A flexible FPGA SoC based multi-frequency EIT Hardware Platform

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Abstract— **Electrical Impedance Tomography (EIT) is a functional real-time imaging modality based on measurement and reconstruction of spatial impedance distributions inside an object under test. The measurements are based on the injection of small well known alternating currents (AC) and the measurement of the developing voltages on the objects surface. The known currents and the measured voltages are used to calculate transfer impedances which are used as input data for the subsequent image reconstruction [1-3].**

This work describes a flexible Field Programmable Gate Array (FPGA) System on Chip (SoC) based multi-frequency EIT hardware platform. The developed system is intended to be used as flexible research platform for different EIT applications. For first evaluations of the platform three different applications have been selected: real-time monitoring of Irreversible Electroporation (IRE), intracranial EIT and micro EIT.

IRE is a permanent permeability change of the cell plasma-membrane due to an applied electric field. This effect is e. g. used for ablations during operations. Currently there is no real-time feedback available for IRE. The goal of this tryout is to visualize the effects of IRE in real-time with EIT. The idea of using EIT in intracranial applications is based on the wish to acquire more information about the electrical behavior of brain matter. The measurements should be carried out by implanting micro-electrodes in or onto the brain. This will allow collecting more information of brain behavior and build-up and therefore leading to the development of better diagnostic and treatment methods. For the third application a micro-electrode vessel has been manufactured, to measure the spatial impedance distributions of the containments of that vessel in real-time. This measurement setup will allow measuring e. g. diffusion processes, but can also be used for material analysis [2].

The developed hardware platform contains 16 voltage and 16 current channels, but it can be cascaded to increase the number of channels. To keep the structure simple just one voltmeter and one current source are implemented. Subsequent multiplexers (LTC1391CGN from Linear Technology) allow multiplexing of the voltmeter and the current source to the different channels. To keep multiplexer capacitances low the implemented multiplexing strategy allows only the multiplexing between an odd-even electrode-combination. The voltage channels are decoupled by buffer circuits to maintain low input capacitances and therefore high input impedances. The current source is built as a Voltage Controlled Current Source (VCCS), based on an AD8130 from Analog Devices. It maintains high output impedance over a broad frequency range of 10 kHz to 250 kHz and allows arbitrary output current waveforms. The input voltage of the VCCS is generated with a FPGA using Direct Digital Synthesis (DDS) in combination with a Digital to Analog Converter (DAC, LTC1668 from Linear Technology) with up to 50 Mega Samples Per Second (MSPS) and a resolution of 16 bit. The voltmeter is implemented with a Programmable Gain Instrumentation Amplifier (PGA, AD8250 from Analog Devices) in combination with an Analog to Digital Converter (ADC, LTC2296 from Linear Technology). The ADC allows sampling rates up to 25 MSPS and has a resolution of 14 bit. After the data has been acquired and was preprocessed by the FPGA, it is transmitted via a USB 2.0 Interface to a host computer for subsequent image reconstruction. The USB link is bidirectional and allows a throughput up to 40 MB/s; additionally the configuration of the embedded hardware is also possible via that link. The actual image reconstruction is done with Mathworks Matlab in combination with EIDORS [3] on the host computer.

Keywords—**Field-Programmable-Gate-Array (FPGA), System on Chip (SoC), Direct Digital Synthesis (DDS)**

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