Development of A Digital Resistivity Meter Based on Microcontroller

Yohandri, Mairizwan and Akmam
Physics Department, Faculty of Mathematics and Natural Science, Universitas Negeri Padang
Padang, Indonesia
yohandri@fmipa.unp.ac.id

***Abstract*—Resistivity meter is a useful instrument in geophysics for determining the characteristic of rock composition and underground material based on resistivity of the soil. In addition, this instrument can be performed to specify bedrock depth estimation of building foundations and to estimate there is geothermal potential. In this work, development of a digital resistivity meter based on microcontroller will be presented. The measurement was done by injecting current to the ground through two electrodes. The voltage is measured between two other electrodes corresponding to the configuration and distance of the electrode. The distance between two electrodes can be varied to get the resistance of each measurement point. The performance of digital resistivity meter had been confirmed which several features, including variable current injection, rapid measurement process, produced a big amount of data that brought a high accuracy. Measured results shown the developed system satisfy for the resistivity meter to determine the characteristics of soil and rock.**

Keywords—resistivity meter; digital; microcontroller; geophysics; current injection.

I. INTRODUCTION

Indonesia has developed and mastered the exploration technology, mining and mineral cultivating. Study and development of exploration system of mining was needed as Indonesia has a great mineral. Geoelectical methods, one of the methods, is used to specify the characteristic of resistivity and electrical flow on rocks and other materials in the earth. Those characters could be studied by doing a measurement on the surface and underground of the earth [1,2]. The measurement consists of potential field and current, naturally or by current injection. Geoelectrical methods consist of resistivity method, self-potential, and induced polarization.

The resistivity is one of methods to analyze the structure of soil and mineral layers. Resistivity meter is needed in several government instance, education, private mining, and research institution. The resistivity meter function is to identify material and structure of the earth layer to the resistance of those materials. The use of resistivity meter is not only for mineral exploration, but also useful in investigating the kind of structure of the material. On the other hand, a resistivity meter could also to be used to identify the characteristic of soil layer, which is needed by a researcher to analyze the building and bridge foundation. Moreover, it could be used to estimate bedrock depth for building foundation.

Currently, the resistivity meters that exists is expensive and not owned by many research institutions. For educational purposes, an expensive resistivity meters use is risky and has a large risk of damage. Therefore, a low cost resistivity meter obligatory to be developed. In this paper, the development of a digital resistivity meter based on microcontroller will be presented.

A microcontroller can be implemented in the resistivity meter system. Several instruments based on microcontrollers have been developed successfully, such as instruments for education [3-4] and sports science research [5]. The development of a digital resistivity meter based on a microcontroller provides many advantages including low cost, easy to repair, data can be recorded digitally and can be programmed according to the design of the system. In next section, the theory of application and target will be discussed in section two and three, respectively. Method of the research will be explained in section four. Finally, the results and conclusion from this work will be presented in section five and the last section.

II. THEORY OF APLICATION

Geoelectrical (Resistivity Meter) was first used by Conrad Schlumberger in 1912. Geoelectric one of the geophysics methods to know the change of resistant type of rock composition under the ground by giving high-voltage electric current DC (‘Direct Current’) to the ground. Injection of electric current is done by two ‘current electrode’ A and B that injected to the ground with spesific distance. The longer the distance of electrode AB will cause the flow of electric current penetrated the rocks composition deeper [6].

Resistivity meter as one of the geoelectric methods is done to identify the characteristic of resistivity and electric flow on rocks and another material in the earth by injecting electric current. Electric current that flow on homogeny resistive media has a flow scheme as shown in the Fig. 1.

978-1-5386-5457-6/18/$31.00 ©2018 IEEE

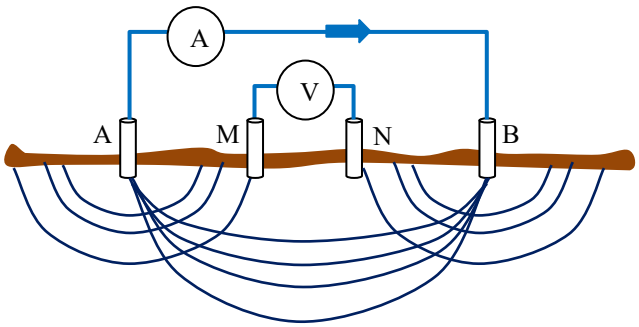

Fig. 1. Scheme of electric current flow on resistivity meter

Electricity voltage is given to point A and B with $V_A > V_B$. On the position between A and B, most of the electric current flown on depth d AB/3. This electric current is known as I inject. The dash line shown equipotential field, given VM' = V_M and $V_{N'} = V_N$. By doing this, we could see VMN on depth d by measuring V_{MN} on the surface. Then, knowing the value of I inject and $V_{M'N'}$, we could get the value of $R_{M'N'}$ on depth d [1,7].

The result of measurement and elaboration then is correlated to geology science to get the information of geology characteristic of the ground. Resistivity measurement concept is modified from resistant measurement of sample in the laboratory with the equation.

$$R = \rho \frac{L}{A}$$

Here R is resistant (Ω), ρ is resistivity (Ωm), L is length (m) and A is section area (m^2). Whereas conductivity can be formulated as.

$$\sigma = \frac{l}{\rho}$$

Digital resistivity meter worked by injecting electric current to each electrode as an injected sequence without moving manually current electrode and potential electrode which took more time[1,8]. It was because operator has to move electrode every injection repeatedly and as we know in every geoelectric survey we have several injection points. Digital resistivity meter has a lot of electrode, thus allow us to inject the current without moving the electrode.

Understanding the characteristic of rocks layer to 300 m depth under the surface is profitable to identify the possibility of finding aquifer layer, a rocks layer known as bearer water layer. Generally, people looked for 'confined aquifer', aquifer layer that confined by water impermeable layer on the top and below them such as clay layer. Confined aquifer has a relative far recharge, thus the availability of water under drill point will not be affected by the change of weather surrounding it.

Resistivity Meter could detect mine layer that has a contras resistivity than their top and below layers. It could also be used to estimate bedrock depth for building foundation[9]. Geoelectrical method also gives the possibility of finding geothermal under the surface. However, this method just one of the several geophysics methods that used to find the exact position of geothermal source under the surface.

III. Inovation Target

Production of digital resistivity meter for mineral exploration application with an automatic control system would need component and equipment that available in Indonesia, thus operation process and handling can be done easily. The obstruction faced by researchers, to explore the condition and characteristic of inner earth cause of the expensive device, could be handled by the digital meter device with the automatic control system. This system can be operated directly by students as an aspirant researcher, therefore, the students have knowledge and insight in the geophysics exploration field.

The current from DC source was injected to sthe earth bottom through electrode current. Meanwhile, capacitor on the transmitter will be charged. Voltage reaction as the effect of current injection is measured through potential electrode by the potentiometer. In general, resistivity meter system consists of voltage converter, programmed connector, control system and electrodes. Diagram of the resistivity meter is shown in Fig 2.

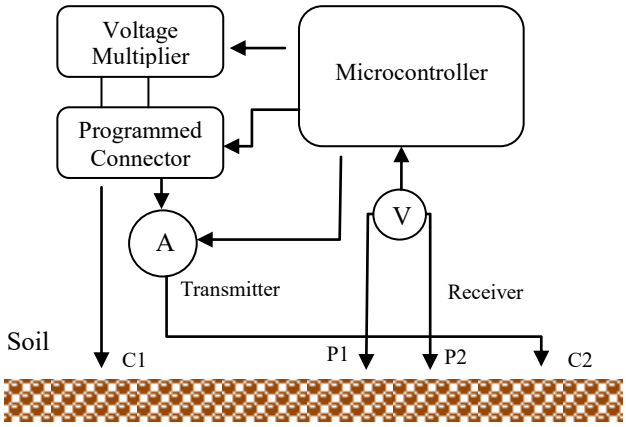

Fig. 2. Diagram of resistivity meter

Development process was started from determination of the characteristics of the components which will be used, study of measurement device and appropriate technique, devise design from a certain component and equipment, device production, calibration, observe the characteristics of measurement results, and the final aim to produce reliable resistivity meter.

IV. Materials and Method

The design of digital resistivity meter has characteristics that can reach higher power measurement because it has many electrodes and supported by microcontroller system, so that the measurement process can be faster and more efficient. The resistivity meter components are generally consisted of current injection control system, electrode, display, and battery as a source of energy and also equipped with software that uses in control.

The current injection control is carried out with a voltage-folding system. The voltage of a 12 Volt source is amplified

using a step-up transformer and then a voltage is folded. The amplified voltage values can be varied as need with max values reaching 1000V. Then the current be injected and measured, the value of current and the injection time will be controlled using a microcontroller.

The reading system of the received voltage values will be done by using sensors connected to the microcontroller. The start time and the duration of the received voltage readings will also be controlled using a microcontroller [10]. The result of this reading will be converted into resistivity value.

The manufacturing of the digital resistivity meter system based on the theory analysis started from the determination of the type of components and tools that have operational capability at high power, the schematic design of the control system circuit, the design of the current injection system. The component utilizing is aimed to avoid damages the equipment and can produce optimum output. After the design, mechanism model and planning system were determined. The next step is the fabrication process. This research has been done in Physics Laboratory State University of Padang. The process utilizes well calibrated equipment, so that each stage of this circuit can function optimally. After all the manufacturing process is completed will be carried out measurement experiments in the field

The manufacture of resistivity meter system is designed to work and have static characteristics based on the components and mechanical systems. Implementation of electronic systems can be seen in the block diagram in Fig. 3.

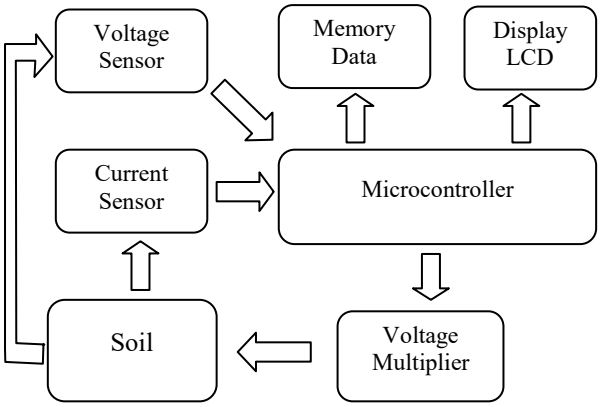

Fig. 3. Block Diagram of resistivity system

For data acquisition, the resistivity meter is interfaced to a computer that control current injection and read the current and voltage. Resistivity value is obtained using Arduino microcontroller. The flow chart of the resistivity meter working process is shown in Fig. 4.

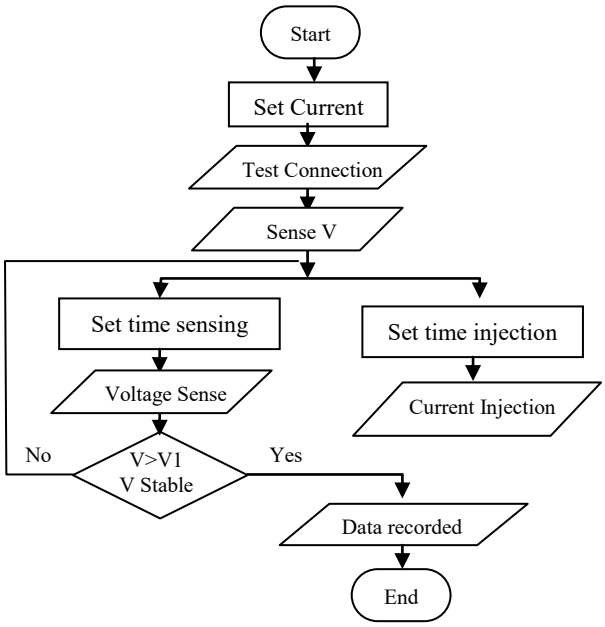

Fig. 4. Flowchart of resistivity meter

Testing of tools and data retrieval system is done by geoelectric method using Wenner configuration. The electric current is injected into the ground through the electrode, in the presence of electric current flow will cause the electric potential difference in the ground, the electric potential difference is measured using the sensor through the electrode connected to the ground with the configuration according to Fig 1. When the position of the electrode distance AB changed then the electric voltage read by the MN will also change. In addition, the different types of rocks and soil will cause the voltage readings to change. From the result of measurement of current and potential difference to variation of electrode distance hence can be derived variation of price of barrier type of each layer of the soil.

V. RESULTS AND DISCUSSION

The test result of the implementation of resistivity meter is done in four stages. The first test is to calibrate the function of each component used. The second step is done by testing the accuracy of multiplier voltage value for current injection. The third test is to measure injected current and voltage that received on electrode receiver. The last test is to determine accuracy and precision in controlling and measuring on resistivity meter.

The third and last test is directly done on soil media that prepared. Electrode is entered directly to the soil. Current injection process is done periodical for six seconds in every injection, and voltage reading will be done after two seconds from the time injection started. Based on the experiment, measured data is produced and the comparison between measured and reference data is presented in Fig. 5. Based on Fig. 5, the measured and reference data show the high accuracy of resistivity meter system.

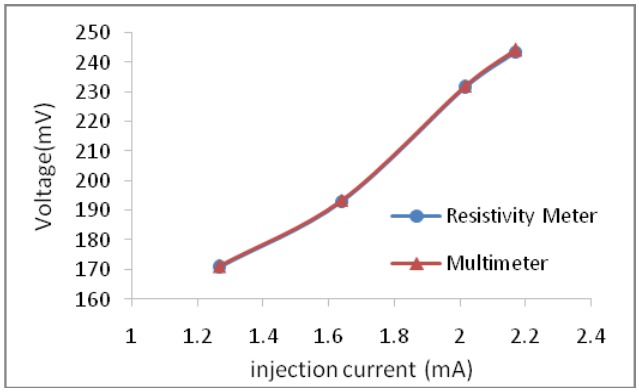

Fig. 5. Measured data of the system and standard device plotted as a function of injection current

The result of resistivity meter system shown that the current value that injected is perpendicular to the change of voltage inside the soil as plotted in in Fig. 6.

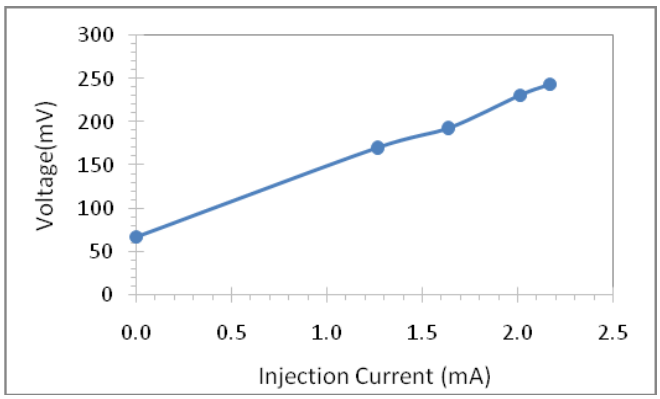

Fig. 6. Measured voltage plotted as a function of injection current

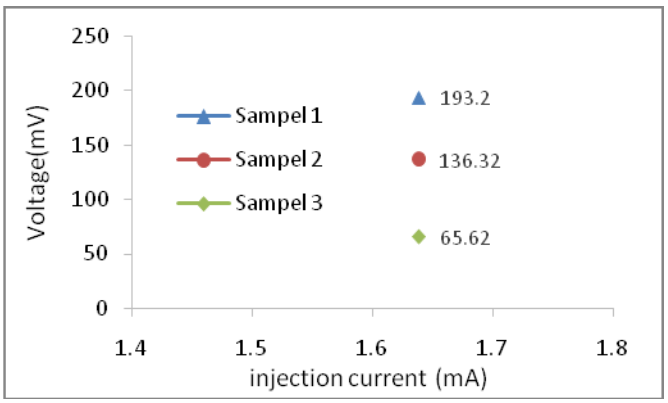

Fig. 7. Measuring the voltage of the system for 3 soil type

The of resistivity meter experiment is done with three different types of soil with different condition, and also different in water content. For every soil condition, the different value of resistivity is obtained. The different in resistivity is caused by conductivity of each soil affected by soil structure, water content, and the temperature. Therefore, in every different soil composition and layer gives different resistivity, thus resistivity meter can be used to identify structure and characteristic of rocks and soil as can be seen in Fig. 7

VI. Conclusion

This digital Resistivity meter is design to identify and measure the resistivity value of soil and rocks. Resistivity meter can be used to identify the type of resistance on rock formations underground by giving DC current that has high voltage to the ground. Injected current uses two current electrodes, which are entered into the ground with specific distance. Therefore, geophysical exploration to observe the subsurface condition using electrical characteristic of rocks can be done.

Acknowledgment

This research was supported by Ministry of Research, Technology and Higher Education, Indonesia. This work under National Strategic Research Grant (PSNI) with grant number 842/UN35.2/PG/20118.

References

[1] Akmam, Existence of Spring in Batulimbak Village Simawang Kecamatan Rambatan Kabupaten Tanahdatar. Prosiding Seminar PPD Forum HEDS 2004 Bidang MIPA, ISBN 979-95726-7-3. Hlm 593-608, 2004.

[2] Eko Agus Irianto, Endah Rahmawati, "Prototipe Alat Ukur Resistivitas Tanah dengan Metode Four-Point Probes", Prosiding Pertemuan Ilmiah XXVIII HFI Jateng & DIY, Yogyakarta, 26 April 2014.

[3] Yulkifli, Yohandri and Kurniati R, "Development of digital viscometer based on sensor technology and microcontroller", Journal of Physics: Conference Series, Volume 1040, 2018

[4] Yulkifli, Zurian A. and Yohandri, Development of Gravity Acceleration Measurement Using Simple Harmonic Motion Pendulum Method Based on Digital Technology and Photogate Sensor, IOP Conference Series: Materials Science and Engineering, Volume 335, 2018

[5] Ihsan N, Yulkifli and Yohandri, Development of Speed Measurement System for Pencak Silat Kick Based on Sensor Technology. IOP Conference Series: Materials Science and Engineering, Volume 180, Number 1, 2017

[6] Igboama W. N. and Ugwu N. U, "Fabrication of resistivity meter and its evaluation", American Journal Of Scientific And Industrial Research, 2011

[7] K.S Awotoye and A.O.I.Selemo, "Design And Construction of a resistivity meter for shallow investigation", Nigeria Journal of Physics Vol 18 2006, Submitted

[8] Mikailu A., Abdullahi I., Sani M.G., Muhammad S. "Development of Digital Resistivity Meter" Advances in Physics Theories and Applications, Vol.42, 2015

[9] Sugito, Zaroh, I., Indra, P.J., 2010. Investigasi Bidang Gelincir Tanah Longsor Menggunakan Metode Geolistrik Tahanan Jenis di Daerah Kebarongan Kec. Kemranjen Kab. Banyumas. Berkala Fisika ISSN : 1410 - 9662 Vol. 13 , No. 2, April 2010, hal 49 – 54

[10] John G. Webster "Measurement, Instrumentation and Sensors", Handbook, CRC Press, IEEE Press, 1999