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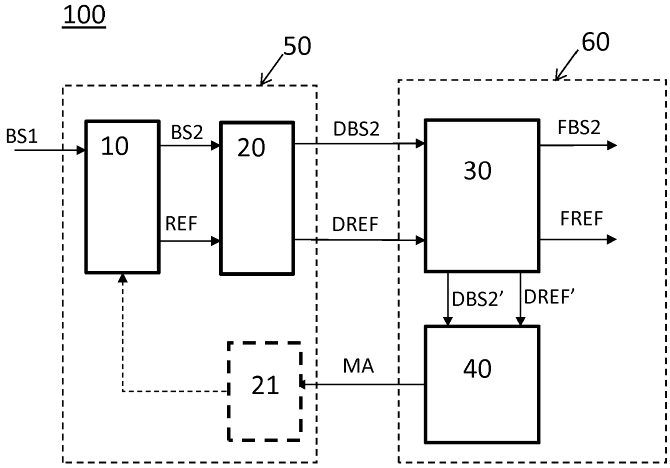
(54) **System and method for acquisition of biopotential signals with motion artifact reduction in real time operation**

(57) The invention relates to a biopotential signal acquisition system (100) comprising: an analogue readout unit (10) configured to receive an analogue biopotential signal (BS1) and to extract an analogue measured biopotential signal (BS2) and an analogue reference signal (REF); an ADC unit (20) configured to provide a digital version of the analogue measured biopotential signal (DBS2) and the analogue reference signal (DREF); a first digital filter unit (30) comprising a cascaded integrator-comb filter (32) configured to provide a first digital filtered version (DBS2', DREF') of the digital measured biopotential signal (DBS2) and the reference signal (DREF); and a second digital filter unit (40) configured to calculate a digital motion artifact estimate (MA) based on said first digital filtered version signals (DBS2', DREF'). The invention further relates to an electronic device and a method for acquisition of biopotential signals.

Figure 1



EP 2 904 963 A1

Description

Technical Field

[0001] The present invention relates generally to the field of biopotential signal acquisition systems and more specifically to a system and a method for acquisition of biopotential signals with motion artifact reduction using digital adaptive filtering.

Background

[0002] Ambulatory monitoring of biopotential signals, such as electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), etc., is a highly relevant topic in personal healthcare. A key technical challenge in such application environments is overcoming motion artifacts that significantly affect the recorded biopotential signals. An approach to reduce motion artifacts makes use of digital adaptive filtering. For example, a known biomedical acquisition system with motion artifact reduction is disclosed in EP 2 591 720 A1, which uses digital adaptive filtering (e.g. a LMS filter), implemented in a digital domain, to calculate a motion artifact estimate which is then fed back to the analogue domain and subtracted from the measured ECG before final amplification.

Summary

[0003] According to one aspect of the present invention, a new biopotential signal acquisition system is provided with improved motion artifact reduction. According to another aspects, the invention is also advantageous for ambulatory and/or low power biopotential monitoring applications.

[0004] According to an exemplary embodiment, there is provided a biopotential signal acquisition system comprising: an analogue readout unit configured to receive an analogue biopotential signal and to extract an analogue measured biopotential signal and an analogue reference signal; an ADC unit configured to provide a digital version of the analogue measured biopotential signal and the analogue reference signal; a first digital filter unit comprising a cascaded integrator-comb filter configured to provide a first digital filtered version of the digital measured biopotential signal and the reference signal; and a second digital filter unit configured to calculate a digital motion artifact estimate based on said first digital filtered version signals.

[0005] The analogue biopotential signal may be acquired, for example, from at least one electrode attached to a body. Advantageously, by calculating the digital motion artifact estimate using the digital filtered version of the signals at the output of the cascaded integrator-comb filter, the signal group delay is reduced. Furthermore, the convergence speed for calculating the motion artifact estimate in the second digital filter unit is reduced. In consequence, according to the present invention, system real-time response with motion artefact reduction is improved. In addition, in view of the technique according to the present invention, power consumption is also reduced.

[0006] According to an exemplary embodiment, the second digital filter unit implements or runs a digital adaptive filter.

[0007] According to an exemplary embodiment, the cascaded integrator-comb filter has a sampling frequency higher than the frequency band of the digital adaptive filter.

[0008] According to an exemplary embodiment, the digital adaptive filter is an LMS filter.

[0009] According to an exemplary embodiment, the ADC unit comprises a Sigma-Delta ADC.

[0010] According to an exemplary embodiment, the the analogue reference signal is an electrode-tissue impedance signal.

[0011] According to an exemplary embodiment, the analogue biopotential signal is an ECG signal.

[0012] According to an exemplary embodiment, the system is implemented on a single integrated circuit.

[0013] According to an exemplary embodiment, the calculated digital motion artifact estimate is converted to an analogue signal and fed to the analogue readout unit for motion artifact reduction.

[0014] According to an exemplary embodiment, the first digital filter unit further comprises a halfband decimation filter and a finite impulse response filter connected to the cascaded integrator-com filter.

[0015] There is also provided and electronic device comprising a biopotential signal acquisition system according to any of the embodiments herein described.

[0016] There is also provided a method for acquisition of biopotential signals, comprising: extracting, from an analogue biopotential signal, an analogue measured biopotential signal and an analogue reference signal; converting the analogue measured biopotential signal and an analogue reference signal into digital signals; filtering said digital measured biopotential signal and reference signal with a cascaded integrator-comb filter; and calculating a digital motion artifact estimate based on the digital filtered versions of the digital measured biopotential signal and the reference signal at the output of the cascaded integrator-comb filter.

[0017] According to an exemplary embodiment, the method further comprises converting the digital motion artifact estimate into an analogue signal and using said analogue motion artifact estimate for extracting the measured biopotential signal.

[0018] Certain objects and advantages of various new and inventive aspects have been described above. It is to be understood that not necessarily all such objects or advantages may be achieved in accordance with any particular embodiment of the present invention. Those skilled in the art will recognize that the solution of the present invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages without necessarily achieving other objects or advantages.

Brief description of the drawings

[0019] The above and other aspects of the system and method for acquisition of biopotential signals according to the present invention will be shown and explained with reference to the non-restrictive example embodiments described hereinafter.

Figure 1 shows a first exemplary block diagram of a biopotential signal acquisition system according to an embodiment of the invention.

Figure 2 shows a second exemplary block diagram of a biopotential signal acquisition system according to an embodiment of the invention.

Detailed description

[0020] In the following, in the description of exemplary embodiments, various features may be grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This is however not to be interpreted as the invention requiring more features than the ones expressly recited in the main claim. Furthermore, combinations of features of different embodiments are meant to be within the scope of the invention, as would be clearly understood by those skilled in the art. Additionally, in other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure the conciseness of the description.

[0021] **Figure** 1 shows a first exemplary block diagram of a biopotential signal acquisition system **100** according to an embodiment of the invention. The system comprises an analogue domain part **50** configured to receive at least one analogue biopotential signal **BS1,** which may be acquired, for example, from at least one sensor electrode attached to a living being body, and comprises an analogue readout unit **10** configured to extract at least one analogue measured biopotential signal **BS2** and at least one analogue reference signal **REF** from said received analogue biopotential signal **BS1.** The analogue measured biopotential signal **BS2** and the analogue reference signal **REF** are then provided to an analogue-to-digital converter (ADC) unit **20,** which comprises one or more ADCs configured to convert those signals into digital versions **DBS2, DREF** which are then handled in the digital domain part **60** of the system.

[0022] A first digital filter unit **30** receives the digital versions of the measured biopotential signal **DBS2** and the reference signal **DREF** and is configured to generate a digital filtered version of the measured biopotential signal **FBS2** and the reference signal **FREF.** The first digital filter unit **30** may comprise, for that purpose, according to an embodiment of the invention, a cascaded integrator-comb filter **32,** a halfband decimation filter **34** and a finite impulse response filter **36,** as will be further described in relation to **Figure 2.**

[0023] A second digital filter unit **40** is connected to the first digital filter unit **30** and receives intermediate digital filtered versions of the measured biopotential signal **DBS2'** and the reference signal **DFREF',** and is configured to calculate an estimated noise or motion artifact estimate **MA.** The motion artifact estimate **MA** may be used to reduce the motion artifact from the biopotential signal. According to an embodiment of the invention, the motion artifact estimate **MA** may be, for example, converted to an analogue signal and fed to the analogue readout unit **10** for motion artifact reduction in the analogue domain part **50.**

[0024] According to an exemplary embodiment, the second digital filter unit **40** may implement or run a digital adaptive filter, for example, a Least Mean Square (LMS) filter. But other types of digital adaptive filters may be implemented.

[0025] According to an exemplary embodiment, the analogue-to-digital converter (ADC) unit **20** comprises a Sigma-Delta ADC. This is advantageous since it increases the analogue-to-digital signal resolution of the acquisition system and the techniques herein described are particularly beneficial in combination with a Sigma-Delta ADC.

[0026] According to an exemplary embodiment, the analogue biopotential signal **BS1** is an electrocardiogram signal and the reference signal **REF** is an electrode-tissue impedance signal. Other reference signals could be used, such as for example, a galvanic skin response (GSR), a photoplethysmogram (PPG) or a bio impedance signal. Other biopotential signals may be also used.

[0027] According to an exemplary embodiment, the first digital filter unit **30** and the second digital filter unit **40** may be implemented in hardware and/or software, in a dedicated digital domain part **60** and integrated in the same chip as the analogue part **50,** for example in analogue-digital mixed signal implementations. This is advantageous for example to reduce the signal group delay and/or to reduce the power consumption for real-time biopotential signal acquisition applications.

[0028] **Figure 2** shows a second exemplary block diagram of a biopotential signal acquisition system **100** according to an embodiment of the invention. Basically the same working principle as the one explained **Figure 1** applies, but the details of the first digital filter unit **30** are now shown. According to an embodiment of the invention, the first digital filter unit **30** may comprise, a cascaded integrator-comb (CIC) filter **32,** a halfband decimation (DEC) filter **34** and a finite impulse response (FIR) filter **36.** This is particularly suitable for post processing of the digital signals provided by the ADC, and more particularly, a Sigma-Delta ADC. In general, the filter chain of the first digital filter unit **30** serves for decimation, integration of the signal and high frequency filtering. A different filter chain combination as the one shown in Figure 2, for post processing of the digital signals, may be envisaged and is a design choice.

[0029] According to an exemplary embodiment, the second digital filter unit **40** is connected to the output of the CIC filter **32,** so that it receives a first digital filtered version **DBS2', DREF'** of the digital measured biopotential signal **DBS2** and the reference signal **DREF.** The second digital filter unit **40** then uses those received signals **DBS2', DREF'** to calculate a motion artifact estimate **MA.**

[0030] Advantageously, according to the invention, the CIC filter **32** is designed with a sampling frequency that is higher than the frequency band of operation or final sampling frequency of the digital adaptive filter implemented in the second digital filter unit **40.** Therefore, the digital adaptive filter operation is not affected by frequency noise which lies above its frequency band of operation. According to the invention, the digital adaptive filter is designed to work as a low pass filter and therefore is not affected by high frequency noise. Accordingly, the digital adaptive filter can be advantageously directly connected to the CIC filter output. This is beneficial for example to reduce the signal group delay and/or increase the convergence speed for calculating the motion artefact estimate and/or reduce the power consumption in real-time biopotential signal acquisition applications. According to an exemplary embodiment of the invention, the CIC filter **32** has a sampling frequency of 1 KHz and the digital adaptive filter works at frequencies lower than 512 Hz.

[0031] Also advantageously, according to an embodiment of the invention, the system enables a low-latency feedback of the motion artifact estimate **MA** to the analogue part **50.** This is particularly useful, for example in mixed signal filter implementations.

Claims

1. A biopotential signal acquisition system (100) comprising:

an analogue readout unit (10) configured to receive an analogue biopotential signal (BS1) and to extract an analogue measured biopotential signal (BS2) and an analogue reference signal (REF);
an ADC unit (20) configured to provide a digital version of the analogue measured biopotential signal (DBS2) and the analogue reference signal (DREF);
a first digital filter unit (30) comprising a cascaded integrator-comb filter (32) configured to provide a first digital filtered version (DBS2', DREF') of the digital measured biopotential signal (DBS2) and the reference signal (DREF); and
a second digital filter unit (40) configured to calculate a digital motion artifact estimate (MA) based on said first digital filtered version signals (DBS2', DREF').

2. A biopotential signal acquisition system (100) according to claim 1, wherein the second digital filter unit (40) implements or runs a digital adaptive filter.

3. A biopotential signal acquisition system (100) according to claim 2, wherein the cascaded integrator-comb filter (32) has a sampling frequency higher than the frequency band of the digital adaptive filter.

4. A biopotential signal acquisition system (100) according to claim 2 or 3, wherein the digital adaptive filter is an LMS filter.

5. A biopotential signal acquisition system (100) according to any of the previous claims, wherein the ADC unit (20) comprises a Sigma-Delta ADC.

6. A biopotential signal acquisition system (100) according to any of the previous claims, wherein the analogue reference signal (REF) is an electrode-tissue impedance signal.

7. A biopotential signal acquisition system (100) according to any of the previous claims, wherein the analogue biopotential signal (BS1) is an ECG signal.

8. A biopotential signal acquisition system (100) according to any of the previous claims, implemented on a single integrated circuit.

9. A biopotential signal acquisition system (100) according any of the previous claims, wherein the calculated digital motion artifact estimate (MA) is converted to an analogue signal and fed to the analogue readout unit (10) for motion artifact reduction.

10. A biopotential signal acquisition system (100) according to any of the previous claims, wherein the first digital filter unit (30) further comprises a halfband decimation filter (34) and a finite impulse response filter (36) connected to the cascaded integrator-com filter (32).

11. Electronic device comprising a biopotential signal acquisition system (100) according to any of claims 1 to 10.

12. A method for acquisition of biopotential signals, comprising:

extracting, from an analogue biopotential signal (BS1), an analogue measured biopotential signal (BS2) and an analogue reference signal (REF);
converting the analogue measured biopotential

signal (BS2) and an analogue reference signal (REF) into digital signals (DBS2, DREF);
filtering said digital measured biopotential signal (DBS2) and reference signal (DREF) with a cascaded integrator-comb filter (32);
calculating a digital motion artifact estimate (MA) based on the digital filtered versions (DBS2', DREF') of the digital measured biopotential signal (DBS2) and the reference signal (DREF) at the output of the cascaded integrator-comb filter (32).

13. A method for acquisition of biopotential signals according to claim 12 further comprising converting the digital motion artifact estimate (MA) into an analogue signal and using said analogue motion artifact estimate for extracting the measured biopotential signal (BS2).

Figure 1

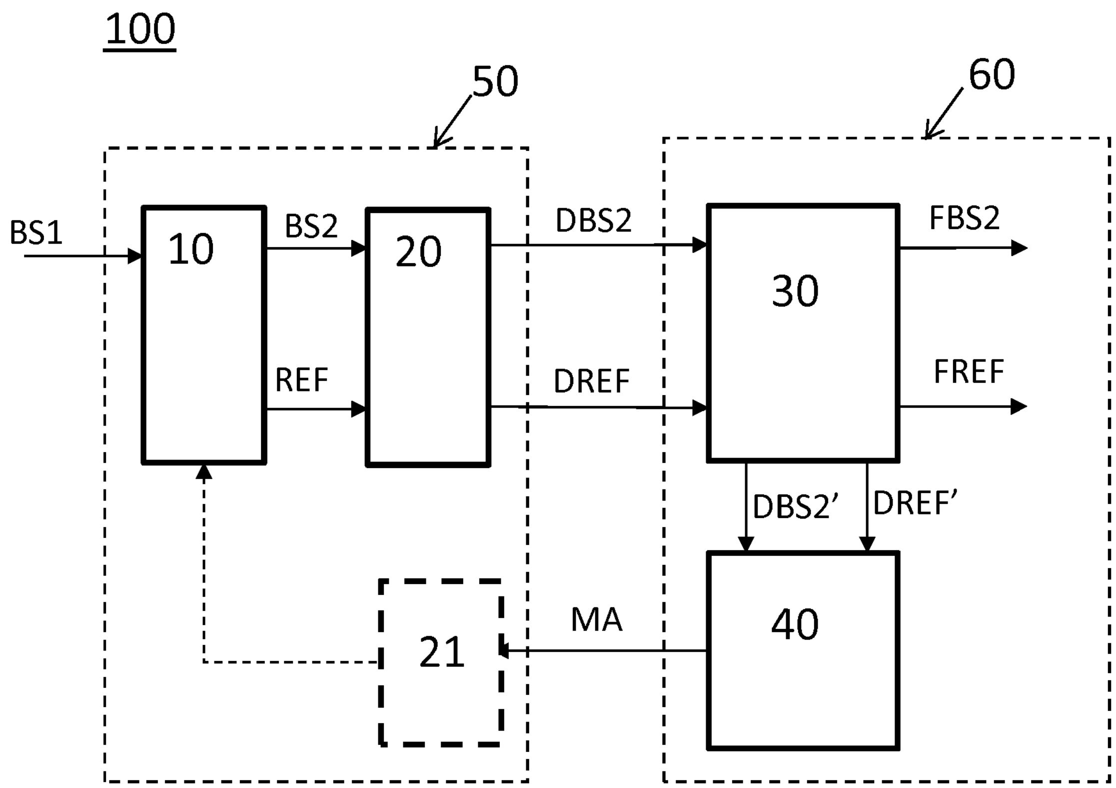
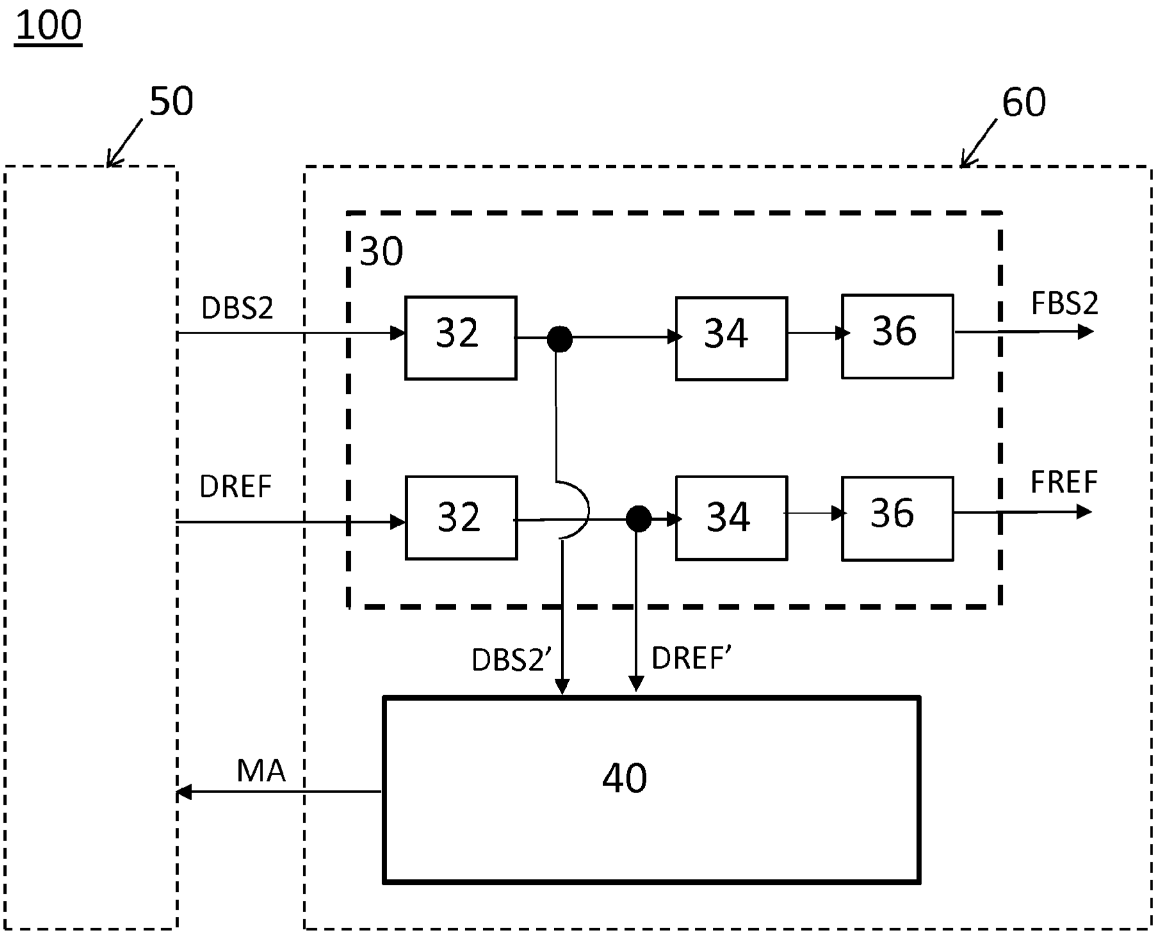

100
50
60
BS1
10
BS2
20
REF
DBS2
DREF
30
FBS2
FREF
DBS2'
DREF'
40
MA
21

Figure 2



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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 4192

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	SUNYOUNG KIM ET AL: "Real time digitally assisted analog motion artifact reduction in ambulatory ECG monitoring system", THE EFFECT OF APPLIED COMPRESSIVE LOADING ON TISSUE-ENGINEERED CARTILAGE CONSTRUCTS CULTURED WITH TGF-BETA3, IEEE, 28 August 2012 (2012-08-28), pages 2096-2099, XP032463352, ISSN: 1557-170X, DOI: 10.1109/EMBC.2012.6346373 * page 2096 - page 2098 * * figure 2 * -----	1-13	INV. A61B5/00 A61B5/04 A61B5/0402
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	4 July 2014	Vanderperren, Yves

CATEGORY OF CITED DOCUMENTS

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 2591720 A1 **[0002]**

patsnap

专利名称(译)	用于在实时操作中获取具有运动伪影减少的生物电势信号的系统和方法		
公开(公告)号	[EP2904963A1](EP2904963A1)	公开(公告)日	2015-08-12
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CPC分类号	A61B5/7207 A61B5/04012 A61B5/04017 A61B5/0402 A61B5/0476 A61B5/0488 A61B5/7214		
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审查员(译)	VANDERPERREN，YVES		
其他公开文献	EP2904963B1		
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摘要(译)

本发明涉及一种生物电势信号采集系统（100），包括：模拟读出单元（10），被配置为接收模拟生物电势信号（BS1）并提取模拟测量的生物电势信号（BS2）和模拟参考信号（REF）。;ADC单元（20），被配置为提供模拟测量的生物电势信号（DBS2）和模拟参考信号（DREF）的数字版本;第一数字滤波器单元（30），包括级联积分器 - 梳状滤波器（32），其被配置为提供数字测量生物电势信号（DBS2）的第一数字滤波版本（DBS2'，DREF'）和参考信号（DREF）;第二数字滤波器单元（40），被配置为基于所述第一数字滤波版本信号（DBS2'，DREF'）计算数字运动伪影估计（MA）。本发明还涉及一种用于获取生物电势信号的电子设备和方法。

Figure 1