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

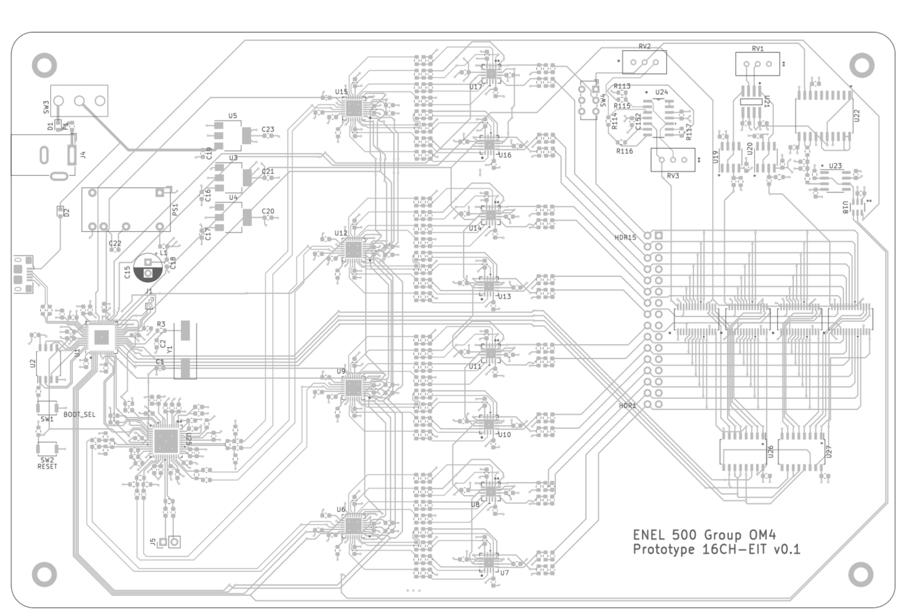
- Basic arbitrary waveform generators can generate simple waveforms, such as **sine, sawtooth, and square** waves.
- Electrical impedance tomography is generally performed by injecting sinusoidal current into a test environment.
- These goals are quite complimentary, so we can create a device that does 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.

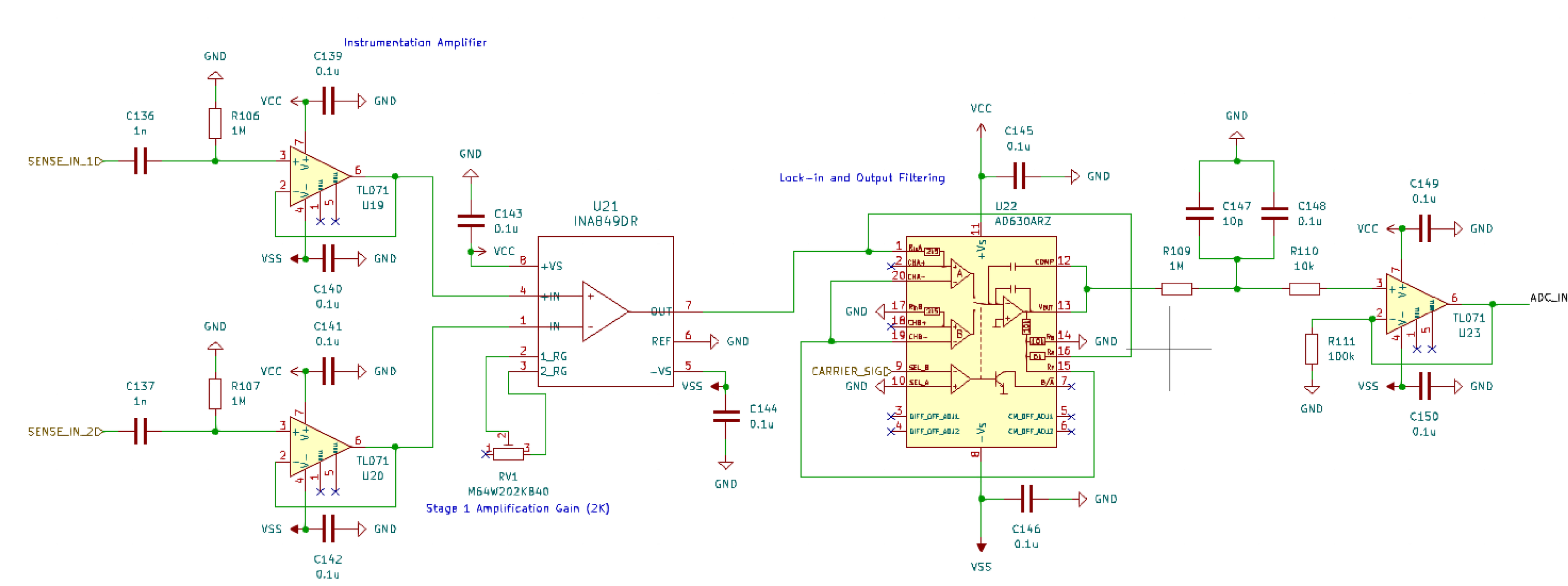
PCB Statistics:

- 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**.



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)

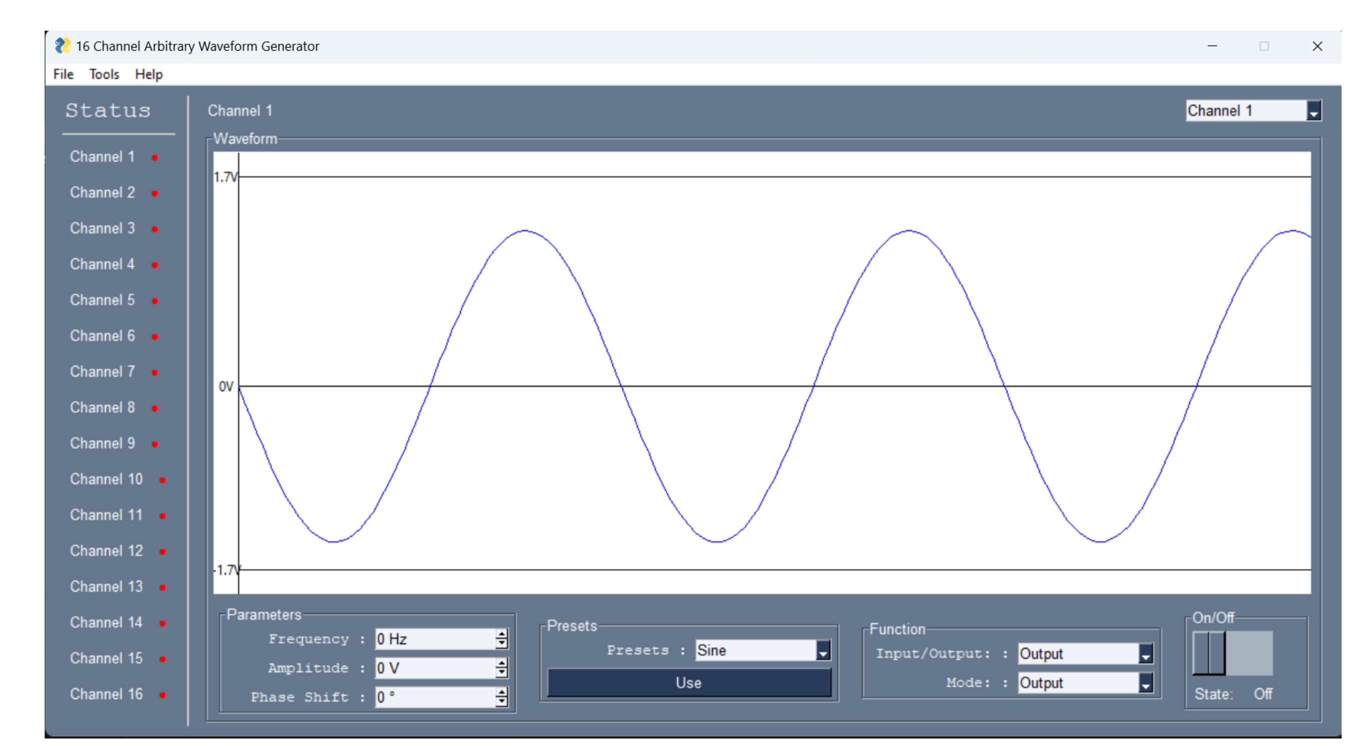
EIT relies on sending a current between two electrodes and measuring the voltage between the other electrodes. Using a forward or reverse solver**, a 2D tomographic map of impedances** can be generated and displayed.

- **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.



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