tion checkers. Assertion properties and checking are also included in a distributed manner across the entire design.

Commercializing research results

For the last five years, the VLSI lab at Democritus University of Thrace has focused on the design of NoC architectures. During this time we had already developed a complete SystemVerilog-based NoC architecture including highly-parametrizable register transfer language (RTL) models of NoC components, such as network routers and AMBA AXI4.0-compatible network interfaces.

After reviewing this area, Think Silicon opted to license the NoC technology developed by the VLSI Lab. The NoC architecture was then customized to meet the company's requirements as part of a one-year development project set out in a contract.

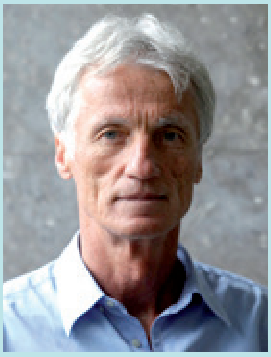
Think Silicon's portfolio includes GPUs, display processors, graphics accelerators and GPGPU accelerators focusing on ultra-low power consumption and thus on extension of the battery life. The licensed NoC technology is embedded inside the graphics IP commercialized by Think Silicon rather than being presented as a standalone product.

In future, the NoC architecture could be delivered as standalone IP to systems-on-chip in other areas such as the automotive sector, data centres, networking or mobile computing. However, achieving this goal would require a significant amount of effort which could only be achieved by a dedicated spin-off company.

Business opportunities for European semiconductor researchers

In the area of integrated-circuit design and computer architecture, one of the major problems facing industry is complexity and the verification of functionality and product quality (performance and power). Any new feature added or architecture developed should be adequately verified both in isolation as well as a part of an already complex system. Hence solutions that can automate verification or the design of verification-friendly protocols and architectures would have a clear impact on future products. In my opinion, this is especially important for SMEs specializing in innovative solutions which lack the resources to carry out proper verification of their new ideas and whose technology may not be adopted as quickly as it could be.

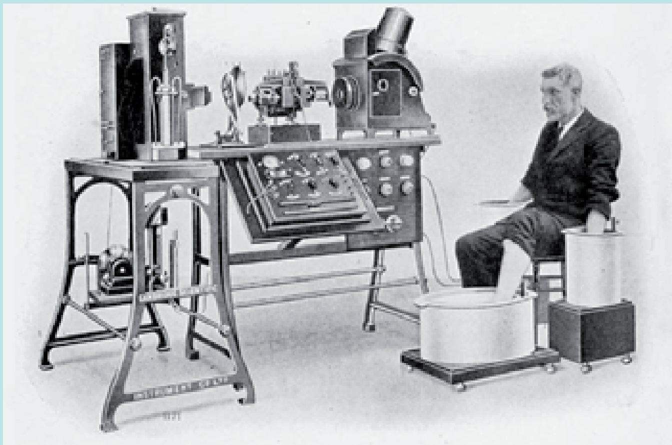
WIRELESS, WEARABLE AND USER-FRIENDLY ECG SENSORS



Roman Trobec and Aleksandra Rashkovska, Jožef Stefan Institute, Ljubljana

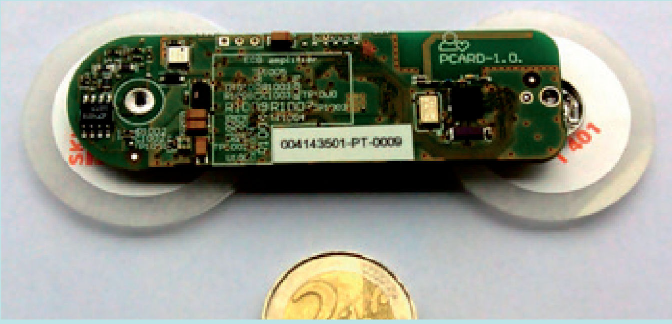
Our innovation is a miniature device with an electrocardiogram (ECG) sensor. This wearable multifunctional body sensor measures differential surface potential (ECG) between two proximal electrodes. The moderate resolution ECG is suitable for long-term personal cardiac activity monitoring, as well as for clinical use. Besides ECG, other features can be extracted from the potential measured, such as muscle activity and respiration. The sensor can also detect information about the measurement conditions such as movement and temperature, thus providing information that allows for ambient intelligence.

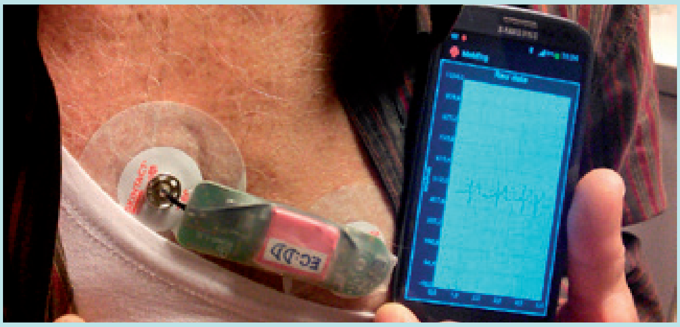
High quality ECG was first measured by Willem Einthoven at the beginning of the 20th century with his invention of the string galvanometer. Today, a range of ECG devices are used in medicine, from the standard 12-lead ECG, where wires are connected to electrodes placed on 10 locations of the body, to multichannel ECG body surface mapping systems, to the Holter monitor, where a lower number of electrodes are connected with wires to a small portable recorder that obtains a continuous ECG measurement over several days, and finally to the (wireless) implantable loop recorder which measures ECG for a period of several years.



An early commercial ECG machine

Our solution was inspired by the multichannel ECG with 64 electrodes on the surface of the body. We recognized that a significant amount of information about heart activity could be measured just through the electric potential between two neighbouring multichannel electrodes. Such an approach enables non-invasive measurement with a single channel of bipolar ECG without wires.





The compact wireless ECG sensor can transmit data to PDAs such as smartphones

Additionally, a low-power radio and processor can be placed on such devices for continuous wireless transmission of data to a nearby personal digital assistant (PDA), such as a smartphone or tablet. Using a PDA offers the possibility of WiFi internet access to a safe storage server for further storage and processing.

Our solution is situated between the Holter monitor and the implantable loop recorder with the possibility of immediate access to the measured data. It is therefore most appropriate when heart rhythm and ECG need to be monitored in an unobtrusive, non-invasive way for a period of several hours to several days. If the battery is charged periodically and the electrodes are replaced, the monitoring period could be prolonged to weeks or even months.

Mainstreaming mHealth: a market opportunity

The project arose in response to the lack of widely accepted mobile health (mHealth) solutions, despite the world of ubiquitous mHealth-enabling ICT devices. The key weakness of the approaches implemented so far is that they focus mainly on the technology, while the importance of its acceptance by users and health care practitioners is largely neglected.

Our ambition is to bring an mHealth solution into the mainstream of modern healthcare – a solution which will be supported by medical experts and users as well as being CE certified. Expected outcomes include:

- An ergonomically co-designed, widely accepted wireless body sensor.
- A formal model of holistic health management: clinical models, domain and data-driven platforms, users' communication interfaces, and personal records with users' medical history.
- Fully operating pilot systems with more than 100 volunteer test users.

The ultimate goal is to deliver a medically certified device ready for mass production and further industrialization.

Wide range of potential usage scenarios

It has been shown that the ECG measurements from the sensor are suitable for medical use, in particular for detection of arrhythmias where the ECG timing is important. This has been confirmed by several clinical evaluations. Using ambient data, it is possible to determine the conditions in which the measurements were taken. Hence the sensor can provide solutions for continuous monitoring of heart activity in hospitals, health centres, nursing homes, older people's housing, health resorts and similar. The exceptionally lightweight, unobtrusive design of the sensor allows it to be used while engaging in sporting activities or during intense physical work.

Use of the sensor is not limited by the user's age, sex, weight, height or other personal characteristics, or by current health status.

From lab to market

The work needed to progress an innovation from a laboratory prototype to the market is often underestimated. First, it's essential to have a competent investor who can invest in knowledge, certification, production and marketing. In our case, the investor established a spin-off company because doing so allowed ownership of an independent business entity, tax flexibility and career opportunities for enthusiastic engineers and medical doctors. However, this requires certification for quality management systems, which is quite a complex task.

To ensure success, an experienced and devoted team is a must; we are lucky enough to benefit from a great team for this project.

RESEARCH AND DEVELOPMENT

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Have you successfully transferred research results to industry? Send your submission to the HiPEAC Technology Transfer Awards. Further information: www.hipeac.net/research/technology-transfer-awards