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Research Article

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A Study Experimental of Design Considerations of Constant Input Current Source

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Abstract

Resistivity geoelectrical method is a method to determine the value of rock resistivity. The measuring tool for resistivity geoelectrical method is a resistivity meter. One of the important features in designing resistivity meter is providing the constant current for various types of resistive loads. The difference on rocks resistance values is caused by the factor of rock types, temperature, and mineral composition. This research is aimed at designing and analyzing a set of constant current source applied at a circuit of current measurement tool based on LM324. To deal with this problem, five variations of current source were built as well as tested. The research shows the constant current was successfully built with five constant current variations with voltage 30V and tested on the loads of 56 Ohm to 1000 KOhm. The test on integrated constant current circuit measurement, and voltage worked properly on resistance (22 – 46000) Ohm.

Keywords: Current, Voltage, Constant current, Measurement, Resistance

1. **Introduction**

The electrical resistivity method is one of the most promising geophysical methods for characterizing subsurface conditions, aimed at describing the thickness structure under surface as well as its resistivity value [1],[2]. The collected data is the potential values and current occuring from the process of current injection to the earth surface [3].

The measuring tool in geoelectrical survey is namely meter resistivity [4],[5]. Electrical resistivity tests have been widely conducted in multiple scales, from a few centimeters to kilometers [2]. The geoelectrical survey is commonly used for surveying soil water [6],[7] and civil engineering, mainly for land subsidence and settlement observation [8], [9].

Some researches on both analog and digital design of resistivity meter prototype have been conducted. The analog resistivity meter fabrication consists of two multi meter in which each is used for a separate current and voltage reading. Commonly, the analog resisitivity meter does not use constant current source [10].

Meanwhile, digital resistivity meter is based on micro controller and sensor to measure current and voltage [11],[12]. The challenge on designing resistivity meter is providing constant current input source to share resistive loads.

The source of constant current is one of the main components of resistivity measure. The constant current source is needed to keep the constant current injection during data acquisition. The current needs to be always constant as rocks have various resistance values, which will lead to unstable current. The rock resistance is various and depends on its type, temperature, and mineral properties.

Other advantage of constant current is to protect the hardware of any device. In mostly electrical devices the source of constant current should have a limit on maximum current. Therefore, if constant current exceeds the predetermined maximum limit, the device can be protected and no damage will occur. [13]. Some researches had successfully designed the *resistivity meter prototype* with constant current source such as a constant current circuit with variations of current value of 0,1mA, 1mA and 10mA [14]; variation of constant current of 5mA and 10mA [15].

A research by Fatahillah showed the built *resistivity meter* that had current variation 5mA and 10mA with the measuring maximum resistance value of current 5 mA was 14000 Ohm and 10 mA was 6500 Ohm[15]. Mikailu, et al, designed the constant current based on LM714. Op Amp LM714 had maximum voltage supply input as much as 22V[14]. The size of voltage source affected the size of the designed constant current source. The test on the research was on the resistor with the resistor range only 0-1000 Ohm.

Based on the above explanation, this research aims at optimizing constant current circuit source based on LM324 with five variations of current. Next, analysis will be conducted on factors influencing measurement, correction and deviation standard. Op amp LM324 has its own specification with the maximum input of voltage for 32V, thus, it can generate a higher source of voltage compared to the previous research. All this are meant to testing on resistance value bigger than 1000 Ohm. In this research, the resistor test is applied on the range from 0 to 1000 Kohm. This research is purposed to build a model of a circuit creating a constant current supply with 5 current variations and voltage supply 30V.

Ohm's law is used in the analysis of this research by measuring the current value of the voltage drop across the reference resistor. The research method used is a direct comparison method using a digital multimeter for constant current, current, and voltage calibration data. Current sensors are needed to protect components by monitoring system performance [16].

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The calculation and measurement of current data can be divided through several theories of current sensor measurements regarding basic physical principles. The basic principles of physics can be explained through:

1. Ohm's law to find the value of resistance.
2. Faraday's law.
3. Magnetic field sensor.
4. Faraday rotation.

Based on the above theoretical principles, there are two types of current sensor measurements: direct and indirect. Generally this type of measurement is carried out through a direct measurement method based on Ohm's law principle [17]. Ohm's law is used to determine the resistance value by multiplying the current and voltage data. Furthermore, Ohm's law is a derivative of Lorentz's law (Equation 1.) which states

$$J = \sigma (E + v \times B) \quad (1)$$

J = Electric Current Density (A/m2)
σ = Conductivity
E = Electric Field Intensity (V/m)
v = charge velocity
B = Magnetic Flux Density (T)

Based on the above formula, the velocity of the charge has a small value. Therefore, the second equation:

$$J = \sigma E \quad (2)$$

Equation 2. is an equation for Ohm's law of resistance and states that the voltage drop across a resistor is proportional to the current flowing. This simple relationship can be used to determine current [18].

2. Experimental Design

Commonly, the design of prototype consists of hardware and software circuits. The hardware comprises of voltage source, constant current circuit, current sensor circuit, voltage sensor circuit, and data presentation circuit. On the other hand, the software system consists of programming built in microcontroller. The tests and designed prototype calibration are of important. Below are the explanation on design creation and circuit tests.

2.1. Hardware design

Hardware design had microcontroller type STM32F103C8T6 functioning as processor connected software. The microcontroller received input from current sensor and voltage. Next, the accumulated data was stored in micro-SD and displayed on LCD. The following are circuits of hardware divided into some parts **(**Figure 1).

2.2. Design of Current constant circuit

The constant current source is realized through supporting components as seen on the following block diagram (Figure 2.). The circuit was designed as the current source injection transmitted with the stabil current not affected by voltage.

The constant current circuit was made without paying attention on voltage and thus only keeping the current flow constantly. Based on the block diagram (Figure 2), MOSFET was used to switching input power. The Output of current was in accordance to set point value where potentiometer multiturn could automatically be managed

2.3. Current and Voltage Sensor Design

The circuit of current sensor and voltage was realized in some sub systems such as voltage measurement, current measurement, data controller, processor, and data display in a form of a LCD. The voltage measurement used the principal of voltage divider consisting of two resistors connected in serial, and the reference voltage was gained across the resistor branching points.

On the other hand, the current measurement used the principal of resistor shunt as a variable. Resistor shunt is mostly used for its advantages such as low prices, high effectivity, good reliability and performance [19][20]. Resistor shunt has technology best applied on some types of current, either direct or alternate current [21].

On voltage sensor, the output voltage was turned to be ADC value. The current data and voltage were determined through the value of analogue-to-digital converter (ADC). Further, the voltage was divided with current to find out the value of its resistance. The data from circuit calibration was sent to micro SD. The Data of current and load voltage were calculated through the process of linier calibration between sensor voltage, load current, and voltage [22].

The following are diagram block of current measurement circuit and voltage (Figure 3). Based on figure 3, the input of data from current and voltage were collected and changed into buffer cache. The conversion ensured the sensor reading not drop when read by STM32. Meanwhile, STM32 functions as a controller and data collection were displayed on LCD and saved in SD card.

2.4. Testing on Hardware Systems

Testing on hardware and software systems is conducted to analyse whether the system works properly in accordance to the output, and to find out the performance of each component. The hardware test involved test on current measurement and voltage circuit, and constant current circuit. On hardware, the tests were applied on each component.

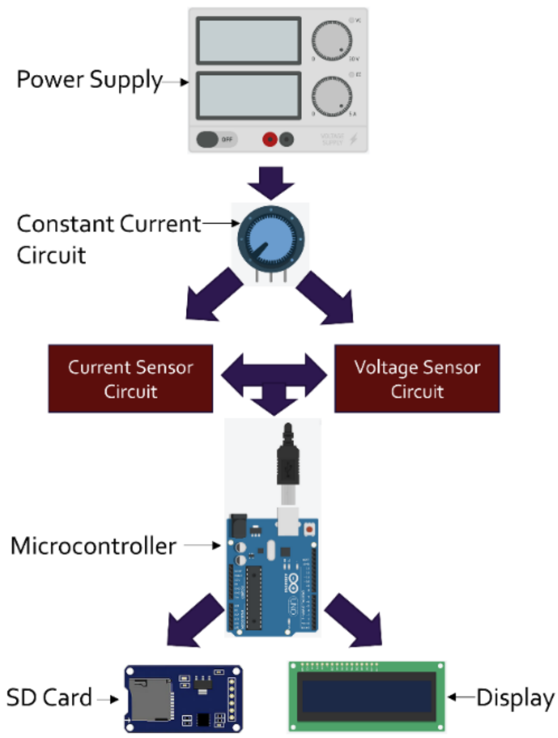

Fig. 1. Hardware System Diagram.

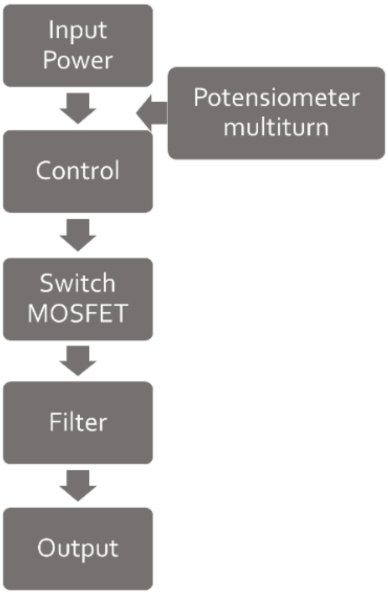

Fig. 2. Block diagram of constant current circuit design.

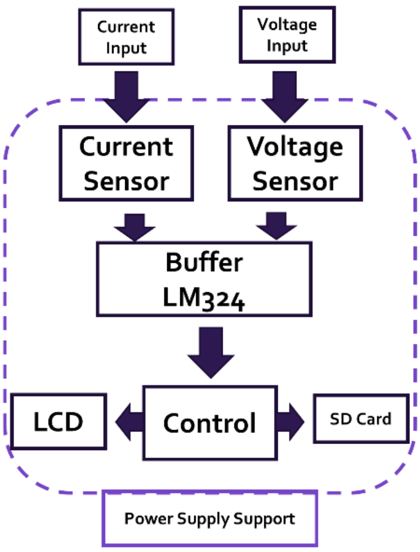

Fig. 3. The Current and voltage meter design.

2.5. Error Analysis Measurement

This involved error analysis in measuring the current and voltage in order to compare between the testing tools and standard prototype tools. This research involved the calculation of the average value, correction value, and standard deviation with the formulation [23]:

Average

$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_n}{n} \quad (3)$$

Standard deviation

$$SD = \sqrt{\frac{\sum(\bar{x} - x_i)^2}{n-1}} \quad (4)$$

Error value

Error = | Test Value – Standard Value | (5)

SD = population standard deviation
n = the size of the population
x_i = each value from the population
$\bar{x}$ = the population mean

3. Results and Discussion

3.1. A Constant Current Source Circuit

The testing was conducted on the constant current source circuit used as injection current built from LM324. The constant current source consisted of external PCB circuit as the main supporter and main circuit in PCB.

The primary circuit in the PCB (Figure 4.) consists of several components, including:

1. Input power for the constant current circuit coming from the power supply
2. MOSFET IRF540 is used for switching
3. The LC filter is used to smooth the MOSFET output so that the noise produced is minor.
4. Power regulators and filter capacitors are used to supply the circuit
5. The MOSFET driver IC is used to control the MOSFET
6. The sawtooth signal generator was used for comparison with feedback from sensor
7. IC comparator is used to generate PWM wave from the comparison of the error value and sawtooth wave
8. IC LM 324 amplifier is used to amplify the feedback signal from the current sensor, which is still small
9. The TIP 41 transistor is used to linearly control the input power
10. Relays are used to transfer from linear systems to PWM systems
11. Input the measured resistance
12. Current sensor using the resistor
13. Rotary switch/ Potentiometer As a regulator of the desired setpoint current variable
14. Trimpot to set the setpoint

The testing on constant current source involved resistor as load variation. The constant variation current were tested in five variations namely 0.1 mA, 1 mA, 16 mA, 20 mA, 22 mA with 30 V as power source.

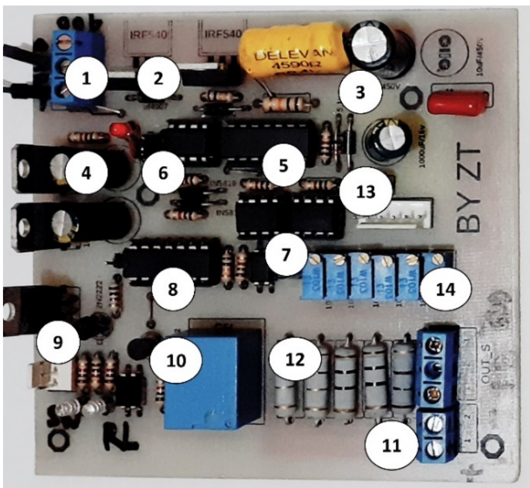

Fig. 4. Schematic and circuit of constant current.

3.2. Constant Current Source Circuit Testing

The results of the constant current source characterization are shown in Table 1. From Table 1, the calculation value of the standard deviation is based on equation 4. The calculation of the standard deviation shows how far there are statistical data deviations. Table 1 illustrates the lower the standard deviation value, the closer it is to the average.

Then the constant current circuit was tested to measure the load in the range of 1 to 1000 KOhm. Each resistor was measured in seven repeatability. Figure 5 shows that the current remains constant until the load is 1000 Kohm.

3.3. Current and Voltage Meter Design

The design of current and voltage measurement consisted of some components such as (Figure. 6):

1. The voltage sensor circuit which is a voltage divider.
2. Current sensor circuit with 1kOhm Shunt Resistor.
3. Microcontroller STM32 as a control.
4. Relay for switching to the measured medium.
5. Relay for the constant current input.
6. The input voltage, MOSFET, and LM324 driver as a buffer so that the input voltage does not drop.
7. The viewer is an LCD.
8. On/off button and LED indicator.

Table 1. Data acquisition results

Variation Constant Current (mA)	Current Average (mA)	Error (%)	Standard Deviation
0,1	0,1	0	0.006
1	1	0,06	0.086
16	16,9	0,05	7,1E-15
20	20,5	0,02	3,55E-15
22	22	0	0,003

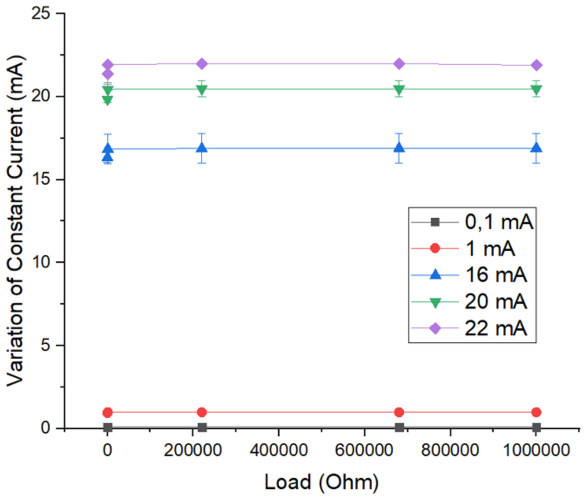

Fig. 5. Graph of Test Result Data Constant Current Source.

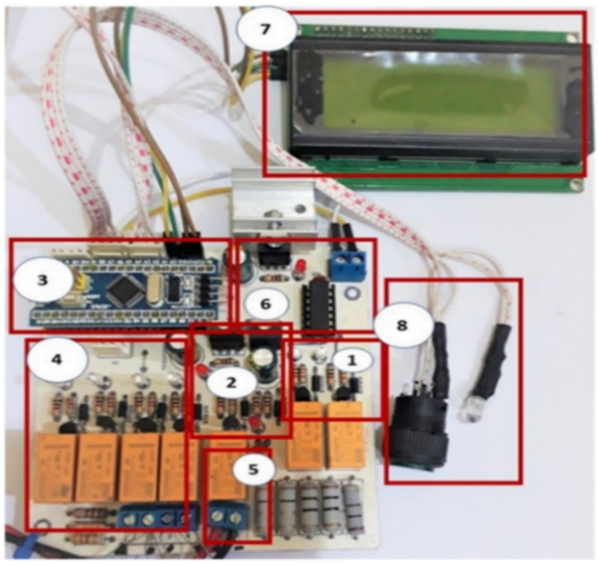

Fig. 6. Schematic and circuit of measuring current and voltage.

The injected source of current should be controlled to measure the voltage on electrode of a surface. Some current sources are floated to prevent the end of the load impedance being grounded [24].

The voltage measurement was conducted on each load, and each measurement was repeated ten times. The recorded data was voltage data in milivolt while current in miliampere. The use of data logger on arduino and LCD eased data recording in microSD as well as monitor serial showed on IDEA arduino monitor. The measurement used not only designed tools but also multi meter as the data to compare the results of measurement.

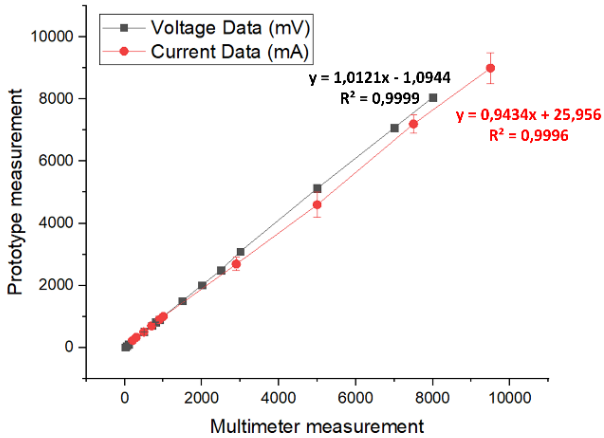

Fig. 7. Graph of current and voltage circuit test data.

3.4. Ammeter and Voltmeter Testing

The measured voltage value was the analogue signal changed into digital through microcontroller. The testing was conducted to compare the voltage measurement data read by prototype circuit and then compared to standard multi meter with relevant literature. From the measurement, the error number was found as much as 0,02%. It means it is accurate or precise.

Figure 7 is the data of current measurement using a circuit of resistor shunt with resistor variation as the load. The recorded data was compared to multimeter calculation. The error number from the calculation averagely was 0,01%. The error percentage could be caused by sensitivity or limited resolution of voltage measurement reading on the designed prototype. This was caused by the instability of the voltage during data acquisition process, this resulted in the difference on reading.

3.5. Integration Testing
The next testing method was the circuit test on prototype from measurement. The testing was meant to find out the system reliability of the built prototype. The measured value on this system depends on the instrument calibration, sampling process, data processing, and the influence of each sensor. The relevant source of uncertainty is shown on the diagram of cause and effect on figure 8.

The last testing was integrating the circuit of constant current source, current sensor and voltage compared to multimeter. The measured medium was the resistor value. The testing conducted seven times repetition in order to get the data of voltage and average current. This testing referred to resistance value printed on resistor body. This resistance value can be calculated from the data off voltage and current using Ohm law. Figure 9 shows data from integrating test on the circuit that shows the data of resistor load measurement using designed prototype. Based on the graph, the value of determined coefficient or R square was 0,999 or similar to 99,9%.

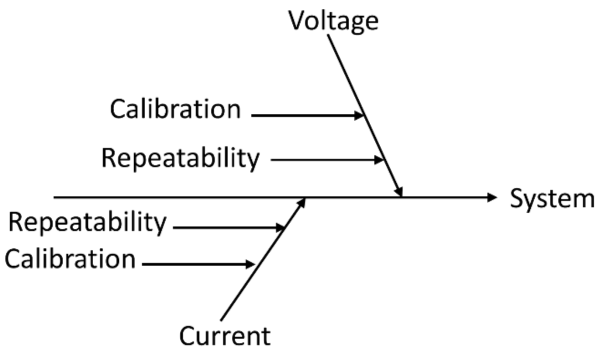

Fig. 8. Cause effect diagram.

The R Square was gained from the calculation of correlation coefficient squared. This number signals that the variable of X1 and X2 simultaneously influenced variable Y. On the other hand other variable from other regression equation influenced the rest. Therefore, there was an outlier on the position of 46000 Ohm as a result of the decrease on measurement ability after reaching the maximum limit. It is concluded that the accuracy of tool had decreased.

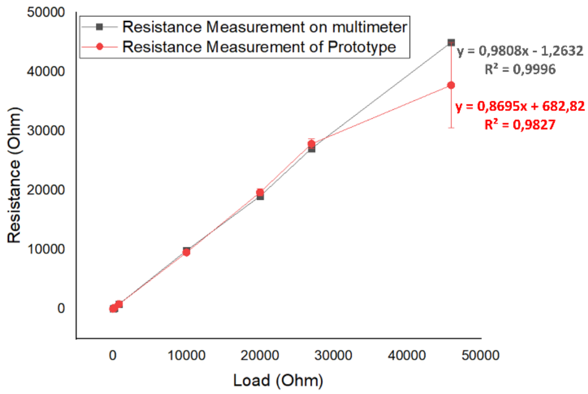

Fig. 9. Prototype Integration Testing.

4. Conclusion

The results illustrate that the constant current source was successfully built with various constant current 0,1 mA,1 mA, 16 mA, 20 mA, 22 mA with source of voltage 30V and tested on the loads 56 Ohm to 1000 KOhm. The error values found in the current sensor and voltage sensor measurements are 0,01% and 0,02% which was still considered as good. On the integration test of the constant current circuit, the current and voltage measurement could work well on the maximum resistor of 46000 Ohm.

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Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this article.

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