A high accuracy Bioimpedance Measurement System

System design and first measurements

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Motivation and aims

- Provide a high accuracy bioimpedance measurement system (BMS) in a frequency range of 10 kHz to 250 kHz with current amplitudes from 30 µA to 5 mA.
- Load impedances from $Z_L = 10 \, \Omega \ldots 20 \, k\Omega$.
- Allowing of real time measurements of phase and magnitude.
- Employing the advantages of an Embedded System with an FPGA System on Chip (SoC) architecture.
- Be in compliance with the IEC 60601-1, the electrical safety standard for medical devices.
System architecture

**Figure 1.** Concept of the BMS architecture. One current channel with a Voltage Controlled Current Source (VCCS), two similar designed high resolution ADC channels for current and voltage measurement.
Software architecture

Figure 2. BMS software architecture. A mixture of Matlab, VHDL and C allows a flexible, fast and powerful software development.
Figure 3. Manufactured BMS PCB - main components are FPGA (A), DAC (B), VCCS (C), ADC (D), USB interface (E), current out and current in connectors (F), differential voltage connectors (G), PGAs and band pass filters (H), power supply (J).
First results – time domain

Figure 4. Sampled signals of both ADC channels. $f_{\text{sample}} = 6.25$ MHz, current excitation $I = 2.5$ mA, $f = 48.828$ kHz. Measured on an electrode phantom.
First results - frequency domain

**Figure 5a, 5b.** Discrete Fourier Transform of the sampled data. 100 periods are measured, $f_{\text{sample}} = 6.25$ MHz, current excitation $I = 5$ mA, $f = 48.828$ kHz. Reached SNR is about 80 dB, with an SFDR of about 60 dB. Measured on an electrode phantom.
First calibration results

Figure 6. Calibration results for $|Z|$. Without calibration the total error of $|Z|$ is smaller than 0.5%. The balanced system can reach a total error smaller than 0.1% over the whole frequency range.
First calibration results

Figure 7. Calibration results for the phase angle Phi. Without calibration the total error of Phi is in a range of ±3°. The balanced system can reach a total error smaller than ±0.1° over the whole frequency range.
Summary and outlook

• We successfully developed and manufactured a prototype of a Bioimpedance Measurement System (BMS), based on a System on Chip (SoC) FPGA architecture.

• The system is in principle in compliance with the IEC 60601-1, the electrical safety standard for medical devices.

• The prototype is able to generate arbitrary waveforms and measures in a frequency range of \( f = 10 \text{ kHz} \ldots 250 \text{ kHz} \), with load impedances of \( Z_{\text{DUT}} = 10 \Omega \ldots 20 \text{ k}\Omega \).

• High accuracy impedance measurements can be reached with an magnitude error of about 0.1 % and a phase error of less than 0.2 °.

• The temporal impedance resolution is about \( T_{\text{measure}} = 10 \text{ ms} \) at \( f = 10 \text{ kHz} \) with an SNR of about 80 dB.

• We are thinking of making the design public domain with the beginning of the next year.
Thank you for your Attention

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financed by the European Union,
European Regional Development Fund (ERDF)