Development of a System for Multiplexed High-Resolution Multimodal Signal Acquisition

Degree programme: Master of Science in Engineering
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The Institute for Human Centered Engineering has developed a multiplexed multimodal miniaturized catheter. However, there is no commercially available device that allows measurement and control of the device under tight time constraints. In this thesis the requirements were evaluated and a dedicated modular front-end was developed. By using a high speed analog front-end, a system on chip, and multiplexed drive circuits, minimal settling and measurement times were achieved.

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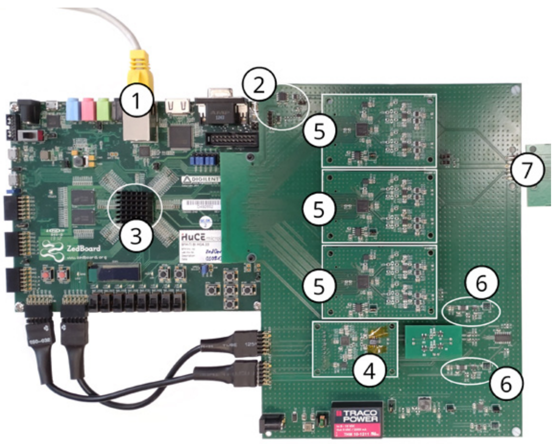
Motivation

The continued miniaturization of transducers, in combination with advancements in flexible printed circuit board technologies, has enabled the fabrication of smart catheters that integrate multiple sensing modalities on a single device. As a result, it is now possible to simultaneously acquire bio-signals from several vital organs, locations, and modalities at a suitable orifice (such as the esophagus). To facilitate multi-modal signal acquisition, the Institute for Human Centered Engineering (HuCE) is seeking a versatile interface that can acquire bio-signals with a novel, flexible, liquid-crystal polymer (LCP)-based catheter integrating multiple multiplexed sensors (e.g., electrodes for bio-potential/impedance, pressure, oximeter and temperature sensors).

Goal

The focus of this thesis is the development of a dedicated front-end design for the acquisition of high-resolution, time-multiplexed, multimodal biosignals with a single system. By supporting a wide range of modalities and short switching and measurement times, quasi-simultaneous data should be available. A modular design should allow for easy modification and expansion.



Overview: 1) TCP/IP 2) Node selection and detection unit 3) Zynq SoC 4) DDS 5) Analog Frontend 6) DAC 7) Catheter

Results

A common analog interface optimized for multiple sensor types has been developed. By using a System on Chip (SoC), multiple channels can be measured simultaneously. Parallel pipelined filtering allows simultaneous use of averaging and lock-in amplifiers that include a signal decimation stage. This allows low-frequency and high-frequency signals to be separated in the same measurement. A dedicated digital processing path records the raw data and the corresponding filter position, allowing timing optimization. A multiplexer, combined with a direct digital synthesizer (DDS) and two digital-to-analog converters (DAC), allows multiple sensing modalities to be driven with minimal setup time.
High-speed, pipelined analog-to-digital converters (ADCs) reduce measurement time and enable high-frequency excitation signal acquisition. 16-bit resolution allows low gain operation for reduced settling time and noise. Settling times of less than 1 us maximize usable measurement time. By selecting a pin-compatible family, the sampling rate can be increased from 25 MSPS to 125 MSPS, allowing higher frequency measurements such as ultrasound.
With 10 sensor nodes, a maximum sampling rate of 650 Hz with catheter response time and 2 kHz without can be achieved.
A TCP/IP server allows data and configuration exchange. It is also possible to measure raw data without any digital processing.

Outlook

By sharing resources such as dividers and magnitude calculations between processing pipelines, logic cell and DSP usage can be further reduced and silicon efficiency improved.
This, combined with a reduction in the number of lanes used in the LVDS interface, would allow an increase in the number of parallel sensor acquisitions possible.