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Simulation of System for Impedance Measurement in a Circular Phantom using EIT Method

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Abstract: ***The most common cancer that is found in women is Breast cancer. We can avoid risk of breast cancer by detecting it at an early stage. There are many techniques to detect and diagnose breast cancer such as Mammography, Ultrasound, Thermography, MRI (Magnetic Resonance Imaging), EIT (Electrical Impedance Tomography). We can improve survival rate by early detection of breast cancer. Mammography is the basic method of diagnosing breast cancer; but Infrared Breast thermography technique provides information based on the temperature changes in breast. Also, due to the low quality of ultrasound images and the complex breast structure, ultrasound image segmentation is a challenging task. The basic imaging technique for the detection and localization of breast tumours are mammography and ultrasound. Electrical Impedance Tomography is a new and improved method which is an imaging modality that can be used for image conductive subjects. An EIT system uses an array of surface electrode which applies current to an imaging object & resulting voltages are measured on the periphery. The measurement results are given as an input to a reconstruction algorithm to produce an image of impedance distribution of the object. This methodology is simple to prepare and use, low cost is another advantage. The Proteus 5.0 software is used for the implementation of whole circuitry.***

Keywords: (EIT) Electrical Impedance Tomography, Proteus 5.0, Resistors, Signal Generator, VOC, Multimeter, Digital Oscilloscope.

I. INTRODUCTION

There are two types of cancers: Benign Tumours and Malignant Tumours. Benign Tumours - these types of tumours are Non - Cancerous. It can be removed and not come back in most of the cases. It is seen that it does not spread to other parts of the body and does not invade other tissues. Malignant Tumours - These types of tumours are Cancerous. This type of tumours can invade and damage nearby tissues and organs. The cancerous cell can break away from malignant tumours and enter the bloodstream or lymphatic system to form secondary tumours in other parts of the body. An unwanted lump or mass is the most common symptom of breast cancer. A mass which is painless, hard in shape and has irregular edges is more likely to be cancer, but tender, soft, or rounded mass also can be a breast cancer. They can even be painful. For all these reasons, it is important that we should notice any new breast mass, lump, or breast change and if it is so then, it is necessary that we should take advice from a doctor. Even without having any risk factors some women will get breast cancer. Having a risk factor does not mean we will get the disease and not all risk factors have the same effect. Even though more women have some risk factors, all of them do not get breast cancer. So, detecting breast cancer at an early stage is the best way to avoid risk of cancer. By using (EIT) Electrical Impedance Tomography we can detect and diagnose cancer at an early stage.

EIT (Electrical Impedance Tomography) is a Non-Invasive medical imaging technique in which we are applying current to the surface of the body through contact electrodes and resulting surface voltages are used in reconstruction of image. EIT is the best alternative to all other previously used methods because it is cost effective, affordable to the common man, easy, portable, no special attention required there is no change in surface temperature and any harmful radiations as all the previous techniques have [5]. We have implemented this method by using Proteus 5.0 Software and Voltage measurement has been taken.

II. MOTIVATION

In terms of cancer mortality among the women population, breast cancer is the most common one. Early detection of breast malignant tumour plays a crucial role in the survival rate. In 2016, it was expected 57,960 new cases in Brazil, corresponding to a risk of 56.20 per 100,000 women. The American Cancer Society's estimates that in 2013-2014 from 296,980 new cases of female breast cancer, 39,620 were fatal. European studies show a 38 to 48 reduction in mortality for women screened, with sufficient follow up time, in mammographic population based programs. 21.3% of breast cancer mortality reduction was registered from 1975 to 2000 in the United States [2]. Part of that reduction was to the combination of screening and adjuvant therapy. This data justifies seeking for efficient detection methods, with high sensitivity and specificity in order to prevent false positives. 10% of screening mammograms give false-positives, leading to unnecessary biopsies, traumatizing the patient physically and mentally.

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Early diagnosis is vital for successful treatment of the disease and decreasing breast cancer mortality rate. The most common methods for detecting the breast diseases are Mammography, Doppler Ultrasonography, Magnetic Resonance Imaging (MRI), Computed Tomography Laser Mammography (CTLM), Positron Emission Mammography (PEM) etc. Mammography is imaging modality the most widely used for breast cancer screening. However, mammography leads to unnecessary biopsies due to the low specificity, and the ionizing radiation of this imaging modality increases the health risks for the patients and physicians. Thus Due to the advantages of low-cost, portability, non-invasiveness, and real-time imaging capability, EIT has become an important complementary to all other previous techniques for breast cancer screening.

III. SYSTEM BLOCK DIAGRAM

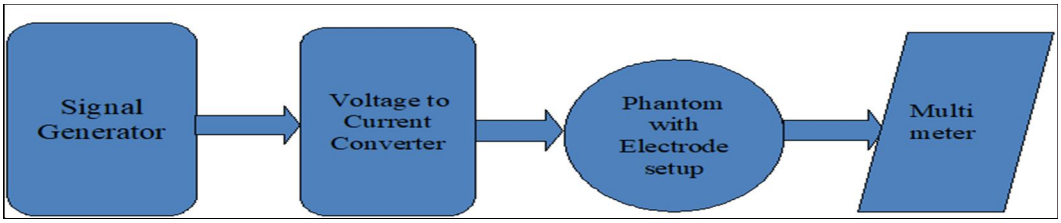

Fig1.System block diagram

System Flow

1) Both blocks such as signal generator and voltage to current converter, apply alternate constant current to a pair of electrodes at constant frequency.
2) Array of sixteen electrodes arranged on inner surface of phantom with normal saline as a phantom solution
3) Multimeter can be for measurement of voltage in between consecutive pairs of electrodes.
4) An image reconstruction algorithm can be further used for reconstruction of images based on voltage datasets.

IV. DESIGN OF EIT SYSTEM

A. *Simulating Methods and Voltage Measurements*

For reconstruction of the conductivity and permittivity within an object based on the conditions of voltage and current on the surface of the object, an Electrical impedance tomography method is used. To find out the conditions of the current and voltage on the surface, current can be injected through electrodes set in contact with the surface and developed voltages can be measured. There are many ways in the current- injecting electrodes, voltage measuring electrodes and current patterns. This section describes various methods by which the current is injected and the voltages are measured. *Various Current Injecting Methods*: There are different injecting techniques for current injection; Adjacent Current Drive, Opposite Method, Trigonometric Method, Cross Method.

1) *Adjacent Current Drive:* The adjacent drive method also called the neighbouring method, is the most common current driven pattern. In this method, the current is applied through adjacent electrodes and sequentially the voltage is measured from all adjacent pairs of electrodes without the pairs containing a single or both the current electrodes. For a 16-electrode EIT system with a circular phantom structure which is surrounded by 16 surface electrodes named as the electrode - 1 to electrode-16. In this method P1 is the first current projection. Here, current is injected through electrode - 1 and electrode - 2 and the voltage differences (V1,V2,V3,V4,V5 . . ., V13) are measured in a sequential manner. For second current projection (P2), through electrodes-2 and electrodes-3 current is injected and the voltage differences (V1, V2, V3,... V13) are measured in sequential manner with 13 electrode pairs 4 to 5, 5 to 6, … and 16 to 1. We are not measuring Voltage between pairs (1 to 2), (2 to 3), or (3to4). Therefore, this current projection (P2) gives us thirteen differential voltage readings. This process can be repeated until current injection has been done between all 16 adjacent pairs of electrodes. This is called a frame of data which will produce 16 X 13 = 208 measurements. The adjacent method provides N2 measurements, where N is the number of electrodes .The voltage is not measured at a current injecting electrode to avoid the problem of unknown contact impedance.so the number of total measurements is reduced to N(N −3). According to four-electrode reciprocity theorem the mutual impedance is preserved under an interchange of injection and measurement pairs for any measurement set. Hence, only N(N − 1)/2 of the measurements are independent. So, it is common to use all N (N − 3) measurements in most reconstruction algorithms. Thus total 208 measurements are produced by a 16 electrode system, out of which 104 are independent but all 208 measurements are used in the reconstruction algorithm.

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2) *Opposite Method:* The opposite or polar drive pattern , which is commonly used in brain EIT, applies current through electrodes that are 180° apart while voltage differences are measured on the remaining electrodes. Therefore, this method is also known as the Opposite Method. Voltage differences are measured on the voltage electrodes with respect to the electrode (Known as the voltage reference electrode) adjacent to the current-injecting electrode. For the first current projection (P1) of the opposite method, through electrode-1 current is injected and electrode-9, and the differential voltages (V1, V2, V3, V13) are measured sequentially from 13 electrode pairs 2 to 3, 2 to 4, . . . and 2 to 16 considering the electrode-2 as the reference. Therefore, projection P1 gives a total thirteen differential voltage readings. The second current projection-2 that is (P2), the current is injected through electrodes-2 and electrode-10 and the differential voltages (V1,V2,V3,V5,V6,V7,..., V13) are sequentially measured from the thirteen electrode pairs 3 to 4, 3 to 5,... and 3 to 6, considering electrode-3 as the voltage reference electrode. Hence, the second current projection that is P2 gives a total thirteen differential voltage readings. This process can be repeated until current injection has been done between all 16 electrode pairs. Therefore, in the opposite method, the EIT system yields a total of 16 X 13 = 208 voltage measurements. Thus, with sixteen electrodes the opposite method produces 16 X 13 =104 measurements out of which half measurements are independent. Thus, the opposite method has some disadvantages that are, for the same number of electrodes, available current injections that can be applied is less than for the adjacent method. This method gives a better distribution of the sensitivity; this is because of current travels with greater uniformity through the imaged body. Hence, as compared to the adjacent method, the opposite current injecting method is less sensitive to conductivity changes at the boundary.
3) *Trigonometric Method:* In all other methods, current has been injected with a pair of electrodes and the differential voltages have been measured between different pairs of electrodes without the current electrodes. This current injection method also called as adaptive method or trigonometric method. In this method current is injected through all electrodes and voltages are measured from all other electrodes. Many independent current injectors are needed because current flows through all electrodes at the same time. For 16electrode EIT system 16 current injectors are needed. The electrodes can be fed a current from -I to +I, which allows different current distributions. In a trigonometric method, the boundary potentials are measured with respect to a single grounded electrode. So, this method produces 15 voltage measurements for a 16-electrode EIT system. Other projections are obtained after the current projection is rotated one electrode increment. As a result, this current injection method produces eight different current projections yielding 8 X 15 = 120 independent voltage data [7]. The current drivers are needed for each electrode and the unknown contact impedance will have an effect on the reconstruction is noticeable disadvantage of this method.
4) *Cross Method:* The cross or diagonal drive pattern is rarely used. Adjacent electrodes are selected as current and voltage references for the cross method. In this method first current is injected between electrodes 16 and 2, while 13 measurements are taken using electrode-1 as the reference against the 13 electrodes. Hence the current is injected through electrode-16 and electrode-2 and the differential voltages (V1,V2,V3....V13) are measured sequentially with 13 electrode pairs 1 to 3, 1 to 4,...1 to 5 considering electrode-1 as the voltage reference. Hence, 13 differential voltage data is obtain from this cross method. Next 13 voltage measurements are taken using electrode-1 as the reference while current is applied to electrodes 16 and 4. This is repeated for currents injected between electrodes (16 to 4), (16 to 8), (16 to 10), (16 to 12), (16 to 14). The entire procedure yields 7 X 13 = 91 measurements [7].

B. Simulation on a Proteus 5.0 Software

1) *Proteus Software:* Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The Software is mainly used to create schematics and electronic prints for manufacturing printed circuit boards by Electronic design engineers and technicians. We have used Proteus 5.0 software for implementation of Whole circuitry of Electrical Impedance Tomography.
2) *Connections and Specification of Components:* We have simulated system block diagram on Proteus 5.0 software. Here, we have used a signal generator for injecting current, Op-amp (operation amplifier Ic-741) is used to amplify current, Ammeter to indicate current. Ammeter is used before an array of electrodes to know how much current we are applying to them. In Proteus software, we cannot make a circular phantom that is why we have used 12 resistors array as an electrode. By using 12 resistors, we have made a phantom like circuitry in which 12 resistors are connected along phantom. Digital Oscilloscopes are used for display purposes, as shown in (Fig2).

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Ic-741(Operational Amplifier) is total eight pin IC(Integrated – Circuit) and has pin configuration such as Pin No-1 and Pin No-5 are offset Null, Pin No-2 is Inverting pin and Pin No-3 is Non – Inverting pin, Pin No-4 and Pin No-7 are Power(-) and Power(+) pins and Pin No-8 is Not – Connected pin. Hence, for simulation circuit Pin No-3 is connected to positive terminal of signal generator and Pin No-2 is connected to ground as we are using Non – Inverting Op-amp IC, Pin No-7 and Pin No-4 are connected to positive five volt(+5V) and Negative five volt(-5V) Power Supply and Pin No-6 which is output pin of Op-amp IC is connected as input to ammeter to indicate how much amount of current we are applying to resistors array. After injecting current to resistors array set we will calculate voltage readings. We have used Digital Oscilloscope for display purpose. We have used Six – Channel Oscilloscope.

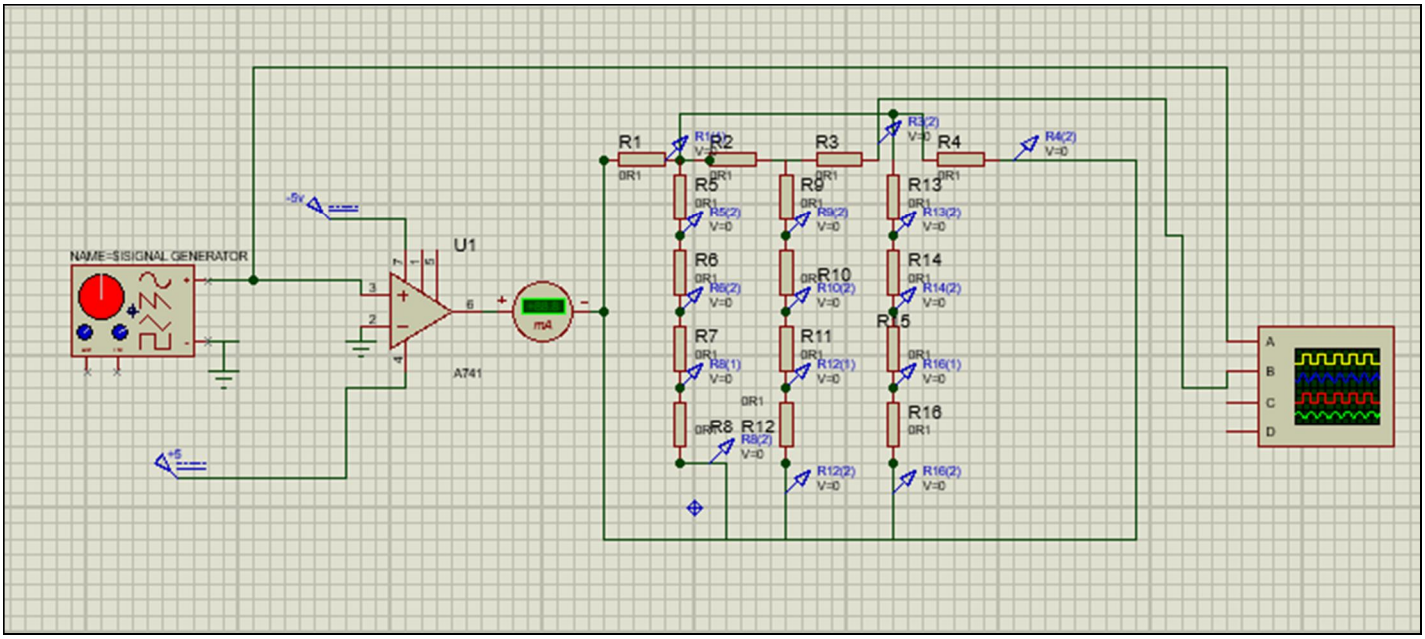

Fig2: Simulation of EIT System on Proteus Software

V. RESULTS

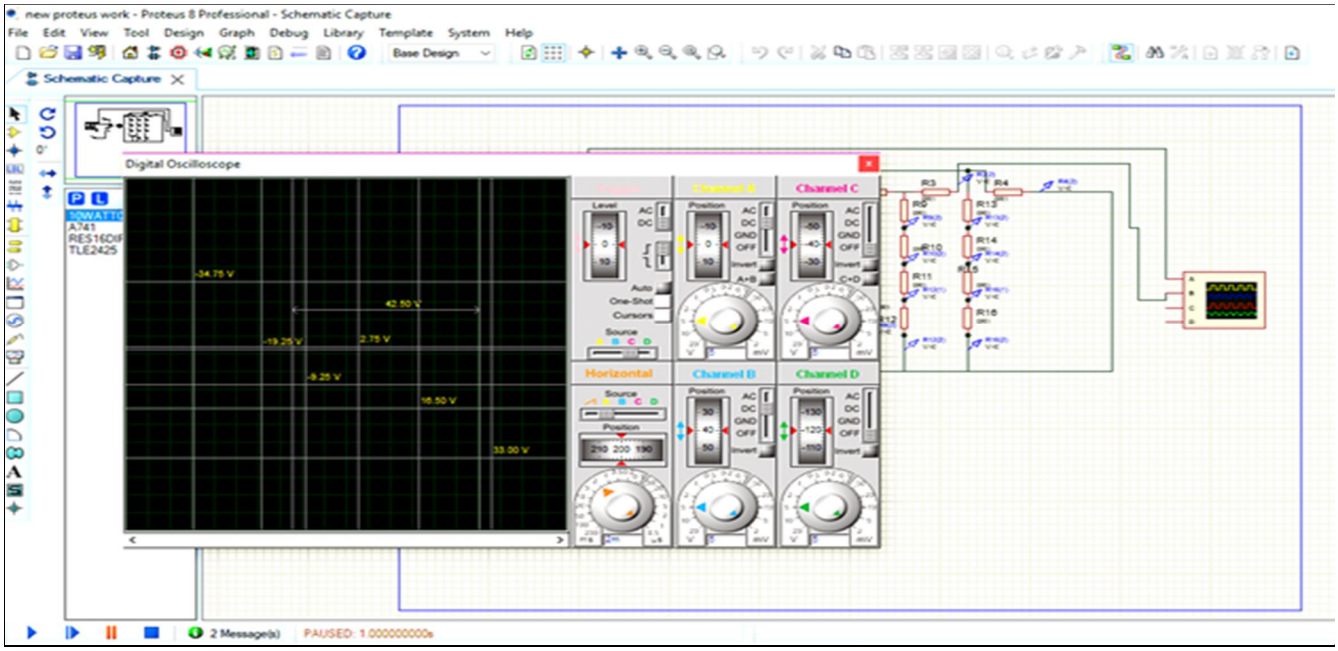

Fig3:Result-1 of Simulation

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After connecting components of circuitry. For simulation we can do following process Debug>> Run Simulation. By doing these we are getting this results. We have used six channel Oscilloscope in that channel C and D are OFF as they are not connected to circuitry.

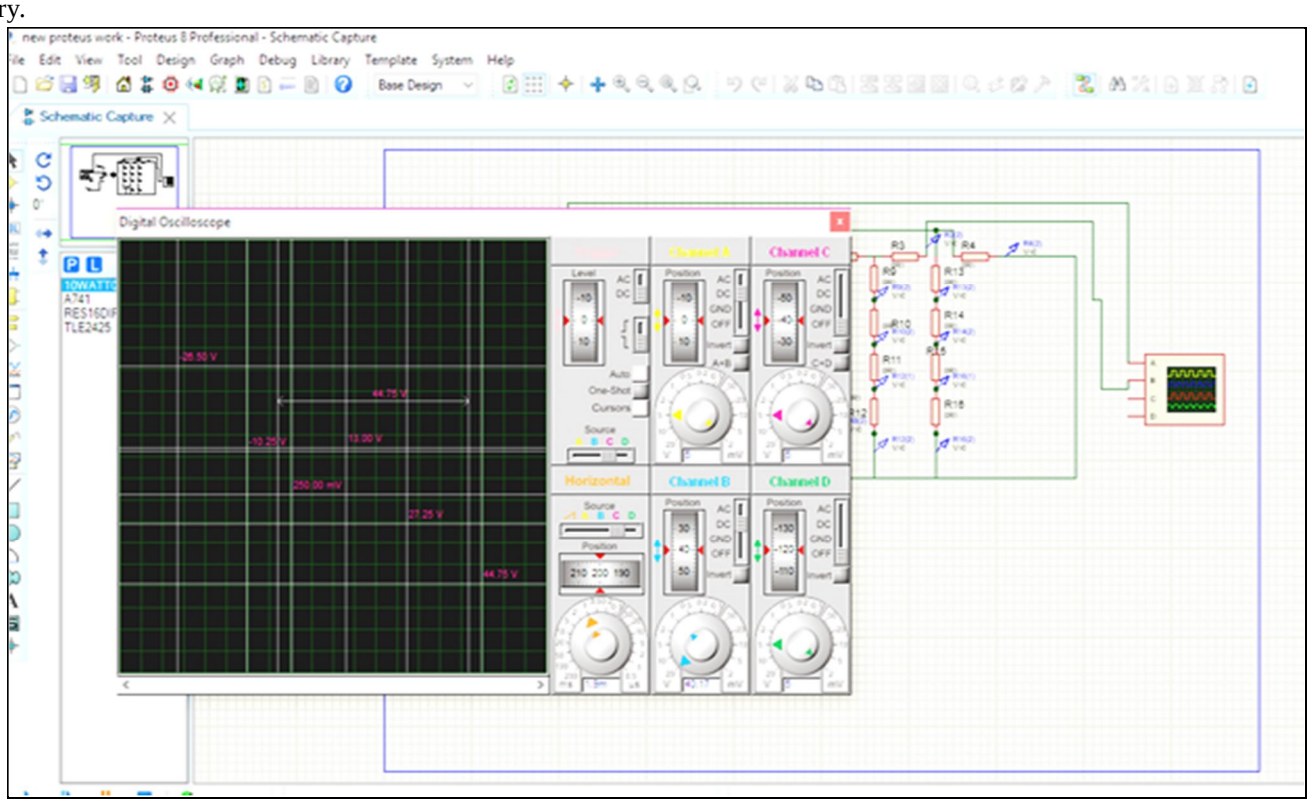

Fig4:Result-2 of Simulation

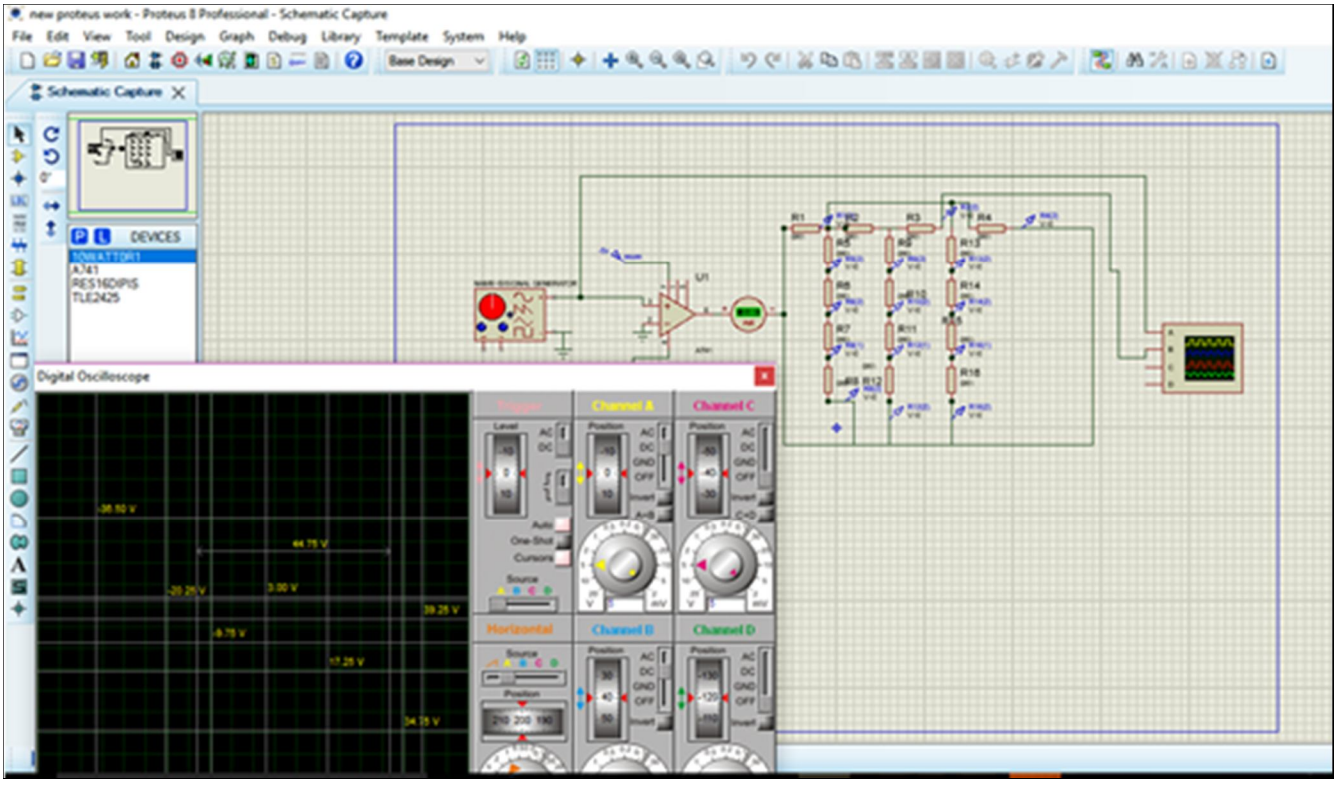

Fig5:Result-3 of Simulation

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This all are the outputs that we have obtained after simulating the circuitry of EIT on Proteus 5.0 Software. After injecting currents through contact electrodes to the surface of the body we can get voltage readings. All the figures (Fig3, Fig4 and Fig5) shows Simulation Results. In all figures, Voltage readings have displayed using Digital Oscilloscope.

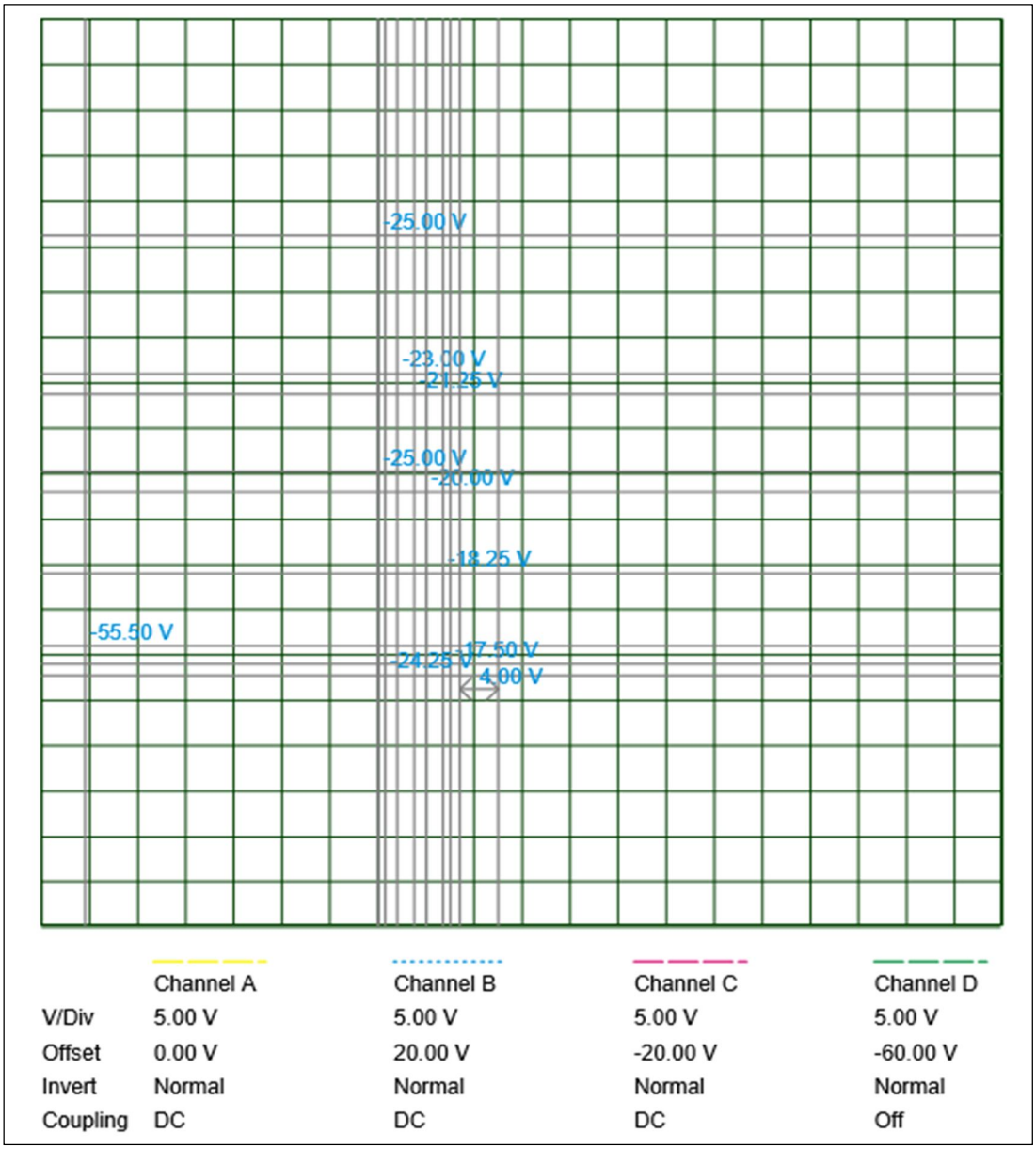

Fig6:Display of Result on Digital Oscilloscope

Fig6 Shows Voltage output on a Digital Oscilloscope, Here Specification of Digital Oscilloscope has specified.

VI. CONCLUSION AND FUTURE WORK

EIT is a Non Invasive medical imaging technique in which current is applied to the surface of the body through contact electrodes and resulting surface voltages are used in reconstruction of image. EIT is best alternative to all other previously used methods because of it is cost effective , affordable to common man, easy, portable, no any special attention is required, no harmful radiations, and there is no change in surface temperature. EIT based reconstruction imaging is an alternative to traditional imaging techniques useful for imaging breast and brain tumours at an early stage. The conductivity distribution depends on the material of electrodes, number of electrodes and the type of medium used in the experiment. We can use this voltage reading for future work such as Image Reconstruction.

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The images can be reconstructed from the boundary data collected from the phantom or object with different current patterns using Electrical Impedance. Different materials have different electrical properties. Due to these differences, the images for unhealthy tissue will be different from a healthy one. There are many different image reconstruction methods for EIT. In general, they can be mainly classified into two categories: a) Direct methods b) Iterative methods for two dimensional (2D). In this Image reconstruction mainly used criteria are A) Tikhonov Regularization and B) Hyperparameter.

VII. ACKNOWLEDGEMENT

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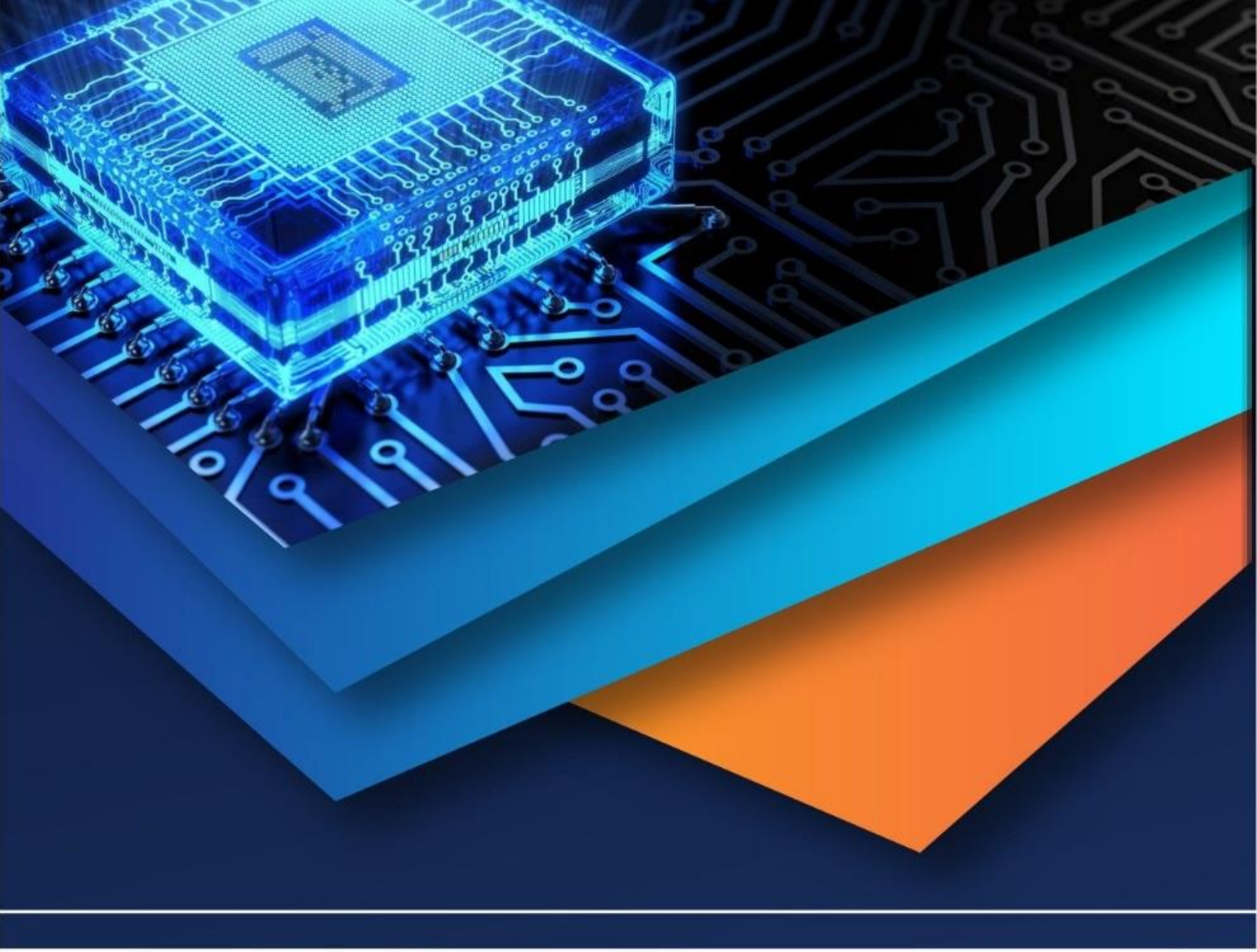

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