

DOI: 10.5604/01.3001.0010.4591

## MEASURING DATA ACQUISITION HARDWARE FOR ELECTRICAL IMPEDANCE TOMOGRAPHY

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**Abstract.** This article presents the design of the device with active electrodes to examine the flood embankment. There was discussed the method of determining the conductivity. The presented solution was based on electrical impedance tomography. There was described the concept of active electrodes and measuring equipment for data acquisition. Electrical impedance tomography, which is based on measuring potential difference, can be used to calculate conductivity. The problem depends on the fact that every material has unique conductance.

**Keywords:** Electrical Impedance Tomography, Active Electrodes, Flood Embankment

### SYSTEM AKWIZYCJI DANYCH W ELEKTRYCZNEJ TOMOGRAFII IMPEDANCYJNEJ

**Streszczenie.** W tym artykule przedstawiono konstrukcję urządzenia z aktywnymi elektrodami do badania stanu wału przeciwpowodziowego. Omówiono metodę wyznaczania konduktywności. Prezentowane rozwiązanie zostało oparte na elektrycznej tomografii impedancyjnej. Opiszono koncepcję aktywnych elektrod i sprzętu pomiarowego do akwizycji danych. Elektryczna tomografia impedancyjna, która jest oparta na pomiarze różnicy potencjałów może być użyta do pomiaru konduktywności. Sposób, w jaki może być zdefiniowany polega na tym, że każdy materiał ma unikalną przewodność.

**Słowa kluczowe:** elektryczna tomografia impedancyjna, aktywne elektrody, wał przeciwpowodziowy

### 1. System with Active Electrodes

Electrical impedance tomography (EIT) is known that the inverse problem is nonlinear and highly ill-posed [1,8-10]. The problem is the low level of measured values which should be measured quite accurately and in a very short time. EIT involves placing electrodes on the examined object. The two electrodes are connected to AC power and the voltage drop is measured on others [3, 7]. Then, power supply is connected to the next two electrodes, and measuring steps are repeated until each electrode is connected to power supply. Figures 1 and 2 present electrodes and model measurements of the flood embankments.

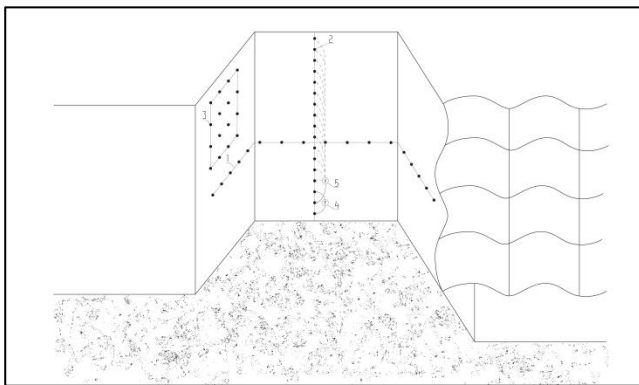


Fig. 1. The profile of the flood embankments

Figure 2 shows a plan view of an electrode with a straight front, with cross-section. Active electrode is designed to be placed in the ground, and its aim is to introduce current and measuring potential differences. The electrode consists of two parts: an active electrode and a quick rotating, which enables the galvanic connection of the active electrode portion of the electric wire. The active part of the electrode is made of rod 1, the tapered tip 2 and 3 lesions according to the drawing, which allow you to quickly pivot connection with the second part of the electrode. The electrode is located in the insulation 4. The second element electrodes - quick swivel consists of six parts: the cylindrical cap comprising a connector 7, the housing 8 of the spring 9, the tab 11, the locking ring spring 10, and connecting pins 12.

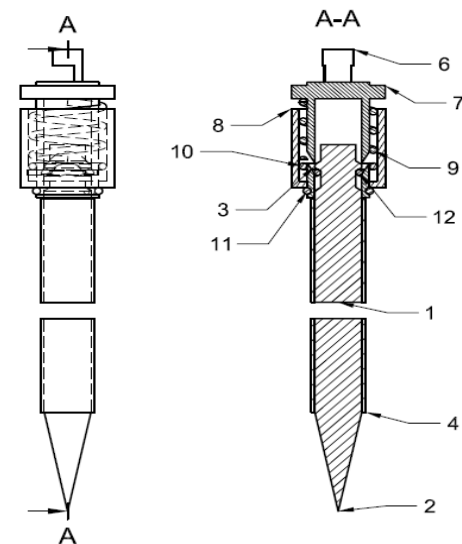


Fig. 2. The construction of active electrodes

### 2. EIT measurement device

The measurement in electrical impedance tomography involves placing electrodes on the examined object. This solution allows to obtain a conductivity distribution within the test object, and this consequently allows a distinction between materials of different conductivity. In carrying out further measurements over time and comparing them with previous we can observe the changes occurring in the study area [4]. Figure 3 presents the electrode arrangement for one projection angle [2, 5, 6].

The resolution of the image depends on the number of electrodes used and the accuracy of measured signals. To enhance the resolution, the number of electrodes should be increased. Then the number of necessary measurements will increase, which will result in greater demand for memory [11-14]. Figure 4 shows an exemplary result of the reconstruction of measurements on the circular container with 16 electrodes. The container was filled with water, in which was an empty glass bottle. Its position is marked with light green color.

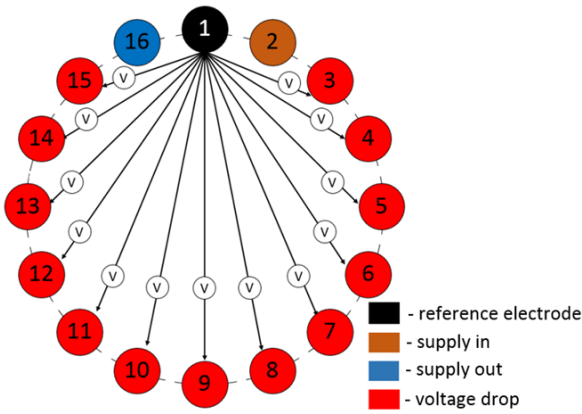


Fig. 3. Electrode arrangement for one projection angle

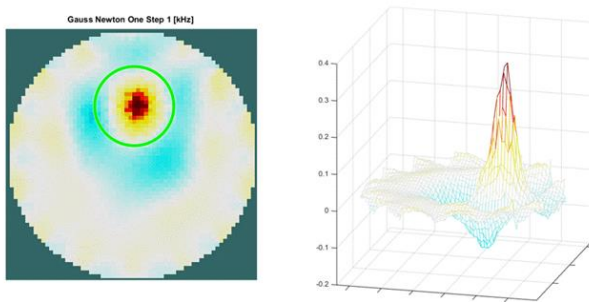


Fig. 4. An exemplary result of the reconstruction of measurements on the circular container with 16 electrodes

After achieving good with results, there was created a prototype of our device (Fig. 5). Its aim is to verify the repeatability of test results by eliminating laboratory equipment, and to validate the use of simple and cheap electronics the structure of the EIT.

The asset of such a device is to put the generator and the multiplexer on a small single circuit board, which allows mobility and enhances work comfort. Another advantage of this device is that the power supply voltage is 12V, and the maximum current is 60 mA, this reduces the energy requirements for carrying out image reconstruction of the test area.

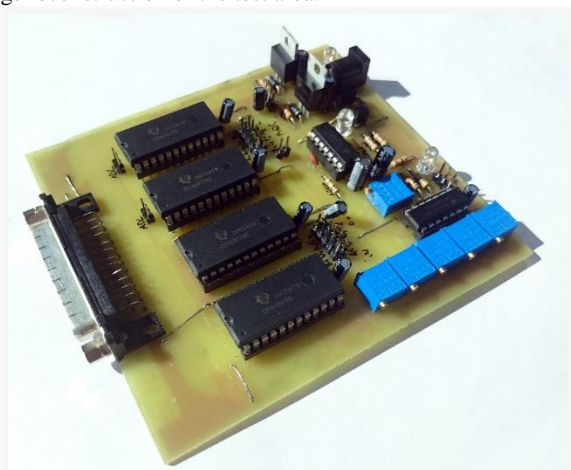


Fig. 5. The prototype of measuring device

The prototype device is controlled from a program written in LabView. The device allows for measurement of voltage drops for all angles of projection and save them to a file. The measuring device includes a program written in LabView environment, microcontroller evaluation board STM32 F4 Discovery, board with the generator and multiplexers. The general scheme of cooperation between all the components of the measurement system is shown in Figure 6.

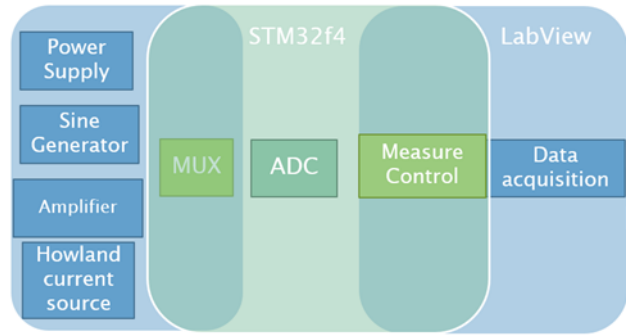


Fig. 6. Scheme of the block diagram operation of the measuring device

**Modules measuring system - components**

**A. Measuring module Smart EIT in SMD – block (Fig. 7):**

- 12V DC power supply,
- power supply LED,
- voltage regulator lm7805 and lm 7905,
- diodes,
- filtering capacitors.

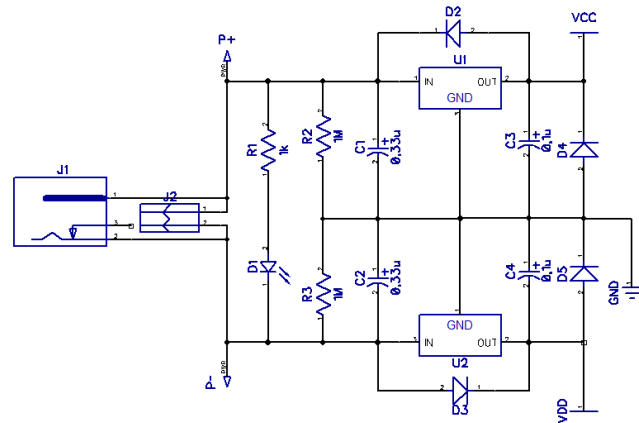


Fig. 7. Measuring module Smart EIT in SMD – power block

**B. Measuring module Smart EIT in SMD – generator (Fig. 8):**

- power control,
- two frequencies of 1 kHz and 50 kHz.

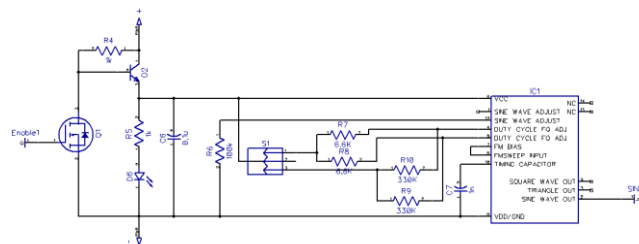


Fig. 8. Measuring module Smart EIT in SMD – generator

**C. Measuring module Smart EIT (Fig. 9):**

- DC signal filters,
- adjust the level of the control voltage,
- voltage follower,
- a Howland current pump.

**D. Measuring module Smart EIT in SMD – multiplexer (Fig. 10):**

- output to the electrode,
- 16-channel multiplexers,
- output connectors for ADC.

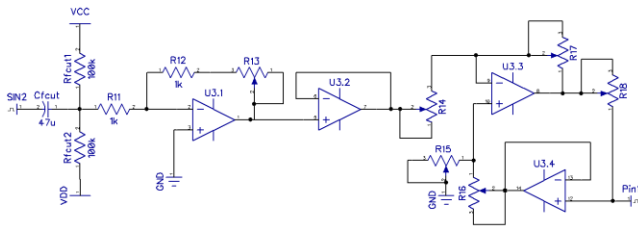


Fig. 9. Measuring module Smart EIT

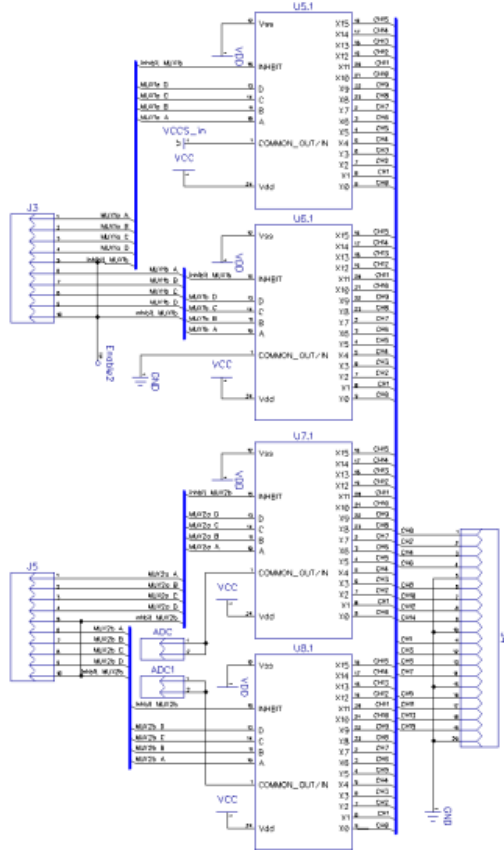


Fig. 10. Measuring module Smart EIT in SMD – multiplexer

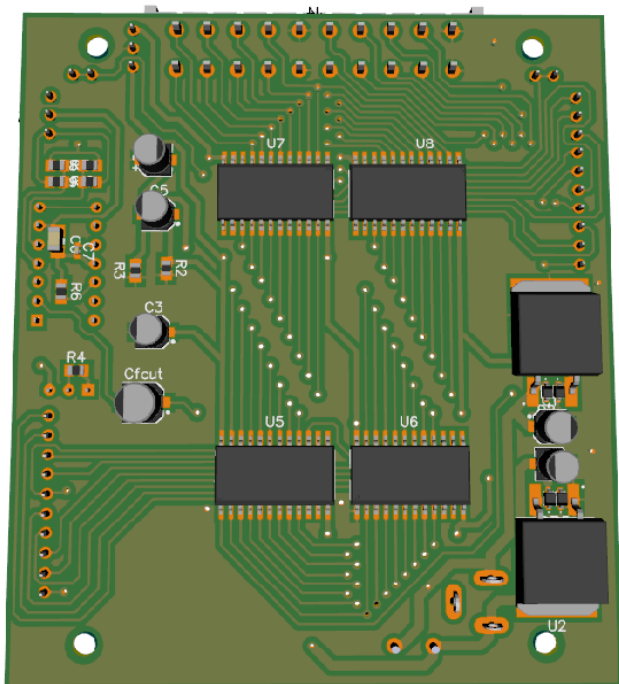


Fig. 11. Measuring module Smart EIT in SMD – plate

Figure 11 presents the measuring module Smart EIT in SMD.

E. Active electrode (Fig. 12):

- measurement of potential differences on the individual electrodes,
- chip LTC 2495,
- I2C communication,
- manual addressing - 27 addresses,
- 12V power supply,
- stabilizing voltage,
- signaling work LEDs
- RJ-45 connector.

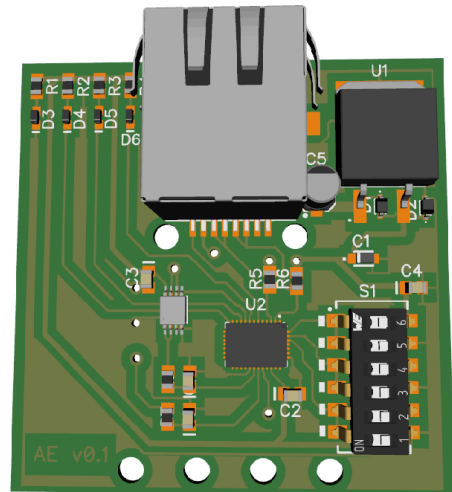


Fig. 12. Active electrode

F. Active electrode – power (Fig. 13):

- lm7905 voltage stabilizer,
- diodes,
- filter capacitors,
- power supply LED.

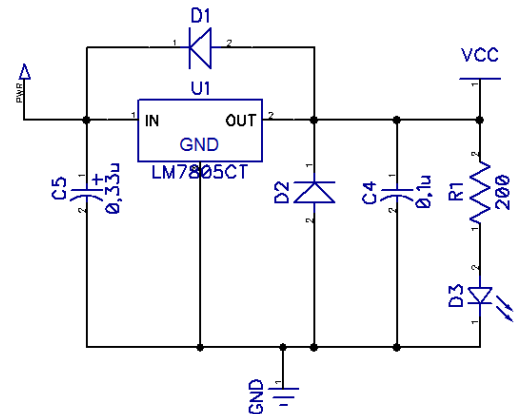


Fig. 13. Active electrode – power

### 3. Results

Achieved test results of the geometrical model were satisfactory. The flood embankment model was applied with water on the upstream side. Water line was near to the last 16 electrodes. The water started to percolate into the soil of the embankment model. Measurements of the potential were performed after 30 minutes. Measurements of the potential were performed at different angles of projection whereby the information needed to determine an approximate distribution of conductivity inside the object is obtained. The measurement system (flood embankment model, device and active electrodes) was presented in Figure 14. Figure 15 shows the image reconstruction with real data taken 15 minutes after flooding.



Fig. 14. The measurement system (flood embankment model, device and active electrodes)

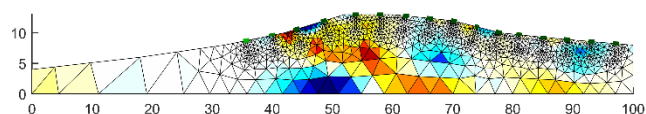


Fig. 15. The image reconstruction with real data obtained by the Gauss Newton method

#### 4. Conclusion

In this paper, there was presented the construction of the device with active electrodes to examine the flood embankment. The prepared solution was based on electrical impedance tomography. The device parameters are correctly assumed. According to our analysis and design, it is possible to build a small system EIT system to monitor flood embankments. A new nondestructive device was tested on the laboratory model. The flood embankment model was applied with water on the upstream side. The test results for prototype device were promising.

#### Acknowledgments

Projekt współfinansowany przez Unię Europejską z Europejskiego Funduszu Regionalnego. Działanie 1.4 – wsparcie projektów celowych. Umowa nr UDA-POIG.01.04.00-06-007/10-00. Nazwa Beneficjenta - Netrix S.A. dawniej Net-Art Paweł Rymarczyk. Tytuł projektu „Implementacja nowatorskich metod tomografii impedancyjnej do badania stanu wałów przeciwpowodziowych” (2011–2015).

#### References

- [1] Adler A., Lionheart W.R.B.: Uses and abuses of EIDORS: an extensible software base for EIT, *Physiological Measurement*, Vol. 27, 2006.
- [2] Gunna D.A., Chambers J.E., Uhlemanna S., Wilkinson P.B., Meldrum P.I., Dijkstra T.A.: Moisture monitoring in clay embankments using electrical resistivity tomography, *Construction and Building Materials*, 2014.
- [3] Hoła J., Matkowski Z., Schabowicz K., Sikora J., Nita K., Wójtowicz S.: Identification of Moisture Content in Brick Walls by means of Impedance Tomography, *COMPEL*, Vol. 31, Issue 6, 2012, 1774–1792.
- [4] Holder D.S.: *Electrical Impedance Tomography: Methods, History and Applications Series in Medical Physics and Biomedical Engineering*, London 2005.
- [5] Jones G., Sentenac P., Zielinski M.: Desiccation cracking detection using 2-D and 3-D Electrical Resistivity Tomography: Validation on a flood embankment, *Journal of Applied Geophysics*, Vol. 106, 2014.
- [6] Leondes C.T.: *Medical imaging system techniques and applications*, Gordon and Breach Science Publishers, Amsterdam 1997.
- [7] Rymarczyk T.: “Using electrical impedance tomography to monitoring flood banks”, *International Journal of Applied Electromagnetics and Mechanics* 45, 2014, 489–494.
- [8] Rymarczyk T., Filipowicz S.F., Sikora J., Polakowski K.: A piecewise-constant minimal partition problem in the image reconstruction, *Przegląd Elektrotechniczny*, R. 85 NR 12/2009, 141–143.
- [9] Rymarczyk T., Adamkiewicz P., Duda K., Szumowski J., Sikora J.: New Electrical Tomographic Method to Determine Dampness in Historical Buildings, *Achieve of Electrical Engineering*, v.65, 2/2016, 273–283.
- [10] Sankowski D., Sikora J.: *Electrical capacitance tomography: Theoretical basis and applications*, Wydawnictwo IEL, Warszawa 2010.

- [11] Sikora J., Wójtowicz S.: *Industrial and Biological Tomography: Theoretical Basis and Applications*, Wydawnictwo IEL, Warszawa 2010.
- [12] Smolik W., Radomski D.: Performance evaluation of the iterative image reconstruction algorithm with sensitivity matrix updating based on real measurements for electrical capacitance tomography, *Meas. Sci. Technol.* Vol. 20, No. 11, 2009, 115502.
- [13] Wajman R., Fiderek P., Fidos H., Jaworski T., Nowakowski J., Sankowski D., Banasiak R.: Metrological evaluation of a 3D electrical capacitance tomography measurement system for two-phase flow fraction determination; *Meas. Sci. Technol.*, Vol. 24, 2013, No. 065302.
- [14] Wang M.: *Industrial Tomography: Systems and Applications*, Elsevier 2015.

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otrzymano/received: 20.09.2016

przyjęto do druku/accepted: 15.02.2017