BESTPRACTICE
RESEARCH PROJECT
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DESIGN AND IMPLEMENTATION OF A LOW POWER, LOW COST, MOBILE ECG MONITOR

Project lead
Prof. Dr. Markus Nauroth
Department of Information Systems

Cooperation partner
Dr. Petro Saridakis (cardiologist)

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Contact
markus.nauroth@fh-mainz.de

Research topic and goal

The research project focuses on designing and implementing a low power, low cost, mobile ECG monitor. The project is split into several phases, with a first prototype based on off-the-shelf evaluation models for converting the analogue heart signals into a digital bit stream as well as low cost computational components for transmitting the data wirelessly to a display device (e.g. smartphone, tablet).

Follow-on phases aim at converging currently separated components into a fully integrated design. A commercially available version could consist of wristbands worn on both wrists or across breast and waist, which would read the heart signal, convert the data and send it via Bluetooth to a displaying device. Alternative implementations could incorporate the required functionality into the electrodes required to read off the heart signals.

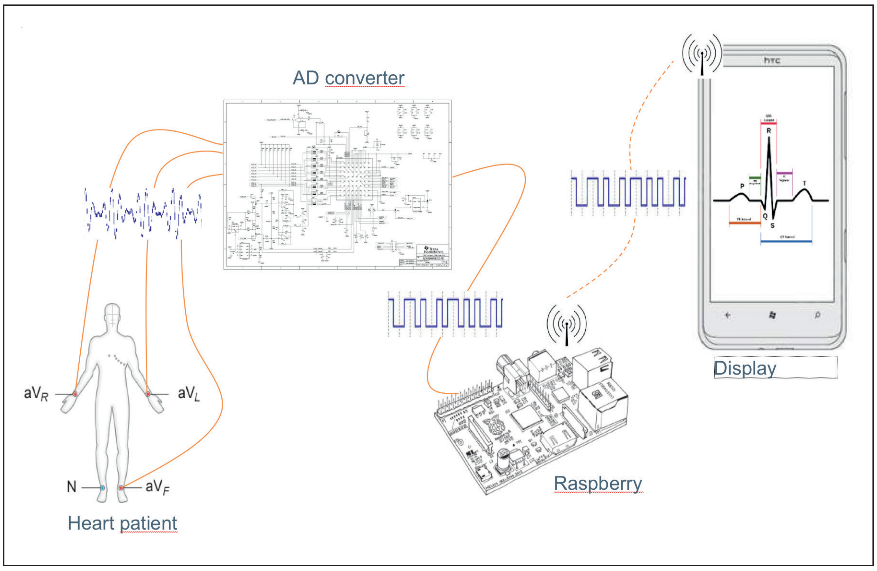

Fig 1: Schematics of the phase 1 ECG monitor

Rational / Motivation for conduction this research

Over the past few years, one can observe several trends that support the development of so-called wearable technology in general and heart tracking devices in particular:

- According to the latest statistics from various government organisations, heart diseases account for approx. one out of four deaths. It is therefore the second most prominent cause of death, trailing only cancer. Permanent heart signal tracking would help predict strokes or any abnormal behaviour.
- The number of people conducting endurance sports regularly has increased significantly over the past few years. While in the 90's, roughly 5m runners finished in at least one of the most prominent US running events, that number has more than tripled by now. The majority of those participating in these events use advanced technology to track their performance and optimise their training, with heart signals used most often as a key indicator.
- Both size and price of those technology components required to build a mobile ECG monitor have dropped significantly. While todays AD converters incorporate the majority of functionality in a single chip, those components go for less than $20 and operate on a single standard coin battery for months. The same holds true

for the wireless technology required to transmit the data, with the latest Bluetooth 4.0 standard particularly aimed at low-energy consumption.

- Smartphones and tablets nowadays have sufficient computational power to not only graphically display the heart signals but also conduct the required analysis to identify any abnormal behaviour, with an option of contacting a cardiologist immediately in an emergency.

All these trends currently lead to the development of a multitude of devices subsumed under the broader context “wearable technology”. Market research suggests that over the coming years both breadth and depth of functional capabilities of these devices will grow exponentially, with both small start-ups (e.g. FitBit, Pebbles, BodyMedia) and established key players (e.g. Samsung, Apple, Microsoft) investing in this market.

Design and Implementation - Phase 1

The first prototype (as in Fig 1) consists of an analogue/digital-converter evaluation module (Texas Instruments ADS1298 EVM) and a low-cost computing device (Raspberry Pi Model B) as well as a smartphone (Samsung Galaxy S3). Here, data is being collected via standard ECG cables (ECG Cable 10 Leads for Philips/HP) and converted into a digitized bit stream using an eight channel, 24bit AD-Converter (TI ADS1298). The ADS1298 provides a SPI (Serial Peripheral Interface) as well as an I2C (Inter-Integrated Circuit) interface which allows external devices to communicate with the AD converter. In this case, the SPI interface (DOUT signal) is used to read off the bit stream, with the CS and DRDY indicating that new data is available and the SCLK signal providing the timing required to synchronise the data transfer. As the AD converter offers conversion rates of up to 32k SPS (Signals per Second), the SPI interface is using a 2.048 MHZ clock.

Fig 2: Sample ECG data

In order to operate all devices required access to a power outlet is required. Therefore the current release can only operate stationary, though with slight adaptations a mobile version can be envisioned. For example, the Raspberry Pi, currently reading off the digital data from the AD converter and forwarding that data via Bluetooth to the displaying device, could be replaced by a dedicated Bluetooth chip (e.g. the Texas Instruments CC2541 chip) which offers the same functionality but consumes only a fraction of the power required by the Raspberry Pi.

Results

The heart signals (as in Fig 2) show all the expected features of an ECG curve. Some artificial features of the signal are due to the fact that the AD converter is powered via a power outlet, adding a 50 Hz noise to the measured heart signal.

Tests have shown that it is equally important to use well-shielded cables. It is therefore imperative to add a GND to every cable to avoid any signal interference, i.e. from wireless devices nearby (e.g. 3G/LTE mobile or WLAN routers). Also, all terminal pads need to be shielded sufficiently.

Current application

In its current release, the ECG monitor incorporates all basic functionality required to read and display the basic heart signals. As this version requires access to a power outlet and therefore needs to operate stationary, it is suitable for a cardiologist’s office. Alternatively the device can be installed in a patience’ home, monitoring the patience heart signals during daytime activities or sleep.

Outlook

The ultimate goal of this research project is to develop a low power, low cost, wearable mobile ECG monitor. Key design imperatives include maximising convenience in wearing the necessary gear, lowest possible power consumption, and the use of off-the-shelf products