

# An introduction to future truly wearable medical devices - from application to ASIC

# An introduction to future truly wearable medical devices—from application to ASIC

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***Abstract*— This talk will provide an introduction to the "Towards future truly wearable medical devices: from application to ASIC" mini-symposium. For user comfort and acceptance long term physiological sensors must be discrete, comfortable and easy to use. These requirements place stringent limits on all aspects of the system design: from the overall application aim, to power generation issues, to low power electronic design techniques. For successful devices design issues in all of these areas must be solved simultaneously. The work here presents an overview and introduction to these topics.**

## I. INTRODUCTION

A large number of members of the IEEE Engineering in Medicine and Biology Society are interested in some form of prolonged physiological monitoring. This could be ECG (electrocardiogram) for heart monitoring; EEG (electroencephalogram) for brain monitoring; breathing rate monitoring; blood pressure monitoring; fall detection; or one of many others. From the end user perspective, these prolonged monitors must have a wide range of features. They must be:

- small, discrete, socially acceptable, easy to use, long lasting, accurate, reliable, and ubiquitous.

Devices satisfying all of these criteria are termed *wearable medical devices* to distinguish them from current devices which are only portable. The development of wearable medical technology will be essential for future personalised and preventative medical care.

From the researcher perspective satisfying all of these requirements simultaneously is daunting, and this is without including the medical and electronic requirements of the device. Sampling rates, signal-to-noise ratios, safety regulations and other specifications must also all be met. This mini-symposium will provide an overview of the major challenges affecting wearable device development, and recent progress towards their solution. We will discuss: what are the challenges?; what is the state-of-the-art?; and what are the future research questions?

## II. OBSTACLES TO WEARABLE TECHNOLOGY

For the design of wearable sensor nodes three major areas will be considered. As will become apparent, these major obstacles to wearable technology development cannot be overcome in isolation. Applications specific requirements, guides, specifications and aims are essential.

### A. Low power electronics and signal processing

A classical wearable physiological sensor must contain a front-end analogue amplifier, an analogue-to-digital converter, and a wireless transmitter. It has been estimated that for truly wearable systems all of these stages must operate with an average power consumption of less than 140 $\mu$W [1]. This is a challenging aim. Online signal processing, also on the wearable sensor, can be used to help meet this challenge, but at the cost of requiring detailed algorithm development and verification [2]. Even then, a successful algorithm must operate with very low power consumption.

### B. Power autonomy

The power consumption budget can be increased by the use of physically larger batteries at the cost of system size. Historically the capacity of off-the-shelf batteries has doubled only every 5–20 years [3], and so capacities of sufficiently small, and medically approved, batteries are unlikely to reach satisfactory values in the near future. Instead, long term autonomous operation can be achieved using power-scavenging techniques. Here energy is harvested from the ambient environment of the user, for example from body heat or movement [4], and it is believed that such techniques may harvest up to 100 $\mu$W significantly relaxing the power constraints. However, there are open research questions over the amount of power that can be produced, the physical size of the energy harvester and the non-constant nature of the power source.

### C. Physiological application

Wearable technology has potential applications in many different medical areas. Even taking just one, say wearable EEG for brain monitoring, there are many potential end usage situations. The requirements for Brain-Computer Interface (BCI) EEG systems may be very different to those for epilepsy diagnosis. This will require different processing electronics, with differing power budgets. Also, keeping a medical device attached to the body for days, weeks or months at a time is not a trivial problem. In recent years there has been significant progress on dry electrodes (for example [5]) which do not require conductive gel, but changing any part of the electrode attachment stage will also affect the specifications required for the following circuit stages.

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## III. REALISING WEARABLE TECHNOLOGY

The "Towards future truly wearable medical devices: from application to ASIC" mini-symposium will investigate the state-of-the-art in all of the above areas: wearable applications, energy harvesting, and low power signal processing and transceiver electronics, in a holistic manner.

To realise truly wearable technologies this holistic approach is essential, breaking traditional discipline boundaries. For example, it is not enough to solve issues $A$) and $B$) above without simultaneously considering $C$); the particular application sets detailed requirements which must drive and guide the entire system design, so that an integrated solution is achieved at all of the design levels. Multiple, different systems may be necessary for each overall application aim, and a different approach taken in each case.

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