I. Publications in Indicator B4

B4.1:Dobrev D, Neycheva T, Mudrov N. (2008) Bootstrapped two-electrode biosignal amplifier. Medical and Biological Engineering and Computing, 46, 6, ISSN:0140-0118, 613-619. SJR (Scopus):0.581, JCR-IF (Web of Science):1.843, Q2 (Web of Science),
http://link.springer.com/article/10.1007%2Fs11517-008-0312-4#/page-1

Abstract:

Portable biomedical instrumentation has become an important part of diagnostic and treatment instrumentation. Low-voltage and low-power tendencies prevail. A two-electrode biopotential amplifier, designed for low-supply voltage (2.7–5.5 V), is presented. This biomedical amplifier design has high differential and sufficiently low common-mode input impedances achieved by means of positive feedback, implemented with an original interface stage. The presented circuit makes use of passive components of popular values and tolerances. The amplifier is intended for use in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

B4.2:Dobrev D, Neycheva T, Mudrov N. (2005) Simple two-electrode biosignal amplifier. Medical and Biological Engineering and Computing, 43, 6, ISSN:0140-0118, 725-730. SJR (Scopus):0.564, JCR-IF (Web of Science):1.484 Q2 (Web of Science),http://link.springer.com/article/10.1007%2FBF02430949#/page-1

Abstract:

A simple, cost effective circuit for a two-electrode non-differential biopotential amplifier is proposed. It uses a "virtual ground" transimpedance amplifier and a parallel RC network for input common-mode current equalisation, while the signal input impedance preserves its high value. With this innovative interface circuit, a simple non-inverting amplifier fully emulates high CMRR differential. The amplifier equivalent CMRR (typical range from 70-100 dB) is equal to the open loop gain of the operational amplifier used in the transimpedance interface stage. The circuit has very simple structure and utilises a small number of popular components. The amplifier is intended for use in various two-electrode applications, such as Holter-type monitors, defibrillators, ECG monitors, biotelemetry devices etc.

B4.3:Dobrev D, Alnasser E, Neycheva T. (2021) Lossy Integrator Readout Circuit With Active Bias Point. IEEE Sensors Journal, 21, 22, IEEE, ISSN:1530-437X, DOI:10.1109/JSEN.2021.3118045, 25808-25817. SJR (Scopus):0.926, JCR-IF (Web of Science):4.325 Q1, не оглавява ранглистата (Web of Science) ,
https://ieeexplore.ieee.org/document/9559972

Abstract

The charge-generating sensors are widely used in many applications in consumer, automotive and medical electronics. They generate a charge proportional to the applied input quantity: pressure, temperature, acceleration, strain, light, etc. Usually, charge amplifiers are used to register such signals. The charge amplifier is an integrator that integrates the input current over time. In continuous-time signal processing, a parallel resistor is used to dissipate the energy stored on the integration capacitor, and such self-zeroed integrator circuits are known as lossy integrators. To achieve low-frequency operation, when a capacitor is in the picofarad range, a very high-ohmic resistor, in the range of gigaohms, must be used. Such a high-ohmic resistor increases the output offset voltage to an unacceptable level. To overcome the output offset problems, a composite charge amplifier has been recently introduced. This paper presents an innovative lossy integrator readout circuit which contains only one opamp in the feedback. The circuit can be easily adapted to the needed gain and cut-off frequency. Its operation is validated by experimental results. The

sufficiently low high-pass cut-off frequency allows the circuit to be used for biosignal amplification. Heart and respiration rates can be easily recorded with piezoelectric sensors attached to the wrist or lung wall. The presented circuit can benefit many applications where charge-to-voltage conversion is needed.

B4.4: Neycheva T, Stoyanov T, Abacherli R, Christov I. (2013) High resolution 16-channel ECG tester simulator for online digital-to-analogue conversion of data from PC. *Computing in Cardiology*, vol. 40, pp. 457-460, ISSN: 2325-8853, IEEE, SJR:0.234, Q3 (Scopus), https://ieeexplore.ieee.org/document/6713412

Abstract:

Recent design of electrocardiographic simulators should be consistent with the international standard IEC 60601-2-47 issued 2012, which recommends the measurements, detections and interpretative statements of the ECG to be tested by digitized ECGs signals taken from five standard databases.

In accordance with this recommendation we designed a high-resolution ECG tester simulator for direct digital-to-analogue conversion of data from PC. The signals selected from a database are sent from the PC to the Simulator via USB. The prototype has 16 independents channels, high sampling frequency of 2 kHz, and 286 nV/bit amplitude response of the analogue output. The power-line interference is minimized by a galvanic isolation of the communication between the PC and the simulator. The need of build-in circuit for a Wilson Central Terminal is avoided by the use of 12-Standard-leads to 8-primary-leads transfer formulas.

In-house PC software in Visual C is developed to select and control the operation mode of the simulator. The transmitted signals are real-time visualized on the PC monitor.

B4.5: Christov I, Neycheva T, Schmid R, Stoyanov T, Abächerli R. (2017) Pseudo real-time low-pass filter in ECG, self-adjustable to the frequency spectra of the waves. *Medical & Biological Engineering & Computing*, vol. 55 (9), pp. 1579-1588, DOI: 10.1007/s11517-017-1625-y, ISSN: 1741-0444, Springer, ISI IF: 1.971, Q2 (Web of Science), https://link.springer.com/article/10.1007/s11517-017-1625-y

Abstract

The electrocardiogram (ECG) acquisition is often accompanied by high frequency electromyographic (EMG) noise. The noise is difficult to be filtered, due to considerable overlapping of its frequency spectrum to the frequency spectrum of the ECG. Today filters must conform to the new guidelines (2007) for low-pass filtering in ECG with cutoffs of 150 Hz for adolescents and adults, and to 250 Hz for children. We are suggesting a pseudo real-time low-pass filter, self-adjustable to the frequency spectra of the ECG waves. The filter is based on the approximation procedure of Savitzky-Golay with dynamic change of the cut-off frequency. The filter is implemented pseudo real-time (real-time with a certain delay). An additional option is the automatic on/off triggering, depending on the presence/absence of EMG noise. The analysis of the proposed filter shows that the low frequency components of the ECG (low-power P- and T-waves, PQ-, ST- and TP-segments) are filtered with a cut-off of 14 Hz, the high-power P- and T-waves are filtered with a cut-off frequency in the range of 20-30 Hz, and the high-frequency QRS complexes are filtered with cut-off frequency of higher than 100 Hz. The suggested dynamic filter satisfies the conflicting requirements for a strong suppression of EMG noise, and at the same time a maximal preservation of the ECG high frequency components.

B4.6: Christov I, Neycheva T, Schmid R. (2017) Fine tuning of the dynamic low-pass filter for electromyographic noise suppression in electrocardiograms. Computing in Cardiology, 44, IEEE, ISSN:2325-887X, DOI:10.22489/CinC.2017.088-007, 1-4. SJR (Scopus):0.191, Q3 (Scopus) http://www.cinc.org/archives/2017/pdf/088-007.pdf

Abstract

In a series of publications, we have proposed and discussed the effectiveness of a dynamic low-pass filter for electromyographic (EMG) noise suppression in electrocardiograms (ECG). The goal of this study is to analyze the filter, and to suggest a better tuning for increasing the noise suppression and, at the same time, decreasing the signal distortion. The principle of the filter is the creation of a function called 'wings' for evaluation of the frequency spectra of the ECG waves. This function controls the dynamic cutoff frequency of an approximation procedure proposed by Savitzky and Golay, making it adjustable to the frequency spectra of ECG waves. The new way of forming the "wings" function permits: (i) stronger filtration of the low-frequency ECG components, (ii) reduced filtration in the transition zones of low to high frequency and vice versa (the highly diagnostic QRS onsets and offsets), and (iii) no filtration of the QRS zones of highest frequency. The newly suggested dynamic low-pass filtration of ECG performs better than the one suggested in the most recent publication.

B4.7: **Christov I, Krasteva V, Simova I, Neycheva T, Schmid R. (2018) Ranking of the most reliable beat morphology and heart rate variability features for detection of atrial fibrillation in short single lead ECG. Physiological Mesurement, 39, 9, IOP Science, ISSN:0967-3334, DOI:10.1088/1361-6579/aad9f0, 094005-15 pages. ISI IF:2.246 Q2 (Web of Science)**
http://iopscience.iop.org/article/10.1088/1361-6579/aad9f0

Abstract

This study participated in the 2017 PhysioNet/CinC Challenge dedicated to the classification of atrial **fibrillation** (AF), normal sinus rhythm (Normal), other arrhythmia (Other) and strong noise, using single-lead electrocardiogram (ECG) recordings with a duration <60 s. The aim is to apply a linear threshold-based strategy for arrhythmia classification, ranking the most powerful time domain ECG features that could be easily reproduced on any platform. An algorithm for time domain ECG analysis was designed to extract 44 features with focus on the following: noise detection; heart rate variability (HRV) analysis; beat morphology analysis and delineation of P-, QRS-, and T-waves in the robust average beat; detection of atrial activity by the presence of P-waves in the average beat and atrial fibrillatory waves (f-waves) during TQ intervals. A linear discriminant analysis (LDA) classifier was optimized on the Challenge training set (8528 ECGs) by stepwise selection of a nonredundant feature set until maximization of the Challenge F1 score. Heart rate (HR) was an independent factor for the LDA classifier design, particular to bradycardia (HR ⩽ 50 bpm), normal rhythm (HR = 50–100 bpm), tachycardia (HR ⩾ 100 bpm). The algorithm obtained official Challenge F1 scores of 0.80 (Overall), 0.90 (Normal), 0.81 (AF), 0.70 (Other), and 0.54 (Noise) on the hidden Challenge test set (3658 ECGs). This is equivalent to a true positive rate (TPR) = 90.1% (Normal), 81.5% (AF), 67.7% (Other), and 69.5% (Noise), and a false positive rate (FPR) = 13.6% (Normal), 2.3% (AF), 7.7% (Other), and 1.5% (Noise). The top five features, which together contributed to about 94% of the maximal F1 score were ranked: (1) proportion of RR intervals differing by >50 ms from the preceding RR interval; (2) Poincaré plot geometry estimated by the ratio of the minor-to-major semi-axes of the fitted ellipse; (3) P-wave presence in the average beat; (4) mean percentage of the RR interval first differences; and (5) mean correlation of all beats against the average beat. The global rank of feature extraction methods highlighted that HRV alone was able to provide 92.5% of the maximal F1 score (0.74 versus 0.8). The added value of more complex ECG morphology analysis was less significant for Normal, AF, and Other rhythms (+0.02 to 0.08 points) than for Noise (+0.19 points); however, these were indispensable for wearable ECG recording devices with frequent artefact disturbance.

B4.8: Dobrev D, Neycheva T. (2022) High-quality biopotential acquisition without a reference electrode: power-line interference reduction by adaptive impedance balancing in a mixed analog–digital design. Medical & Biological Engineering & Computing, 60, Springer Nature Switzerland AG, ISSN:0140-0118, DOI:10.1007/s11517-022-02586-0, 1801-1814. JCR-IF (Web of Science):3.079 Q2 (Web of Science) https://link.springer.com/article/10.1007/s11517-022-02586-0

Abstract

Power-line-interference (PLI) is one of the major disturbing factors in almost all ground-free biopotential acquisition applications. The body is a volume conductor and collects PLI currents. Some of these currents pass through the sensing electrodes, then the electrode cables, and finally via the amplifier input impedances they reach the signal ground. The electrode impedances and the amplifier input impedances form an impedance bridge. Due to electrode impedance instability over time, the bridge tends to be imbalanced and produces differential PLI which is amplified together with the useful signal. This paper describes a powerful mixed analog–digital solution for automatic impedance bridge balance using software PLL for line synchronization. The approach is implemented and validated through recorded real ECG signals. The PLI is canceled by adding part of the common-mode voltage, with automatically adjusted amplitude and phase, to the useful differential biosignal. The described approach produces high-quality biosignals without the need for a common-mode reference electrode. It is applicable to all biosignals taken with surface electrodes like ECG, EEG, EMG, EOG, etc., and can benefit all diagnostic and therapeutic medical devices where these signals are in use.

B4.9: Neycheva T, Dobrev D, Krasteva V. (2022) Common-Mode Driven Synchronous Filtering of the Powerline Interference in ECG. Applied Sciences, 12, 22, MDPI, ISSN:2076-3417, DOI:10.3390/app122211328, 11328-1-29. JCR-IF (Web of Science):2.838, Q2 (Web of Science) https://www.mdpi.com/2076-3417/12/22/11328

Abstract:

Powerline interference (PLI) is a major disturbing factor in ground-free biopotential acquisition systems. PLI produces both common-mode and differential input voltages. The first is suppressed by a high common-mode rejection ratio of bioamplifiers. However, the differential PLI component evoked by the imbalance of electrode impedances is amplified together with the diagnostic differential biosignal. Therefore, PLI filtering is always demanded and commonly managed by analog or digital band-rejection filters. In electrocardiography (ECG), PLI filters are not ideal, inducing QRS and ST distortions as a transient reaction to steep slopes, or PLI remains when its amplitude varies and PLI frequency deviates from the notch. This study aims to minimize the filter errors in wide deviation ranges of PLI amplitudes and frequencies, introducing a novel biopotential readout circuit with a software PLI demodulator–remodulator concept for synchronous processing of both differential-mode and common-mode signals. A closed-loop digital synchronous filtering (SF) algorithm is designed to subtract a PLI estimation from the differential-mode input in real time. The PLI estimation branch connected to the SF output includes four stages: (i) prefilter and QRS limiter; (ii) quadrature demodulator of the output PLI using a common-mode driven reference; (iii) two servo loops for low-pass filtering and the integration of in-phase and quadrature errors; (iv) quadrature remodulator for synthesis of the estimated PLI using the common-mode signal as a carrier frequency. A simulation study of artificially generated PLI sinusoids with frequency deviations (48–52 Hz, slew rate 0.01–0.1 Hz/s) and amplitude deviations (root mean square (r.m.s.) 50–1000 uV, slew rate 10–200 uV/s) is conducted for the optimization of SF servo loop settings with artificial signals from the CTS-ECG calibration database (10 s, 1 lead) as well as for the SF algorithm test with 40 low-noise recordings from the Physionet PTB Diagnostic ECG database (10 s, 12 leads) and CTS-ECG analytical database (10 s, 8 leads). The statistical study for the PLI frequencies (48–52 Hz,slew rate≤0.1 Hz/s) and amplitudes (≤1000 uV r.m.s., slew rate≤40 uV/s) show that maximal SF errors do not exceed 15uV for any record and any lead, which satisfies the standard requirements for a peak ringing noise of < 25 uV. The signal-to-noise ratio improvement reaches 57–60 dB. SF is shown to be robust against phase shifts between differential- and common-mode PLI. Although validated for ECG signals, the presented SF algorithm is generalizable to different biopotential acquisition settings via surface electrodes (electroencephalogram, electromyogram, electrooculogram, etc.) and can benefit many diagnostic and therapeutic medical devices.

B4.10: Dobrev D, Neycheva T, Mudrov N. (2008) Digital lock-in techniques for adaptive power-line interference extraction. Physiological Measurement, 29, 7, ISSN:0967-3334, 803-816. SJR (Scopus):0.691, JCR-IF (Web of Science):1.951 Q3 (Web of Science)
http://dx.doi.org/10.1088/0967-3334/29/7/009

Abstract:

This paper presents a simple digital approach for adaptive power-line (PL) or other periodic interference extraction. By means of two digital square (or sine) wave mixers, the real and imaginary parts of the interference are found, and the interference waveform is synthesized and finally subtracted. The described technique can be implemented in an open-loop architecture where the interference is synthesized as a complex sinusoid or in a closed-loop architecture for automatic phase and gain control. The same approach can be used for removal of the fundamental frequency of the PL interference as well as its higher harmonics. It is suitable for real-time operation with popular low-cost microcontrollers.

II. Publications in Indicator G7

Г7.1:Dobrev D, Alnasser E, Neycheva T. (2021) Application of Active Biased Integrators for Biosignal Processing. XXX International Scientific Conference Electronics (ET), 2021, IEEE, ISBN:978-1-6654-4518-4, DOI:10.1109/ET52713.2021.9580163, 1-5 Без JCR или SJR – индексиран в WoS или Scopus (Scopus)
https://ieeexplore.ieee.org/document/9580163

Abstract :

Active biased integrators (ABI) have recently been reported. The ABI is an innovative continuous-time lossy integrator characterized by a very low high-pass cutoff frequency in the millihertz range. ABI is used to amplify signals generated by sources with capacitive output impedance. This paper presents some novel ABI applications for biosignal amplification. It is shown that the heart rate and respiration activity can be easily monitored with piezoelectric sensors directly connected to ABI. The achieved very low high-pass cutoff frequency of 0.05 Hz allows ABI to be successfully used for processing ECG signals acquired with capacitive electrodes.

Г7.2:Dobrev D, Neycheva T. (2020) Correlated Multiple Sampling Techniques for Sensor Signal Conditioning. 2020 XXIX International Scientific Conference Electronics (ET), IEEE, ISBN:978-1-7281-7426-6, DOI:10.1109/ET50336.2020.9238159, 1-4. SJR (Scopus):0.11 SJR, непопадащ в Q категория (Scopus) https://ieeexplore.ieee.org/document/9238159

Abstract:

Correlated Double Sampling (CDS) is a widely used technique in sensor signal conditioning. It effectively cancels offset and low-frequency (flicker) noise. CDS is a discrete time signal processing technique, implemented with Switched Capacitor (SC) circuits or after ADC with a Digital Signal Processing (DSP) algorithm. This paper describes a simple approach wherein the CDS technique is extended to Correlated Multiple Sampling (CMS) techniques, and with the price of processing of

more samples, the new CMS techniques greatly improves the amplifier offset and flicker noise suppression.

Г7.3:Christov I, Gotchev A, Bortolan G, Neycheva T, Raikova R, Schmid R. (2020) Separation of the electromyographic from the electrocardiographic signals and vice versa. A topical review of the Dynamic procedure. International Journal Bioautomation, 24, 3, Institute of Biophysics and Biomedical Engineering at the Bulgarian Academy of Sciences, ISSN:1314-2321, DOI:10.7546/ijba.2020.24.3.000744, 289-317. SJR (Scopus):0.178 Q3 (Scopus) http://biomed.bas.bg/bioautomation/2020/vol_24.3/files/24.3_08.pdf

Abstract:

Electrocardiographic (ECG) and electromyographic (EMG) signals are inevitably and simultaneously recorded from the same electrodes and are respectively useful signal and noise in electrocardiography, and vice versa in electromyography. The frequency domains of the two signals overlap, making it difficult to filter the noise without distortion of the useful signal.
An original 'dynamic method' for separation of the two signals was created. In a series of publications that began in 1999 with filtering of EMG noise from ECG signal, we have described the method and have made a number of improvements such as noise analysis and automatic on/off triggering in presence/absence of noise, online application, and tuning the parameters, to fulfill the last filtering recommendations of the American Heart Association.
No matter if the Dynamic procedure is to be used in electrocardiography or in electromyography, the method contains the following: (i) Evaluation of the frequency bands of the ECG signal; (ii) filtering (suppression) of the EMG signal by dynamic change of the size of the filtering window for maximal preservation of the morphology of the ECG waves. The cutoff frequency is individual for any signal sample and varies from 13 Hz at the linear segments of the ECG signal, trough 25 Hz for the T-waves of high amplitude, and up to 400 Hz for the QRS-complexes; (iii) EMG signal separation by subtraction of the filtered ECG signal from ECG + EMG initial signal.
With the current review, we are attempting to summarize all done over the years on the Dynamic procedure.

Г7.4:Christov II, Neycheva TD, Raikova RT. (2019) ECG-noise removal from EMG-signal by subtraction of hybrid template of averaged PQRS- T intervals. Proc. 2019 IEEE XXVIII International Scientific Conference Electronics (ET2019), IEEE, ISBN:978-1-7281-2574-9, DOI:10.1109/ET.2019.8878620, 1-4 Без JCR или SJR – индексиран в WoS или Scopus (Scopus)

Abstract:

The frequency domains of the ECG and EMG signals overlap, making it difficult to filter the ECG noise without distortion of the EMG signal. A method of EMG denoising by subtraction of averaged P-QRS-T interval is known in the literature. The proper functioning of the method depends on how the template is formed. Several ways of forming ECG-template have been tested in the current study, and has been proven that the 'hybrid' is the best i.e. high-frequency components, as QRS, are taken from the unfiltered EMG+ECG, while the low-frequency – from the averaged signal. The good performance of the hybrid method is proven by almost complete identity of initial and processed EMG, when compared by fast Fourier transform (FFT). The presence of ectopic beats in the averaged ECG-template worsens the performance and a way to overcome the problem is proposed.

Г7.5:Tulyakova N., Neycheva T., Trofymchuk O., Stryzhak O.(2018) Locally-adaptive Myriad Filtration of One-dimensional Complex Signal. International Journal Bioautomation, 22, 3, ISSN:1314-1902, DOI:10.7546/ijba.2018.22.3.275-296, 275-296. SJR (Scopus):0.231 Q3 (Scopus) http://www.biomed.bas.bg/bioautomation/2018/vol_22.3/files/22.3_07.pdf

Abstract:

Locally-adaptive algorithms of myriad filtering are proposed with adaptation of a sample myriad linearity parameter K, depending upon local estimates of a signal, and with “hard” switching of sliding window length settings and a coefficient which influences on the parameter K. Statistical estimates of the filters quality are obtained using a criterion of a minimum mean-square error for a model of one-dimensional complex signal that includes different elementary segments under conditions of additive Gaussian noise with zero mean and different variances and possible spikes presence. Improvement of integral and local performance indicators is shown in comparison to the highly effective non-linear locally-adaptive algorithms for the considered test signal. Having a complex signal of high efficiency, one of the proposed algorithms provides nearly optimal noise suppression at the segments of linear change of a signal; other algorithm provides higher quality of step edge preservation and the best noise suppression on a const signal. Better efficiency in cases of low and high noise levels is achieved by preliminary noise level estimation through comparison of locally-adaptive parameter and thresholds. It is shown that, in order to ensure better spikes removal, it is expedient to pre-process the signal by robust myriad filter with small window length. The considered adaptive nonlinear filters have possibility to be implemented in a real time mode.

Г7.6:Neycheva T, **Dobrev D. (2022) Design of Fractional Filters for Power-line Interference Suppression in ECG Signals. XXXI International Scientific Conference Electronics (ET), 2022, IEEE, ISBN:978-1-6654-9878-4, DOI:10.1109/ET55967.2022.9920330, 1-6 Без JCR или SJR – индексиран в WoS или Scopus (Scopus)** https://ieeexplore.ieee.org/document/9920330

Abstract:

The sampling interval is the unit step in which a discrete biosignal can be easily shifted during the digital filtering process. It allows the design of linear-phase filters with constant group delay characteristics. In many cases, the sampling interval is insufficiently short to ensure the required frequency response of the filter. This paper presents a novel approach for design of fractional filters, which is applied to several common types of comb filters. The effectiveness of the approach is illustrated by filtering of the power-line interference in real ECG signals. The presented fractional filters have a simple design, which is suitable to different biosignal acquisition applications where filtering of various noises is strongly mandatory.

Г7.7:Dobrev D, Neycheva T. (2016) Automatic Common Mode Electrode-amplifier Impedance Balance with SPLL Synchronization. Proc. 2016 XXV International Scientific Conference Electronics (ET), IEEE, ISBN:978-1-5090-2883-2, DOI:10.1109/ET.2016.7753473, 1-4 Без JCR или SJR – индексиран в WoS или Scopus (Scopus) http://ieeexplore.ieee.org/document/7753473/

Abstract:

Power-line interference (PLI) is a major disturbing factor in almost all groundfree biosignal acquisition applications. The main cause of interference is body to amplifier Wheatstone bridge imbalance. The bridge is formed from electrode impedances and the amplifier common mode input impedances. Because the electrode impedances vary with time, the Wheatstone bridge tends to be imbalanced, and produces differential PLI which is amplified together with the useful signal. The interference can be canceled only when the bridge is kept continuously in balanced conditions. It was shown how the Wheatstone bridge can be adjusted to maintain balanced conditions by means of two digital synchronous demodulators. For proper demodulation, an accurate synchronization with PLI is needed. Recently, dedicated software PLL (SPLL) for PLI synchronization was developed implemented and tested. This paper presents a complete impedance balancing approach wherein synchronization to PLI is done with the designed SPLL. The stability of the whole system is proven by Matlab mixed signal simulations. The presented approach is applicable in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г7.8:Dobrev D, Neycheva T. (2016) Automatic current driven electrode-amplifier impedance balance with SPLL synchronization. Proc. 2016 XXV International Scientific Conference Electronics (ET), 16498728, IEEE, ISBN:978-1-5090-2883-2, DOI:10.1109/ET.2016.7753472, 1-4 Без JCR или SJR – индексиран в WoS или Scopus (Scopus) http://ieeexplore.ieee.org/document/7753472/

Abstract:

Power-line interference (PLI) is a common disturbing factor in almost all ground free biosignal acquisition applications. The main cause of interference is the body to amplifier Wheatstone bridge imbalance. The bridge is formed from electrode impedances and the amplifier common mode input impedances. Because the electrode impedances vary with time, the Wheatstone bridge tends to be imbalanced and produces differential PLI which is amplified together with the useful signal. The interference can be canceled only when the bridge is kept continuously in balanced conditions. It was shown how the Wheatstone bridge can be adjusted to maintain balanced conditions by means of Voltage-Controlled-Current-Sources (VCCSs) and synchronous detection. For proper demodulation, an accurate synchronization with PLI is needed. Recently, dedicated software PLL (SPLL) for PLI synchronization was developed implemented and tested. This paper presents a complete, VCCS based, impedance balancing approach wherein synchronization to PLI is done with the designed SPLL. The stability of the whole system is proven by Matlab mixed signal simulations. The presented approach is applicable in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г7.9:Dobrev D, Neycheva T. (2022) Open-loop Software Automatic Gain Control: Common-mode Power-line Interference Stabilization During ECG Recording. XXXI International Scientific Conference Electronics (ET), 2022, IEEE, ISBN:978-1-6654-9878-4, DOI:10.1109/ET55967.2022.9920322, 1-6 Без JCR или SJR – индексиран в WoS или Scopus (Scopus) https://ieeexplore.ieee.org/document/9920322

Abstract:

Automatic gain control (AGC) units are widespread in modern telecommunication systems. The main function of AGC is to stabilize the amplitude of the processed signal. AGC generates a constant amplitude output signal when the input signal level changes. This article describes an all-digital architecture for automatic open-loop gain control designed to generate constant amplitude of the power-line interference extracted from the common-mode signal during ECG biopotential recording. The presented open-loop AGC has a very simple architecture and can be applied to other applications where AGC functionality is needed.

Г7.10:Dobrev D, Neycheva T. (2020) Software Automatic Gain Control for Common Mode Interference Stabilization. 2020 XXIX International Scientific Conference Electronics (ET), IEEE, ISBN:978-1-7281-7426-6, DOI:10.1109/ET50336.2020.9238268, 1-3. SJR (Scopus):0.11 SJR, непопадащ в Q категория (Scopus) https://ieeexplore.ieee.org/document/9238268

Abstract:

Automatic gain control (AGC) circuits are used in many systems where the amplitude of the input signal can vary over a wide dynamic range. The role of the AGC is to provide relatively constant amplitude of the output signal, regardless of changes in the input signal. This paper presents software automatic gain control (SAGC) designed to stabilize the amplitude of the common mode interference. The described SAGC provides a constant amplitude output signal for software PLL synchronization to the power-line frequency. The presented SAGC has simple structure and can be easily adapted to other signal processing applications where automatic gain control is required.

III. Publications in Indicator G8

Г8.1: Dobrev D, Neycheva T. (2012) Simple Two-Electrode Bootstrapped Non- Differential Biopotential Amplifier. Annual Journal of Electronics, 6, 1, Technical University - Sofia, ISSN:1314-0078, 8-11 Национално академично издателство

Abstract:

A simple two-electrode non-differential biopotential amplifier, designed for low-supply voltage (1.8–5.5V), is presented. The amplifier architecture is based on a transimpedance interface stage which retains the potential at one input virtually equal to the circuit ground and allows the potential at the other input to be amplified by a simple non-differential amplifier. The output of the transimpedance stage drives a parallel RC network connected to the other input, maintaining the input common mode interference currents balanced. Thus, simple non-inverting amplifier can emulate a high CMRR differential. The amplifier also features bootstrapped input impedance achieved by means of negative impedance converter organized around the first amplification stage. The amplifier is intended for use in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г8.2: Dobrev D, Neycheva T. (2011) Bootstrapped instrumentation biosignal amplifier. Annual Journal of Electronics, 5, 2, Technical University - Sofia, ISSN:1313-1842, 76-79 Национално академично издателство

Abstract:

Portable biomedical instrumentation has become an important part of diagnostic and treatment instrumentation. Low-voltage and low-power tendencies prevail. A two-electrode biopotential amplifier, designed for low-supply voltage (1.8–5.5V), is presented. This biomedical amplifier design has high differential and sufficiently low common-mode input impedances achieved by means of positive shunt-shunt feedback, implemented in a standard instrumentation amplifier scheme. The presented circuit makes use of passive components of popular values and tolerances. The amplifier is intended for use in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г8.3: Dobrev D, Neycheva T, Mudrov N. (2009) Transformerless High-quality Electrocardiogram and Body Impedance Recording by an Amplifier with Current-Driven Inputs. Internat. Journal Bioautomation, 13, 4, Institute of Biophysics and Biomedical Engineering Bulgarian Academy of Sciences, ISSN:1314-2321, 1-6 Национално академично издателство
https://www.biomed.bas.bg/bioautomation/2009/vol_13.4/files/13.4_1.01.pdf

Abstract:

Measurement and recording of changes in bioelectrical impedance in vivo has become a widely used method with various clinical applications. It includes basal impedance Zo, relative changes ΔZ or its derivative dZ. Many applications related to cardiac and respiratory function require simultaneous electrocardiogram, impedance-cardiogram and/or respiration signals recording and analysis. Accurate recording of body impedance is limited by high common-mode voltages at the amplifier inputs combined with the influence of the output impedance of the used current source. A circuit concept for a simultaneous high-quality electrocardiogram and bioimpedance acquisition is proposed, profiting from advantages offered by a previously specially designed amplifier with current-driven inputs, yielding to low common-mode and high differential-mode input impedances.

Г8.4: Neycheva T, Dobrev D. (2005) Photoplethysmographic detector for peripheral pulse registration. International Scientific Conference Electronics (ET) 2005, Technical University - Sofia, 31-36 Национално академично издателство http://ecad.tu-sofia.bg/et/2005/pdf/Paper043-T_Neycheva.pdf

Abstract :

In this paper a low-power photoplethysmograph for heart rate detection by the amplitude demodulation of the reflected from the skin and tissue light is proposed and described. The optical sensor consists from six infrared photoreceivers placed in a circle around one infrared led. The use of only one emitter in switch mode and synchronous detection of the received signal defines the achieved low-power consumption. The device can be used for fast heart rate registration, for example in emergency cases or in addition to existing defibrillators and/or monitoring systems.

Г8.5: Neycheva T, Stoyanov T. (2007) High-resolution front-end for ECG signal processing. *Proc. 16-th Internat. Sci. Conf. "Electronics'2007"*, Sozopol, Sept.19-21, 2007, book 2, pp. 61-66, ISSN:1313-1842, Technical University – Sofia,
https://ecad.tu-sofia.bg/et/2007/ET2007%20Book2/Electronic%20Medical%20Equipment/61-Paper-T_Neycheva.pdf

Abstract:

This paper presents research system with 12 channel high-resolution (24 bits) front-end for ECG signal processing. The implemented high-resolution data conversion makes the system suitable for recording of late potentials which are microvolt-level high-frequency waveforms in the terminal portion of the QRS complex in patients prone to sustained ventricular tachycardia. The front-end consists of 12 channel ECG amplifier built on body potential driving concept. The amplifier outputs are connected to 12 delta-sigma ADCs. The whole ADCs work synchronously at 8 kHz sampling frequency and their output data are transferred to PC via USB. The presented system could be useful in other signal processing applications where multi-channel, high-resolution, data conversion is needed.

Г8.6: Neycheva T, Stoyanov T, Krasteva V, Iliev I, Tabakov S, Tsibulko V, Jekova I. (2015) High-Resolution Signal Acquisition Module Recording 18-Lead ECG for Person Authentication. Annual Journal of Electronics, 9, Technical University of Sofia, ISSN:1314-0078, 1-4 Национално неакадемично издателство http://ecad.tu-sofia.bg/et/2015/ET2015/AJE-2015/001_Paper-I_Jekova.pdf

Abstract:

This paper presents a high-resolution 16-channel ECG acquisition module with 24-bit amplitude resolution and sampling rate of 2 kHz. The module is applied for collection of ECG database for the aims of development and testing of methods for person authentication via ECG. Such database could support the definition of optimal number of ECG leads and the optimal feature set and would facilitate the decision about the ECG applicability as a person biometric characteristic in different environments.

Г8.7: Dobrev D, Neycheva T, Krasteva V, Iliev I. (2010) High-Q comb FIR filter for mains interference elimination. Annual Journal of Electronics, 4, 2, Technical University - Sofia, ISSN:1313-1842, 126-129 Национално академично издателство

Abstract:

This paper presents a linear phase comb filter for power-line interference suppression. By a correlated average using samples delayed on multiple power-line periods, and subtracting the result from the input stream, a high-pass comb filter with high-Q notches at all power-line harmonics is attained. The high-pass roll-off of the filter is compensated with appropriate low-pass roll-off, and the resultant characteristic has an all-pass (flat) frequency response and notches only at the power-line harmonics. The filter design is based on a high-pass high-Q comb filter, in parallel with a low-pass moving-average stage to restore the low-frequency filtered components. The Q-factor depends on the time for averaging. The presented filter is evaluated by Matlab simulations with real ECG signal contaminated with high amplitude power-line interference. The simulations show that this filter has minimal influence on the processed ECG signal. Due to the filter's constant group delay (linear phase response) and high-Q notches only at the power-line harmonics, the presented filter is appropriate for power-line rejection in almost all biosignal acquisition applications. The filter is applicable for real-time execution by means of conventional low-cost microcontrollers.

Г8.8: Neycheva T, Dobrev D. (2010) Integer Coefficients Comb Filter for Mains Interference Extraction. Annual Journal of Electronics, 4, 2, Technical University - Sofia, ISSN:1313-1842, 130-133 Национално академично издателство

Abstract:

This paper presents integer coefficients high-Q comb filter for power-line (PL) or other periodical interference extraction. The filter concept relies on averaged half PL period first differences resulting in comb high-Q teeth at odd harmonics of PL interference. The presented filter is evaluated by Matlab simulations with real ECG signal contaminated with high amplitude PL interference. The made simulations show that this filter accurately extracts the PL interference. It passes only the odd harmonics of PL interference and can be used for extraction of any kind of odd harmonic interference, including rectangular shape. Once extracted PL interference can be subtracted from the input, and depending on the group delay requirements, the filter structure can be selected to have linear (constant group delay) or minimum (minimum group delay) phase response. The filter Q factor is proportional to the number of processed PL periods. For higher Q factors more stages could be cascaded. The presented filter has simple structure, suitable for real-time operation with popular low-cost microcontrollers.

Г8.9: Dobrev D, Neycheva T, Mudrov N. (2009) High-Q Comb Filter for Mains Interference Suppression. Annual Journal of Electronics, 3, 1, Technical University - Sofia, ISSN:1313-1842, 47-49 Национално академично издателство
http://ecad.tu-sofia.bg/et/2009/ET_2009/AEM2009_1/Electronic%20Medical%20Equipment/47-Paper-T_Neycheva1.pdf

Abstract:

This paper presents a digital high-Q comb filter for power-line (PL) interference suppression. The filter structure is based on a high-Q first difference filter, paralleled with a lossy integrator stage to restore the low-frequency filtered components. The presented filter is evaluated by Matlab simulations with real ECG signal contaminated with high amplitude PL interference. The made simulations show that this filter has minimal influence on processed ECG signal. Due to its high-Q notches only at PL harmonics the presented filter is appropriate for almost all biosignal acquisition applications. The filter is suitable for real-time operation with popular low-cost microcontrollers.

Г8.10: Dobrev D, Neycheva T, Mudrov N. (2009) Simple High-Q Comb Filter for Mains Interference and Baseline Drift Suppression. Annual Journal of Electronics, 3, 1, Technical University - Sofia, ISSN:1313-1842, 50-52 Национално академично издателство
http://ecad.tu-sofia.bg/et/2009/ET_2009/AEM2009_1/Electronic%20Medical%20Equipment/50-Paper-T_Neycheva2.pdf

Abstract:

This paper presents a simple digital high-Q comb filter for baseline wander and power-line (PL) interference suppression. The filter concept relies on a first difference – a discrete version of the signal first derivative, resulting in a high-pass roll-off in combination of the so called a comb frequency response. The presented filter is evaluated by Matlab simulations with real ECG signal contaminated with high amplitude PL interference. The made simulations show that this filter has minimal influence on processed ECG signal. Due to its high-pass characteristic and high-Q notches only at PL harmonics the presented filter is appropriate for almost all biosignal acquisition applications where PL interference and baseline drift suppression is needed. The filter is suitable for real-time operation with popular low-cost microcontrollers.

Г8.11: Neycheva T, Dobrev D, Mudrov N. (2009) High-Q Bandpass Comb Filter for Mains Interference Extraction. Internat. Journal Bioautomation, 13, 4, Institute of Biophysics and Biomedical Engineering Bulgarian Academy of Sciences, 7-12 Национално академично издателство
https://www.biomed.bas.bg/bioautomation/2009/vol_13.4/files/13.4_1.02.pdf

Abstract:

This paper presents a simple digital high-Q bandpass comb filter for power-line (PL) or other periodical interference extraction. The filter concept relies on a correlated signal average resulting in alternating constructive and destructive spectrum interference i.e. the so-called comb frequency response. The presented filter is evaluated by Matlab simulations with real ECG signal contaminated with low amplitude PL interference. The made simulations show that this filter accurately extract the PL interference. It has high-Q notches only at PL odd harmonics and is appropriate for extraction of any kind of odd harmonic interference including rectangular shape. The filter is suitable for real-time operation with popular low-cost microcontrollers.

Г8.12: Dobrev D, Neycheva T, Mudrov N. (2008) Simple high-Q comb filter for mains interference suppression. International Scientific Conference Electronics (ET) 2008, 1, Technical University - Sofia, ISSN:1313-1842, 25-30 Национално академично издателство
http://ecad.tu-sofia.bg/et/2008/ET2008_Book1/Electronic%20Medical%20Equipment/25-Paper-T_Neycheva1.pdf

Abstract:

This paper presents a simple digital high-Q comb filter for power-line (PL) (or other periodical) interference suppression. The filter concept relies on a correlated signal average resulting in alternating constructive and destructive spectrum interference i.e. to the so called a comb frequency response. The presented filter is evaluated by Matlab simulations with real ECG signal contaminated with high amplitude PL interference. The made simulations show that this filter has minimal influence on processed ECG signal. Due to its allpass (flat) frequency response and high-Q notches only at PL harmonics the presented filter is appropriate for most biosignal acquisition applications: ECG, EEG, EMG, etc. The filter is suitable for real-time operation with popular low-cost microcontrollers.

Г8.13: Dobrev D, Neycheva T. (2014) Current Driven Automatic Electrode Impedance Balance for Ground-free Biosignal Acquisition. Annual Journal of Electronics, 8, Technical University - Sofia, ISSN:1314-0078, 62-65 Национално академично издателство
http://ecad.tu-sofia.bg/et/2014/ET2014/AJE_2014/062-D_Dobrev2.pdf

Abstract:

Power-line interference (PLI) is a common disturbing factor in almost all two-electrode biosignal acquisition applications. The main cause of interference is the body to amplifier Wheatstone bridge imbalance. The bridge is formed from electrode impedances and the amplifier common mode input impedances. Because the electrode impedances vary with time, the Wheatstone bridge tends to be imbalanced and produces differential PL interference which is amplified together with the useful signal. The interference can be canceled only when the bridge is kept continuously in balanced conditions. This paper describes a powerful concept for PLI cancellation wherein by two Voltage-Controlled-Current-Sources (VCCS) enclosed in two control loops, the active and reactive components of the amplifier input impedances are synthesized and automatically adjusted to maintain balanced conditions. The main advantage of the presented approach is that the interference is canceled on a hardware level where it is generated, without influencing the spectrum of the useful signal. The method is applicable in all ground-free applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г8.14: Dobrev D, Neycheva T. (2013) Digital Lock-in Technique for Input Impedance Balance in Two-electrode Biosignal Amplifiers. Annual Journal of Electronics, 7, Technical University - Sofia, ISSN:1314-0078, 64-67 Национално академично издателство

Abstract:

Power-line (PL) interference is a major disturbing factor in almost all two-electrode biosignal acquisition applications. The main cause of interference is the body to amplifier Wheatstone bridge imbalance. The bridge is formed from electrode impedances and the amplifier common mode input impedances. Because the electrode impedances vary with time, the Wheatstone bridge tends to be imbalanced and produces differential PL interference which is amplified together with the useful signal. The interference can be canceled only when the bridge is kept continuously in balanced conditions. This paper describes a method wherein by two digital lock-in demodulators in two digitally regulated control loops, the active and reactive components of the amplifier input impedances are adjusted to maintain balanced conditions. The main advantage of the presented approach is that the interference is canceled on a hardware level wherein it is generated, without influencing the spectrum of the useful signal. The method is applicable in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г8.15: Dobrev D, Neycheva T. (2011) Increased power-line interference rejection by adaptive common mode impedance balance. Annual Journal of Electronics, 5, 2, Technical University - Sofia, ISSN:1313-1842, 80-83 Национално академично издателство

Abstract:

Power-line (PL) interference (hum) is a major disturbing factor in almost all two-electrode biosignal acquisition applications. The picked up by the body interference current multiplied by the difference in electrode impedances is converted into a differential input voltage which is amplified together with the useful signal. Thus, the electrode impedance imbalance is appeared as a main cause for higher interference level in two-electrode by comparison with three electrode amplification techniques. The converted into differential voltage PL interference can be canceled only when the two shoulders of the bridge performed from the electrode impedances and the amplifier input common mode impedances are balanced. This paper presents a method for such continuous adaptive balance. The advantage of the method is that the interference is canceled on a hardware level wherein it is generated without influencing the spectrum of the useful signal. The method is applicable in various two-electrode applications, such as Holter monitors, external defibrillators, ECG monitors and other heart beat sensing biomedical devices.

Г8.16: Dobrev D, Neycheva T, Mudrov N. (2008) Frequency response of digital lock-in technique for powerline interference extraction. International Scientific Conference Electronics (ET) 2008, 1, Technical University - Sofia, ISSN:1313-1842, 31-36 Национално академично издателство
http://ecad.tu-sofia.bg/et/2008/ET2008_Book1/Electronic%20Medical%20Equipment/31-Paper-T_Neycheva2.pdf

Abstract:

Power-line interference is a common problem in almost all biosignal acquisition applications. Recently a smart approach for PL suppression, called lock-in technique, was developed. This paper discusses the behavior of open-loop lock-in technique in frequency domain. It shows that the low-pass transfer function of the used filter is converted to high-pass function by a simple subtraction from unity and then it is transposed in two sidebands around PL frequency. Thus, the flatness roll-off characteristic of the used low-pass filter is very important for achievement of final rippleless frequency response of the lock-in filtering approach. A simple digital low-pass filter is proposed to be used in cases when a maximallyflat frequency response is needed.

Г8.17: Dobrev D, Neycheva T. (2015) Software PLL for Power-line Interference Synchronization: Implementation and Results. Annual Journal of Electronics, 9, Technical University - Sofia, ISSN:1314-0078, 18-21 Национално академично издателство
http://ecad.tu-sofia.bg/et/2015/ET2015/AJE-2015/018_Paper-T_Neycheva2.pdf

Abstract:

Power-line interference is a common disturbing factor in almost all two-electrode biosignal acquisition applications. Many filtering procedures for mains interference elimination are available, but all of them are maximally effective when the filter notches are positioned exactly at the power-line harmonics, i. e. when the sampling rate is synchronous with the power-line frequency. Moreover, various lock-in techniques, such as automatic common mode input impedance balance, require precise in-phase and quadrature phase references, synchronous with the powerline interference. Recently a design methodology of software PLL for power-line synchronization was published. This paper describes the results of its practical realization.

Г8.18: Dobrev D, Neycheva T. (2014) Software PLL for Power-line Interference Synchronization: Design, Modeling and Simulation. Annual Journal of Electronics, 8, Technical University - Sofia, ISSN:1314-0078, 58-61 Национално академично издателство
http://ecad.tu-sofia.bg/et/2014/ET2014/AJE_2014/058-D_Dobrev1.pdf

Abstract:

Power-line interference is a common disturbing factor in almost all two-electrode biosignal acquisition applications. Many filtering procedures for mains interference elimination are available, but all of them are maximally effective when the filter notches are positioned exactly at the power-line harmonics, i. e. when the sampling rate is synchronous with the power-line frequency. Moreover, various lock-in techniques, such as automatic common mode input impedance balance, require precise in-phase and quadrature phase references, synchronous with the powerline interference. This paper describes in depth a design procedure of software PLL, generating synchronous reference to the common mode power-line interference, and achieved from its analog prototype using s to z backward difference transformation. The main advantage of the presented approach is that the synchronization is done in software, so it has no production cost. The presented PLL is intended for use in ECG signal processing, but it can be used after easy adaptation in various digital signal processing applications, where frequency synchronization is needed.

IV. Publications in Indicator E26

E26.1: Dobrev D, Dobreva T. (2021) BG67325. Method and device for correlated multiple sampling with high-order noise shaping
https://patentimages.storage.googleapis.com/5a/88/26/603d045595efde/BG67325B1.pdf

Abstract:

The present invention consists of method and apparatus for signal processing wherein by Correlated Multiple Sampling a noise shaping of arbitrary high order is obtained. The present invention covers also all electronic devices using this method, and comprising of: sensor or signal source (1), modulator (2), amplifier (3) and Correlated Multiple Sampling demodulator (4), wherein by Correlated Multiple Sampling demodulation a low-pass filtering for the signal, and a high-pass filtering for the noise are achieved, and the orders of signal and noise transfer functions depend on the number of processed samples. With the described invention, a better offset and low frequency noise filtering is attained, and the dynamic range is improved.

E26.2: Dobrev D, Dobreva T. (2023) BG67598. Method and device for acquisition and synchronously biosignal filtering
https://patentimages.storage.googleapis.com/0b/a3/38/aa9ba981407763/BG67598B1.pdf

Abstract:

The presented invention consists of a method and apparatus for recording and synchronous filtering of biosignals, wherein by amplification and analog-to-digital conversion of differential and common-mode input voltages, and synchronous, common-mode driven, orthogonal amplitude demodulation of power-line interference in the output signal. Demodulated components of the power-line interference are filtered and integrated, then remodulated and subtracted from the input signal in a closed-loop digital algorithm with negative feedback that automatically minimizes the disturbance error in the output signal, which tends to ±1 LSB at steady state. The subject of the present invention are also all electronic devices using this method and containing the following separate parts: electrodes for capturing biosignals (1), amplifier and analog-to-digital converter of the differential input voltage (2), amplifier and analog-to-digital converter of the common-phase input voltage (3), digital part (4), where an algorithm for synchronous filtering of biosignals is implemented by means of software or hardware. The presented invention is applicable to all permanent biosignals obtained with electrodes from different places of the body, with or without a reference electrode, such as: electrocardiogram, electroencephalogram, electromyogram and others.