



# Development A Low-Cost Electrical Impedance Tomography System For Non-Invasively Detecting Abnormal In Breast Tissue - Phantom Study

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## Abstract

Electrical Impedance Tomography (EIT) is known as non-invasive method to detect and classify the abnormal breast tissues. Reimaging conductivity distribution within an area of the subject reveal abnormal tissues inside that area. In this work, we have created a very low-cost system with a simple 16-electrode phantom for doing research purposes. The EIT data were measured and reconstructed with EIDORS software.

## 1 Introduction

Electrical Impedance Tomography (EIT) has become a new potential method for detection and monitoring breast abnormal tissues [1][8]. The conductivity difference between typical tissues and abnormal ones plays a vital role in this method. The significant advantages of this method are non-invasive, no ionizing radiation and relatively cheaper than recently method such as mammogram,

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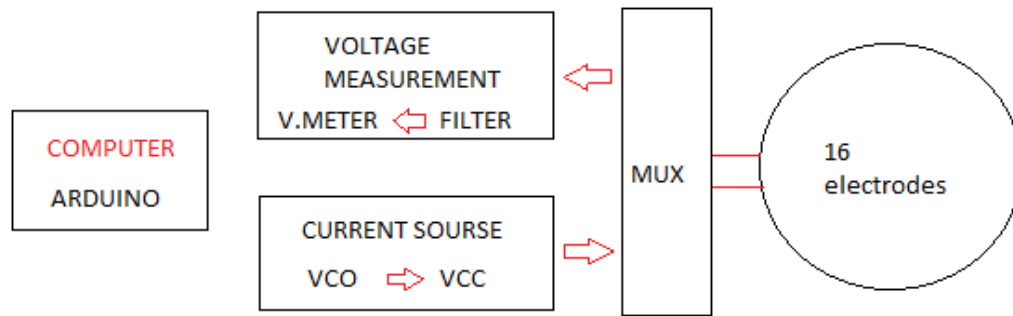
magnetic resonance imaging (MRI), ultrasound [2][2] [5], [8]. The generated voltages distribution will be measured around the boundaries of interest area and the data supports to reconstruct conductivity distribution images. The electrical properties of biological tissues are dependent on the capacitive and resistive properties that contribute to impedance measurements. Significantly, the impedance of abnormal breast cells are comparatively different than normal ones [7]. Therefore, EIT is an ideal technique for early detecting breast cancer [6].

Breast cancer is the most popular cancer among women and nearly 270,000 new cases were diagnosed in 2019. More than 3.8 million US women with a history of breast cancer were alive on January 1, 2019. Some of these women were cancer-free, while others still had evidence of cancer and may have been undergoing treatment. More than 150,000 breast cancer survivors are living with metastatic disease, three-fourths of whom were originally diagnosed with stage I-III. Approximately 1 in 8 women (13%) will be diagnosed with invasive breast cancer in their lifetime and 1 in 39 women (3%) will die from breast cancer[3].

Nevertheless, the application of EIT in breast abnormal tissues monitoring still has drawbacks and limited due to barely researches. Thus, this work creates a simple and relatively low-cost concept for further investigation.

## 2 Materials and Methods

EIT phantom model consist of a current source, multiplexer module, voltage measurement and a control unit.



**Figure 1:** Basic simple EIT Phantom System

### 2.1 Current Source

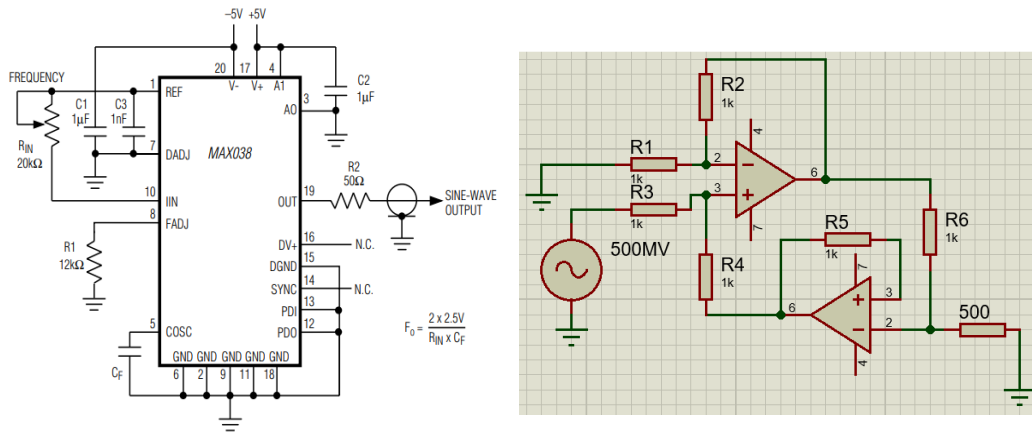
A typical current source has two main parts: a Voltage-Controlled Oscillator (VCO) and a Voltage-to-Current converter (VCC) part [9]. The VCO part generally create a precise sinusoidal waveform which is popular in the most experiences. The wave form must have low output impedance, wide

bandwidth and gradual amplitude among the frequency range. We use the IC MAX038 to meet all strictly demand and the price is also reasonable [10]. Additionally, the fine VCC part, which is based on Howland, support to deliver 9 mA current over a wide range between 50Hz to 100MHz.

### 2.1.1. Voltage-Controlled Oscillator

The schematic circuit is demonstrated in the Fig. 1. It is evident that IC MAX038 has been utilized in waveform generator part. The price of this IC is around 1 – 3 dollars each which is relatively cheap. The signal frequency can easily adjust by changing the value of capacitance ( $C_F$ ) and resistance ( $R_{in}$ ) as showed in Fig. 2.

$$F_0 = \frac{2 \times 2.5V}{R_{in} \cdot C_F}$$



**Figure 2:** Waveform Generator & Voltage-To-Current Converter Diagram

### 2.1.2. Voltage-to-Current Converter

A sinusoidal voltage signal of high bandwidth (50Hz to 10MHz) at the VCO output is fed to VCC (Fig. 2) which is basically a modified Howland Current Pump. VCC is made with two Op-Amp AD811 which is high speed Op-Amp and having wide bandwidth [12]. VCC has capability of injecting 9 mA current to Phantom with maximum load of 3.2kΩ.

## 2.2 Multiplexer Module (MUX)

A high-speed multiplexer with 16 output which are connected to the phantom electrodes can be added to the instrumentation design. 74HC4067, 16 channels analog multiplexer/demultiplexer is used as MUX in our design (Fig. 3) [11]. For 16 electrodes phantom system, 4 ICs will be needed. Two of them are applied for injecting the current and the two others are used for voltage measuring between the rest pairs of adjacent electrodes. The digital bits demand to control each MUX to switch the current source and the voltage measurement are working by Arduino microcontroller [13]. Every multiplexer requires four digital bits. In this work, 16-bit digital data are operated using Arduino 2560 and a coding program is written to convert it to 16-bit digital data required for automatic switching of VCC and voltage measurement. The circuit of MUX module is showed in Fig. 3

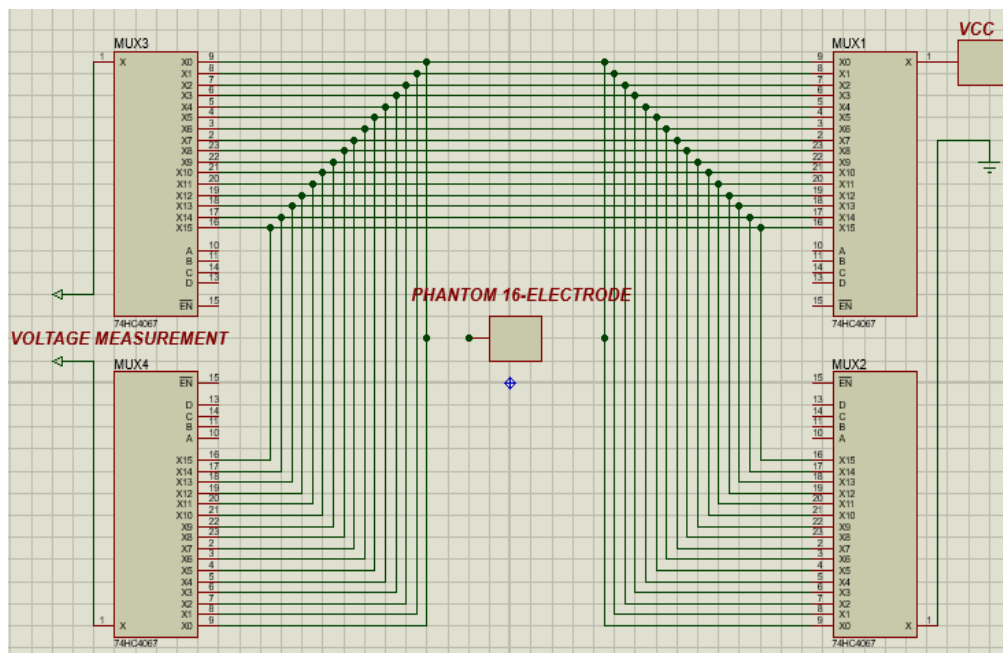


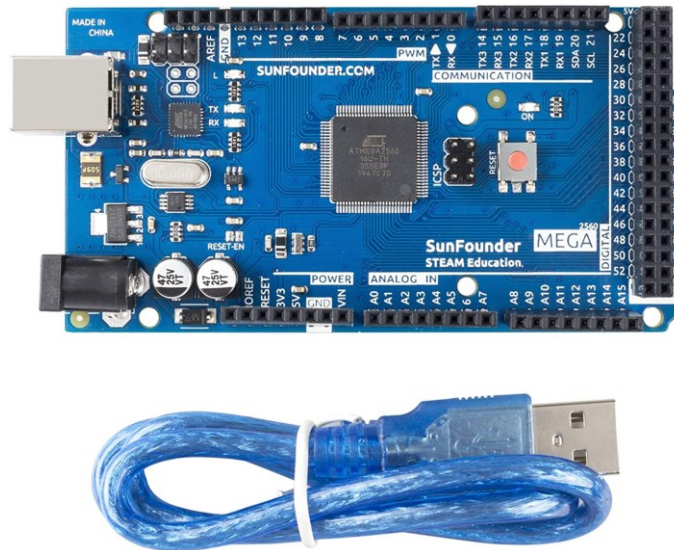
Figure 3: Multiplexer Module

## 2.3 Voltage Measurement

In EIT system, a sinusoidal signal of constant amplitude is injected to one pair of electrodes at the boundary of the phantom, then the boundary potentials are measured. Before measuring, the signal will have to go through an instrumentation amplifier and three filter: 50Hz notch filter, low pass filter and high pass filter in order to get rid of noise. Then the 16:1 Mux which have responsibility for voltage measuring will connect directly to Arduino and boundary potentials are collected, then being converted to Excel data for image reconstruction.

## 2.4 Control Unit

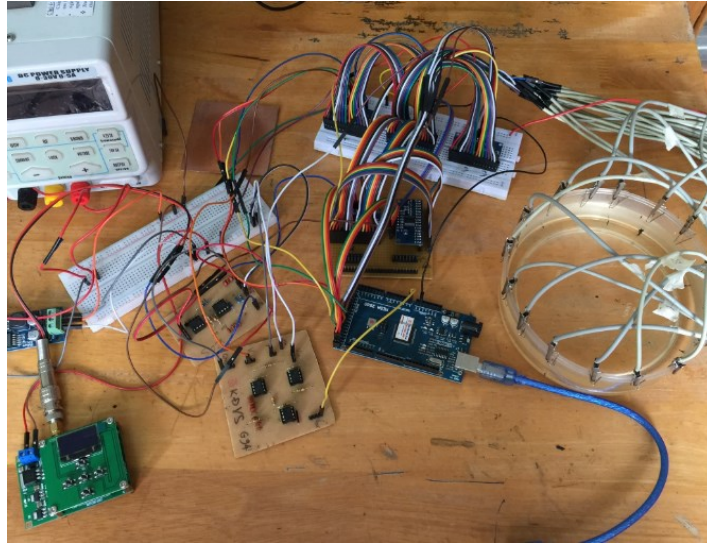
Arduino Atmega-2560 is a microcontroller board based on the Atmega2560 (ATMega2560, n.d.). It has digital pins which control MUX module and Analog pins for voltage measurements.



**Figure 4:** Arduino ATMEGA 2560

## 2.5 Phantom

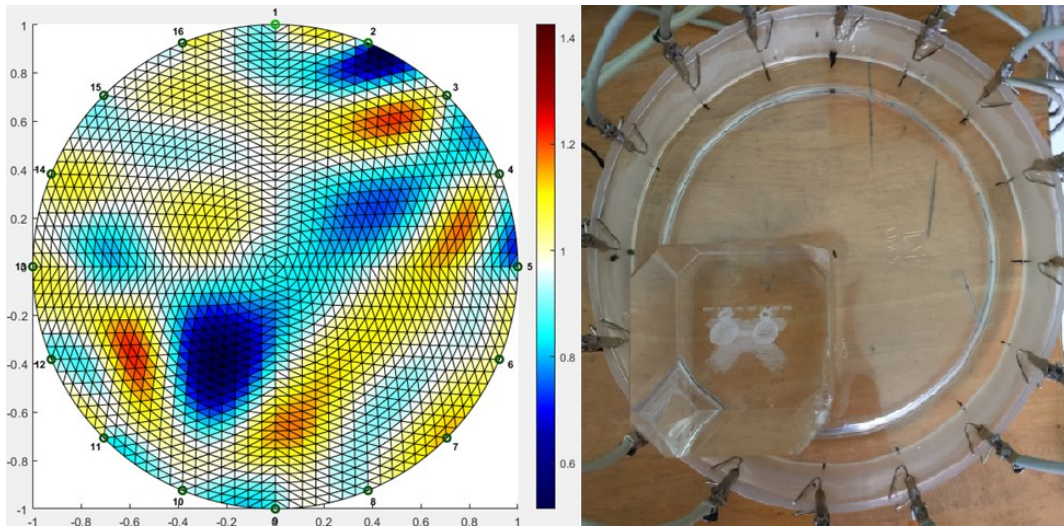
The practical phantom is a shallow glass tank (150 mm diameter) and sixteen stain steel electrodes equally spaced on the inner wall (Fig. 3). Electrodes are rectangular shaped and cut from 1mm thick high-quality stain steel sheet (style 304). All the electrodes are fixed with paper clip, which is easy for changing and moving. The EIT electrodes are connected to system through standard ECG wires with steel crocodile clips (Fig. 3). The phantom is filled with a NaCl solution. A plastic rectangular block is used to represent as abnormal area in human breast.



**Figure 5:** Assembled EIT hardware

### 3 Reconstruction

Potentials are collected with different frequency from 50Hz to 100MHz then the resistivity images are reconstructed with EIDORS software. EIDORS is Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software. It bases on MATLAB and provides algorithms for forward and inverse modelling for EIT. The inner area (diameter 150 mm) are discretized with a triangular element mesh using finite element method (FEM) [1],[2].



**Figure 6.** Reconstructed images by using EIT phantom at 1 MHz with plastic rectangular block near 11<sup>th</sup> electrode

## 4 Conclusion

In general, the final results of this simple phantom system are relatively acceptable with some advantages such as low cost and fast measurement timing (less than 5 minutes). The system also addresses noise issue by adding some filters. EIT technique, which reconstruct conductivity distribution images, is promising in biomedical area. Breast cancer is an area that EIT is potential in taking the place of recent method. Nevertheless, the spatial quality of the images still being a concern of EIT and need further investigation.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Acknowledgment

This research is funded by Ho Chi Minh City University of Technology (HCMUT) - VNUHCM under grant number SVOISP-2021-KHUD-86. We acknowledge the support of time and facilities from Ho Chi Minh City University of Technology (HCMUT) - VNUHCM for this study.

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