the electrocardiograph device is removably attached to the mobile electronic device.

17. The system of claim 1, wherein the signal-related data includes 6-lead electrocardiogram data comprising Lead I, Lead II, Lead III, aVR, aVL, and aVF.

18. The system of claim 1, wherein the three electrodes are fixed immovably to the outside of the housing of the electrocardiograph device.

19. The system of claim 1, wherein the three electrodes comprise dry electrodes.

20. The system of claim 19, wherein the electrocardiograph device further comprises program instructions stored on the one or more computer readable storage media that, when executed by the controller, direct the controller to compensate for higher impedance of the dry electrodes.

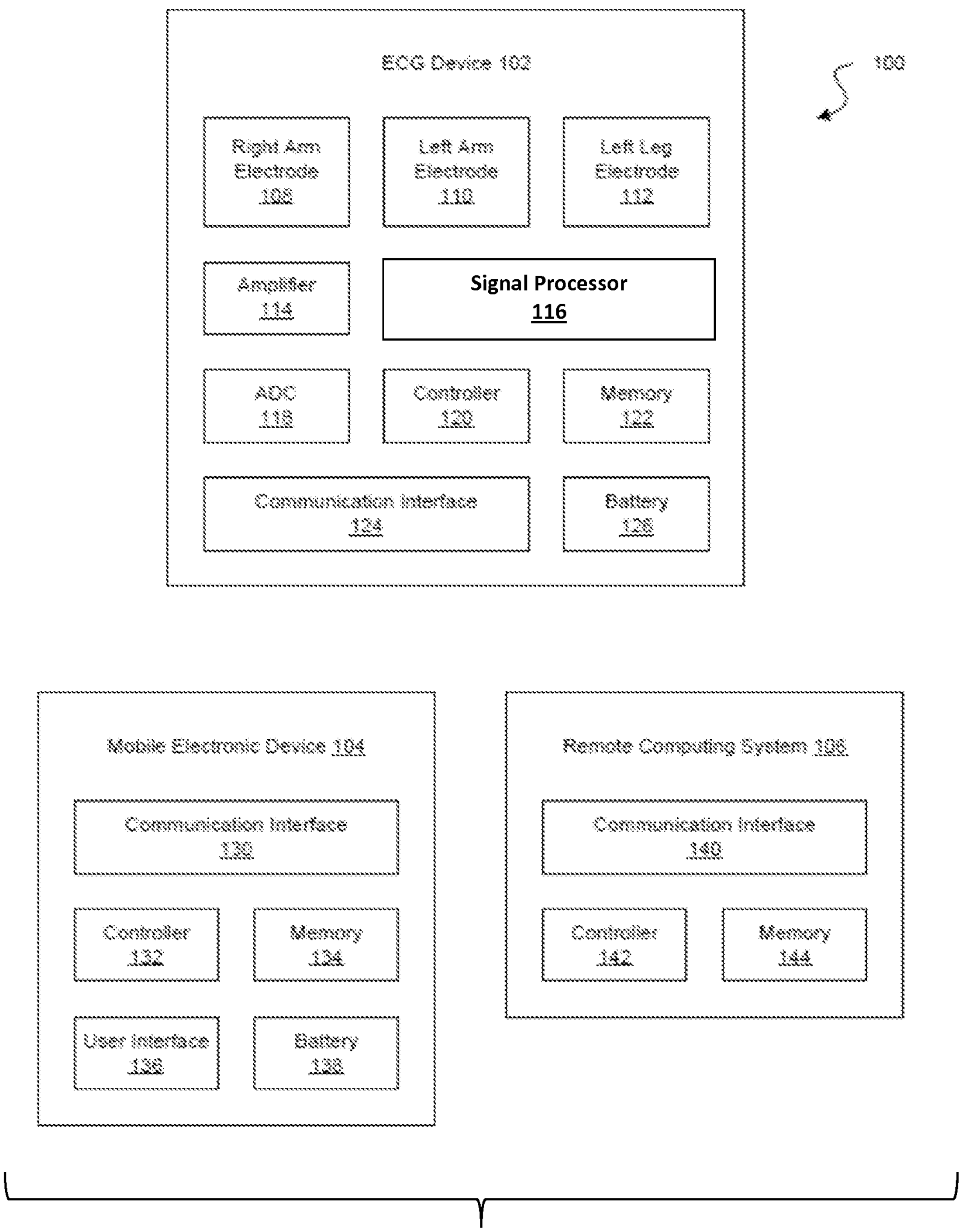
ECG Device 102
100
Right Arm Electrode 108
Left Arm Electrode 110
Left Leg Electrode 112
Amplifier 114
Signal Processor 116
ADC 118
Controller 120
Memory 122
Communication Interface 124
Battery 126
Mobile Electronic Device 104
Communication Interface 130
Controller 132
Memory 134
User Interface 136
Battery 138
Remote Computing System 106
Communication Interface 140
Controller 142
Memory 144

FIG. 1

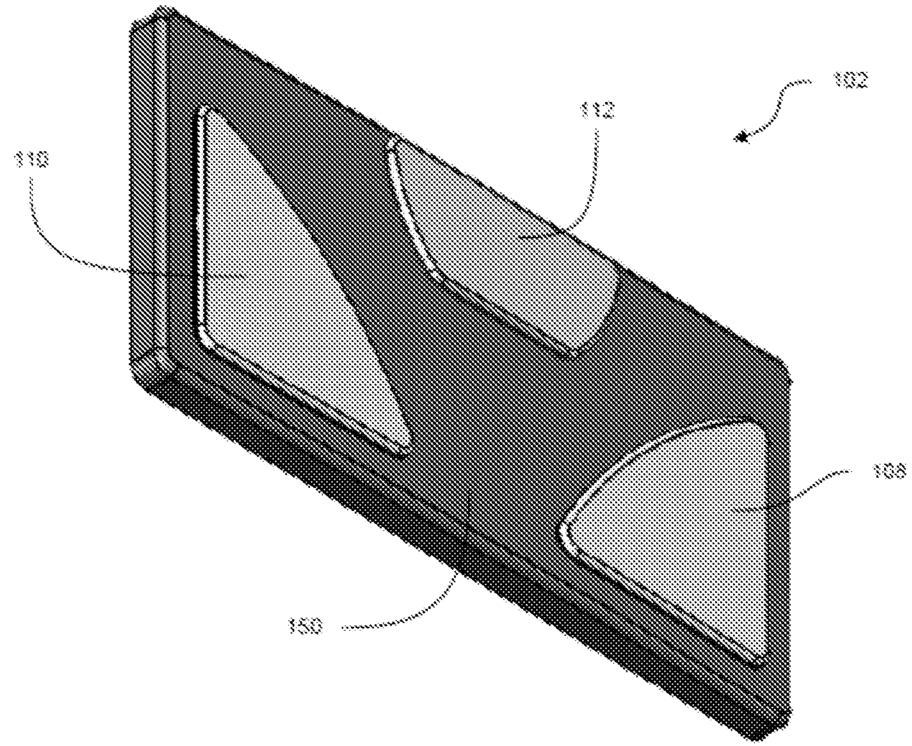
102
112
110
108
150

FIG. 2

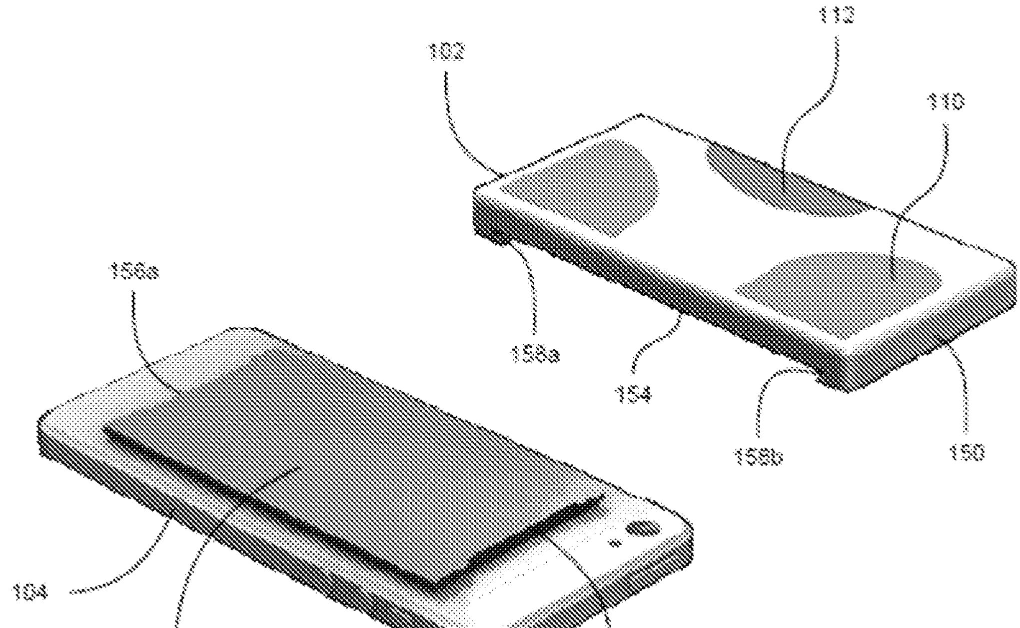
112
102
110
156a
158a
154
158b
150
104
152
156b

FIG. 3

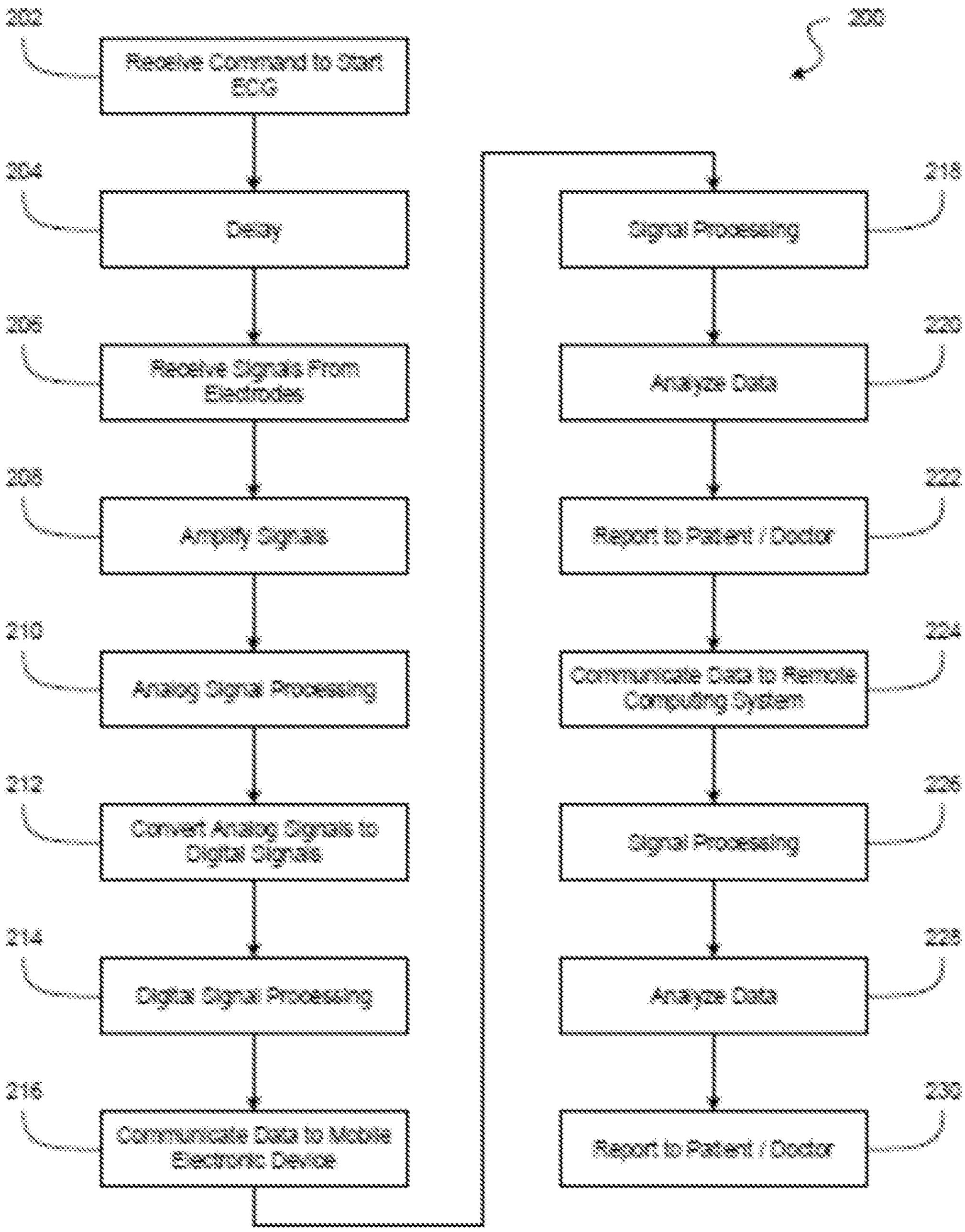
202
Receive Command to Start ECG
204
Delay
206
Receive Signals From Electrodes
208
Amplify Signals
210
Analog Signal Processing
212
Convert Analog Signals to Digital Signals
214
Digital Signal Processing
216
Communicate Data to Mobile Electronic Device
200
218
Signal Processing
220
Analyze Data
222
Report to Patient / Doctor
224
Communicate Data to Remote Computing System
226
Signal Processing
228
Analyze Data
230
Report to Patient / Doctor

FIG. 4

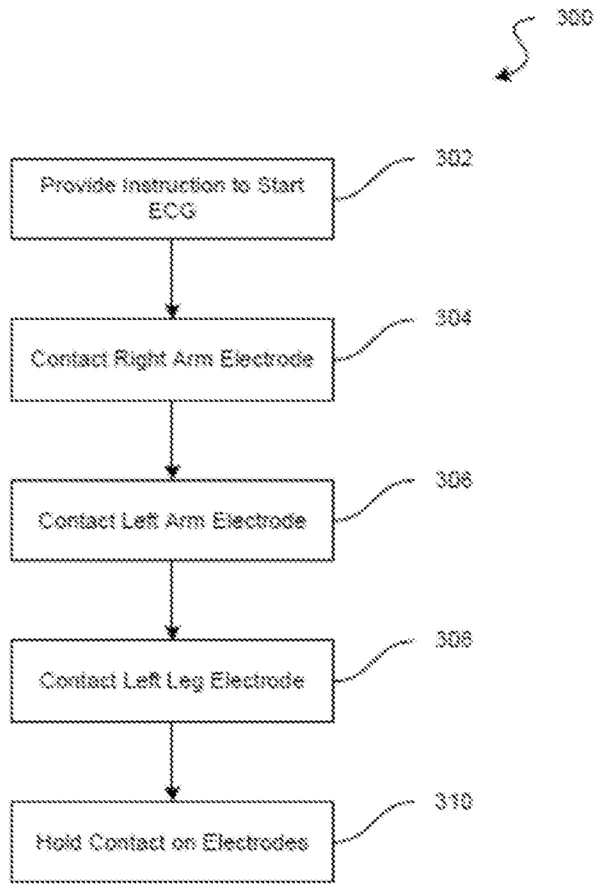
300
Provide Instruction to Start ECG
302
Contact Right Arm Electrode
304
Contact Left Arm Electrode
306
Contact Left Leg Electrode
308
Hold Contact on Electrodes
310

FIG. 5

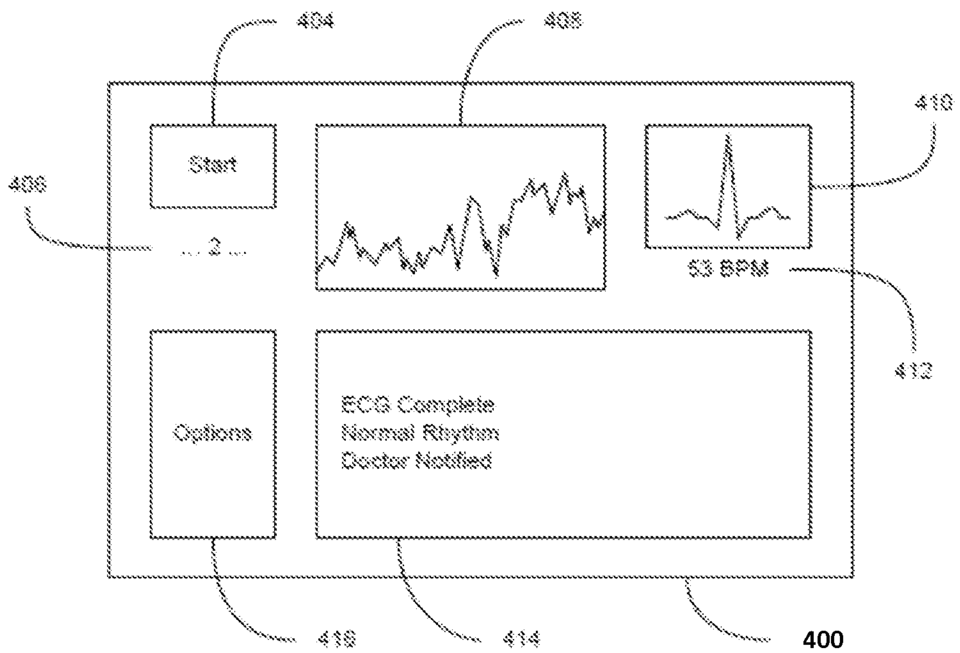
404
408
410
406
Start
... 2 ...
53 BPM
412
Options
ECG Complete
Normal Rhythm
Doctor Notified
418
414
400

FIG. 6

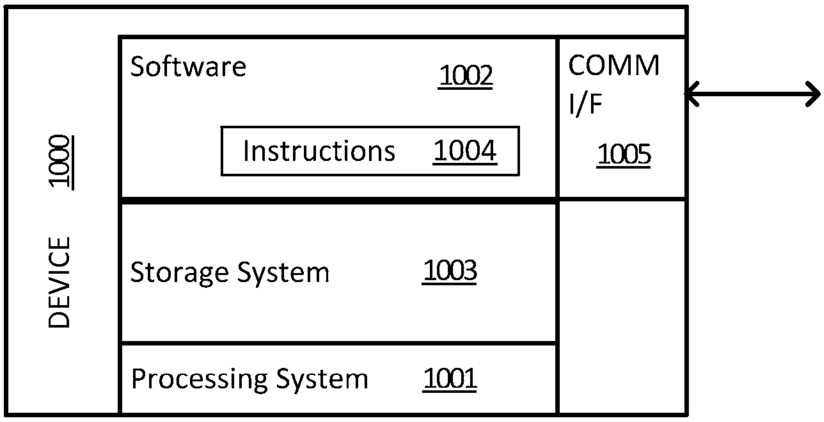
DEVICE
1000
Software
1002
Instructions
1004
Storage System
1003
Processing System
1001
COMM
I/F
1005

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/060761

A. CLASSIFICATION OF SUBJECT MATTER

A61B 5/0404(2006.01)i, A61B 5/0402(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B 5/0404; A61B 5/04; A61B 5/0402; A61B 5/0205; A61B 5/0408; A61B 5/0432

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: electrode, electrocardiogram

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0114166 A1 (AMIT BAXI) 24 April 2014 See abstract, paragraphs [0027]-[0041], claims 9,23 and figures 1,2,6A.	1-19
Y		20
Y	US 2006-0015033 A1 (DANIEL BLAKLEY et al.) 19 January 2006 See abstract, paragraphs [0035]-[0038], claim 33 and figure 1.	20
A	US 2011-0160601 A1 (WANG YANG et al.) 30 June 2011 See abstract, paragraphs [0041]-[0044] and figures 1-3.	1-20
A	WO 2010-038156 A1 (KONINKLIJKE PHILIPS ELECTRONICS N.V.) 08 April 2010 See abstract, pages 8-13 and figures 1-5.	1-20
A	US 2009-0099469 A1 (PAMELA A. FLORES) 16 April 2009 See abstract, paragraphs [0026]-[0030] and figures 1-4.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 February 2016 (29.02.2016)	**29 February 2016 (29.02.2016)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
COMMISSIONER
Telephone No. +82-42-481-8116

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/060761

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014-0114166 A1	24/04/2014	None	
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		US 7245961 B2	17/07/2007
		WO 2006-019573 A1	23/02/2006
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		CN 102113884 B	05/11/2014
WO 2010-038156 A1	08/04/2010	CN 101965151 A	02/02/2011
		CN 101965151 B	05/12/2012
		EP 2262421 A1	22/12/2010
		JP 2011-519305 A	07/07/2011
		JP 5489043 B2	14/05/2014
		RU 2010141543 A	20/04/2012
		RU 2501520 C2	20/12/2013
		US 2011-0125040 A1	26/05/2011
US 2009-0099469 A1	16/04/2009	None	