Non-Invasive Pulse Monitoring Sensor

R. Gentsch, B. Gros, J. Krauss, V. Neuman, P. Renevey, P. Theurillat, C. Verjus, R. Vetter, P. Celka•

Portable heart rate monitoring devices are classically composed of a processing device and an external probe. Nevertheless, the use of an external probe is often considered as inconvenient. In the framework of CSEM's research activity of developing innovative portable biomedical devices, a reliable and robust heart rate monitor (so called HRM devices) for portable audio devices has been developed and patented.

Heart rate is a useful indicator of physiological adaptation and intensity of effort. Therefore, heart rate monitoring is an important component of cardiovascular fitness assessment and training programs. Portable heart rate monitors (HRM devices) such as telemetric ECG Holter systems, electronic stethoscopes and pulse oximeters, which have been available for decades, have proved to be accurate and valid tools for monitoring and recording in-field pulse measurements. Nevertheless, commercial HRM devices make use of an external and cumbersome probe, often considered to be a drastic reduction of the user comfort.

In the framework of its biomedical research activity, CSEM has developed and patented a heart rate monitor, located at the ear cartilage and combined it with a portable audio device. The resulting headphone of the portable CD/MP3 player is of small size and weight. It incorporates the functionality of an integrated, reliable heart rate monitor with no inconvenient, external probe, i.e. without any comfort constraints. The measured heart rate is displayed on the remote control unit of the audio device and can be fed back to the user via the headphone in the form of an acoustic signal or a verbal indication.

The earphone prototype of the portable audio device is shown in Figure 1. It incorporates an optical sensor (infrared light emitter and a photodiode), a multi-axis accelerometer system and a digital processor unit. The calculated heart rate is sent to the portable audio device. The technology of the embedded HRM device is based on the multi-channel measurement of the subcutaneous blood flow. Typically, an optical sensor provides emitted light, which is then scattered through the tissue of the ear cartilage, where it is submitted to modifications due to reflection, refraction and absorption. The resulting optical measurement, after propagation through the tissue of the ear cartilage, is based on photoplethysmography (PPG), which has been used widely over the past for the estimation of physiological parameters such as oxygen saturation and pulse rate. Corruption of the PPG signal is caused by ambient light and motion of the subject. These artifacts lead to erroneous interpretation of PPG signals and degrade the accuracy and reliability of PPG-based algorithms for the estimation of cardiovascular parameters. In order to circumvent the drawback of motion artifacts, a two-axis accelerometer system is used to provide a reliable motion reference. Efficient removal of motion related artifacts in the optical signals is achieved by applying non-linear model-based processing techniques. Data fusion of signals coming from an optical sensor and from a two-axis accelerometer is a solution for a robust and practical measurement of the heart rate at the ear cartilage.

Figure 1: Heart rate sensor integrated in a commercial earphone.

The validity of this new and innovative heart rate measurement concept at the ear cartilage has been proven during extensive tests under different physiological conditions and with numerous users. Figure 2 shows a sample of the measured heart rate of the HRM headphone device during a running exercise outdoor lasting of 15 minutes. The measured heart rate is compared to the results of a commercial pulse measurement device using a chest belt probe and proves to be precise and reliable.

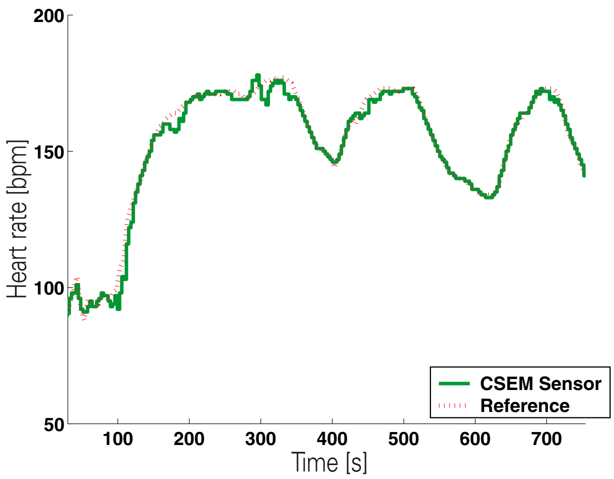

Figure 2: Measurements with CSEM integrated heart rate sensor during a running exercise outdoor compared to a commercial pulse measurement device using a chest belt probe.

CSEM is currently working on the integration of additional physiological parameters such as the measurement of the saturation of oxygen in the blood (SpO_2 parameter) into the HRM headphone prototype device.

• Griffith University, School of Engineering, Australia