PULSEMON – Advances in Wrist Sensors Measuring Heart Rate and Heart-rate Variability

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Heart rate (HR) and heart rate variability (HRV) are key human vital sign parameters in medical and sports applications. Whereas in Intensive Care Units (ICU) the monitoring of HR and HRV help to detect pathologies, the supervision of these vital signs aim at optimizing athlete' performance in the sports domain. The objective of the multidisciplinary research project PulseMon is to implement and validate CSEM proprietary photoplethysmograph at the wrist by improving aspects such as miniaturization, integration, comfort and signal quality.

Today heart-rate (HR) and heart-rate variability (HRV) are measured with the help of an electrocardiogram (ECG). ECG devices such as portable HOLTER systems are cumbersome and require the fixation of multiple gel electrodes on the chest of the patient. In the sports domain ECG is measured with an integrated chest belt which sends the data wirelessly to a watch device. For different use scenarios such as sleep disorder analysis or the athlete recovery analysis in the sports domain, a comfortable, non-obtrusive and miniaturized solution is requested.

The use of the photoplethysmography technology offers such a lightweight and simple solution to measure HR and HRV especially when integrated into a wrist device. However, to allow photoplethysmography to become competitive regarding available commercial devices, the measurement quality must be improved considerably. It becomes even more difficult to reach the required signal quality when the photoplethysmograph is integrated into a wrist device, where the measurement is realized by reflective means. In addition, power consumption is a key aspect for a portable device aiming at long-term monitoring of weeks or even months.

To overcome the limitations of photoplethysmography at the wrist, several approaches have been identified and explored further to improve CSEM proprietary technology and increase signal quality and precision, namely:

- the opto-mechanical aspects and how the optical sensors are designed and fixed on the wrist;
- the electronic aspects which is linked to the power consumption and size of the wrist device.

The success for an optimal signal quality requires a good tight fixation of the device on the wrist, ensuring that the optical sensors are continuously in contact with the skin. However, the criteria of a good tight fixation are difficult to measure and therefore not very well known up to this date. CSEM has developed a solution with stretchable electronics technology in order to ensure a permanent contact of the wrist device with the skin with a well-controlled force.

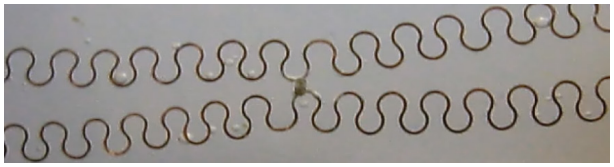

Figure 1: Stretchable electronics strap example

The stretchable electronics technology places the electronic components on a stretchable support in such a way that the soldering points will not break when the substrate is stretched. Several different methods were implemented and validated and very encouraging results have been achieved so far. Thanks to the technology of stretchable electronics, the sensor weight has been reduced considerably as well. A wrist device with a stretchable instrumented strap will now be built to demonstrate the improvements made.

The realization of an Application Specific Integrated Circuit (ASIC) helps further to reduce size and the power consumption of the targeted wrist device. This is particularly the case for the front-end interfaces, which convert the optical signal(s) measured by one or several photodiode(s) into digital signals, which are fed as input to the pulse rate detection algorithms, which have been further optimized. Moreover, the integration of the electronics components reduces the power consumption at least by a factor three compared to the already-power-optimized conventional electronics. Figure 2 shows a simplified bloc diagram of the implemented ASIC.

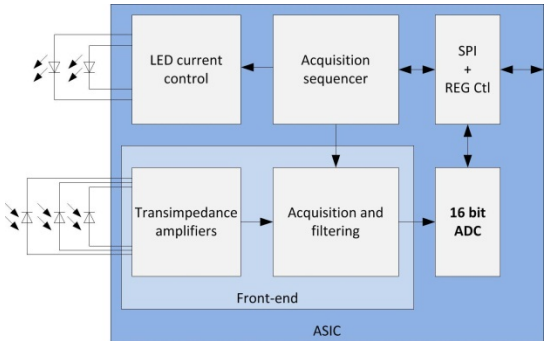

Figure 2: ASIC block diagram

The developed ASIC includes a three-channel photo-plethysmography front-end as well as a LED-current controller, which is appropriate for pulse rate measurement. By setting a simple parameter at runtime, one pulse oximeter measurement channel is used instead of multichannel heart rate. Both LED pulse controller and measurement sequencer are integrated in the ASIC thanks to CSEM experience in mixed signal integration. This key feature relaxes the microcontroller from power consuming sequencing tasks. Last but not least, a high resolution (16 bits) ADC converter has been integrated into the ASIC, saving another external expensive and power consuming component. This ASIC is now in production and will be available in 2013.

This multidisciplinary research activity opens new innovative perspectives to improve further CSEM's proprietary photoplethysmography technology at the wrist. By optimizing both, opto-mechanical interface and data acquisition building block the system dimension, the power consumption and last but not least the device price will be reduced further. This activity has been funded by the SFOTE and CSEM thanks the Swiss Government for its support.