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Ph.D. Public Defense

Friday, April 5, 2013
2:00 PM
Hopeman Engineering Building 335

A Non-contact, Low-noise Electrocardiogram Sensor ASIC Employing Motion Artifact Reduction

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The development of sensitive, non-contact electric field sensors to measure weak bioelectric signals such as the ECG and EEG will be useful both in the development of unobtrusive clinical sensors, for example sensors built into beds, chairs or other furniture, as well as for user-worn personal health monitoring devices. In this thesis we summarize our work on a number of specific challenges in the development of non-contact ECG sensors. First, we considered the design of the sensor preamplifier. A detailed analysis has been conducted to compare the performance of a traditional source follower voltage amplifier and the charge mode amplifier that we are developing. We have adapted circuit designs that were developed previously for piezoelectric vibration sensors that incorporate a double feedback loop to cancel the input transistor leakage current while providing stable operation and fast settling time without the need for high value resistors, which are imprecise, unstable and expensive. The measured input referred noise of the new preamplifier design is comparable to the best low-noise high-input impedance preamplifiers reported in the literature while retaining the above-mentioned practical advantages.

We also considered motion artifacts that arise from the relative movement of the capacitive ECG electrodes and the subject, which modulates the signal source impedance and thereby the preamplifier gain to create large signal distortions. This is especially problematic in user-worn ambulatory monitoring in which the electrode to subject gap may be changing continually. To compensate, we employed 1st and 2nd order gradiometer designs and found that improvement in the signal to motion artifact ratio is possible with 2nd order gradiometers. A Matlab based simulation tool that enables the assessment of different electrode configurations and placements on the subject has been developed to support further refinement of such designs. Even with higher order differential electrodes, motion artifacts remain a key stumbling block, which has led us to develop a new method for the electronic cancellation of motion artifacts by employing a continuous ancillary measurement of the electrode-subject spacing. We describe this new method and our preliminary laboratory measurements that illustrate its effectiveness. We also present work on compensation for static charge generation that employs a multi-layer actively driven over-electrode.

A design for a complete non-contact cardiac monitoring system is then presented, which includes a multilayer static charge compensation electrode, a conceptual ASIC design that includes the ECG sensor preamplifier and the ancillary displacement sensor readout circuit, data storage and a wireless transceiver unit. The ASIC design of the analog front-end and motion compensation circuits enables a compact, low- power system that will be compatible with long-term ambulatory personal health monitoring use.