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学位論文題目	A Study on Common-mode Noise and Artefact Solution for Noninvasive Biopotential Acquisition Circuits （非侵襲式生体信号取得回路におけるコモンモードノイズ低減手法及びアーティファクト対策に関する研究）
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論文内容の要旨

As the aging society problem draws great attention, the sensing technology and monitoring scheme of biopotential signals has advanced tremendously over the years. The biopotential signals include electrocardiogram (ECG), electroencephalogram (EEG), electrooculogram (EOG) and many others. They are widely employed in medical and healthcare applications. For example, the body area network (BAN) with wearable sensing technologies can collect these signals as vital data for health-state monitoring, which is considered as an emerging solution to soaring healthcare costs and shortages of medical resources. The potential of biosignals is still to be exploited when sensing technologies advance further. In addition to medical treatment and healthcare, they could also be considered as an irreplaceable interface between human body and machines. In the literature, applications like activity recognition, driving assistance or human computer interface were mentioned by researchers.

Common-mode (CM) noise source like the power line, electromagnetic interference (EMI) and artefacts can severely interfere the detection progress of biopotentials. The imbalance of the EBI impedance allows the CM noise converting into a differential

mode interference voltage. In this study, a core idea runs through all our works: electrode-body (EBI) impedance imbalance cancellation-based CM noise and artefact solution for biopotential acquisition circuits. Contents of the thesis is as follows.

Chapter 1 is the introduction to this thesis.

Chapter 2 discusses EBI impedance imbalance cancellation-based CM noise rejection for contact biopotential acquisition. Circuit analyzation gave the exact noise rejection performance of a simple differential amplifying circuit, a DRL circuit and a proposed imbalance cancellation design employing digital potentiometers mathematically. Simulation evaluations were performed and the results showing that at 60 Hz our proposal can exceed the performance of a DRL circuit by more than 20 dB in rejecting the CM noise output when the imbalance of EBI impedance is 100 kΩ, and always perform better in an tunable imbalance range of 390.0 Ω to 200 kΩ, with better stability than DRL in biopotential frequency range 0.01 ~ 1 kHz.

Chapter 3 is about CM noise rejection for noncontact biopotential acquisition. Circuit analyzation and simulation evaluations were performed on two different circuit designs at the first place. Simulation results showed the effectiveness of both designs, driving down the CM noise output by more than 60 dB and 150 dB, when the capacitance imbalance is perfectly cancelled. Because that frequency change causes impedance for capacitance, we evaluated the frequency domain characteristics for them. The results show that the imbalance cancellation strategy always works well at 0.01 Hz to 10 kHz, which could be considered as a reasonable range for the biopotential signals. Experimental result showed that at 60 Hz, the CM noise output can be driven down by more than 20 dB when the imbalance is 200 pF, proving the feasibility of our approach.

Chapter 4 proposes an EBI impedance imbalance monitoring method. Experiments are performed and the results showed that the 1 kHz injection signal can track the capacitance change of 0 to 400 pF with good linearity, and the detection process can avoid any interference from the biopotential signal.

Chapter 5 introduces our work on signal processing based EOG artefact solution and analysis on the relation between CM noise and artefact. Experiments on 3 kinds of artefacts were performed and a change of 23 dB was observed when there is an interpreted imbalance change of 14 kΩ to 203 kΩ. Based on our work on EOG artefact solution and the CM noise vs. artefact issue, a novel idea about rejecting the artefacts through EBI imbalance cancellation is revealed.

Chapter 6 is a summary of the thesis.

論文審査結果の要旨

As the aging society problem draws great attention, the sensing technology and monitoring scheme of biopotential signals has advanced tremendously over the years. The biopotential signals include electrocardiogram (ECG), electroencephalogram (EEG), electrooculogram (EOG) and many others. They are widely employed in medical and healthcare applications. For example, the body area network (BAN) with wearable sensing technologies can collect these signals as vital data for health-state monitoring, which is considered as an emerging solution to soaring healthcare costs and shortages of medical resources. The potential of biosignals is still to be exploited when sensing technologies advance further. In addition to medical treatment and healthcare, they could also be considered as an irreplaceable interface between human body and machines. In the literature, applications like activity recognition, driving assistance or human computer interface were mentioned by researchers.

Common-mode (CM) noise source like the power line, electromagnetic interference (EMI) and artefacts can severely interfere the detection progress of biopotentials. The imbalance of the electrode-body (EBI) impedance allows the CM noise converting into a differential mode interference voltage. In this study, a core idea runs through all EBI impedance imbalance cancellation-based CM noise and artefact solution for biopotential acquisition circuits.

In this thesis, the applicant first discussed EBI impedance imbalance cancellation-based CM noise rejection for contact biopotential acquisition. Circuit analyzation gave the exact noise rejection performance of a simple differential amplifying circuit, a driven right leg (DRL) circuit and a proposed imbalance cancellation design employing digital potentiometers mathematically. Simulation evaluations were performed, and the results show that the proposal can exceed the performance of a DRL circuit by more than 25 dB at 60 Hz in rejecting the CM noise output when the imbalance of EBI impedance is 100 kΩ, and always perform better in an tunable imbalance range of 390 Ω to 200 kΩ than DRL in biopotential frequency range of 0.01 - 1 kHz.

Then the applicant discussed CM noise rejection for noncontact biopotential acquisition. Circuit analyzation and simulation evaluations were performed on two different circuit designs at the first place. Simulation results showed the effectiveness of both designs, driving down the CM noise output by more than 60 dB and 150 dB, when the capacitance imbalance is perfectly cancelled. Because that frequency change causes impedance for capacitance, the applicant evaluated the frequency domain characteristics for them. The results show that the imbalance cancellation strategy always works well at 0.01 Hz to 10 kHz, which could be considered as a reasonable range for the biopotential signals. Experimental result showed that at 60 Hz, the CM noise output can be driven down by more than 20 dB when the imbalance is 200 pF, proving the feasibility of the proposed approach. In addition, the applicant also proposed an EBI impedance imbalance monitoring method. Experiments were performed and the results showed that the 1 kHz injection signal can track the capacitance change of 0 to 400 pF with good linearity, and the detection process can avoid any interference from the biopotential signal.

Finally, the applicant introduced the above work to signal processing based EOG artefact solution and analysis on the relation between CM noise and artefact. Experiments on 3 kinds of artefacts were performed and a change of 23 dB was observed when there is an interpreted imbalance change of 14 kΩ to 203 kΩ. Based on the work on EOG artefact solution and the CM noise vs. artefact issue, a novel idea about rejecting the artefacts through EBI imbalance cancellation was revealed.

In conclusion, the content of this thesis has been published as three journal papers, and is well worth the award of a Doctor of Engineering degree.