A wearable device (10) for acquiring electrocardiographic (ECG) signals is described, which comprises an envelope (11) comprising a first electrode (14) arranged on a first surface (15) and a second electrode (16) arranged on a second surface (18), the first electrode (14) to be placed in contact with the skin of a subject to be monitored and the second electrode (16) being accessible to be placed in contact with the skin of another part of the subject different from the part in contact with the first electrode (14), the device (10) comprising an electronic circuit (20) with a supplying section (30), an analogue section (40) connected to the first electrode (14) and to the second electrode (16) and adapted to filter the signal acquired by the first electrode (14) and by the second electrode (16), and a digital section (50) connected to the analogue section (40) and adapted to acquire the output signal from the analogue section (40).
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WEARABLE DEVICE FOR ACQUIRING ELECTROCARDIOGRAPHIC SIGNALS (ECG) SIGNALS

The present invention refers to a wearable device for acquiring electrocardiographic (ECG) signals.

In particular, the invention refers to a wearable device by a subject to be monitored, adapted to acquire electrocardiographic (ECG) signals under mono-derivation.

The device of the invention further allows storing acquired data and transmitting them to an electronic device connected in wireless mode, like a personal computer or a smartphone, which processes and displays these data or sends them to a remote processing center.

Devices for acquiring electrocardiographic (ECG) signals are known, and can be devices for clinical use or portable or wearable devices.

These known devices, however, are not satisfactory and have the following problems: known
devices for clinical use must be installed by specialized personnel and require the connection of cables and the use of gel on signal acquiring electrodes to obtain a stable contact between the electrode and the surface of the skin of the subject to be monitored; portable devices have reduced sizes and can be handled better than devices for clinical use, but anyway also require the connection of cables, and the use of gel on the electrodes; known wearable devices are not able to perform an acquisition of electrocardiographic (ECG) signals for a clinical use, but are only cardiac frequency meters and in some cases use signal filtering techniques which can distort its information content.

Object of the present invention is solving the above prior art problems, by providing a wearable device for acquiring electrocardiographic (ECG) signals which allows acquiring electrocardiographic (ECG) signals for a clinical use, though being wearable with comfort, being free of cables or of the need of applying gel on the electrodes.

The above and other objects and advantages of the invention, as will appear from the following
description, are obtained with a wearable device
for acquiring electrocardiographic (ECG) signals as
claimed in the independent claim. Preferred
embodiments and non-trivial variations of the
present invention are the subject matter of the
dependent claims.

It is intended that all enclosed claims are an
integral part of the present description.

The present invention will be better described
by some preferred embodiments thereof, provided as
a non-limiting example, with reference to the
enclosed drawings, in which:

- Figure 1a, 1b show two views of a wearable
device for acquiring electrocardiographic
signals (ECG) according to the present
invention;

- Figure 2 is a block diagram of an electronic
circuit of a wearable device for acquiring
electrocardiographic (ECG) signals according
to the present invention;

- Figure 3 is a block diagram of a first section
of the electronic circuit schematized in
Figure 2;

- Figure 4 is a block diagram of a second
section of the electronic circuit schematized in Figure 2; and

- Figure 5 is a block diagram of a third section of the electronic circuit schematized in Figure 2.

With reference to the Figures, a preferred embodiment of the wearable device 10 for acquiring electrocardiographic (ECG) signals of the present invention is shown and described. It will be immediately obvious that numerous variations and modifications (for example related to shape, sizes, arrangements and parts with equivalent functionality) can be made to what is described, without departing from the scope of the invention, as appears from the enclosed claims.

The wearable device 10 for acquiring of electrocardiographic (ECG) signals according to the invention comprises an envelope 11 comprising a first electrode 14 arranged on a first surface 15 and a second electrode 16 arranged on a second surface 18, said first electrode 14 being adapted to be placed in contact with the skin of a subject to be monitored and said second electrode 16 being accessible in order to be placed in contact with
the skin of a part of the body of the subject to be monitored different from the part in contact with the first electrode 14; preferably, the first electrode 14 and the second electrode 16 are arranged opposed on two surfaces 15, 18, one opposed to the other.

Preferably, the wearable device 10 for acquiring electrocardiographic (ECG) signals is wearable through a wrist band or a strap of the type adopted for wrist-watches, with the first electrode 14 resting onto the wrist of the subject to be monitored, in particular onto the internal part of the wrist or flying region, while the second electrode 16 is oriented towards outside and is accessible for the hand of the subject to be monitored which does not wear the device 10.

Namely, the wearable device 10 is capable of individually detecting all three signals which represent the three main perspectives covering the heart of a person, namely the perspective between the two arms, and the perspective between each arm and one leg. The wearable device 10 is capable of detecting all three main perspectives individually:

1) if the electrode along the lower surface of
the wearable device 10 is put in contact with the left wrist and the one on the upper surface is put in contact with the right wrist, it is possible to record the electro-cardiograph along the first perspective;

2\) if the electrode of the lower surface is put in contact with the left ankle, and the user touches the electrode on the upper surface with his right wrist, it is possible to record the electro-cardiograph along the second perspective; and

3\) if the electrode of the lower surface is put in contact with the left ankle, and the user touches the electrode on the upper surface with his left wrist, it is possible to record the electro-cardiograph along the third perspective.

In particular, the electrodes 14, 16 are of the dry type and are adapted to be used dry, without the need of applying gel on their surface, and in a known way one of the electrodes 14, 16 is connected to a positive pole and the other one to a negative pole of an electronic circuit 20, which is preferably contained in the envelope 11.

The electronic circuit 20 comprises a supplying section 30 and an analogue section 40.
connected to a digital section 50; the supplying section 30 is connected to the analogue section 40 and to the digital section 50.

The supplying section 30 is electrically connected and supplies the analogue section 40 and the digital section 50 and comprises a battery 33; preferably, the supplying section 30 comprises a charger 32 connected to an interface 31, for example of the micro-USB type, adapted a connect it to an electronic device, for example a personal computer, to a power supply or to other devices which can be connected to the interface 31 in a known way; the charger 32 is connected to the battery 33, for example a rechargeable lithium battery, and takes care of recharging it.

The battery 33 is in turn connected to a DC-DC converter 34 which is electrically connected to the analogue section 40 and to the digital section 50 and supplies them.

The analogue section 40 is connected to the first electrode 14 and to the second electrode 16 and takes care of filtering and conditioning the signal of the differential type acquired by the two electrodes 14, 16.
The analogue section 40 comprises a first differential amplification and pre-filtering stage 41, connected to the electrodes 14, 16 and a second amplification and filtering stage 42, connected to a third amplification and filtering stage 43 and to the first differential amplification and pre-filtering stage 41.

The first differential amplification and pre-filtering stage 41, the second amplification and filtering stage 42, the third amplification and filtering stage 43 and the feedback stage going from the third amplification and filtering stage 43 to the electrodes 14, 16 (Figure 4) are all connected to a "virtual ground", this providing the advantage of a better operation with single, and not double, supply.

The wearable device 10 thereby uses the first electrode 14 and the second electrode 16 as differential inputs to the first differential amplification and pre-filtering stage 41 and to the second amplification and filtering stage 42, without using a third ground electrode. With the correct value of their parameters, this type of designs allows obtaining results which are
comparable with those from systems with three electrodes, thereby reducing the costs for performing an ECG with two electrodes 14, 16 only. Moreover, in this particular configuration, the risk of having a dispersed current is reduced.

In a preferred way, the output signal from the first differential amplification and pre-filtering stage 41 is fed back to the electrodes to exploit the Driven Right Leg circuit.

In a preferred way, the output signal from the third amplification and filtering stage 43 is fed back to the electrodes to reduce the interference of the "common-mode" type.

The analogue section 40 further comprises an analogue-digital converter (ADC) 44 to which the output signal from the third amplification and filtering stage 43 is sent to convert the analogue signal into a digital signal and send it to the digital section 50 connected to the analogue-digital converter (ADC) 44.

The digital section 50 comprises a microcontroller 51 adapted to acquire the output signal from the analogue section 40, in particular from the ADC converter 44, and to store into a
memory, for example contained in the electronic circuit 20 of the device 10.

In a preferred way, the output of a voltage reference 999 is connected to the ADC converter 44.

Preferably, the digital section 50 comprises a wireless interface module 52, preferably a Bluetooth module, adapted to be interfaced and transmit data to an external device 55, for example a personal computer or a smartphone which can be connected through the wireless interface module 52 to the device 10; in particular, through the wireless interface module 52, the device 10 for acquiring electrocardiographic (ECG) signals is interfaced with an app of the smartphone or with a software of the personal computer adapted to process data detected by the electrodes 14, 16 to generate the electro-cardiogram.

Preferably, the digital section 50 comprises a user interface module 53 connected to the microcontroller 51 and to an interface of the device 10, for example composed of keys.

The operation of the wearable device 10 for acquiring electrocardiographic (ECG) signals will now be described, in the embodiment which provides
the wearable device on a wrist of the subject to be monitored and connectable through Bluetooth to a smartphone or to a personal computer.

The device 10 is worn on a wrist of the subject to be monitored, fastened with a strap and with the first electrode 14 which is in contact with the skin, next to the internal part of the wrist or flying region, while the second electrode 16 is oriented towards outside and is accessible to the other hand of the subject to be monitored which does not wear the device 10.

Now the data acquisition is started through the app installed on the smartphone (or the program installed on the personal computer) connected to the device 10 in Bluetooth mode.

Then, the subject to be monitored touches the second electrode 16 with the hand which does not wear the device 10; after an interval of time adequate to end the data acquisition is passes, for example about 10 seconds, the subject can detach his hand from the second electrode 16 and observe the ECG layout on the screen of the smartphone or of the PC, save it and data can be sent to a remote medical center, for example through and-mail, and
used for the remote monitoring of the subject.

Advantageously, the wearable device 10 for acquiring electrocardiographic (ECG) signals of the invention allows acquiring electrocardiographic

5 (ECG) signals for a clinical use without requiring the presence of connected cables and is operating 24 hours a day; advantageously, the device 10 of the invention is not invasive, is of a simple use and does not require the presence of specialized

10 personnel for its installation.
CLAIMS

1. Wearable device (10) for acquiring electrocardiographic (ECG) signals comprising:
   - an envelope (11) comprising a first electrode (14) arranged on a first surface (15) and a second electrode (16) arranged on a second surface (18), said first electrode (14) being adapted to be placed in contact with the skin of a subject to be monitored and said second electrode (16) being accessible in order to be placed in contact with the skin of a part of the body of the subject to be monitored different from the part in contact with the first electrode (14);
   - an electronic circuit (20) comprising a supply section (30), an analogue section (40) connected to the first electrode (14) and to the second electrode (16) and adapted to filter the signal acquired by the first electrode (14) and by the second electrode (16), and a digital section (50) connected to the analogue section (40) and adapted to acquire the output signal from the analogue section (40),
characterized in that the analogue section (40) comprises a first differential amplification and pre-filtering stage (41), connected to the electrodes (14, 16) and a second amplification and filtering stage (42), connected to a third amplification and filtering stage (43) and to the first differential amplification and pre-filtering stage (41), and further comprises an analogue-digital converter (ADC) (44) to which the output signal from the third amplification and filtering stage (43) is sent to convert the analogue signal into a digital signal and send it to the digital section (50) connected to the analogue-digital converter (ADC) (44), the wearable device (10) using the first electrode (14) and the second electrode (16) as differential inputs to the first differential amplification and pre-filtering stage (41) and to the second amplification and filtering stage (42), without using a third ground electrode.

2. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to claim 1, characterized in that the first electrode
(14) and the second electrode (16) are of the dry type, one of the two electrodes (14, 16) being connected to a positive pole and the other one to a negative pole of the electronic circuit (20).

3. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to claim 1 or 2, characterized in that the first electrode (14) and the second electrode (16) are arranged opposed on two surfaces (15, 18) of the envelope (11), one opposed to the other.

4. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to any one of the previous claims, characterized in that the supply section (30) comprises a battery (33) connected to a DC-DC converter (34) which is electrically connected to the analogue section (40) and to the digital section (50) and supplies them.

5. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to claim 4, characterized in that the supply section (30) comprises a charger (32) connected to the battery (33) and to an interface (31) adapted to connect the charger (32) to an electronic device.

6. Wearable device (10) for acquiring
electrocardiographic (ECG) signals according to any one of the previous claims, characterized in that the analogue section (40) comprises a first differential amplification and pre-filtering stage (41), connected to the electrodes (14, 16) and a second amplification and filtering stage (42), connected to a third amplification and filtering stage (43) and to the first differential amplification and pre-filtering stage (41), and further comprises an analogue-digital converter (ADC) (44) to which the output signal from the third amplification and filtering stage (43) is sent to convert the analogue signal into a digital signal and send it to the digital section (50) connected to the analogue-digital converter (ADC) (44).

7. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to claim 6, characterized in that the output signal from the third amplification and filtering stage (43) is fed-back to the electrodes (14, 16) to reduce the interference of the "common-mode" type.

8. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to any
one of the previous claims, characterized in that the digital section (50) comprises a microcontroller (51) adapted to acquire the output signal from the analogue section (40) and to store it into a memory.

9. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to any one of the previous claims, characterized in that the digital section (50) comprises a wireless interface module (52) adapted to be interfaced and transmit data to an external device (55) connectable through the wireless interface module (52) to the device (10).

10. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to claim 8 or 9, characterized in that the digital section (50) comprises a user interface module (53) connected to the microcontroller (51) and to an interface of the device (10).

11. Wearable device (10) for acquiring electrocardiographic (ECG) signals according to any one of the previous claims, characterized in that it is wearable through a wrist band or a strap with the first electrode (14) resting onto the wrist of
the subject to be monitored, in particular to the internal part of the wrist or flying region, while the second electrode (16) is oriented towards outside and is accessible for the hand of the subject to be monitored which does not wear the device (10).
**INTERNATIONAL SEARCH REPORT**

**International application No**
PCT/1T2017/000227

A. **CLASSIFICATION OF SUBJECT MATTER**

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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

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. **DOCUMENTS CONSIDERED TO BE RELEVANT**

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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
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European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer: Mecking, Nikolai
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<td>US 2016/192857 A1 (LEE YONG JIN [KR])&lt;br&gt;7 July 2016 (2016-07-07)&lt;br&gt;paragraphs [0020] - [0044], [0058], [0059]; figures 1-5</td>
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<td>US 5289824</td>
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<td>US 5317269 A</td>
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<td>US 5191891</td>
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