ECG12CS—12-lead ECG Monitoring System with Cooperative Sensors

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The goal of ECG12CS is to implement a wearable 12-lead electrocardiogram (ECG) monitoring system with dry electrodes. The system also fulfils international medical standards in terms of safety and signal quality. To that end, the system uses cooperative sensors. Cooperative sensors are a novel electronic architecture based on active electrodes that allows the acquisition of biosignals (e.g., ECG, electroencephalogram, bioimpedance, etc.) on patients in a comfortable and easy-to-integrate manner. One advantage of this technology developed and patented by CSEM is the extremely simple connection requirement that makes the sensors easy to integrate in a vest or any other garment.

In recent years, many different wearable sensor systems for measuring ECG have been developed and placed on the market. First sensor designs were relatively bulky (centralized electronics box, cumbersome connectors, shielded cables, etc.) and required the use of gel electrodes to get signals of best quality. Today, however, there is an increasing demand for systems which can be comfortably worn in daily life [1]. One of the main challenges in the development of such systems is the size and weight reduction of its elements. Additionally, the integration (in particular the cabling) of the sensors in a wearable monitoring device should be simple from a manufacturing and usage point of view.

Figure 1 shows the novel electronics architecture developed by CSEM (patent pending) for a 12-lead ECG monitoring system. This architecture includes one guard sensor and nine measuring sensors. Each measuring sensor measures the biopotential (e.g., ECG) at its specific location (measured as v_0 to v_8). All voltage measurements are referred to the same voltage potential picked up on the measurement wire (*meas. wire* in Figure 1) and controlled by the guard sensor thanks to the voltage source v_{cm}. By controlling this common mode voltage it is possible to compensate external electromagnetic noise. As a consequence external wires (*meas. wire* and *comm. wire*) do not require any shielding to get signals of best quality [2], even in an electromagnetically noisy environment, which is one of the main advantages of this novel architecture.

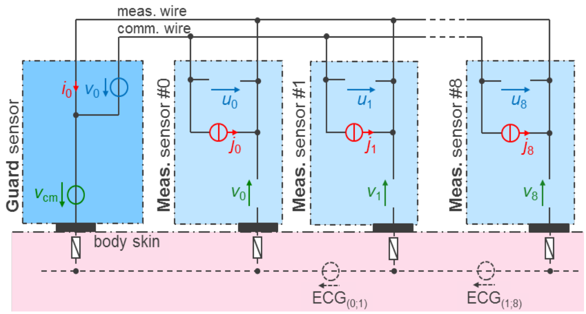

Figure 1: ECG12CS circuit with 1 guard and 9 measuring sensors.

Since ECG signals (measured at v_0 to v_8) are locally amplified and digitized in each measuring sensor, a duplex communication between sensors has been implemented to allow centralized data management (e.g., storage) in the guard sensor. To allow this duplex communication, a second wire is used, namely the communication wire (*comm. wire*). This wire links together all sensors and is in parallel with the *meas. wire* (see Figure 1). For the communication between the guard (communication master) and measuring sensors, the guard sensor sends small voltage impulses with v_0. These impulses are sensed by other sensors as u_0 to u_8. The communication in the other direction is performed with small current impulses generated by j_0 to j_8 which are sensed as i_0 by the guard sensor. Since the current sources j_0 to j_8 are in parallel, each measuring sensor communicates in turn with the guard sensor to avoid current overlap [3].

A 12-lead ECG configuration including the guard sensor and nine measuring sensors is shown in Figure 2 (up left) as well as the final implementation of a measuring sensor (up right). Each sensor has its own electronics and power supply (e.g., a rechargeable battery). External wires (*meas. wire* and *comm. wire*) are two non-shielded conductive wires simply knitted in the garment and attached to sensors via snap buttons. These two wires are also used when the garment is not worn to simultaneously recharge all sensors without having to remove them from the garment.

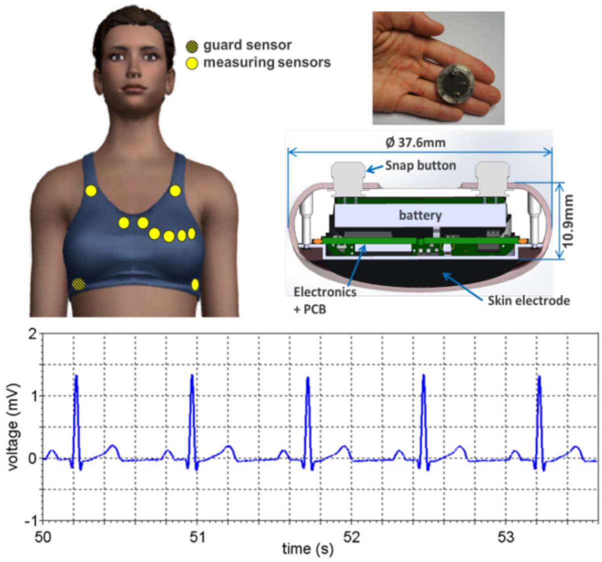

Figure 2: Sensors placement for a 12-lead ECG monitoring system (up left), final implementation of a measuring sensor (up right), and acquired ECG (from simulator) showing that the communication between sensors does not interfere with the measured signal.

[1] Y. L. Zheng, *et al*., "Unobtrusive sensing and wearable devices for health informatics", IEEE trans. on biomed. eng. 2014, 61(5), 1538-54

[2] M. Rapin, *et al*., "Cooperative dry-electrode sensors for multi-lead biopotential and bioimpedance monitoring" Physiol Meas. 2015 Apr. 36(4), 767-83

[3] M. Rapin, *et al*., "Cooperative sensors: a new wired body-sensor-network approach for wearable biopotential measurement", MobiHealth Conference, London (GB), October 14–16, 2015