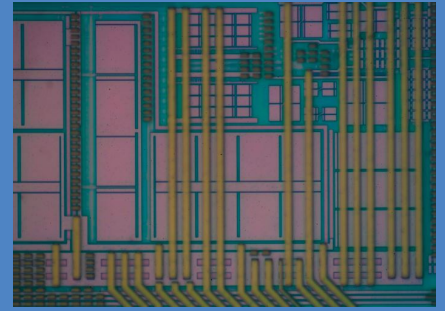




WearMeSoC

MULTI FUNCTIONAL WEARABLE WIRELESS MEDICAL
MONITORING BASED ON A MULTI CHANNEL DATA ACQUISITION
AND COMMUNICATION MANAGEMENT SYSTEM ON A CHIP



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What it's about...

Developing a chip that will enable very small wearable medical monitors with wireless connectivity to small phones and tablets.

Context and project goals

For both in- and outpatient applications the electronic interface to typical sensors and electrodes is still embodied in size and weight that prevents it from being used in the convenient and flexible way expected by new visions of healthcare provision. Integration of the plethora of functionalities required in a wearable medical monitor, including the management of wireless connectivity and its power consumption, holds the key to the breakthrough required for clinical and user acceptance of many continuous use cases.

A highly integrated system on a chip (SoC) will be developed in this project, starting from a multi-channel data acquisition integrated circuit already developed by the principal investigator ETH recently. The new SoC will improve existing design by incorporating on chip many of the conceptual design innovations such as DC connectivity and mains interference cancellation that are currently realized off-chip on a large FPGA. It will more-over incorporate multi-channel transimpedance and charge amplifiers for current, charge and optical sensors. Temperature sensors and actuating functions for stimulation will also be incorporated to make the IC truly multi functional, therefore useable in as many future applications as possible.

Experience from previously engineering portable medical monitors shows that what limits miniaturization even in single function applications is the large variety of critical support functions that need to be realized with separate commercial chips, especially when wireless connectivity is involved. The latter's high power consumption mandates a large battery, unless data transmission can be managed to occur at high rate but in bursts. Frequency and duration of such bursts must be adaptable depending on the use cases. The management of data buffering, storage, interaction between on-chip and off-chip memories and intelligent control of the wireless modem so that it stays connected to the base unit or station even when little transmission is taking place, requires highly sophisticated digital logic and control functions to be integrated on chip. This doesn't exist today and will be realized in the proposed project. Battery and power management circuits for the operation of all the ICs on the monitor PCB, control and data interface between the SoC and the wireless modems and memory, management of a small display (LCD or LED) are all to be integrated before the targeted size (match box) and weight (25g) become reachable.

This interdisciplinary project consists of partners from engineering, biomedical signal processing specialists who can advance automated diagnostics for early warning as well as scientific understanding, and clinical researchers who have already worked on convincing use cases that require miniaturized monitors. Their input to the system engineering and SoC definition, drawing from rich experience in using larger portable monitors to actually carrying out case studies previously, will be invaluable to the success of the SoC. The design of the latter is such a complex as well as costly task that it cannot afford frequent specification changes and addition of functionalities. Nevertheless, continual validation by the clinical team using both the prototype existing at the start of the project, the intermediate prototype developed during the project and the final demonstrators will be of crucial importance to achieving the ambitious goals set by this proposal.

Medical research carried out in their own right in the use cases will advance our understanding of sleep disorders and therapy, oximetry and ECG monitoring of cardiac surgical patients in postoperative wards, verification of onset of dementia, physiological responses to adverse environments such as high altitude, air travel and oxygen deprived working environments. Two commercial partners will contribute their knowhow in diagnostics and engineering during the project. They are also motivated to exploit the results of the project and help them reach the market.

How it differentiates from similar projects in the field

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Quick summary of the project status and key results

A modular and multi-functional hardware prototype has been provided to our medical research partners and has been evaluated successfully. While using this hardware platform as a debugging device, a miniaturization of the multi-functional device has been targeted. A first prototype of a medical monitoring SoC based on a parallel ultra-low power (PULP) multi-core processor has developed and successfully evaluated. Recently, a first prototype of a battery-operated biomedical implant device including a wireless link with the dimensions below 1cm³ has been realized.

Success stories

A Versatile Embedded Platform for EMG Acquisition and Gesture Recognition:

The analog front-end IC Cerebro developed at IIS (ETH Zurich) has successfully been implemented in a hand gesture recognition system for an arm prosthesis. The performance of the developed system matches up to a state-of-art high-end active sensor platform at much lower cost. The average accuracy in the recognition of 7 hand gestures is 89.2% (with a maximum of 92%). The joint work opens up the path to affordable and accurate prosthesis devices.

Reference: S. Benatti, B. Milosevic, F. Casamassima, P. Schönle, S. Fateh, Q. Huang, L. Benini, A Versatile Embedded Platform for EMG Acquisition and Gesture Recognition, submitted to IEEE Trans. On Biomedical Circuits and Systems, 2015.

Ultra Low Power and Implantable Biomedical Devices:

Invited due to interests from industry to participate a competition on ultra low power and implantable biomedical devices organized by GlaxoSmithKline (GSK)

Main publications

P. Schönle, F. Schulthess, S. Fateh, R. Ulrich, F. Huang, T. Burger and Q. Huang, A DC-Connectable Multi-Channel Biomedical Data Acquisition ASIC with Mains Frequency Cancellation, Proceedings of the European Solid-State Circuits Conference (ESSCIRC), pp. 149-152, Bucharest, Romania, Sep 2013.

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Peter Achermann and Leila Tarokh, Human sleep and its regulation, *Kosmos* 63 (2(303)): 173-180 (2014).

Stadelmann K, Latshang TD, Lo Cascio CM, Tesler N, Stoewhas AC, Kohler M, Bloch KE, Huber R, Achermann P., Quantitative Changes in the Sleep EEG at Moderate Altitude (1630 m and 2590 m), *PLoS One*. 2013. (In Press) IF: 3.73.

P. Schönle, P. Bunjaku, S. Fateh, Q. Huang, Modular Multi-Sensor Platform for Portable and Wireless Medical Instrumentation, Proceedings of the Biomedical Circuits and Systems Conference (BioCAS).

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S. Benatti, B. Milosevic, F. Casamassima, E. Farella, P. Schönle, P. Bunjaku, S. Fateh, T. Burger, Q. Huang, L. Benini, A Versatile Embedded Platform for EMG Geesture Recognition, *IEEE Transactions on Biomedical Circuits and Systems*, Vol. 28, 2015.

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Marco Tomasini, Simone Benatti, Filippo Casamassima, Bojan Milosevic*, Schekeb Fateh, Elisabetta Farella, Luca Benini, Digitally Controlled Feedback for DC Offset Cancellation in a Wearable Multichannel EMG Platform, Accepted for publication at EMBC'15.

Peter Achermann and Alexander A. Borbély, Sleep Homeostasis and Models of Sleep Regulation, In: Kryger M, Roth T (Eds). *Principles and Practices of Sleep Medicine* (6th edition). Elsevier Saunders, Missouri, in press.

S. D. Segitz, T. D. Latshang, M. Furian, D. Flück, S. Müller-Mottet, S. Ulrich, M. Kohler, K.E. Bloch, Comparison of Visual Spot Checks vs. Trend Analysis of Pulse Oximetry During Six-Minute Walk Tests. , *Respiration* 2014; DOI: 10.1159/000362143 P118.

S. Fateh, P. Schönle, L. Bettini, G. Rovere, L. Benini, Q. Huang, A Reconfigurable 5-14 bit SAR ADC for Battery-Powered Instrumentation, *IEEE Trans. On Circuits and Systems I*.