Analysis of Design Test for Current and Voltage Meters with a Constant Current Source for a Resistivity Meter

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Abstract ***- Resistivity meter is a tool used to measure the resistivity of a medium or material by injecting a current into the earth. The main circuit contained in the resistivity meter is a current source, current meter, voltage meter, and data viewer. The current source is part of an electrical device that functions to conduct electric current. In this case, the constant current application is needed in resistivity measurement because the medium to be measured is the earth. There is a layer of earth rock which causes the instability of the current when it is injected into the earth. This study aims to design a current and voltage meter with a constant current source based on Arduino nano using a Shunt Resistor and ADS1115 as a current and voltage meter. The results of several tests showed that the constant current source circuit can be applied to the current variations of 1.9 mA, 12.5 mA, 18.4 mA, 62.5 mA, 83 mA, and 125 mA. This constant current variation can work on a resistance value of 20 Ω to 680 Ω. The application of constant current sources to current and voltage measurements is successful at a constant current variation of 1.9 mA with a variation of resistance from 4.7 Ohm to 1 MOhm.***

Keywords ***: Resistivity meter; constant current source; LM317; ADS1115; Arduino nano.***

I. INTRODUCTION

Resistivity meter is a tool used to measure the resistivity of a medium or material. This tool is used in geoelectric surveys to determine subsurface structures [1]. The working principle of the resistivity meter is to measure the potential value arising from the injection of a current and then the potential value is measured by the potential electrode [2]. The data obtained from the work of this resistivity meter are the values of current and voltage.

Researchers have conducted several studies related to the design of simple resistivity meters by utilizing a microcontroller to control current and voltage measurements [1], [3], [4], [5]. Meanwhile, the design of an analog resistivity meter uses a multimeter to measure current and voltage [2], [6].

The main circuit contained in the resistivity meter is a current source, current meter, voltage meter, and data viewer. The current source is part of an electrical device that functions to conduct electric current. Current sources are a combination of voltage sources in an electronic circuit. In this case, the constant current application is needed because the medium to be measured is the earth. In the earth, many layers of rock are formed which can disturb the stability of the current flowing in the soil.

The constant current circuit is used to regulate the current by maintaining a constant output current and is not affected by changes in input voltage and output resistance [7]. Constant current sources are also widely used in measurement circuits, such as measuring and classifying resistor valuesand measuring cable resistance. From these measurements, when the current is more stable, it can be said that the measurement will be more accurate. The change in output resistance causes the output voltage to adjust as the load resistance varies; the higher the output resistance, the greater the output Voltage.

Converters in constant current circuits adjust current and voltage depending on the output resistance level [8]. Based on the description above, this research aims to make a design for measuring current and voltage with a constant current source based on Arduino nano as a preliminary study for the manufacture of a resistivity meter.

A. ADS1115 Module

The ADS1115 module is a 16 bit Analog to Digital Converter module which has a better level of accuracy than Arduino which has a resolution of 12 bits. The ADS1115 module consists of four input channels that can convert valuesfor 4 sensors at once. Data from this module will be sent via I2C serial communication consisting of SDA and SCL.

Several studies have discussed the ADS1115 module in the field of chemical instrumentation [9] and environmental monitoring [10]. The following Fig. 1 shows the ADS1115 block diagram.

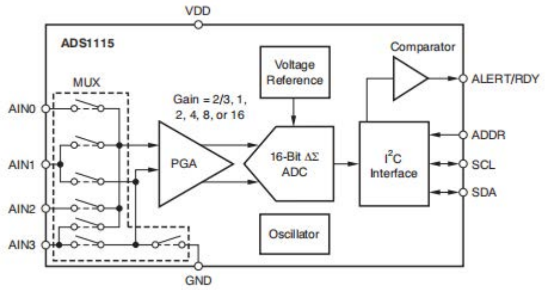

Fig. 1. ADS1115 Functional Block Diagram [11]

B. LM317 amplifier module

The simplest form of constant current source circuit is to use a resistor with LM317. In this circuit, when the voltage from the voltage source is higher than the voltage required by the constant current source, the constant current source circuit will adjust without being hindered by the resistance of the medium. Ohm's Law is applied to calculate the current and voltage values in this simple constant current source.

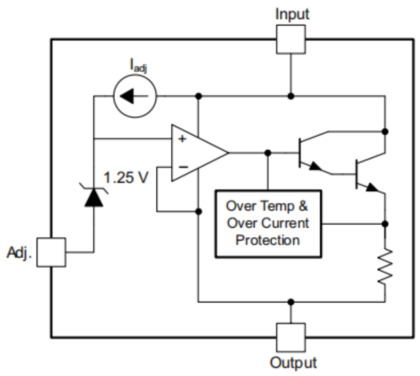

Fig. 2. LM317 Functional Block Diagram [12]

The LM317 (Fig. 2) is a positive voltage regulator capable of producing currents of up to more than 1.5 A over an output voltage range of 1.2 V to 37 V via a 3 terminal arrangement. This voltage regulator can be applied via two external resistors to determine the output voltage [13]. The LM317 can be used as a precision current regulator. Several studies related to the use of LM317 include the use of LM317 as a voltage regulator in relay control designs, DC power supply circuits, and buck converter circuits [14], [15], [16], [17], [18]. [19], [20].

II. METHOD

The general design consists of a series of hardware and software. The hardware system consists of a current source, a constant current circuit, a current meter, and a voltage meter. While the software consists of programming that will be embedded in Arduino nano.

A. Constant current source design

In this research, the constant current source is made from the LM317 circuit. LM317 is a positive DC voltage variation regulator IC chip. This circuit is made without paying attention to the voltage and only keeps the current flowing constant. The constant current source circuit consists of a rotary switch, LM317, and a resistor. Here is a constant current circuit based on LM317 (Fig. 3).

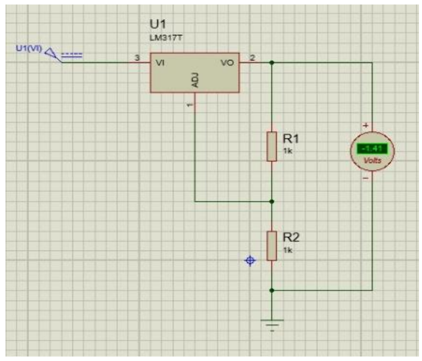

Fig. 3. Constant current test based on LM317

Data acquisition as shown in Fig. 3. utilizes a battery or power supply as a current source. Current flows from the positive pole of the battery to a constant current circuit. The output current is measured towards the ampere meter with resistance R. The data obtained can be checked on the suitability of the current source through the power supply with the ampere meter.

B. Current and voltage meter design

The next hardware design is a circuit measuring current and voltage. The circuit is manifested in several subsystems including a voltage meter with ADS1115, a current meter with an R Shunt circuit, a data controller and a data processor with Arduino nano, and an LCD data viewer. The design of some of these subsystems is presented in Fig. 4 below.

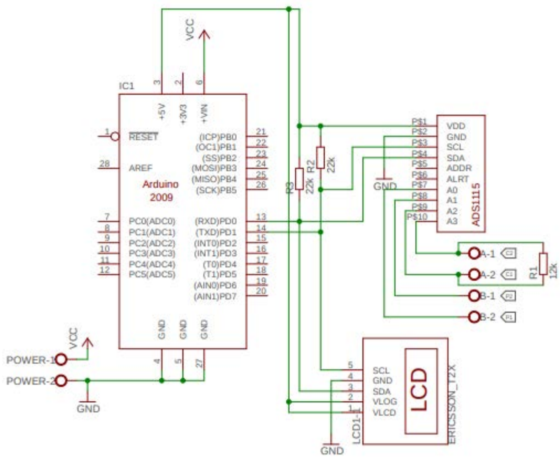

Fig. 4. Current and voltage meter circuit

The series of images above is connected to a DC voltage source. R1, R2, and R3 are reference resistors which are measured using a standard digital meter resistance. Rx is a resistor whose resistance value will be calculated, located between pins A1 and A2 (Fig. 4).

ADS1115 IC is responsible for converting analog quantities (voltage in Rx) into digital quantities. The conversion result will be connected to the Arduino nano using I2C-based communication. Furthermore, via I2C the data is connected to the I2C LCD 20 × 4 modules. Arduino nano as the controller for the ADS1115 module and I2C LCD 20x4 module. LCD uses I2C communication to display the resistance value of the resistor Rx. I2C LCD can be controlled with the I2C / IIC (Integrated Circuit) or TWI (Two Wire Interface) protocols.

Current measurement is done by using a Shunt Resistor. Also known as a shunt ammeter, the principle works by measuring the voltage drop across a known resistance. Ohm's Law states that V = I x R, or solving for I, I = V / R, where I am now, V is the voltage, and R is the resistance. If the resistance is known and the voltage drop is measured, the current can be determined.

III. RESULTS AND DISCUSSION

A. Constant Current Source Circuit Testing

The test using a current source is applied with a constant current source circuit, meaning that the current flowing through the load in the form of a resistor is kept constant in value. A resistor as a supporting component for the voltage regulator for LM317 which is a variable voltage divider circuit with a combination of several resistors.

The Fig. of conservation of energy is inherent in this test. Where the input and output energies are the same. In the constant current source test, the method used is the resistor loading test. This test is made constant into 6 parts.

The results of the characterization of constant current sources are shown in Table 1 with 3 repetitions of data retrieval for each variation of the current through a rotary switch. From the data table 1. It can be explained that the constant current circuit created can be used to measure the resistance value in the range of 20 Ω to 680 Ω. The determination of the value of the variation of resistance is based on Ohm's Law to determine what current value you want to flow if the voltage input is 12 Volt.

TABLE 1. Data acquisition results

Variation Rotary Switch	Current (mA)	Multimeter rated current average (mA)	Standard Deviation
R1 (680 Ω)	1.8	1.89	0.006
R2 (100 Ω)	12.5	12.70	0.006
R3 (68 Ω)	18.4	18.76	0.040
R4 (20 Ω)	62.5	61.95	0.047
R5 (83 Ω)	83	82.90	0.000
R6 (125 Ω)	125	126.57	0.231

From Table 1, the standard deviation calculation value (calculated by equation 1) means that the lower the standard deviation the closer to the average, whereas if the standard deviation value is higher, the wider the range of data variations is.

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}} \quad (1)$$

σ = population standard deviation
N = the size of the population
x_i = each value from the population
μ = the population mean

B. Ammeter and voltmeter testing

Measurement of current and voltage values is carried out to determine whether the prototype made is correct and accurate in data acquisition. The standard used as a reference is the color bracelet (Rx1) and the standard multimeter (Rx2). While the measured resistor lies in the Rx3 data obtained from the LCD reading. The following is a table of current and voltage test results (Table 2).

TABLE 2. Prototype Measurement Data

Rx1 (Ohm) ± tolerance (%)	Rx2 (Ohm)	VRx2 (mV)	Rx3 (Ohm)	Error (%)
4.7 ± 5%	4.7	6.94	4.76	0.013
6	6	6860.29	6.10	0.017
12 ± 5%	11.9	19.23	12.09	0.016
47 ± 5%	46.3	39.82	46.75	0,.010
330K ± 1%	330.3K	3019.67	339739.35	0.029
470 ± 5%	470	1633.13	47.66	0.005
680K ± 5%	674K	682147.9	682.15K	0.003
1M ± 1%	1.001 M	3059.98	85339212.70	0.002

The measurement results of the 8 fixed resistors are measured alternately using a standard prototype and multimeter. Table 2 is the test results without constant current, the data is the average of repeatability of data collection 5 to 10 times.

C. Prototype and Constant Current Circuit Testing

The last test is the application of a constant current circuit to the current and voltage meter prototype. The purpose of this test is to find out whether the current value data detected by the current meter has a stable value (constant current). The results of this test are described in graphical form (Fig. 5) below.

During the test, it can be seen that the current data from the recorded sensor readings is quite stable or constant at a current value of 1.9 mA. This constant current value can be used in resistance measurements from 4.7 Ohm to 1KOhm. More than 1KOhm the data does not match the resistance value of the resistor. The tool testing is carried out with 1 constant current variation and uses a variation of 12 different resistor values.

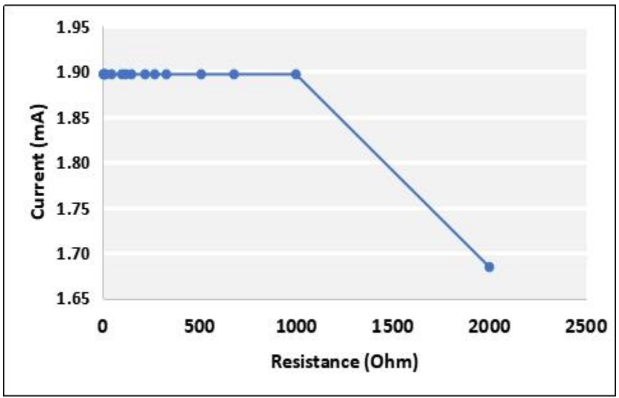

Fig. 5. Constant current circuit application test data on the current and voltage meter prototype

Voltage measurements are made on each resistor and the measurement is repeated ten times. The use of data loggers in the form of Arduino and LCD makes it easy to record data in the form of microSD and serial monitors displayed on the Arduino IDE monitor serial. The data recorded are voltage data in millivolts and current in milliamperes. In addition to using the designed tool, measurements are also carried out using a multimeter as data to compare the measurement results.

IV. CONCLUSIONS

Implementation of constant current sources was successfully carried out at constant current variations of 1.8 mA, 12.5 mA, 18.4 mA, 62.5 mA, 83 mA and 125 mA. In the measurement system, the characteristics for constant current sources can work within a resistance limit of 20 Ω to 680 Ω. A digital resistance data logger system based on Arduino nano has been designed with the main circuit of the current source, current and voltage meter, controller, and data viewer. Applications of a constant current source of 1.9 mA can work well on a variety of resistance from 4.7 Ohm until 1 MOhm.

V. ACKNOWLEDGMENTS

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REFERENCES

[1] A. Mikailu, I. Abdullahi, M. G. Sani, S. Muhammad, P. Unit, and R. Studies, "D*evelopment of Digital Resistivity Meter*" Advances in Physics Theories and Aplications, vol. 42, pp. 56–62, 2015.
[2] J. G. Urang, E. A. Awak, and A. S. Bamidele, "*Design and construction of a simple resistivity meter for resistivity measurement*" Research Journal of Physical Sciences, vol. 6, no. 5, pp. 1–7, 2018.
[3] W. N. Igboama and N. U. Ugwu, "*Fabrication of resistivity meter and its evaluation Fabrication of resistivity meter and its evaluatio*" American Journal Of Scientific And Industrial Research, vol 12, no.5, 2011.
[4] Y. Mairizwan, "*Development of A Digital Resistivity Meter Based on Microcontroller*" TENCON 2018 -Conf., October 2018, pp. 551–554, 2019.
[5] D. Fatahillah and N. Nuryani, "L*ow-cost multi electrode resistivity meter based on the microcontroller for electric resistivity tomography purpose*" 9th International Conference on Physics and Its Applications 2019.
[6] D. G. Toll and A. Hassan, "*Data Acquisition and Control Software for Automated Resistivity Measurements*, Information Technology in Geo-Engineering, 2014.
[7] H. Liu, H. Yuan, Z. Shi, S. Sui, and K. Wang, "*Design of High Precision Digital AC Constant Current Source*, Advances in Engineering Research, vol. 120, pp. 2166–2171, 2017.
[8] T. I. Incorporated, "*How to Design a Simple Constant Current/Constant Voltage Buck Converter*" Texas Instrument, 2018.
[9] James P. Grinias, J. T. Whitfield, E. D. Guetschow, and R. T. Kennedy, "*An Inexpensive, Open-Source USB Arduino Data Acquisition Device for Chemical Instrumentation*" J Chem Educ., vol. 93, no. 7, pp. 1316–1319, 2017.
[10] Q. Jiang *et al.* "*Citizen Sensing for Improved Urban Environmental Monitoring*, Journal of Sensor, pp. 1–9, 2016.
[11] T. I. Incorporated, "*Analog-to-Digital Converter with Internal Reference ADS1115*" 2009.
[12] T. I. Incorporated, "L*M317L 3-Terminal Adjustable Regulator LM317L 3-Terminal Adjustable Regulator"* pp. 1–19*,* 2016.
[13] R. Parab and S. Prajapati, *"IoT based relay operation" International Journal of Engineering and Advanced Technology* , vol. 9, no. 1, pp. 6515–6520, 2019.
[14] C. H. S. Sriya and H. Kumar., "*Adjustable Voltage regulator using LM317*," International Journal of Science and Research, vol. 8, no. 3, pp. 1554–1555, 2019.
[15] C. Udayasri, L. Muniraj, and A. Masilamani, "*Solar Based Adjustable Voltage Regulator Using IC LM317*" Journal of Chemical and Pharmaceutical Sciences. November, pp. 273–275, 2016.
[16] O. Umahon, Jerome, and D. Keshi, "*Design and Implementation of a 12V Automatic Battery Charge*r" International Journal of Scientific Engineering and Research, vol. 6, no. 11, pp. 129–131, 2018.
[17] I. Lita, D. A. Visan, I. B. Cioc, A. G. Mazare, and R. M. Teodorescu, "*Indoor environmental parameters monitoring for building automation systems*" Proc. 8th Int. Conf. Electron. Comput. Artif. Intell. ECAI 2016, vol. 8, pp. 41–44, 2016.
[18] Q. E. A. Waqar and P. M. Z. Khan, "*Simulation And Comparative Analysis of Linear DC Power Supply*" Journal of Engineering Research and Applications., vol. 3, no. 6, pp. 1251–1256, 2013.
[19] Zhimwang, Yahaya, Aminu, and E. Al, "*Design And Construction Of a Dual Regulated ±0-35volts Dc Power Supply Using Lm317 And Lm337 Voltage Regulator*" African Journal of Natural Sciences *2017,* vol. 20, pp. 107–118, 2017.
[20] A. Ballaji and A. M. K, *"Design and Construction of Linear Buck Converter Using Lm317 with Variable Input and Constant*" International Journal of Innovative Research in Science, Engineering and Technology, vol. 7, no. 4, pp. 2836–2844, 2018.