# Towards fully Integrated Cooperative Sensors for Vital Signs Monitoring

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*Cooperative sensors for vital signs monitoring allow a large number of sensors thanks to their connection to a 2-wire bus used for powering and communication. To keep performance over the shared connection high and keep a sensor node versatile, active circuitry and digital control need to be implemented on each node. In this scenario integrated mixed-signal circuits can provide signal condition, control, and signal transmission, all combined in one package.*

The concept of cooperative sensors has been invented and used in various forms and projects within CSEM. The approach aims at avoiding the use of individually connected sensor nodes like commonly found in many biomedical applications such as electrocardiogram (ECG), electroencephalogram (EEG) or bioimpedance measurements. Equipment for these types of measurements usually connect each sensor with at least one individual wire. In many cases this wire must be shielded or even double shielded to bring an unamplified signal to the multi-channel acquisition box. Cooperative sensors on the other hand aim at using a single connection that is shared by all electrodes/ sensor nodes [1].

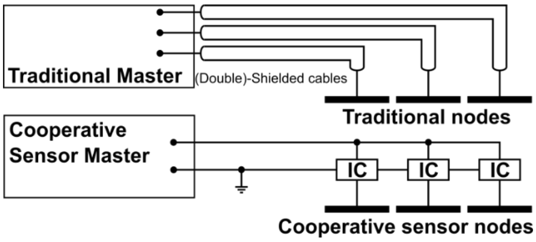


*Figure 1: Comparison of vital signs monitoring conventional vs. cooperative approach on example of ECG.*

The approach however requires some active circuitry directly placed on each node which, when implemented with discrete components, increases the footprint and the weight of an individual node. The use of an application-specific integrated circuit (ASIC) can counteract this by integrating all required subsystems on the node and therefore minimizing the component count on the sensor. Additionally, the circuits can be optimized for the specific application and reduce the power consumption to the absolute minimum. This can further increase the maximum number of connected channels. For this reason, an ASIC is currently developed for a cooperative sensor system acquiring bioimpedance and sound concurrently. Over the 2-wire bus connection provided to the sensor node the IC has to

- Harvest power to supply the IC operation,
- Synchronize with the system master to allow collision-free communication of data and control, and
- Acquire and pre-amplify the sensed signals with respect to the bus potential.

Figure 2 shows the schematic for the cooperative-sensor node. The supply power is derived from an AC source on the master node with the aid of a rectifier stage. The frequency of the AC supply is chosen not to coincide with any of the signal bands the sensors of the system acquire to avoid crosstalk. The recovered charge is stored on external capacitors that serve as short-term energy storage. Once the IC is properly synchronized, the harvesting is disabled on predefined time-periods during which one of the nodes can send an acquired analogue value to the master node. The transmission of an analogue sample to the master is a crucial and challenging part of the design. As the system needs to support many nodes multiplexed over a single connection, the time to transmit a single sample needs to be short to keep the sampling rate of individual nodes high and also leave enough time to deliver power to the nodes. Communication of the samples in the analogue domain is done by transferring a controlled charge over the bus. This also releases the IC from the additional task of analogue-to-digital conversion, reducing the power-budget and the complexity of the circuit. The downside of using analogue transmission is the possibility of noise and crosstalk pickup during the process. A clear definition of required dynamic range together with a strategic selection of gain and sampling rate for each application is needed to ensure that transmitter noise stays below the signal's noise floor.

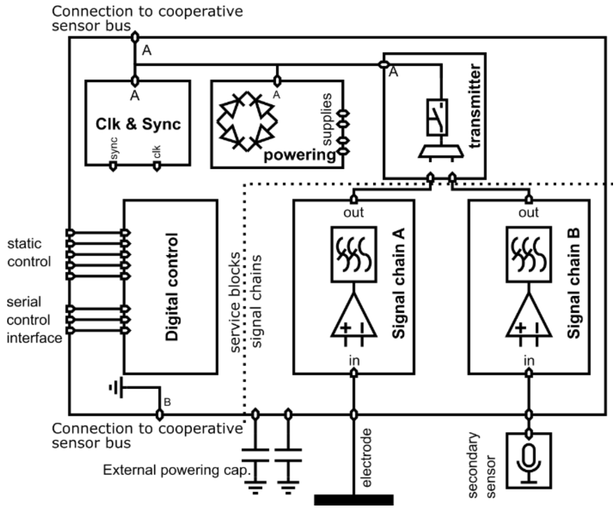


*Figure 2: Block diagram of the cooperative-sensing IC.*

The IC in Figure 2 contains generic service blocks that are not constrained to a specific application, and signal chains for the electrode and an auxiliary sensor. More than one signal chain can be multiplexed onto the transmit path, which makes the approach very versatile and suitable for a multitude of vital-sign monitoring systems. E.g., the potential from an electrode can be multiplexed with a temperature sensor, a microphone, or other supplementary information.

In summary, the presented IC platform is an important step in the process of developing light weight cooperative-sensor systems that can be adapted to a multitude of different applications for vital-signs monitoring.

[1] M. Rapin, J. Wacker, O. Chételat, "Cooperative sensors: a new wired body-sensor-network approach for wearable biopotential measurement", EAI Endorsed Transactions on Collaborative Computing; Ghent Vol. 2, Iss. 7, (Nov. 2016): 151-154. DOI:10.4108/eai.14-10-2015.2261683.