Large Channel Count Arbitrary Waveform Generator (AWG) With Electrical Impedance Tomography (EIT)

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Abstract

• I2Sense Laboratory requires an arbitrary waveform generator (AWG) with many channels for driving test equipment.
• There are few solutions on the market for such devices, since they typically have higher signal quality and integrity requirements. Such devices may cost multiple thousand dollars.
• Electrical Impedance Tomography (EIT) is an emerging field of medical imaging techniques that use injected current instead of ionizing radiation or magnetic fields, like X-ray or MRI technologies, respectively.
• The small size, safety, and cost-effectiveness of EIT makes it an attractive solution for certain applications, such as monitoring lung function, imaging the brain, and early detection of breast cancer without performing a traditional mammogram.

Introduction

• Basic arbitrary waveform generators can generate simple waveforms, such as sine, sawtooth, and square waves.
• Electrical impedance tomography is generally performed by injecting sinusoidal current into a test environment.
• These goals are quite complimentary, so we can create a device that does both for a relatively low price compared to existing solutions on the market. (Hundreds instead of thousands of $)
• The solution is a fully open-source device using readily-available parts.
• The design is adaptable for use as a standalone AWG or EIT device and can also be expanded in the future for use for experimental EIT techniques, like 3D EIT Reconstruction.

Printed Circuit Board (PCB)

• The printed circuit board (PCB) houses the essential circuitry and components that perform the signal generation, capture, communication with the host.
• The board is controlled by the Raspberry Pi RP2040 microprocessor, which handles communication. It runs CircuitPython, a lightweight and easy-to-use version of Python that is designed for embedded applications.

PCB Statistics:
• 4 Layers
• 370 Parts
• 606 Vias
• 1356 Pads

Signal Capture and Filtering

• The accuracy of the tomographic map hinges on the quality of the captured signal, so the quality of the measurement circuit is paramount.
• The incoming signal is amplified, filtered, then processed by a lock-in amplifier. This kind of amplifier is commonly used in biomedical applications for its ability to filter a signal from strong wide-band noise.
• The processed signal is filtered again, and then digitized using an ADC.

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Arbitrary Waveform Generation (AWG)

The market for direct digital synthesis (DDS) generation chips is mainly dominated by Analog Devices. We have chosen the Analog Devices AD9106 for its large number of channels.
• Such devices require a certain amount of supporting devices, such as clock buffers for clean inputs and amplifiers to boost the output of the DDS.
• Since this chip has four channels, and the requirement is to have 16 channels, we need to have four AD9106 chips, and eight two-channel amplifiers.

Electrical Impedance Tomography (EIT)

EIT relies on sending a current between two electrodes and measuring the voltage between the other electrodes. Using a forward or reverse solver, a 2D tomographic map of impedances can be generated and displayed.
• A tri-amplifier Howland current source is used to generate the sinusoidal current from a voltage generated by the DDS.
• We are using the open-source library pyEIT to perform the EIT calculations, as it supports a variety of different EIT models.

Client Graphical User Interface (GUI)

The user communicates and interacts with the board using a graphical user interface (GUI) running on a host computer.
• Communication between the board and the host is done using a simple serial interface, that will work on any modern computer.
• This offloads the burden of calculating EIT meshes to the computer, allowing a close-to-real-time tomographic map.